THE RIVER RESTORATION CENTRE

Working to restore & enhance our rivers

PRACTICAL RIVER RESTORATION APPRAISAL GUIDANCE FOR MONITORING OPTIONS (PRAGMO)

Guidance document on suitable monitoring for river and floodplain restoration projects

Funded by:

Environment Agency

TRRT Thames Rivers Restoration Trust

SEPA Scottish Environment Protection Agency

WATER www.projectwater.eu

2011

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Document Revisions

No.	Details	Date
1	Draft Report	August 2011
2	Final Report	November 2011

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Acknowledgements

The River Restoration Centre is most grateful for the input from Dr. Judy England (Environment Agency), Dr. Andrew Gill (Cranfield University), Dr. Nigel Holmes (Alconbury Environmental Consultants) and Brian Shields (Environment Agency) and their assistance in putting this guidance document together.

We also wish to thank Lucy Shuker (Queen Mary, University of London), Bridget Peacock (The Riverfly Partnership), Anne Powell (Freshwater Biological Association), Julie Wozniczka (OnTrent) and last but by no means at all least, Robert Oates and the Thames Rivers Restoration Trustees for their support and reviewing the many drafts.

Further to the funders of the project, as recognised on the cover, support from the organisations below is also gratefully acknowledged:

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1. Purpose

This is a 'living' document and will be updated as new information and new methods become known.

1.1 How this document can help you

With any river restoration and associated floodplain project it is important to demonstrate its success for wildlife and the extent to which it works with the river"s natural processes. This can only be done through an assessment of the project and this should also highlight any future adaptation that may be necessary.

To indicate the level of success, monitoring needs to be an integral part of the project process, from inception right through to project signoff and beyond. Sound project objectives, that can be measured, need to be defined from the outset; data collected and analysed can then collectively increase the knowledge base. This can then help identify what techniques, or suite of techniques, are most successful for different river types and project aspirations and demonstrate to government and funders alike how, when and where river restoration can be of benefit for a range of environmental, economic and other ecosystem objectives.

All too often, however, monitoring of a project is not seen as a high priority activity because of perceived financial constraints and a lack of guidance to help develop appropriate monitoring levels and methods.

This document therefore aims to provide a set of pragmatic guidelines to help a range of people, from government agencies to community action groups, to determine the necessary level of monitoring based on a project"s size and complexity as exemplified in ***Figure 1.1***. In essence this figure indicates that detailed, resource hungry monitoring might be better focused on technically complex projects, but that there is still a wealth of information that can be much more easily gathered from simpler or smaller projects, providing a robust monitoring strategy is stated as part of a project inception.

The document offers the reader a set of procedures to determine an appropriate monitoring scheme, based on project size, complexity, risk associated with the measures, river type and available funds.

Section 2 provides a conceptual outline of this document and details of where to find guidance that relates to specific questions in the process.

The guidance also points to a vast array of additional information and data sets throughout the UK in ***Section 10*** and ***Appendix 14***.

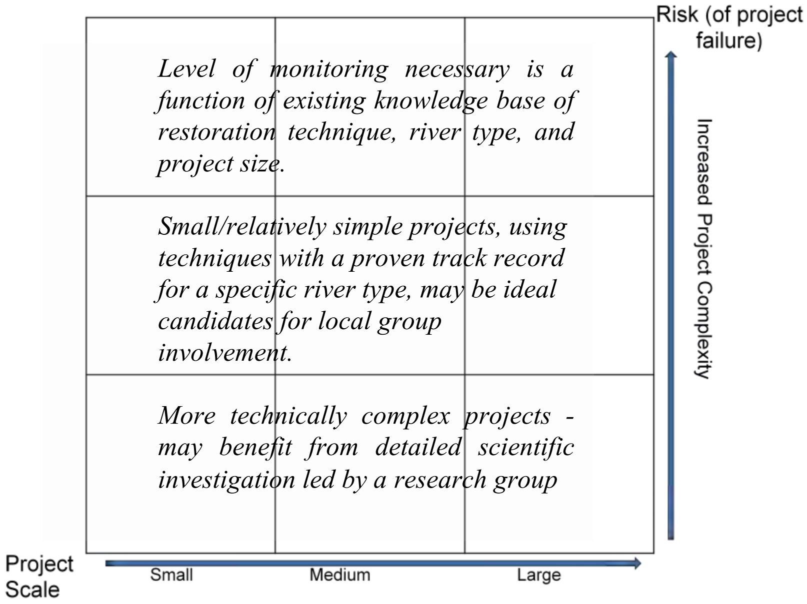

Figure 1.1 Risk-Scale Matrix that is used in the guidelines to help project managers determine appropriate level of monitoring.

1.1.1 What is not covered

This document *does not* intend to duplicate strategic monitoring guidelines already in place related to the statutory European Water Framework Direct (WFD) as outlined in ***Appendix 1***, such as the UKTAG monitoring guidance, the Common Implementation Strategy (2003) for WFD and the SERCON report (Boon et al 1996)) which are generally geared to assessing the ecological and chemical status of whole water bodies. Whilst it is predicted that this guidance document could help to increase the evidence base of specific WFD mitigation measures success, its focus is on wider practical appraisal opportunities.

This document focuses on the linkages between the ecological (wildlife) and hydro-morphological (natural river process and habitat influencing) elements of a river and floodplain restoration project. The social and economic aspects are recognised as equally important and a subsidiary document that focuses on these elements is planned for the future.

1.2 Who will benefit from the guidance?

This guidance aims to assist all practitioners involved in the process of setting monitoring protocols as part of a river restoration project. Because there is a wide range of organisations, with a wide range of knowledge and abilities, this guidance seeks to include monitoring strategies suitable for different groups.

The steps outlined here are therefore intended to support technical staff working for the competent authorities, consultancies and academic institutions as well as organisations with limited funds and a small/volunteer workforce, which may need to demonstrate success to Trustees and other funders.

1.2.1 Key Groups

- *Statutory organisations (examples include)*

  Environment Agency (EA)

  Natural England (NE)

  Scottish Natural Heritage (SNH)

  Scottish Environmental Protection Agency (SEPA)

  Rivers Agency of Northern Ireland (RA)

  Countryside Council for Wales (CCW)

  Northern Ireland Environment Agency (NIEA)

  Local Authorities

  Water Companies

  Internal Drainage Boards

Where; the focus is on measuring river restoration success for compliance with European Directives and to justify the use of public funds.

- *Non-government groups (for example)*

  Rivers Trusts

  The Wild Trout Trust (WTT)

  The Royal Society for the Protection of Birds (RSPB)

  The Wildlife Trusts (WTs)

  Fishing Clubs

  The Riverfly Partnership and other partnership schemes

  Local "friends of the river" groups

Where; there is an aspiration to carry out project monitoring using cost-effective, easily repeatable methods that can be carried out by local enthusiasts, often as part of larger partnership projects.

- *Environmental consultants*

Where; developing cost-efficient, monitoring strategies to measure successes is essential.

- *Research institutions*

Where; the principles can help to refine research opportunities and where research opportunities can be used to field test the PRAGMO approach.

- *Funders*

Where: there is a need to include monitoring as an important element of project delivery to demonstrate that funds have been effectively used. There is also a need to compare the various outcomes from different types of project so that value for money and cost-effectiveness can be assured.

1.3 How to use this document

This document provides details about how to set objectives through to prioritising your monitoring.

It is divided into 2 distinct parts. The **first part** (***Section 2***) provides a summary of the more detailed information held in the main body of the guidelines (***Sections 3*** to ***11***). The aim is to provide an overview of how to work through the main guidance. It enables the reader to decide which section(s) of the core document need to be consulted at a given period in the projects‟ live.

The **second part** comprises ***Sections 3-11*** and accompanying appendices, allowing the person involved with the monitoring to assess specific elements of the guidance such as:

- The guidance rationale in the context of current river restoration understanding.
- The importance of understanding project limitations in the context of sediment and water quality and quantity.
- Making the links between habitats, forms, process and wildlife in the river corridor.
- The importance of why and how to complete robust project and monitoring objectives.
- Making informed decisions about the appropriate level of monitoring (i.e. where to focus resources) based on scale and risk of project failure in the context of different river types using generic case studies.
- Identification of different monitoring methods and, together with some of the appendices, demonstrating method usefulness in the context of river restoration monitoring.
- Discussing the pitfalls of river restoration monitoring in terms of when you complete your monitoring (i.e. what will it tell you?).
- Considering the need to prioritise your monitoring aspirations from the beginning of the project.
- A series of case studies as supporting evidence.

1.4 A living document

This guidance is a „starting point". It will be updated as new methods are developed and used and monitoring is completed. Furthermore, whilst this guidance includes some case studies, in the future it will include more examples of the success of all types of monitoring.

As a user of this guidance the River Restoration Centre would encourage you to keep in contact with us so that we can add new methods and projects to ensure it is kept up to date.

2. Document summary and user guide

2.1 Why use this guidance?

Monitoring of river restoration projects has, in the past, tended to be „ad hoc‟ with little thought given to how the process fits with the project design, implementation, people‟s time commitment and the time required to analyse the information collected.

As a result, river restoration monitoring, even when completed, is rarely adequate to measure success or failure since project objectives are not sufficiently specific or targeted towards delivering any measurable outcomes. Improving monitoring will allow practitioners, stakeholders and other parties interested in river restoration to assess the optimum and most cost-effective methods to use for their particular requirements.

This guidance should enable funders and managers to set up a monitoring strategy from the beginning of a project that will then be able to answer specific questions, including: „how can you demonstrate that a project has achieved its aims and objectives?‟.

A summary of the key processes which need to be considered when developing a monitoring strategy, with links to the relevant parts of the documents, is provided in ***Section 2.8***. This is then translated into a simple flow diagram ***(Figure 2.1)*** showing how to get to a point where you can implement your monitoring strategy.

2.2 Putting your river restoration project into context

River restoration projects will require consent from a statutory organisation and will need to work within the regulatory framework and policy. ***Section 3.2.3*** provides links to where to find more information on current legislation.

In terms of the monitoring, however, it is essential that there is an understanding of the water and/or sediment quality and quantity in your river, since both can have a significant impact on project objectives. This guidance provides information about what to look for in your river and where to find further advice, to help achieve realistic expectations.

2.3 What is your project aiming to achieve?

Monitoring a project and demonstrating success is firstly reliant on a systematic assessment of the project aim(s) and specific target(s). By defining clear, specific and measurable project objects appropriate for your river type, there is more chance that resources can be applied to address specific questions (i.e. monitoring resources can be allocated as an important and integral part of a project at the beginning).

Many projects become difficult to monitor simply because it is not clear what the project is trying to achieve. For example, the main aim of removing a weir might be to improve spawning habitat and the mobility of adult fish, but it will also have a benefit for aquatic and margin-dwelling macro-invertebrates. In terms of understanding what you may wish to monitor, it is likely that some or all of these aspects should be considered (depending on resources). A similar assessment can be completed in terms of physical processes, with in-channel feature formation and the changes in the local river-bed topography being key areas of interest.

2.4 Understanding the links between physical and biological processes

River restoration can only be successful where it has taken account of both the physical factors (i.e. the habitat types such as pools, riffles, berms etc and how they are formed) and the biology (i.e. what species are already in your catchment, can they get to the newly restored reach and what habitats do the species need?). In order to achieve success it is also essential to understand the existing characteristics of your catchment and their impact upon your restoration opportunity; hence, „putting you river in context" becomes a very important early aspect of your river restoration and the monitoring process.

2.5 Determine your 'Specific and Measurable' objectives

The message here is be clear about what you want to achieve for your river restoration project and what aspects you need to know more about. Consider a project where the stated aims are to *„improve the wildlife and work with natural processes"*. Since there are no direct and unequivocal measures of these outcomes, it would be impossible to justifiably demonstrate the success of such a project. Hence the need for defining Specific and Measurable objectives that can be defined as Achievable, Realistic and are Time-bound in terms of the length of the monitoring period and which season should data be collected (following the SMART mnemonic fully explained in ***Section 4***). How to achieve this is outlined as part of the process in these guidelines.

2.6 Appropriate level of monitoring for your project

Monitoring is an extremely important part of a river restoration project that can help increase understanding and also identify future management needs. However, if not carefully designed, it can become resource (time, money and people) heavy. By understanding aspects of your river size and type, the assessment tool/technique (or suite of techniques) you are planning to use and the specifics of what you want to understand, it is then possible to decide the level of resources you need for monitoring. Prioritising monitoring aspirations based on linking to project objectives and funders requirements should also be a key element of the planning process. This will help to define what is feasible in terms of the project budget and possibly persuade funders to contribute more towards the costs of monitoring.

2.7 Which monitoring techniques to use

There are many techniques available. This document provides advice on the different types of techniques and what they might tell you, as well as what use can be made of relevant monitoring already routinely carried out within your catchment. It also identifies the types of techniques that can be used by local groups compared to those that realistically require a high level of expertise to collect data and interpret it in a meaningful way.

2.8 How to use this guidance: a step by step outline from objectives to delivery

The following provides a summary of the key areas covered in this document. It also acts as document map to identify where specific information can be found. ***Figure 2.1*** provides a flow diagram of how to deliver an effective monitoring strategy that is relevant to your river, techniques to be applied and available resources.

SUMMARY OF KEY PROCESS AND COMPONENTS FOR DEVELOPING A MONITORING AND APPRAISAL STRATEGY FOR RIVER RESTORATION (See also Figure 2.1)

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1. Do you understand the fundamental characteristics of your river?

YES *– go to 2*

NO *– refer to further information and/or seek expert advice*

Think about:

- Hydrology – how much water (low and high flows), how variable?
- Water and sediment quality – is it good, poor or bad and what chemicals are present?
- Sediment - how much have you got and what type? It the sediment being mainly transported, eroded or deposited at your potential project site?
- Morphology – how has your river been modified from its natural form?

Further information in document:

- ***Section 3.2.1*** and ***5.1***
- Figures and examples - ***Figure 5.1***
- ***Appendices 5, 6*** and *7*

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2. Is your proposed project likely to lead to an improvement in your river system in line with your aspirations, given its current hydrological, water quality and sediment situation?

YES *– go to 3*

NO *– refer to additional information; consider improving aspects of hydrology, water quality and sediment as necessary; focus monitoring on one or more of these aspects to demonstrate improvement of any interventions designed to improve these aspects (see also* ***Appendix 1****).*

Think about whether water quantity, quality and sediment will contribute to, or limit, some or all of the following:

- Kick-starting and maintaining natural river processes and forms (e.g. bank erosion, pools, riffles, vegetation berms, etc.) and hence provide a diversity of habitat niches?
- Supporting a wide a range of native fauna and flora appropriate to your river system?
- Encouraging the formation of a range of habitats for a specific species and its life cycle stages?
- Have you considered the effect/benefit in terms of achieving the Water Framework Directive targets of Good Ecological Status (GES) or Good Ecological Potential (GEP) (see ***Appendix 1***)?

Further information in document:

- ***Section 5***
- ***Appendix 1***

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3. Can you define 'SMART' project objectives?

YES *– go to 4*

NO *– refer to additional information; ask for additional expert advice (e.g. scoping study of options)*

IT IS ESSENTIAL TO CONSIDER INTEGRATED SMART PROJECT OBJECTIVES THAT CONSIDER BOTH THE ECOLOGY AND THE PHYSICAL PROCESSES

Think about:

- Is the main aim of your project to improve the physical processes of the river or increase the biological diversity of your section(s)?
- If your focus is to increase river forms and processes, what will be the benefit for the ecology (specific fauna and flora and, where appropriate, part(s) of life cycle(s))?
- If your focus is to increase ecological (habitat(s)) diversity for a range of fauna and/or flora which parts of the life cycle are you aiming to restore for and what physical river features are you expecting to form to support this?

- Are your objectives:
    - Clear (Specific)?
    - Quantifiable (Measurable)?
    - Achievable, Realistic and Time-bound?

Further information in document:

- ***Sections 4*** and ***5.2***
- Figures and examples - ***Figure 3.6*** and associated examples***; Figures 5.9 to5.11***
- ***Appendices 4*** and ***8***

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4. Based on project scale and risk (see *Section 6*), can you determine the amount of monitoring necessary to answer questions about your proposed river restoration?

YES *– go to 5*

NO *– identify what you don"t understand, refer to further information, carry out additional research or if necessary take additional expert advice*

Think about:

- Frequency of the use or your selected restoration technique in your catchment
- Frequency of uses across all catchments
- Understanding and defining your catchment type
- Evaluating the risk of failure of project (existing evidence)
- Refer specifically to risk and size diagrams and process in ***Section 5***
- What monitoring has already, or is currently, being done and by whom (e.g. Rivers Trusts, angling clubs, water companies etc.)

Further information in document:

- ***Section 6***
- Figures and examples ***- Tables 6.1 - 6.4***; Examples in ***Sections 6.3.1***
- ***Figures 6.1*** and ***6.2***

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5. Can you set your SMART monitoring objectives to answer your restoration project questions?

***YES** – go to 6*

***NO** – use examples and information in this document to help you formulate your objectives.*

Think about:

- What evidence of success already exists?
- What are your resources (people and budget)?
- What pre-project data you have or can collect?
- Do you have restrictions on timescales for delivery of monitoring outputs?

Further information in document:

- ***Sections 3.1***, ***3.2*** and ***6.4***
- Figures and examples - Example in ***Section 6.4.2***
- ***Appendix 4***

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6. Do you need to prioritise your monitoring?

***YES** – evaluate your resources and identify the most important aspects to monitor*

***NO** – go to 7*

Think about:

- What is the most important aspect to understand (this might be 'to increase scientific evidence' or 'satisfy specific stakeholders''/funders'' requests')?
- What are your resources (people, time and budget)?

Further information in document:

- ***Section 6.4.2***
- Figures, examples and tables - ***Table 6.5***

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7. Select your appropriate monitoring techniques. Are you confident that your chosen suite of monitoring methods can demonstrate project success related to your project objectives?

Think about:

- What is the most important aspect to collect information on for your project (this may be related to increasing scientific evidence or specific stakeholders/funders requests, for example)?
- Timescales - how much time for monitoring (years and number of data collection periods in year)?
- Resources (budget and people),

YES *– implement your monitoring strategy*

NO *– revisit your project and monitoring objects and resources. Redesign accordingly*

Further information in document:

- ***Sections*** *7* and ***8***
- Figures, examples and tables - ***Table 7.1***
- ***Appendices 4*** and ***8 to 13***

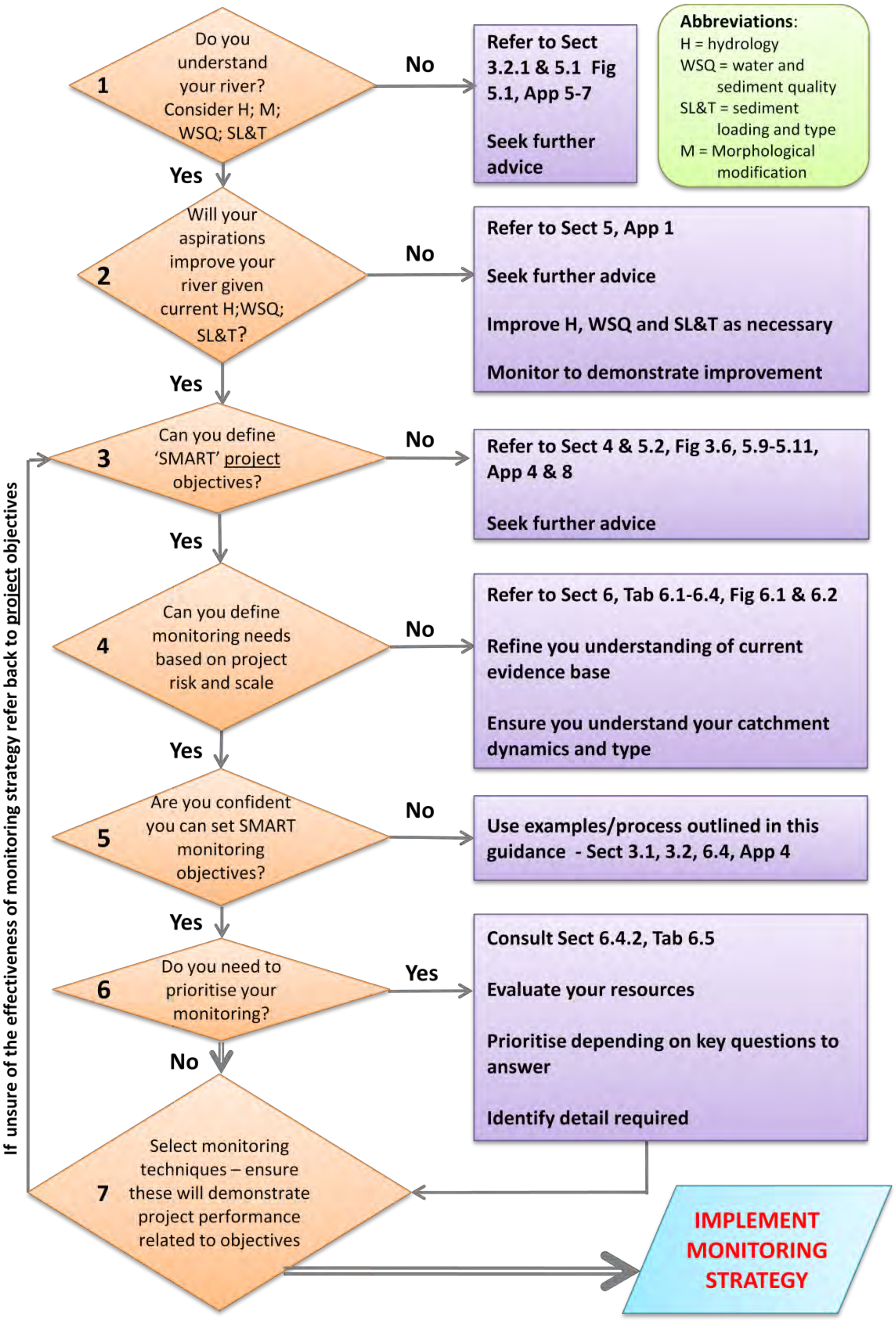


Figure 2.1 Flow diagram of monitoring process – read in conjunction with summary above

3. The context: evidence, your river and policy

3.1 What does the literature tell us?

A full assessment of the available scientific literature is included in ***Appendix 3***. A précis of this is provided below.

The benefit of river restoration (including connection to the floodplain) work, needs to be assessed over both the short and long term to determine the degree of scheme success. Ideally monitoring should be carried out before and after the project implementation for both the affected reach (i.e. the reach where the restoration work was carried out) and a control reach (i.e. one where no work was carried out and one which is also not affected directly or indirectly by the works). In order to carry out such an assessment a combination of qualitative and/or quantitative monitoring needs to be completed but determining the appropriate mix (i.e. where to concentrate effort) requires a clear set of objectives.

It is clear from the literature that river restoration and rehabilitation work generally lacks the evidence to demonstrate ecological and hydro-morphological benefit thus the development of technology and techniques has rather outpaced the supporting science. Most of the evidence is based in the USA where much river restoration began. What monitoring there is most commonly focus on the physical changes of the river rather than identifying specific biological effects.

In general, monitoring is not the norm for enhancement and rehabilitation projects, and so there is a very limited pool of information from which to draw. Where monitoring is undertaken, appraisal is often hampered by the lack of a fully developed concept of the desired project outcomes. When considering specific objectives which may be assessed by monitoring, the complex ecological responses and the variability in measurable ecosystem components are widely discussed issues and need to be considered when setting up a monitoring protocol. Selection of reference sites is recognised as important, and it has generally been suggested that restoration monitoring is best targeted at demonstrating the formation of different features through natural processes. These features and processes may support various habitats – it is preferable to focus on these rather than any specific habitat. The latter rarely demonstrates restoration benefit at a chosen monitoring site unless very a specific formation is met at that point. Under a dynamic river system, this is unlikely to occur.

A question of scale

The spatial extent and period of monitoring must be determined on a case-by-case basis, and depends on the aspects being measured. The spatial extent of data collection in these highly variable systems may require comprehensive coverage and there is a need to pay close attention to the wider context when planning monitoring.

How to proceed?

Beyond practical requirements for adaptive management and feedback to the design of projects and techniques, funding mechanisms and policy drivers increasingly require demonstration of success. Guidance on the monitoring of river restoration is very rare and Phil Roni"s book „*Monitoring Stream and Watershed Restoration*" (2005) is perhaps the only comprehensive document available. The current document (PRAGMO) therefore, building on the frameworks developed in Mant and Janes (2008) and England et al. (2008), represents a significant step forwards in addressing this need. It keeps practitioners in contact with the wide-ranging expertise related to this necessarily interdisciplinary business of river restoration.

3.1.1 Non-academic cited information

There are a number of articles which refer to river restoration monitoring but are not necessarily cited in academic literature. These provide a valuable source of information. This type of evidence is often referred to as „grey" literature and these sources are listed in the references ***Section 12.2*** under a separate heading.

3.1.2 Effective monitoring

River restoration monitoring needs to demonstrate that project objectives have been achieved. Thus, SMART objectives must be set early on in the project as discussed in Roni (2005). The monitoring results can then be analysed to increase the evidence base for restoration schemes and help determine which techniques are most successful, where, and for which objectives. In addition, continuous monitoring can identify where projects may need future adaptation under specific environmental conditions, which makes up an element that is generally referred to as „Adaptive Management" (see ***Appendix 2***, for further explanation and ***Figure 3.1*** below).

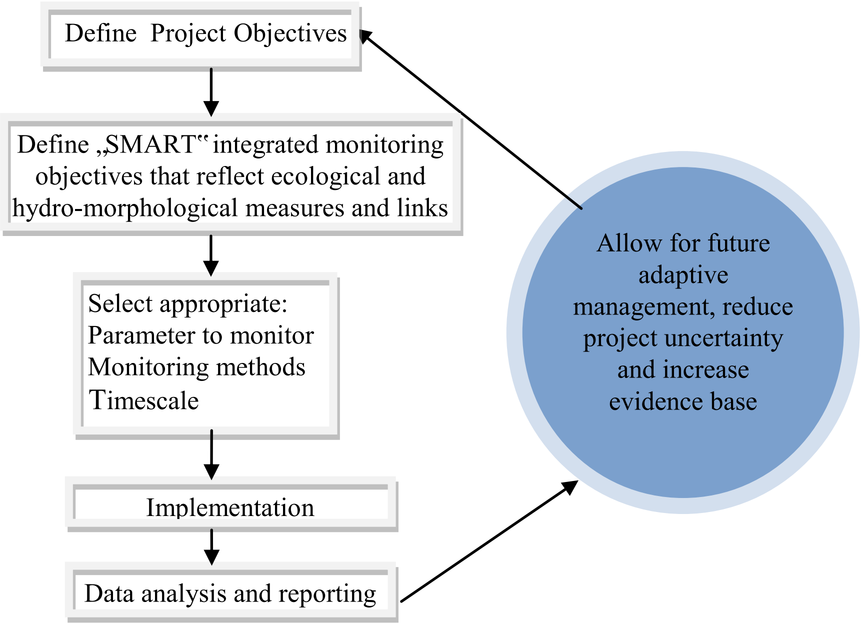


Figure 3.1 Diagram showing the main steps for achieving monitoring and analysis of a river restoration project (adapted from Roni 2005)

Significantly:

To appraise river restoration projects, SMART objectives should be set at the scoping (or preliminary) phase and these must be appropriate for project aspirations.

Objectives at this stage will help to define success criteria and provide a clear indication of financial and staff time commitment.

It is at this stage that crucial baseline monitoring should be collected and/or collated from existing data sets if they exist in a form that is likely to answer project objective(s).

The detail of the monitoring strategy is defined in conjunction with the detailed design phase and before construction so that monitoring can be implemented concurrently.

A clear decision about the amount of project appraisal appropriate in the early stages, should result in more effective post project monitoring to increase the evidence base of project success or failure and identify the need for minor technical adjustments through adaptive management or updated technical design.

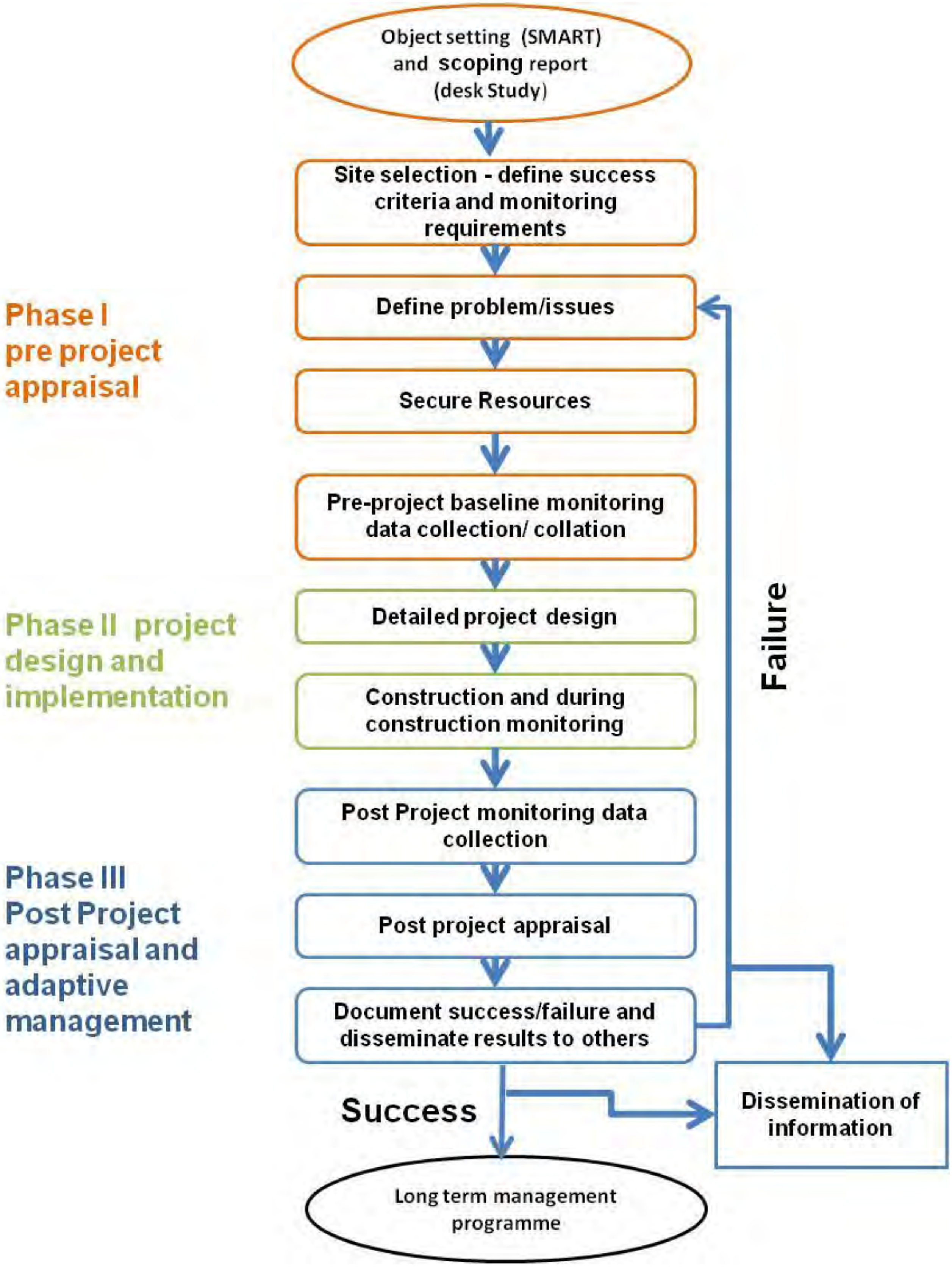


Figure 3.2 Flow Diagram of the Restoration Process Adapted from Lydia Bruce-Burgess's PhD Thesis (2004)

3.2 Understanding your Section of river

3.2.1 Hydrology, sediment and water quality

Before making any decision about what to monitor, or indeed what river restoration method is appropriate, the practitioner must have a good understanding of the hydrology, sediment load and the water quality of the watercourse since all can significantly affect both ecology and hydro-morphology elements. Understanding these aspects in your catchment is critical in terms of setting realistic objectives (***Section 4***) and determining your monitoring strategy (***Section 5***).

The key aspects to understand are as follows:

Water and sediment quality has a major influence on invertebrates (including fish) and aquatic plants success. Many species are intolerant of seriously polluting heavy metals, often associated with road runoff, but biological oxygen demand (BOD), dissolved oxygen levels (DO), phosphorous (P) and nitrogen (N) levels will also impact biodiversity abundance and diversity. These and other chemical constituents can be transported (and in the case of sediment also stored) within the watercourse. How and when this occurs is dependent on the river sediment and catchment type and flow regime.

Figure 3.3 Example of poor water quality from agricultural runoff

Sediment loading is influenced by in-channel erosion and deposition processes. Sediment is also transported into the watercourse in a number of ways. The type and amount of sediment is dependent on landuse (e.g. ploughed fields, deforestation, urbanisation, mining), and the mechanisms by which it enters the watercourse which can be both natural and artificial (e.g. underlying geology through to the drainage network distribution). The extent and type of sediment can have a major impact on the success of a river restoration project; sediment inputs from the sub-catchment should be considered.

Figure 3.4 Large sediment inputs increased by change in land management upstream

Flow regimes changes can significantly affect invertebrate species diversity; water-boatman, ramshorn snail and flatworms, as examples, will be dominant in slower, low flow conditions, as opposed to species which prefer fast flowing water such as most species of stone-, caddis- and mayfly. Often flow change is as a result of over-abstraction or in-channel impoundments, which affect the natural physical river process. Places which were originally fast flow streams may become silt ridden with a resultant decline in the fauna.

Figure 3.5 Mayfly larvae found in faster flowing water

3.2.2 Developing SMART Interrelated Objectives

In some circumstances an assessment of the hydrology, sediment and water quality may indicate that implementing physical river restoration techniques will not, on its own, provide ecological gain. In such cases, it may be preferable to rectify these aspects first and focus monitoring efforts here. More often, however, understanding the baseline hydrology, sediment and water quality are important to understand in terms of defining river restoration project success limitations. This type of information can usually be obtained from consulting the responsible environment agency (EA/SEPA/NIEA) and sources outlined in the appendices to this document, though an understanding of sediment dynamics may require more bespoke assessment. ***Figure 3.6*** maps out some of the influences of these fundamental drivers on aspects which may be monitored and should help define project objective(s) which aim to improve both ecology and hydro-morphology. Both of these are sub-divided based on habitat requirements and associated forms and processes, respectively.

Having gained an understanding of the 3 key aspects of hydrology, sediment and water quality, it becomes feasible to think about what are Specific, Measurable, Achievable, Realistic and Time-bound (SMART) objectives, details of which are outlined in ***Section 4*** of this guidance.

It is essential to recognise the interrelationship between the ecological and hydro-morphological processes. A restoration project is often considered either in terms of restoration of natural forms and processes or improving biodiversity. Usually river restoration starts with the premise that natural process change is necessary to achieve a specific habitat function. However, whilst in some cases restoring morphological diversity and dynamism is the focus, on other occasions it is specifically to address a lost habitat; in such cases, it may be necessary to restore a particular physical feature.

Figure 3.6 demonstrates these linkages and enables the user to think about what a project is setting out to achieve either from a natural process or biodiversity perspective. It ensures that both aspects are considered as part of the objective setting evaluation. The two examples associated with Figure 3.6 demonstrate how an objective can begin to be defined that links the ecological and hydro-morphological elements together.

This process is designed to help the project manager think about the key aspects of the river restoration projects and what it is setting out to achieve and to recognise the inherent complexity.

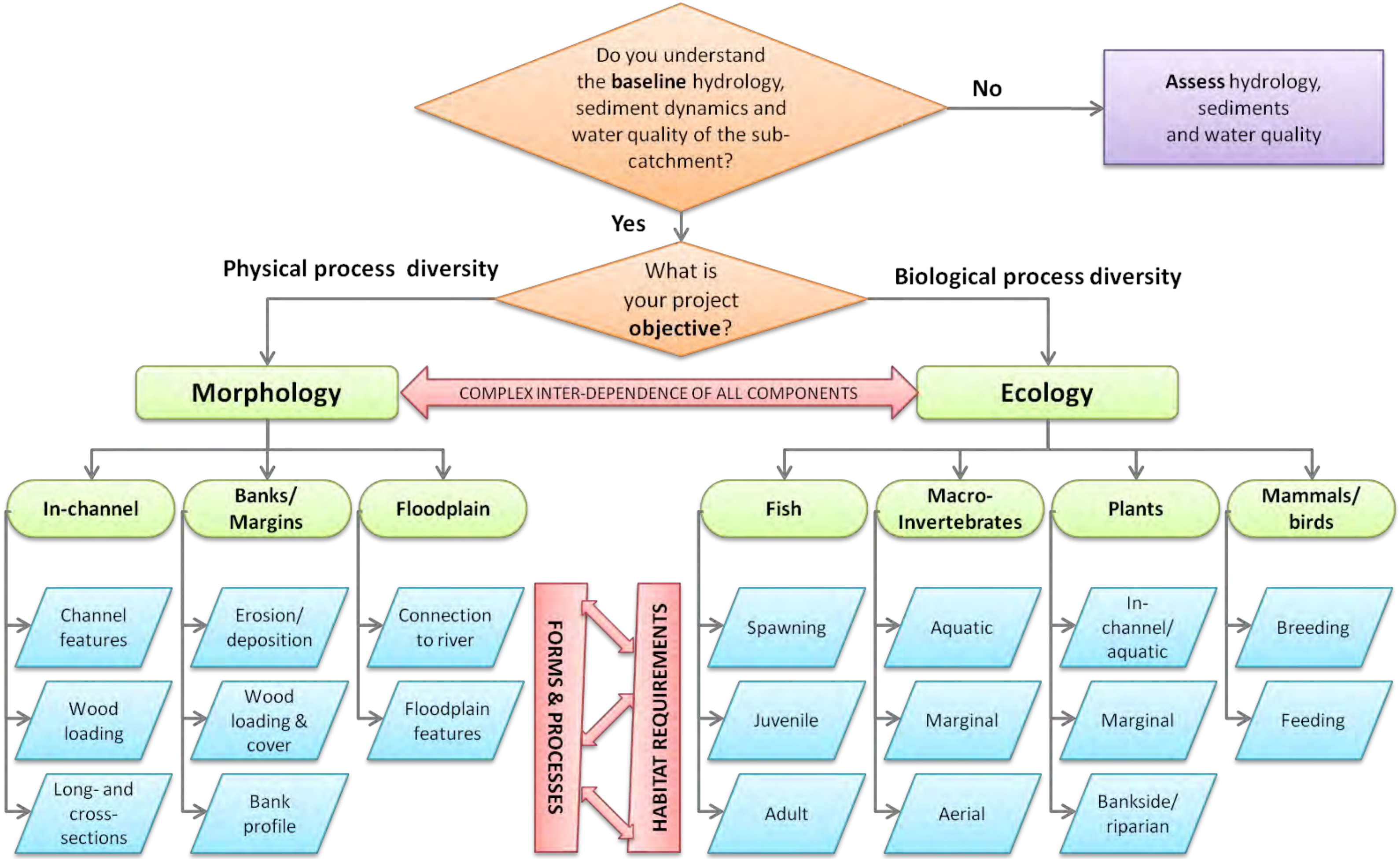
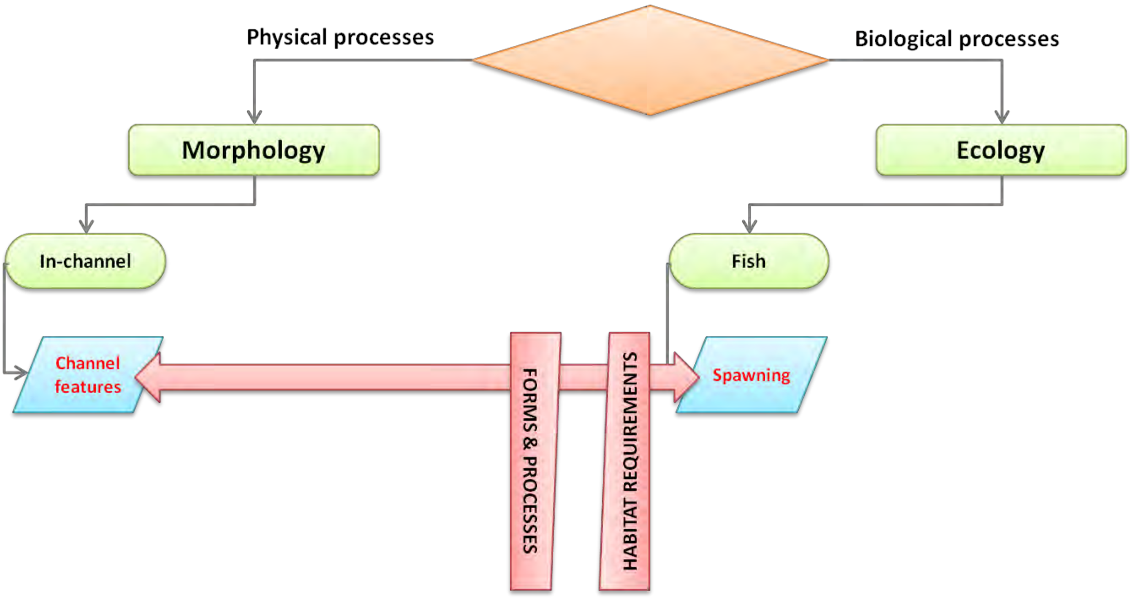


Figure 3.6 Monitoring Decision Flow (see examples below)

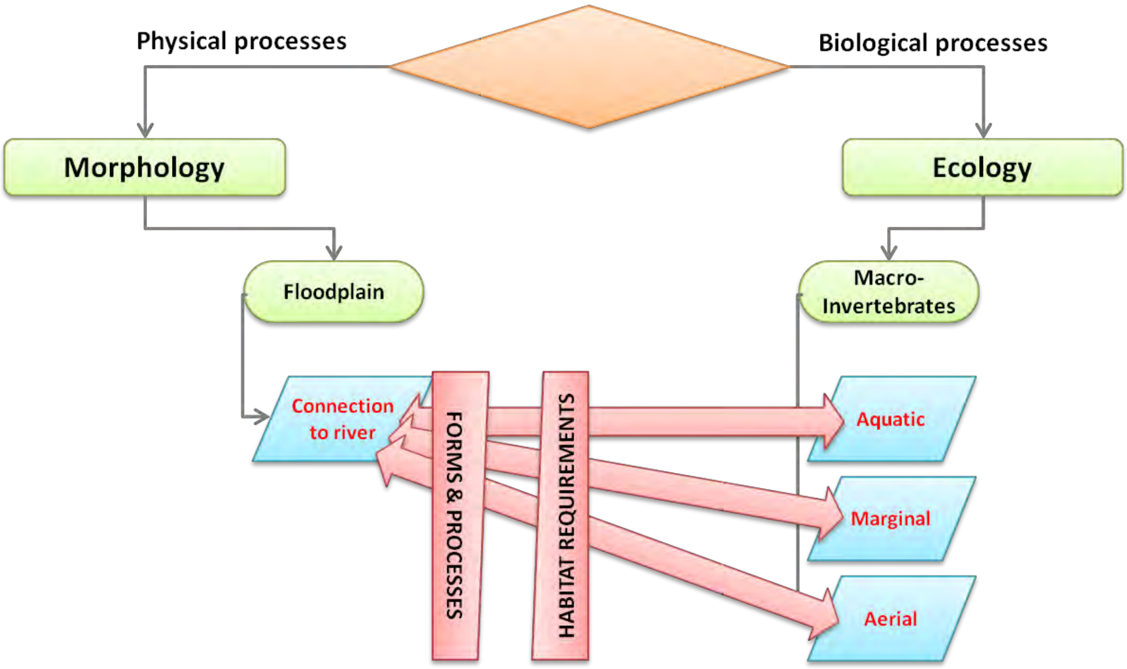
Example 1:

Aim: Increase salmonid spawning and egg survival by introducing gravels and narrowing the river to increase flow velocity variability.



Example 2:

Aim: Restore floodplain connectivity to increase habitat for all invertebrate life stages and types.



3.2.3 Policy and legislation context

It is important to be aware that there are a number of environmental policies and legislative instruments, which vary across the UK countries. Whilst the Water Framework and Habitats Directives are among key drivers for river habitat enhancement across Europe there are, in addition, a number of country-specific regulations for England and Wales, Scotland and Northern Ireland. The following provides information about where to find additional information, but this is primarily referred to in this document so that those aspirations of river restoration are aware that the appropriate statutory organisations should be approached at the inception stage to ensure the smooth running of the project.

A summary of many regulations can be found on the NETREGS site (http://www.netregs.gov.uk/netregs/legislation/current/default.aspx) that identifies all the new environmental regulations for England, Scotland Ireland and Wales during the past 12 months.

Further ***Scottish***-specific information can be found on the easily accessible SEPA website: http://www.sepa.org.uk/water/water_regulation.aspx and the SNH website http://www.snh.gov.uk/protecting-scotlands-nature/protecting-nature/water-framework-directive, relating specific projected areas to the WFD. Most importantly, in the context of river restoration, are the Water Environment"s (Controlled Activities Regulations (2005)) under which all river-related projects must comply. Given the country"s strong interest in its fisheries, there are also a number of protection acts including the:

- Sea Fisheries (Shellfish) Amendment (Scotland) Act 2000
- Salmon and Freshwater Fisheries (Consolidation) (Scotland) Act 2003
- Aquaculture and Fisheries (Scotland) Act 2007

Further ***Northern Ireland*** specific information can be found on the Rivers Agency website: http://www.dardni.gov.uk/riversagency/index/rivers-conservation/european-water-framework-directive.htm and the Northern Ireland Environment Agency website: http://www.doeni.gov.uk/index/protect_the_environment/water/water_framework_directive_.htm . In general however, the Water Framework Directive is being used as a mechanism to deliver environmental gain.

Further ***England and Wales*** specific information can be found on the Defra website at http://archive.defra.gov.uk/environment/quality/water/wfd/ and the Natural England website pointing to their position on the WFD http://www.naturalengland.org.uk/ourwork/position/water/waterdirective.aspx and in terms of conservation law at: http://www.naturalengland.org.uk/regions/south_east/ourwork/standingadvice/protectedspecies/standingadviceconsultation/casestudies.aspx

4. Project Objective Setting

As shown in ***Figure 3.1***, objective setting is of 2 types.

1. Overall project objectives: These help the project team have a clear focus regarding project deliverables. It will also identify what is the most important approach to monitoring in terms of timescale, which aspects to concentrate upon and details necessary to provide conclusive results.

2. Monitoring objectives: This process will help ensure that monitoring is designed to answer specific questions. This may mean that some of the project objectives do not warrant further assessment, whilst others may result in more than one monitoring objective being set.

In both cases, it is recommended that adopting the well defined „SMART" approach will help ensure that sound objectives can be set. More details of this approach can be found in ***Appendix 4*** but in essence the idea is to define objectives which are:

- **S**pecific (concrete, detailed, well defined),
- **M**easureable (quantity, comparison),
- **A**chievable (feasible, actionable),
- **R**ealistic (considering resources), and
- **T**ime-Bound (a defined time line).

4.1 Setting SMART Project Objectives

4.1.1 Stage 1 – Define the Aim

Firstly determine the overall aim of the project. For example:

Restore floodplain dynamics by reconnecting to the river
Increase in-channel habitat heterogeneity (range and diversity)
Increase salmonid spawning opportunities upstream of a weir

You now know what you wish to achieve, but this does not define how you are going to do this or measure success.

4.1.2 Stage 2 – Specific Project Targets

This requires the overall aim to be defined as specific targets. These might include some or all of the following:

Note: These are only suggestions and not an exhaustive list.

Aim: Restore floodplain dynamics by reconnecting to the river

- Cut a new meandering river at a new bed level to encourage a more natural floodplain connectivity flow regime.
- Plant up the floodplain.
- Ensure flood risk to any properties is not negatively affected.

Aim: Increase in-channel habitat heterogeneity

- Increase habitat diversity for macro-invertebrates by improving flow variability.
- Create refuge areas for fish.
- Encourage development of classic chalk stream habitat.

Aim: Increase salmonid spawning opportunities upstream of a weir

- Remove weir structure to restore fish passage to upstream gravel beds.
- Narrow the river to maintain clean gravels in weir location.

You can now identify your key aim(s) and specific targets in terms of river restoration techniques

4.1.3 Stage 3 – Set SMART Objectives

Having identified aims and targets, SMART objectives can be set as shown in the examples below. By adopting this approach questions can be asked at this point in terms of how achievable it might be to:

a) Measure the outcomes of the projects

b) Define what is realistic both in terms of project size and available time/resources.

A, R & T: Determining what is *Achievable* and *Realistic* on your site, and over what *Timeframe*

The examples below identify *Specific* and *Measurable* aspects of project objectives, but the „*A, R* & *T*" of the SMART process should all influence every aspect of these, and apply more generically.

Some things to consider:

A What can be achieved should be determined from a review of evidence of success on other, similar sites to the one in question.

Seek advice, similar examples and perhaps develop some concept of „reference conditions" for what you are trying to achieve, either from literature or a nearby reach within your catchment which has had minimal human intervention.

R Consider carefully your available resources (money, people, and time) and factor in longer-term post-project management which may be necessary (requirements for this will be identified through the monitoring process).

Any major concerns of stakeholders which cannot be eliminated or circumvented may substantially limit what is possible.

T Not only do you have to consider the duration of the project works in order to allocate your resources, but the timing may be crucial.

Seasonality is a major consideration for aspects such as site access (stability of ground for supporting heavy plant); hydrology (bed and banks may not be accessible in high flows); ecological disturbance (e.g., a whole cohort of Salmon may be lost by digging up the bed during/just after the spawning season or bird nesting where floodplain work to be completed) and establishment of vegetation (to name just a few).

Note: The following examples are designed to help with the SMART process and do not cover every option, since targets and objectives MUST be site specific.

Example 1: Restoring a floodplain

Case: Opportunity to recreate meanders on a 2 km reach through open farmland in a lowland clay catchment, to increase connectivity with the floodplain. Floodplain can then be planted with new trees which, in time, should contribute woody debris to the channel and improve biodiversity. Properties nearby must first be flood proofed.

Main targets:

- Cut a new meandering river at a new bed level to encourage a more natural floodplain connectivity flow regime; this should also slow down the velocity locally an help attenuate the peak flows downstream.
- Plant up the floodplain.
- Ensure flood risk to any properties are not negatively affected.
- Increase habitat diversity.

SMART objectives:

Specific

Measurable

- Cut new meandering channel for target reach, to **increase** *channel length* by an **appropriate** *% of the original*, **increasing** *sinuosity*.
- Design new **bed level to increase** *frequency of out-of-bank flows*.
- Plant up **riparian zone** to increase *area of woody vegetation cover*, in **non-uniform patches**.
- Create **wet woodland in the floodplain** by planting with **native species found naturally in the catchment**,, **increasing** *area of woody vegetation coverage*, whilst maintaining **open areas**.
- Create **flood bunds** around **at-risk** properties, **set-back** as far as possible from the river, to maintain **at least current** *protection standards*.
- Increase **macro-invertebrate** *diversity* by increasing **channel and floodplain** *morphological variability* (e.g., **riffles, pools, glides, permanently and seasonally wet floodplain areas**).
- Increase *numbers* **and** *number of species* of **over-wintering wildfowl**.

Example 2: Increasing in-channel habitat

Case: Opportunity to increase in-channel habitat in a lowland chalk catchment. There is space to create some backwater habitat, but for most of the river, current agricultural land use means that options are confined to in-channel habitat enhancement options. Creating a mosaic of habitats for fish, macro-invertebrate, macrophytes and marginal vegetation are all equally important.

Main targets:

- Create refuge areas for fish.
- Encourage development of classic chalk stream habitat.

SMART objectives:

- Excavate **2 backwaters** of **at least 2 m** ***depth***, totaling **at least 50 m2 in** ***area***.
- **Increase** ***variability*** in channel ***width and depth*** by **reducing** ***cross-sectional area*** **locally** in **at least 8** locations, using **appropriate techniques such as brushwood mattresses**.
- **Increase** the ***area of river bed*** **covered by Ranunculus** spp.

Specific

Measurable

Example 3: Weir removal

Case: A 2m high weir, which is an obstacle to salmonid fish, is beginning to degrade in a flashy, high energy catchment with gravel-bedded channels. There is an opportunity to remove this weir. The amount and possible impact of extensive fine and gravel sediment accumulation behind the weir will need to be investigated. It is anticipated that additional work will be needed to narrow the channel where the weir pool is currently.

Main targets:

- Remove weir structure to restore fish passage to upstream gravel beds.
- Narrow the river to maintain clean gravels in weir location.

SMART objectives:

- **Increase** **total number** of **Brown Trout** ***spawning*** on **upstream** gravels **within two seasons**.
- **Increase** the ***total number*** of fish ***(abundance)*** passing through the reach **in November**.
- **Reduce** ***channel width*** **by 30%** for **60 m** upstream of weir location using **locally-sourced, tethered wood** (as a result of the project; i.e. **following groundworks completion**).

Specific

Measurable

Time-Bound

You are now able to establish the likelihood of success of the project, why specific techniques are to be used, what is the associated risk, and estimated time scales for completing the work, any constraints and approximate costs.

NOTE: Depending on available expertise and the type of project it may be necessary to seek expert advice in the form of a short scoping study to establish project risk, appropriateness of techniques and additional studies necessary.

5. Physical and biological process links and limitations

5.1 The importance of understanding your catchment’s hydrology, water quality and sediment

This section and the associated ***Appendices (5-7)*** provide guidance on the importance of considering hydrology, water quality and sediment issues in determining river restoration success as noted in ***Section 2.3.1***. *before* considering the options of any project.

> It is the particular characteristics of the **hydrology, sediment and water quality** which together are the *dominant factors* in the formation and maintenance of the **habitats** present in your river

Figure 5.1 (a sub set of ***Figure 3.6***) reiterates the importance of considering these aspects.

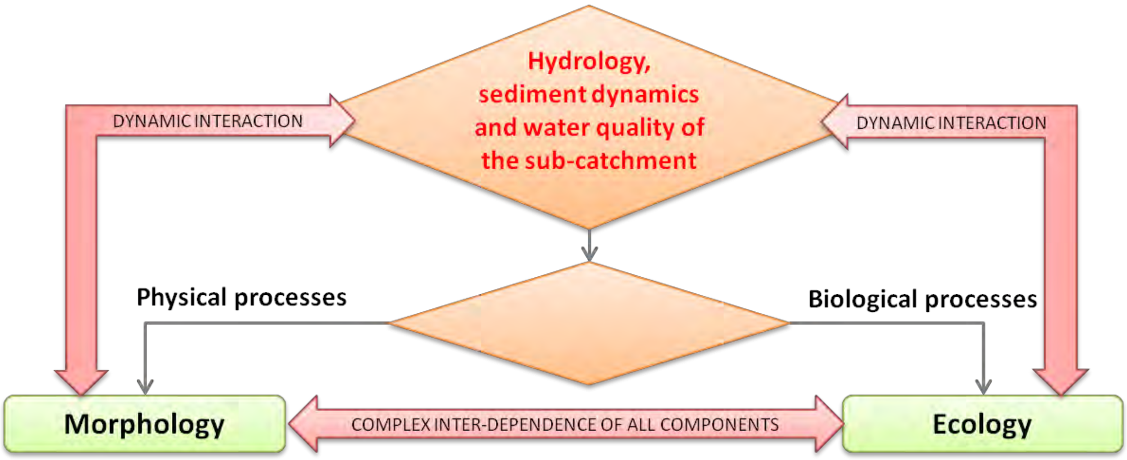


Figure 5.1: Influence of high level forcing components (hydrology, water quality and sediment dynamics) on morphological and ecological responses to river restoration (explained in more detail in the following section).

5.1.1 Hydrology

A detailed explanation of hydrology, as well as some key data sources, is given in ***Appendix 5***. In summary, the discharge (or flow) of a river is a function of the water‟s velocity and the cross-sectional area. Flow is measured in terms of volume rates, denoted as Q and expressed in terms of cubic metres per second or „cumecs‟ (e.g. 3.0 m ^{3} /s or 3.0 cumecs).

That is: $\boxed{Q = V * A}$

Where: Q= flow, V = velocity, A = cross sectional area (i.e. width x depth)

These are the most important but relatively simple variables to measure in terms of hydrology.

In terms of river restoration opportunities the following are important to note:

High (peak) and **low flows** may impose limits on how both the natural processes and biodiversity may respond to in-channel works. Appreciating these limits will help predict what is likely to happen and inform your monitoring needs.

Catchment response (i.e. the hydrological response to the dominant geology and soils) will allow you to estimate the above peak and low flows, as well as the difference between them and the seasonal dynamics. For example, in a heavily urbanized catchment the river will be „flashy" and likely to rise quickly and dramatically in response to rainfall, and fall rather quickly too. In a more permeable chalk catchment there is less immediate runoff and rainfall (having infiltrated into groundwater) and so will be released more gradually to the river.

5.1.2 Water Quality

Pollution, diffuse or from point sources, can also be a significant limiting factor on the kind of responses to restoration activities which can be measured especially in terms of ecological recovery. In broad terms these include the following (more details can be found in ***Appendix 6***):

Organic pollutants comprising both biological as well as chemical agents.

Eutrophication (i.e. enrichment of water bodies with inorganic nutrients such as nitrates and phosphates to the extent that algal blooms quickly develop. This vast biomass out-competes macrophytes, causes the collapse of food webs and dramatically depletes dissolved oxygen, particularly when it begins to decompose).

Acidification often associated with mine drainage.

Heavy metals (e.g. mercury, cadmium and lead) from heavy industry have long residence times and can accumulate in sediment which is important to consider if sediment is to be disturbed as part of the restoration scheme.

Thermal pollution may also be an over-riding limiting factor in freshwaters, again changing the species composition of affected ecosystems.

5.1.3 Sediment movement

The processes of erosion and sediment deposition are particularly important in the generation of habitat diversity in rivers and measuring this change and the physical/biological interaction is often a key component of the appraisal of river restoration activities.

Understanding your catchment influences (both natural such as **geology**, **hydrology** and **catchment response** to rainfall events) and human impacts (e.g. **land use**, **impounding structures** such as weirs etc) will increase the project success confidence. ***Figure 5.2*** provides some examples of the type of activities that can affect the frequency, quantity, type and distance of transport of sediment within the catchment.

Data sources to help define sediment effects in your catchment .

NOTE: Your local ecology or responsible agency fisheries officer can help you to understand the relevance of these documents if necessary.

River Basin Management Plans (RBMPs) provide an overview of sediment issues in specific catchments and are available through the EA, SEPA or NIEA. Pressures and risks maps due to sediment are included. Your local Environment Agency staff can talk you through these to help you understand them.

Proportion of Sediment-sensitive Invertebrates (PSI) index can determine whether or not the invertebrate assemblage is sediment tolerant, or intolerant and may identify whether excessive sedimentation is a significant issue. This data is available from the Environment Agency.

Sediment Matters is an Environment Agency handbook available in early 2011 with an associated e-learning package (Science Report SC080018/SR).

Guidebook of Applied Fluvial Geomorphology is a Defra Science Report FD1914, synthesizing several R&D projects, with associated e-learning package. It provides details on how to evaluate sediment, and where to look for additional information. The e-learning package provides you with an overview about understanding your catchment.

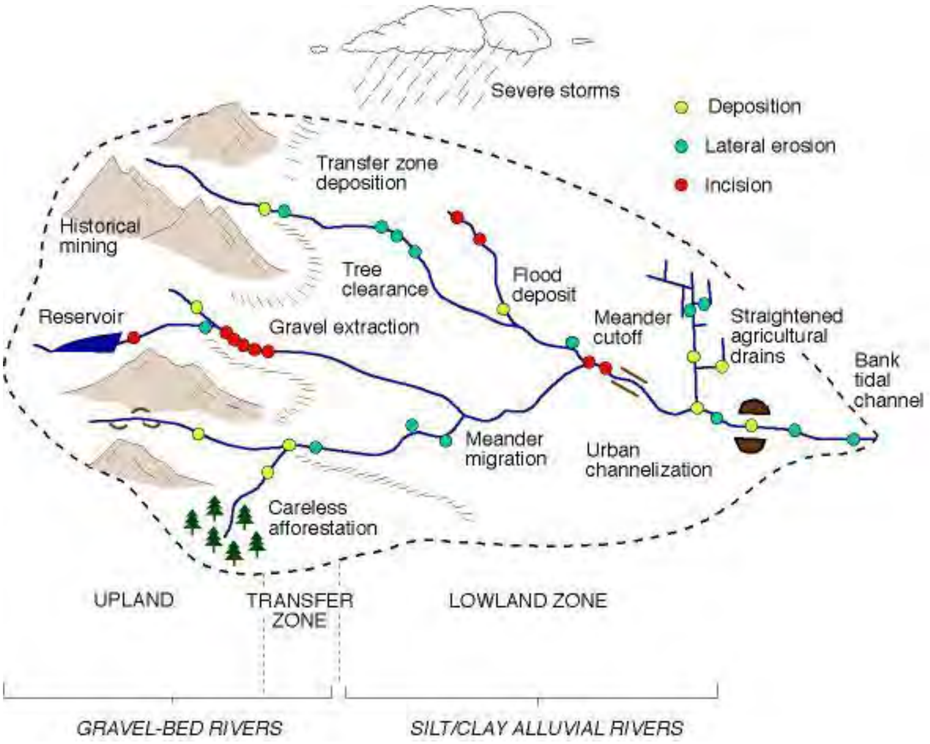


Figure 5.2 From Guidebook of applied fluvial geomorphology (Sear, Newson and Thorne - 2010)

Sediment changes and impact on ecology

Sediment type, location and transportation are an intrinsic part of determining river form and associated habitats. It is generally an increase of fine silty deposit that is detrimental to habitats. However, it should also be recognised that in some instances large deposits of boulders and gravels may be a problem (e.g. where there is sudden bank failure or release of gravel from an upstream source) where this interfaces with existing redds or freshwater pearl mussel beds. The following outlines some of the key elements of importance in this respect.

Fish

Changes in the fish community – some species are adapted to sediment-rich waters, others are not.
Smothering of spawning gravels, of particular impact on salmonids.
Changes in extent of bed-rooted vegetation through excessive siltation and the associated physical and biological habitat structure.
Turbidity, which reduces visibility for visual hunters and can directly damage some species‟ gills.

Invertebrates

Changes in invertebrate community.
Smothering of less mobile species such as bivalve molluscs (e.g. pearl mussels).
In-filling of gravel interstices (gaps between stones), and associated habitat loss.
Changes in plant communities which represent both food and physical habitat.

Plants

Changes in species and functional types present.
Changes in resistance to up-rooting in high flows.
Changes in substrate nutrient availability, as well as possible toxic effects of contaminants.
Floodplain deposition which may smothered plants (although conversely this may be a benefit in introducing new seed source and organic sediment).

Wetland Birds

Changes in prey type available.

5.2 Inter-Relations between Biodiversity and Physical Habitat

Figure 3.6 provides the framework for considering the physical and biological factors which interact in river ecosystems. The following section outlines some of the major interactions and relationships between these aspects in the context of river restoration. The importance of understanding these when deciding what should be monitored should not be underestimated - though many and highly complex, the more these interactions are considered, the more powerful your monitoring. In essence the more complex your physical habitat, the greater diversity of species you might expect (see ***Figure 5.4***).

5.2.1 Fish

Fish distribution is linked with the hydro-morphological characteristics of the river. Species, such as Bullhead, are indicative of fast flowing turbulent waters, whereas others (e.g. Bream) are found in much slower-flowing waters. This is true from the reach to the micro-habitat scale – even strong swimmers will always search out low energy zones such as margins, backwaters and the lee of boulders.

Fish will often move considerable distances up and down the river to meet habitat requirements of different life stages. Spawning may require suitable macrophytes or gravels; juveniles will require refuge from fast flows and predators; and for example different stages will feed on different types of invertebrates.

Figure 5.3 European bullhead; requires turbulent flows and stones for spawning (*Cottus gobio*) (courtesy of James Holloway)

5.2.2 Invertebrates

Invertebrates exist in a wide range of aquatic habitats from silted debris-rich pools to cobbles and boulders in fast flowing upland rivers (see ***Figure 5.5*** and ***5.6***). Channel form and flow are important factors in determining invertebrate habitat. For those invertebrates with an aerial stage, emergent plants are particularly important as a means of leaving the water, and so channel margins are a key factor.

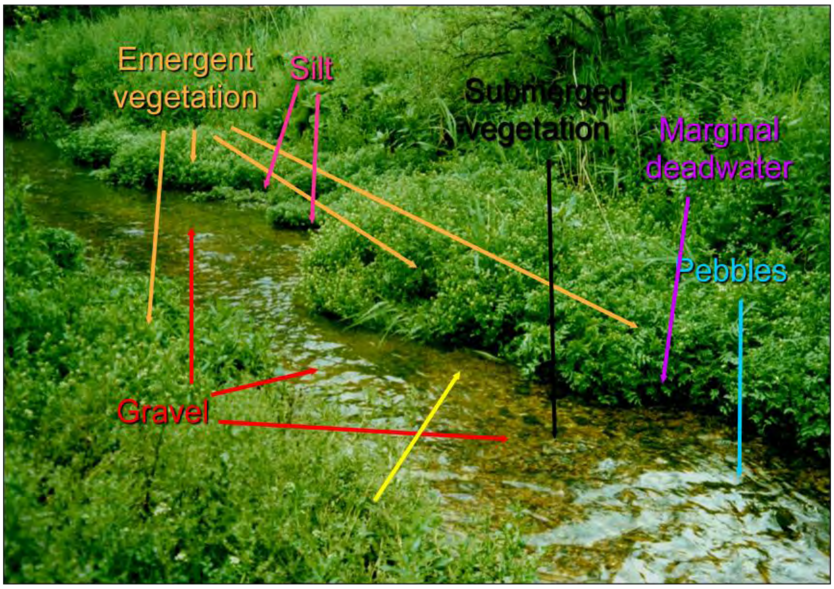


Figure 5.4 Various habitat conditions support a range of species (courtesy of Judy England)

Figure 5.5 Fresh water limpet *(Ancylus fluviatilis)* found in slow flow conditions

Figure 5.6 Caddis fly larva (*Sericostoma personatum)* requiring faster flow conditions to ensure they are not buried by fine sediment.

5.2.3 Plants

Plants exist in river channels, marginal areas, banks and the wider riparian zone and floodplain. Channel shape often determines plant habitat, dictating the water availability at any point on the bed whilst substrate stability is critical, with stable areas colonized much more consistently than unstable areas (see ***Figure 5.7***).

The presence and type of vegetation is a primary influence on habitat for all river biota, and particularly the invertebrates. As well as providing physical structure and influencing flows, plants are both direct and indirect (as a substrate for algae) food sources. In addition they provide cover for young fish to avoid predation, whilst many invertebrates lay their eggs within the plant complexes.

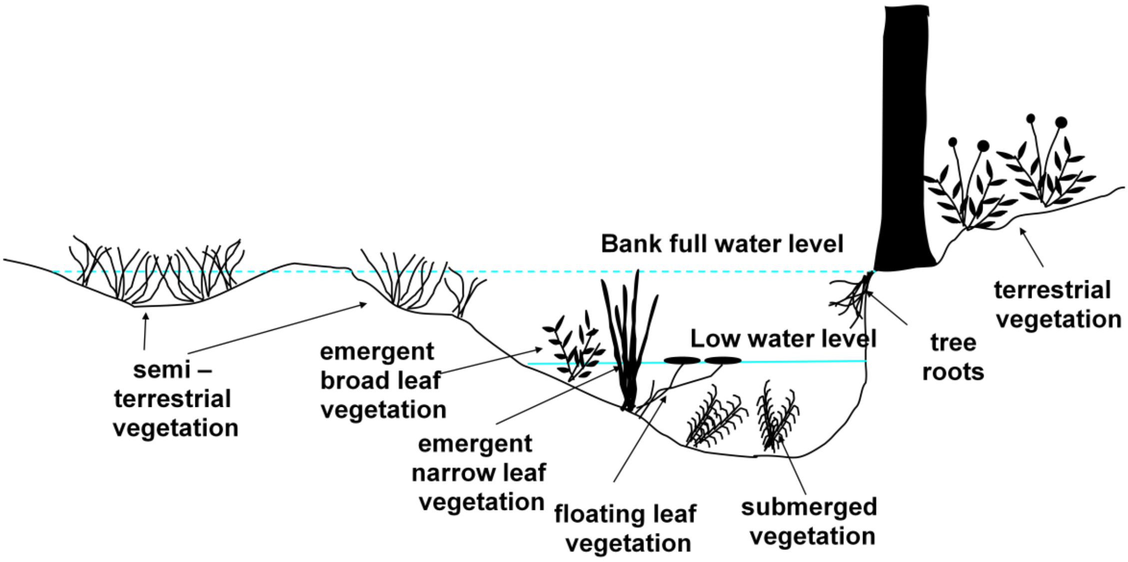


Figure 5.7 Interactions between generic vegetation types and location in a river cross-section (adapted from Judy England)

5.2.4 Mammals and Birds

Whilst there are no strictly aquatic mammals in UK rivers, those such as Otters (***Figure 5.8***) and Water Voles spend much of their lives in and around the water. For Otters, the rivers and streams provide food (fish) and river banks provide shelter and a corridor to move along often over tens of kilometres. Similarly, vertical banks provide the right conditions for Water Voles to burrow into and aquatic plants in the marginal and slower flowing areas provide food and nest material. American Mink is also now a key player in many river corridor ecosystems in the UK.

Numerous bird species rely on watercourses for food, nesting and shelter, and as habitat corridors. Their presence is dictated by the diversity of river habitats and the abundance of the associated species of fish, plants and invertebrates that are vital sources of food.

Figure 5.8 European Otter

5.2.5 In-channel Morphology

Habitat diversity appears to be the chief determinant of species richness in studied streams. Factors influencing habitat distribution include flow velocity, substrate and the presence of wood, detritus and vegetation. All of these affect the key macro-invertebrate assemblages which support higher levels in the food web.

Woody debris provides a food source, habitat structure and both resistance to erosion and local areas of scour. Debris dams also have a significant influence upon morphological process and ecology.

Water velocity at any given point has a direct influence on the macro-invertebrates present and similarly there is a relationship between velocity and substrate composition. Highest velocities are associated with peak „channel forming" flows which result in the most significant geomorphological activity.

Increases in the amount of silt and sand in a river lead to increased instability of the sediments, which often adversely affects fauna.

5.2.6 Banks and Margins

Though the importance of in-channel habitat may be clear, banks and margins often support the bulk of river biodiversity. Marginal vegetation is utilised by macro-invertebrates for egg-laying and emerging, and as a link between aquatic and terrestrial environments for many animals, thus acting as a focus for reproduction and recruitment as well as providing a refuge from high flows.

Riparian zones are also a source of leaf litter, and the structure of the community at a site has been shown to be significantly influenced by the amount of detritus present. This plant material influences habitat structure, but is primarily a food source for „shredder" invertebrates which are a key component of river ecosystems.

5.2.7 Floodplains

Floodplains are important to consider in the context of river restoration since they increase the structural diversity and provide habitats for a wide range of fauna and life stages. Linking the river to the floodplain has an impact on out of bank flows and ultimately, where sediment, water and nutrients are stored both over the short and longer term. Connection is also important for providing refugia for many species and feeding areas for over wintering birds. Some of these inter-relationships are shown in ***Figure 5.9*** below.

5.3 Interacting components – understanding the connections

The following ***Figures (5.10 - 5.12)*** are aimed at helping to understand the connections between the physical and biological processes. The 3 examples follow those outlined in ***Section 4*** and defined as SMART objective: a) Restore floodplain dynamics by reconnecting to the river; b) increase in-channel habitat variability; c) increase salmonid spawning opportunities upstream of a weir). The key point here is it to provide a check to ensure that all links are appropriate. Also refer back to ***Figure 3.6*** for a whole suite of options.

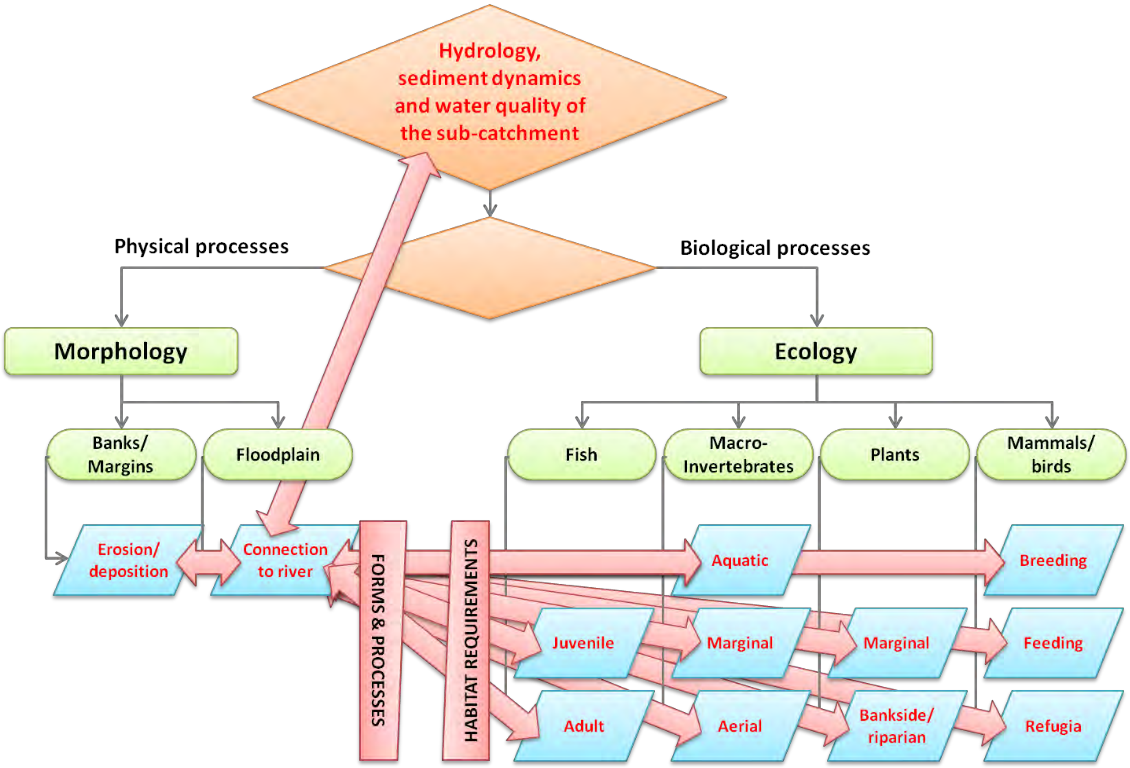


Figure 5.9: Diagrammatic representation of just some of the interdependencies affected by meanders and floodplain restoration.

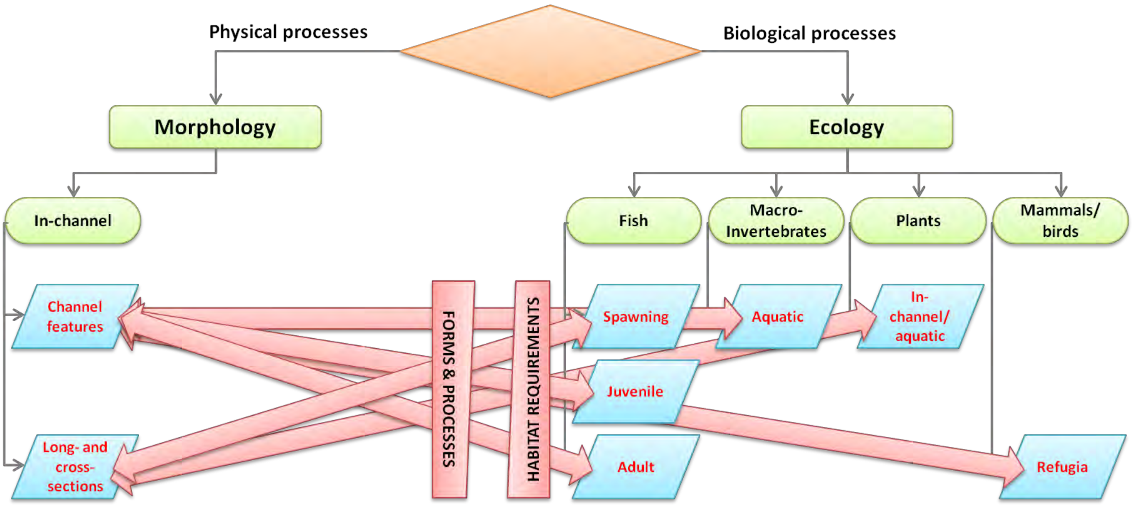


Figure 5.10: Diagrammatic representation of just some of the interdependencies affected by backwaters and narrowing in a chalk stream

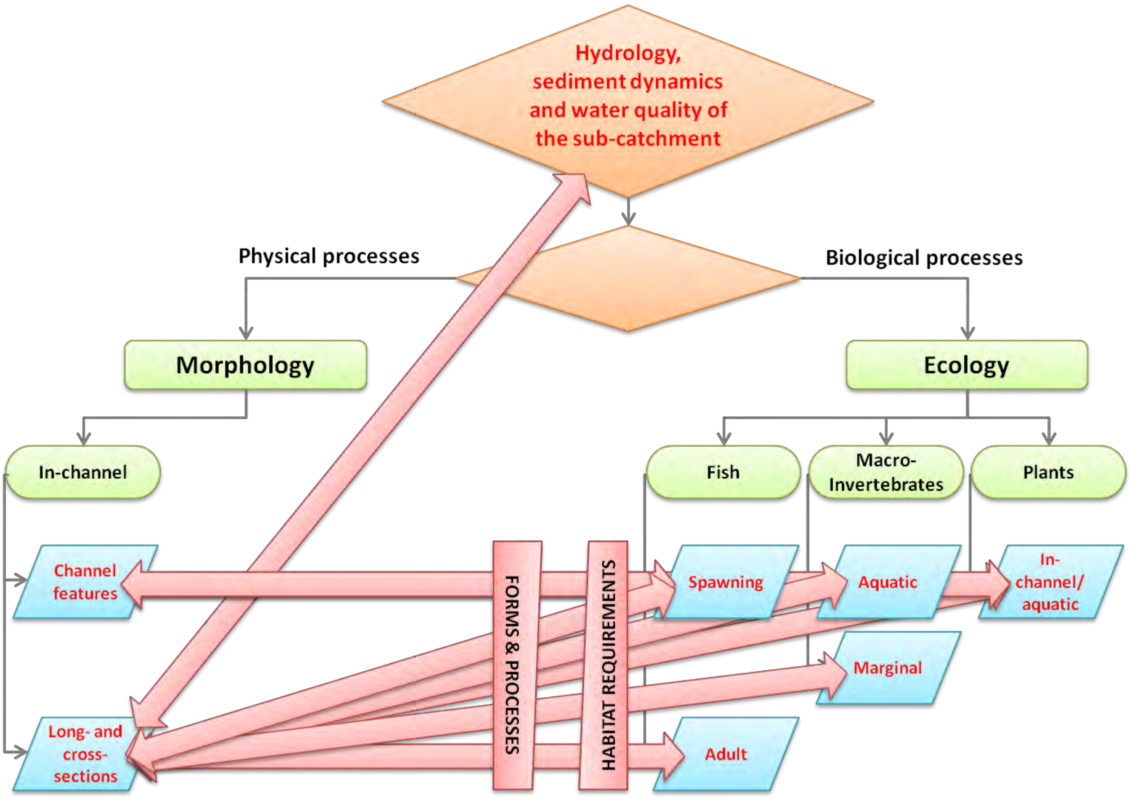


Figure 5.11: Diagrammatic representation of just some of the interdependencies affected by weir removal for fish passage to gravels

6. Determining monitoring objectives appropriate to project risk and scale

Having drawn up your project objectives and identified the associated ecological and morphological response elements, it is necessary to evaluate the „scale“ and „risk“ of the project. This will help to determine how much of your resources should be used for the monitoring aspect of your project.

Working through the matrices below (***Tables 6.1 – 6.4***), will help you with this process by considering all the key factors influencing risk. The overall aim is to identify into which box in ***Figure 6.1*** your project fits. This will help you decide whether your monitoring resources may be better used to fund small scale, low cost appraisal undertaken by a local community group or fishing trust, or instead should be used in conjunction with other resources to fund a highly scientific study. In some cases this may mean that the „ideal“ monitoring programme is not affordable, but the process will help to determine which elements to prioritise.

This is a tricky process, often requiring some expert judgement based on past experiences. If you cannot tap into local know-how, approach groups such as the River Restoration Centre, the The Rivers Trust, Rivers and Fisheries Trusts of Scotland or the Wild Trout Trust who should be able to provide contacts or advice.

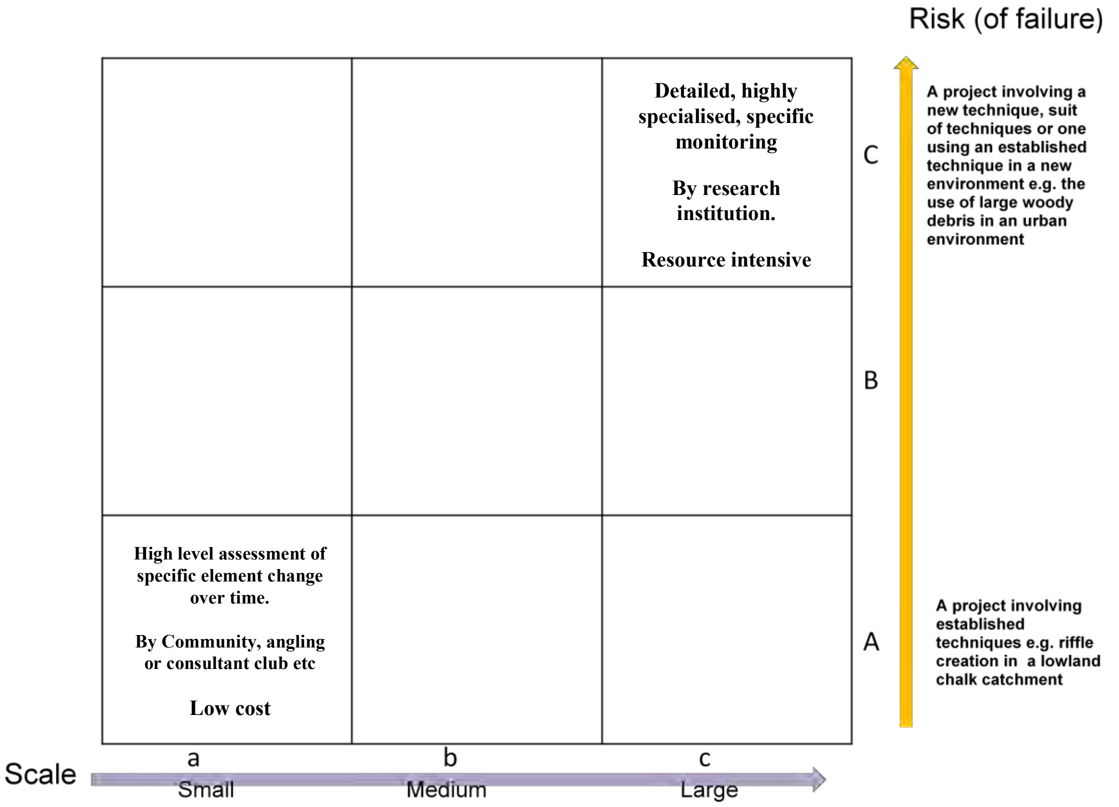


Figure 6.1 Project Size and risk to help identify appropriate monitoring level and hence method(s).

6.1 Determining Project Risk

There are two elements of risk to consider: the degree to which the technique has been tried and tested, and its physical robustness. Both of these depend on the particular catchment and channel setting.

6.1.1 Frequency of successful application and uncertainty in response

Table 6.1 evaluates the frequency of use of a particular technique on your river, or one very similar, together with a more global measure of how well it has been tested. For example, narrowing a channel using brush wood structures is frequently used, with proven success, on chalk streams, but using the same technique on an over-wide higher energy river has been done much more rarely. Similarly, marginal planting is widely employed, but is far more common on lower altitude clay rivers than flashy cobble bed streams, as are measures such as the creation and reconnection of ponds, lakes and wetlands in the floodplain.

Thus:

Brush wood on a chalk stream would score 1 (frequent used in that catchment)

Brush wood in a small Scottish burn would score 3 (frequent use of technique but not in that catchment)

The output is essentially a measure of how unpredictable the response to the restoration works will be.

Table 6.1 Risk Calculation Matrix 1 = FREQUENCY OF SUCCESSFUL APPLICATION

	Frequency of successful technique application in your catchment or very similar			
Frequency of use anywhere		Frequently	Often	Rarely
	Frequently	1	2	3
	Often	2	3	4
	Rarely	3	4	5

6.1.2 ‘Robustness’ and potential for physical failure

Table 6.2 then considers potential „structural‟ failure of the technique(s) in relation to your river typology – in particular, how much energy is in the system. Work completed by Thorne and Sear 2009 (see ***Appendix** 7*) has identified a working river typology for river systems in the UK and can be used as a good basis to help define your river type. The key elements of this are shown in the bullets below, with more details in the Appendix. Each type is related to the broad upland, intermediate and lowland categories in ***Table 6.2***.

Definition of key river types

- Steep headwater channels = *Upland River*
- Pool-Riffle and Plane bed channels = *Intermediate River*
- Wandering gravel-bed rivers = *Intermediate - Lowland River*
- Braided rivers = *Upland River*
- Active Meandering alluvial channels = *Intermediate/ Lowland River*
- Passive Meandering = *Lowland River*
- Groundwater dominated rivers = *Intermediate/Lowland River*
- Channelised watercourses ($\omega > 30$ Wm^{-2}) = *Intermediate/High River*
- Channelised watercourses ($\omega < 10$ Wm^{-2}) = *Lowland River*
- Tide Locked Watercourses = *Lowland River*

Applying the example of brush wood structures in a chalk stream, though the technique may not be the most physically robust or resilient (say, „medium‟), in such a lowland, groundwater dominated river, this does not significantly affect the risk.

Thus: The risk of physical failure is rather low for a lowland river = **2**

Conversely, considering using the same technique in a constrained high energy, mobile gravel bed river would significantly increase the risk of failure, coming out as **4**

Table 6.2 Risk Calculation Matrix 2 FAILURE RISK FOR RIVER TYPE

	River type			
‘Robustness’		Lowland	Intermediate	Upland
	High	1	2	3
	Medium	2	3	4
	Low	3	4	5

6.1.3 Combining uncertainty and failure potential

The two elements of risk are then brought together to give an overall risk factor which ranges from A to C as shown in ***Figure 6.1***.

This then gives you the position in the vertical part of the matrix in ***Figure 6.1***.

Table 6.3 Overall Risk Score

	Frequency of use in your catchment →					
Failure for river type ↓		1	2	3	4	5
	1	A	A	A	B	B
	2	A	A	B	B	B
	3	A	A	B	B	C
	4	A	B	B	C	C
	5	B	B	C	C	C

6.2 Identifying Project Scale

Project scale is best considered as a function of the length and the width of a river as shown in ***Table 6.4***

Table 6.4 Table of Scale Factors Relating to Length and Width of Restoration Reach

	Length →					
Width→		<50m	50-100m	100-200m	200-500m	>500m
	<2m	a	a	b	b	c
	2 -10m	a	a	b	c	c
	>10m	b	b	b	c	c

6.3 Defining you project location in the matrix

Whilst determining the size of your river is relatively easy, the level of risk (of technique failure) is less straight forward to assess.

Project risk can be increased by one of the following:

- Installation of a new technique
- Integrating established techniques in a different way (i.e. mix of techniques together)
- Using an established technique in a different environment
- Situations where several interconnected sites are involved that are being considered together especially where impacts may be cumulative.

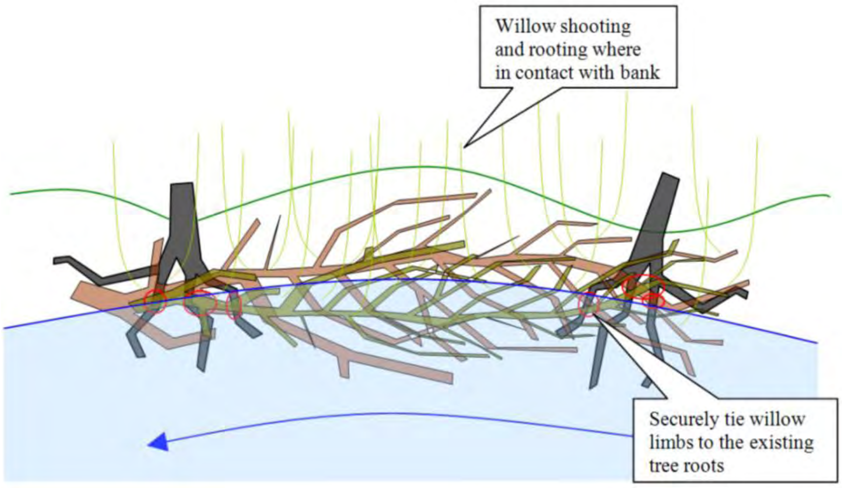


Figure 6.2 A novel combination of techniques

In summary where your project sits in the generic matrix shown in ***Figure 6.1*** is derived from a combination of ***Table 6.3*** and ***6.4***. Using this process can help to assist in determining the validity of your idea AND the level of monitoring that should ideally be undertaken for your project.

Figure 6.3 and the accompanying examples below it, demonstrate this process.

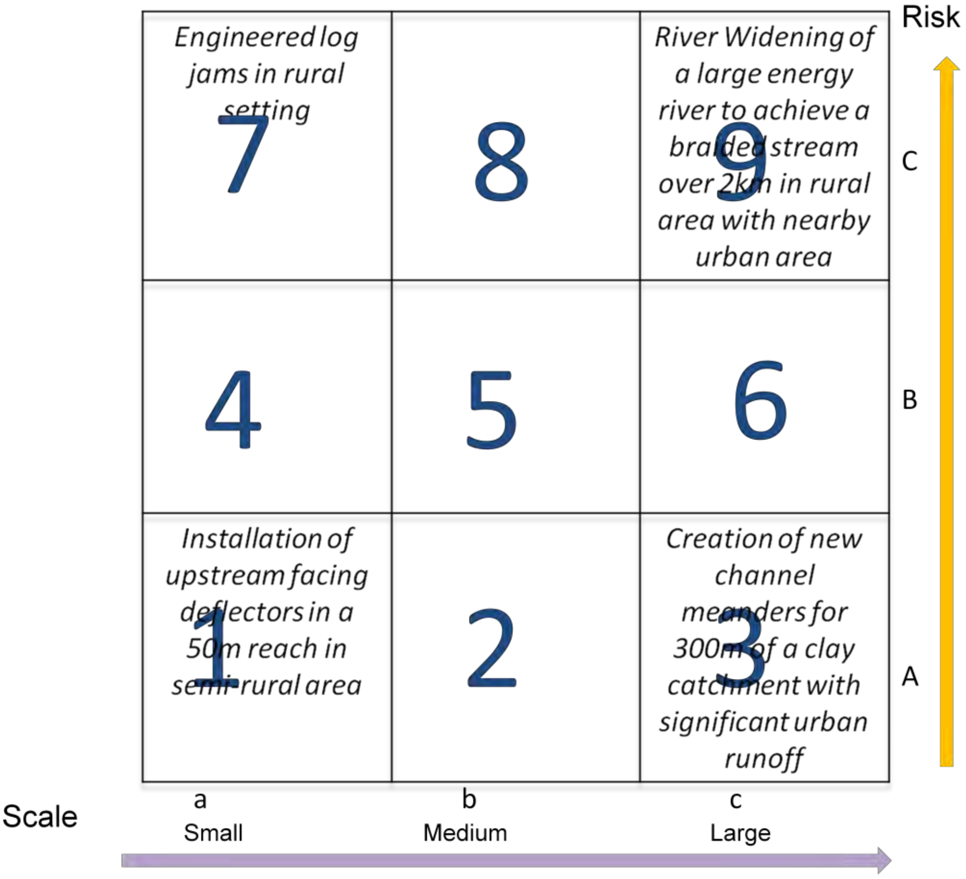


Figure 6.3 Risk and Scale matrix to help determine the appropriate level of monitoring

6.3.1 Examples of how to use the matrices to identify where your project sites in the risk/scale matrix

Installation of Upstream Facing Deflectors in a 50m Reach of Chalk Stream in semi-urban setting

- Upstream facing deflectors are a frequently used method in a chalk stream.

Using Table 6.1 = 1

- The risk of structural failure is low in a low energy predominantly ground water fed stream.

Using Table 6.2 = 1

- Linking scores from both tables to assess the overall risk using ***Table 6.3***.

Overall risk = 'A'

- Project scale is 50m in length and the stream fall in the 2-10m wide category.

Using Table 6.4 = 'a'

Project location in matrix as shown in ***Figure 6.3*** = **BOX 1**

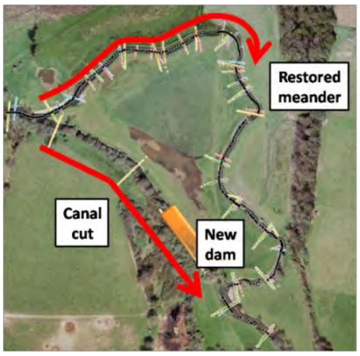
Creation of New Channel Meander for 300m of a Clay Catchment with Significant Urban Runoff

- Creating meanders is tried and tested method but because of the urban development runoff will have increased over that of a natural river system which will increase risk

Using Table 6.1 = 3

- In a lowland river the risk of failure will be low, however given the urban influences and the degree of modification the risk is slightly increased.

Using Table 6.2 = 2



- Linking scores from both tables to assess the overall risk using ***Table 6.3***.

Overall risk = 'A'

- Project length is 300m with an average width of 8m.

Using Table 6.4 = 'c'

By applying risk and scale (i.e. „A‟ and „c‟) as shown in ***Figure 6.3*** **= BOX 3**

Engineered Log Jam in a high energy river in a rural environment

- Engineered log jams have been used especially in the USA. However, the use in the UK is limited so the evidence of success in high energy rivers in the UK is limited so risk will increase.

Using Table 6.1 = 4

- Use of this technique in a high energy river using ***Table 6.2*** would give the risk as 4 (medium risk of failure in a high energy river). The two scores combined would give an overall risk of „**C**‟ from ***Table 6.3***.

Using Table 6.2 = 2

- Linking scores from both tables to assess the overall risk using ***Table 6.3***

Overall risk = 'C'

- Project length is 50m with an average width of 10m or less.

Using Table 6.4 = 'a'

By applying risk and scale („C‟ and „a‟) as shown in ***Figure 6.2*** **= BOX 7**

River widening of a large high energy river to achieve a braided stream over 2km in a rural environment but with an urban area 1.5km downstream

- In this case there is some evidence, especially within some areas of mainland Europe of this type of restoration being carried out. However, the technique, although appropriate for high energy rivers has a limited evidence base of success in the UK.

Using Table 6.1 = 4

- This is a high energy river project with an urban population fairly close, but not in the immediate vicinity of the project. Therefore, although any impact on this area MUST be taken into account in the project design.

Using Table 6.2 = 4

Overall Risk = 'C'

- The scale of this project can be defined as large at 2km and a width that is greater than 10m).

  Using Table 6.4 = 'c'

By applying risk and scale („C‟ and „c‟ as shown in ***Figure 5.2*** **= BOX 9**

SMART monitoring objectives and appropriate monitoring can now be determined

6.4 Setting SMART Monitoring Objectives

Having defined your project (***Section 3***) and considered the development and implementation associated risk, SMART monitoring objectives can then be set.

6.4.1 Is your monitoring achievable and realistic?

What is ***achievable and realistic*** in terms of monitoring will depend on a combination of:

- **Current knowledge** associated with your project (i.e. current knowledge of the river restoration technique that is to be applied) which relates to project risk as depicted in ***Figure 6.3***.
- **Resources** – budget for data collection and analysis; number of people to collect information or will you need to rely on a 3rd part to collect some/all information?
- **Timescale** – how long can you monitor after project completion?
- **Pre-**project data – what is available, in what format, when was the data collected and over what period of time?

Applying these generic questions to each specific monitoring objective will lead to a clear recommendation of what is actually achievable.

6.4.2 Prioritising your monitoring

The techniques and the level of assessment that can be applied to each objective will depend on the importance associated with that objective, and your resources. Ideally, all aspects of a project‟s objectives would be monitored in detail. In reality this is unlikely to be feasible and some level of prioritisation will be necessary for specific aspects as shown in ***Table 6.5***

Table 6.5. An example of prioritising your monitoring, based on the objectives of Example 3 in Section 4.1.3

Priority	Parameter	Purpose of monitoring	Expected outcome
3	Spawning (upstream gravels)	Detect change in spawning rates	Increase in numbers of redds and subsequent fry over period of surveys
2	Spawning (downstream gravels)	Detect change in spawning rates	No deterioration in numbers of redds as a result of weir removal
1	Siltation	Ensure that downstream spawning gravels are not adversely affected by the weir removal	Any fine sediment stored behind the weir will be flushed through the system resulting in no overall change in silt loading of existing spawning gravels.
2	Fish Passage	Demonstrate success of project for fish passage during migration period	Significant increase in migration upstream of brown trout
4	Channel width	Ensure that the technical specification of the river restoration techniques applied to narrow the channel have been successful.	Initial intervention to narrow channel works with natural processes to create a new channel feature appropriate to channel type. Identify any future adaptive management that may be necessary to ensure continuous success of project

In this example, siltation of existing spawning beds has been deemed the most important aspect to assess and has hence been prioritised highly, and will be the main focus of monitoring resources. To support this, though, numbers of redds could be counted by a simple walk over survey – i.e. with limited resource input. Fixed point photography could also provide an idea of the approximate percentage of channel narrowing occurring and identify any future management needs. A decision may be made that electro fishing once a year is the most effective way of measuring fish passage. Appropriate techniques for your project are discussed in more detail in ***Section 7***.

The Mayes Brook experience so far...

Mayes Brook is a case study in ***Section 11*** of this report. The project is at the planning stage and determining monitoring is an integral part of the project. ***Table 6.2*** is a snap shot of the process used so far to prioritise monitoring needs and is proofing to provide a good method.

Table 6.6 A snapshot of the Mayes Brook way of prioritising river restoration monitoring aspirations based on how the objectives fit with the project aims and costs of each element. Priority is based on a combination of need and relation to objectives, data availability, cost and other resources.

Target / Objective: Why?	Measurable: What?	When?	Method:	Who is available to complete monitoring ?	Existing Data?	Estimated Cost?	Priority
Target: Improved river geomorphology as a result of the project: Why: To assess changes to in-stream cross sectional diversity	Change in the river planform	Pre works; as built, just post works and repeat every 2 years.	Fixed point photography mapped with GPS co-ordinates for future use. Note: can link with Urban river corridor survey, river habitat survey and a river corridor survey. RHS / RCS / Biotope data to indicate where to carry out cross sections.	Initial consultant with river restoration expertise. Then follow up by local groups with training.	Some limited fixed point photography	£2000 for initial work	1
Target: Increased fish populations in brook by 2013 Why: To see if the density of fish and the retention of fish has increased and project is resilient to climate change.	Number and types of fish species	April 2012 then every two years	Electrofishing- point abundance survey method	EA will collect this data and will be responsible for it.	Baseline, one off point abundance survey done April 2008	In-house (EA) (3 days work). Externally it would be about £3k	3

7. Selection of appropriate techniques and methodologies

7.1 What will your monitoring tell you?

This section focuses on what level of monitoring is appropriate for your project having set your specific and measurable objectives and determined your time frames and budget. Nearly all monitoring is useful, but it is essential that you use the right „tools for the job" and choose these based directly on your monitoring objectives.

Section 6 explained how to locate where your project sits within the risk/scale matrix (see ***Figure 6.1***). The following section explains the different monitoring techniques which are appropriate for each of the 9 boxes. Small scale projects using tried and trusted techniques may not require the same detail of monitoring as complex large scale projects which are using innovative previously unused methods.

Methods have been divided into a number of different „Functional Groupings" i.e. Ecology, Fisheries, Macrophytes, Hydromorphology (geomorphology) and hydromorphology (hydrology) as shown in ***Figures 7.1*** to *7.5*. Which elements you select from each of these groups will depend on your SMART objectives i.e. what you are trying to achieve will determine what it is you should measure.

7.2 What level of technique should I use

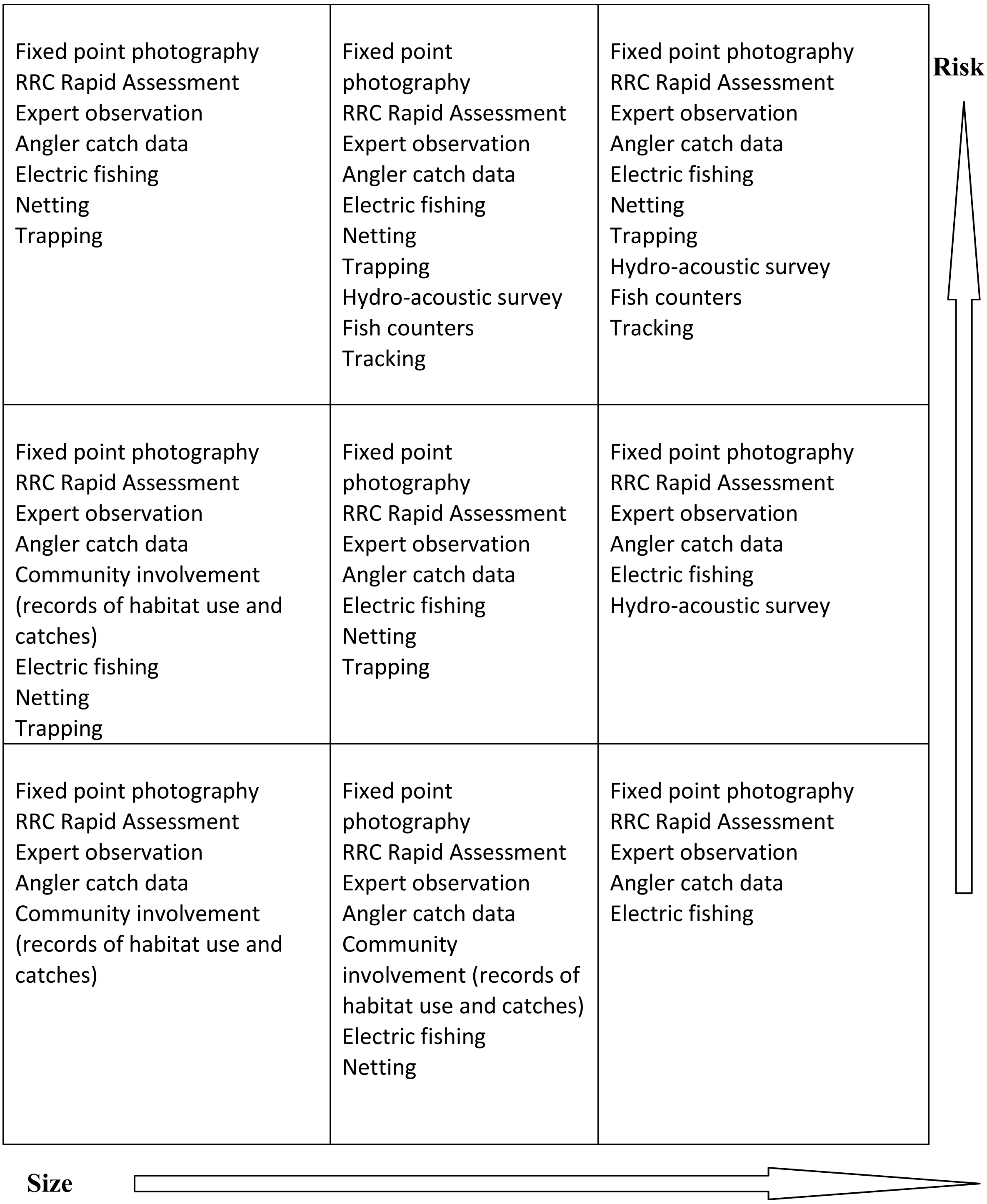
The methods stated here are based on current methods and it should be noted that new/adaptations to existing methods continue to be sought with the advent of new technology and computer processing software. However, many of these more technical innovations are the focus of science teams for research of WFD-specific application. This will not always be applicable where funds are limited and the emphasis is on local community/club interest. Therefore, the tables and lists and associated appendices aim to reflect the need for a range of methods for different groups and application.

Risk

Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and River Corridor Survey (RCS)) Unit-area invertebrate survey Unit-time invertebrate survey	Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) Unit-area invertebrate survey Unit-time invertebrate survey	Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) Unit-area invertebrate survey Unit-time invertebrate survey River Habitat Survey (RHS)
Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) Community Involvement (simple invertebrate assessment)	Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) Unit-area invertebrate survey Unit-time invertebrate survey	Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) Unit-area invertebrate survey Unit-time invertebrate survey RHS
Fixed point photography RRC Rapid Assessment Community Involvement (simple invertebrate assessment)	Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) Community Involvement (simple invertebrate assessment)	Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) Unit-area invertebrate survey Unit-time invertebrate survey RHS

Size

Figure 7.1 Ecology Options/potential surveys



Fixed point photography RRC Rapid Assessment Expert observation Angler catch data Electric fishing Netting Trapping	Fixed point photography RRC Rapid Assessment Expert observation Angler catch data Electric fishing Netting Trapping Hydro-acoustic survey Fish counters Tracking	Fixed point photography RRC Rapid Assessment Expert observation Angler catch data Electric fishing Netting Trapping Hydro-acoustic survey Fish counters Tracking
Fixed point photography RRC Rapid Assessment Expert observation Angler catch data Community involvement (records of habitat use and catches) Electric fishing Netting Trapping	Fixed point photography RRC Rapid Assessment Expert observation Angler catch data Electric fishing Netting Trapping	Fixed point photography RRC Rapid Assessment Expert observation Angler catch data Electric fishing Hydro-acoustic survey
Fixed point photography RRC Rapid Assessment Expert observation Angler catch data Community involvement (records of habitat use and catches)	Fixed point photography RRC Rapid Assessment Expert observation Angler catch data Community involvement (records of habitat use and catches) Electric fishing Netting	Fixed point photography RRC Rapid Assessment Expert observation Angler catch data Electric fishing

Figure 7.2 Fishery Options/potential surveys

Risk

Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) Expert observation	Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) LEAFPACS survey JNCC survey	Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) LEAFPACS survey JNCC survey Quadrat/NVC survey
Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) Community Involvement (simple macrophyte species assessment)	Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) LEAFPACS survey	Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) LEAFPACS survey JNCC survey
Fixed point photography RRC Rapid Assessment Community Involvement (simple key macrophyte species assessment)	Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) Community Involvement (simple key macrophyte species assessment)	Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) LEAFPACS survey

NB Designated sites may need CSM monitoring

Size

Figure 7.3 Macrophytes

Fixed point photography RRC Rapid Assessment Aerial photography Repeat cross-sections Habitat Mapping (Biotope and RCS) Geomorphological mapping Fluvial audit	Fixed point photography RRC Rapid Assessment Topographic survey Aerial photography Repeat cross-sections LiDAR Habitat Mapping (Biotope and RCS) Geomorphological mapping Fluvial audit	Fixed point photography RRC Rapid Assessment Topographic survey Aerial photography Repeat cross-sections Habitat Mapping (Biotope and RCS) Geo RHS LiDAR Fluvial audit
Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) Geomorphological mapping Fluvial audit	Fixed point photography RRC Rapid Assessment Topographic survey Aerial photography Repeat cross-sections Habitat Mapping (Biotope and RCS) Geomorphological mapping Fluvial audit	Fixed point photography RRC Rapid Assessment Topographic survey Aerial photography Repeat cross-sections Habitat Mapping (Biotope and RCS) Geo RHS Fluvial audit LiDAR
Fixed point photography RRC Rapid Assessment Habitat Mapping (Biotope and RCS) Geomorphological mapping	Fixed point photography RRC Rapid Assessment Topographic survey Repeat cross-sections Habitat Mapping (Biotope and RCS) Geomorphological mapping Fluvial audit	Fixed point photography RRC Rapid Assessment Topographic survey Aerial photography Repeat cross-sections Habitat Mapping (Biotope and RCS) Geo RHS Fluvial audit

Risk

Size

Figure 7.4 Hydromorphology - Geomorphology

Risk

Fixed point photography RRC Rapid Assessment Spot gauging Water Level (e.g. gauge board monthly)	Fixed point photography RRC Rapid Assessment Stilling well and level logger Rainfall-runoff modelling (to determine mean daily flows) Spot gauging	Fixed point photography RRC Rapid Assessment Stilling well and level logger Rainfall-runoff modelling (to determine mean daily flows) Spot gauging
Fixed point photography RRC Rapid Assessment Velocity Trash lines	Fixed point photography Spot gauging Water Level weekly dip from gauge board	Fixed point photography Spot gauging Water Level weekly dip from gauge board
Fixed point photography RRC Rapid Assessment	Fixed point photography RRC Rapid Assessment Velocity Trash lines	Fixed point photography RRC Rapid Assessment Velocity Water Level monthly dip from gauge board

Size

Figure 7.5 Hydromorphology-Hydrology

Sections 7.3 - 7.8 provides a short summary of what, in simple terms, data needs to be collected for each method. A fuller explanation of these methods with examples can be seen in Appendices 8-13.

From the figures above it is evident that some methods are identified in more than one Functional Group. ***Table 7.1*** shows each of the methods and links to their associated Functional Group(s). What information can then be gained from each generic method and how this might differ for each grouping is then stated.

7.3 Multi-disciplinary Methods (see Appendix 8)

- **Fixed Point photography**- photographs taken at a set of identical locations before, during, just after and several years after the restoration work.

- **RRC Rapid assessment** – forms are designed to be used with fixed point photography and provide a snapshot of generic information based on expert opinion.
- **Habitat Mapping (biotope)** - mapping of area with the same environmental conditions which provide a habitat for a specific group of plants or animal.
- **Habitat Mapping (RCS)** – mapping vegetation structures along a watercourse and includes a map of physical habitat and a botanical survey.

7.4 Ecology Survey Methods (see Appendix 9)

- **The Riverfly Partnership Anglers' Monitoring Initiative and similar initiatives** - with limited training, monitoring of invertebrate communities can be undertaken.

  (http://www.riverflies.org/)
- **Unit-time invertebrate surveys** – Macroinvertebrates are sampled over a set time period (3 minutes) across the whole width of the river. Abundance for each family (related group of invertebrates) or, with further expertise, species, can be compiled. These data can be statistically analysed to determine a range of indices such as diversity, LIFE, ASPT and BMWP, which can be used more practically to evaluate changes in the invertebrate communities.
- **Unit-area invertebrate surveys** – Samples are taken in a similar way to the above, but from a defined area, until no further organisms are found. These results tell you about both the community and biomass (or total abundance of invertebrate life) for a particular area of interest.
- **River Habitat Survey (RHS) –** Maps habitat using a walk-over survey in terms of vegetation, key morphological features and any additional observation of interest along the river corridor. Spot checks and tick lists of features included and information collected used to provided habitat scores that can be related to other reaches held on a central database
- **Urban River Survey (URS)** – A derivation of a standard RHS, designed specifically for urban water courses

7.5 Fisheries Survey Methods (see Appendix 10)

- **Expert Observation** – habitat suitability, fish passage and fry use areas are observed by fisheries experts via walk over surveys.
- **Angler catch data** - catch records are collated in structured recording schemes
- **Electro-fishing** – fish are stunned with an electric current and float to the surface where they can be collected, counted, measured and weighed; level of analysis can vary for numbers through to species and age categories.

- **Netting (Seine and Fyke)** – fish are caught in nets where they can be counted, weighed and measured.
- **Trapping** is used to monitor migratory fish such as salmon, sea trout and eels. Quantitative population estimates can be calculated using this method.
- **Hydro Acoustic Fish Surveys** – records fish shoals using an echo sounder
- **Fish counters** – used to count migrating fish and determine fish movement.
- **Tagging** – used to determine fish movement.

7.6 Macrophyte Survey Methods (see Appendix 11)

- **Community Involvement -** (simple key macrophyte species assessment)
- **Macrophyte Surveys** - (LEAFPACS Environment Agency survey method)
  Data are collected over 100m reaches. Macrophyte taxa are indentified using the taxa list associated with the method. Coverage for each is also estimated. This method is a key method for providing the quality condition for WFD delivery, though requires specific expertise and training. Documentation can be found at: *http://www.wfduk.org/bio_assessment/rivers_macrophytes_leafpacs*.
- **JNCC survey** - Generally surveys are completed over a 0.5 km reach and distances of around 5km in distance from each other. Good for small streams
- **Quadrat/NVC -** Quadrats are usually 1m squares but this does vary depending on vegetation type and location. Data on % of species is often complimented with associated photography. Macrophytes assessed using the NATION Vegetation Classification

7.7 Geomorphology Survey Methods (see Appendix 12)

- **Aerial photography** – Useful to provide an overview of your river (where not vegetation encroachment.
- **Geo-River Habitats Survey** – an enhanced river habitats survey with more focus on the geomorphology by including additional cross-section information
- **Topographic Surveys** – provides information about river plan and longitudinal changes through time.
- **Repeat Cross Sections** – provides information about a specific section of a river and floodplain and may be related to hydrology and habitat information.
- **Geomorphological Mapping** – map of river bed, bank and floodplain features.

- **Fluvial Audit –** Provides baseline information about a river and its current state in terms of physical processes and more specifically sediment transport, erosion and depositional areas**.**
- **LiDAR –** Particular useful for identifying flood plain levels

7.8 Hydrology Survey Methods (see Appendix 13)

- **Trash lines** – excellent for providing a quick method for identify previous water levels
- **Water Levels** – good for understanding out of bank and bankful frequency of events. Data collection feasible from simple crest stage records to continuous monitoring stations, loggers and download equipment.
- **Spot gauging** – used to gain flow information in ungauged catchments and helps calibrate models
- **Velocities** – can be gained through modelling methods (both empirical equations and computer generated). Also gained from direct measurement with flow velocity meter.
- **Rainfall-runoff** modelling – used to run climate change scenarios and to model flows in ungauged catchments (in conjunction with spot gaugings)

Table 7.1 Methods, Associated Functions and Types

Method	**Function**	**What information can be determined using method**
Fixed point photography	Ecology/Macrophytes/Fisheries/ Geomorphology/Hydrology	**Habitat** change in terms of macrophyte and sediment type and percentage.
RRC Rapid Assessment	Ecology/Macrophytes/Fisheries/ Geomorphology/Hydrology	**Habitat** present in terms of key morphological features, marcophyte and bankside cover, fish absent or present.
Simple invertebrate assessment	Ecology	Can identify if the type of **Invertebrates** which favour natural streams with good water quality are present.
Unit-time invertebrate survey	Ecology	**Invertebrate** densities, abundances of certain species/families and evenness.
Unit-area invertebrate survey	Ecology	Baseline **invertebrate** data. Can establish changes through time and space in assemblages. Analysis of relationships between invertebrates and other aquatic parameters such as flow.
RHS/UHS	Ecology	Calculates general **habitat** quality. Also records the invasive species, channel modification and physical barriers to fish movement.
Habitat Mapping (Biotope and RCS	Ecology/Macrophytes/geomorphology	Records **habitats** present and these can be compared with reference reaches.
Angler catch data	Fisheries	Provides a general outline of **fish population** (e.g. species, numbers and size). Method is selective so may result in a skewed observation but can demonstrate broad positive or negative trends. More applicable to coarse fisheries than to salmonids.
Community involvement (records of habitat use and catches)	Fisheries	Overview of **habitats** present and **number of fish** present.
Electric fishing	Fisheries	Can provide either a qualitative or quantitative **estimate of fish population size** ,at a local scale (tens of metres up to a few hundred metres). Single or timed electric fishing passes provide qualitative estimates, whereas multiple passes, ideally de-limited by stop nets, provide more quantitative estimates. Fish species, numbers, lengths and weights ought to be recorded to allow accurate evaluations of population change. Can be used from bank (wadeable streams for most effective), boat (non-wadeable rivers) or portable back-pack (small streams).
Expert observation	Fisheries	Can provide qualitative data on **habitat quality and/or fish abundance**/population change.

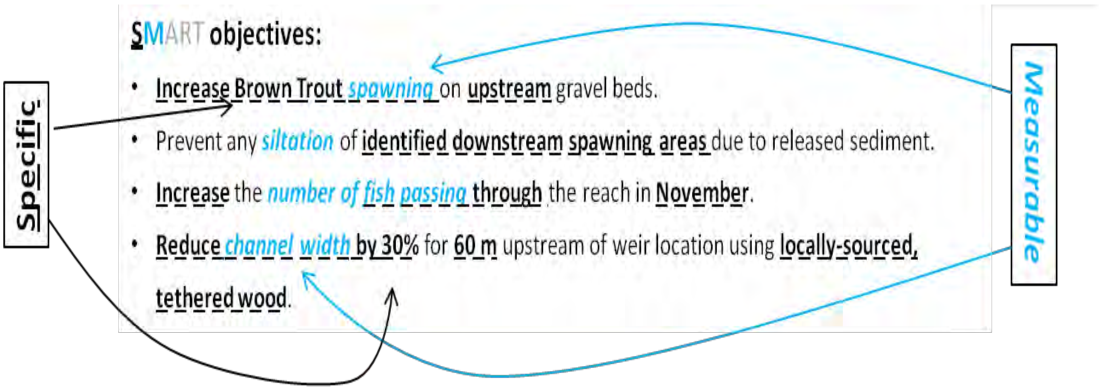
Method	**Function**	**What information can be determined using method**
Fish counters	Fisheries	Can provide quantitative **estimates of fish numbers** over a relatively large scale (several to 10s or 100s of kilometres). Best suited to estimation of numbers of migratory species, such as adult salmon and trout, for example migrating through a fish pass. Generally not suited to monitoring of coarse fish species, or to small scale restorations (10s or 100s of metres).
Hydro-acoustic survey	Fisheries	Can provide quantitative **estimates of fish abundance**, including approximate fish size estimates. Cannot provide fish species identification. Best suited to deep, wide river channels, and best to be carried out at night when fish are dispersed in open water. Interference can arise from macrophyte stands and entrained air from weirs or boat propellers. Species that prefer river bed habitats will be poorly sampled. Technique can be applied over several hundred metres up to 10s of kilometres.
Netting	Fisheries	Seine netting provides qualitative and quantitative **estimates of fish abundance** in suitable habitats – generally wide, deep, slow flowing rivers with no obstructions/snags, therefore more suitable to coarse fish species in lowland rivers. Fyke netting provides qualitative estimates of fish distribution and abundance, but this technique is species and size selective. Best suited for migratory species such as adult eels, or benthic species.
Tracking	Fisheries	Tracking of fish with detectable tags can demonstrate **habitat use** given suitably high frequency and resolution of monitoring. Technique does not provide quantitative fish population estimates. Best to be carried out over 10s to low hundreds of metres in the context of river restoration.
Trapping	Fisheries	Trapping is most effective for **monitoring migratory species** such as adult salmon, trout (usually with fixed-location traps) and eels (usually with fixed traps or fyke nets). Quantitative population estimates can be achieved, usually over extensive river lengths.
Aerial photography	Geomorphology	A cost effective way of identifying key catchment scale **habitat** features (e.g. open areas, tree-lined sections over river etc). In some cases specific river habitats can be observed depending on river size and tree coverage. Now also used to map depth and macrophyte cover using remonte sensing methods where no tree cover interference.
Fluvial audit	Geomorphology	Physical survey of river that provides a baseline of information about the **river type, forms and processes present** for one time period
Geo RHS	Geomorphology	Similar to RHS but can take additional morphological cross sections and collects some specific morphological data.
Geomorphological mapping	Geomorphology	**Planform mapping of river, riparian zone and floodplain t**o provide information about features and sediment characteristics.
LiDAR (high resolution remote sensing) Note: accuracy 0.15m vertical ; grids 1-2m	Geomorphology	Topographic survey – useful information of modelling **floodplain water levels changes** as a result of river and floodplain restoration

Method	**Function**	**What information can be determined using method**
Repeat cross-sections	Geomorphology	Can provide details of a specific **morphological change** over time (width and depth) in river and floodplain
Topographic survey	Geomorphology	Provide detailed **long section and morphological feature level information** and change over time
Rainfall-runoff modelling (to determine mean daily flows)	Hydrology	Modelling allows **climate change scenarios** to be run and can be used to produce **historic flow** series. This would enable decisions to be made about appropriate river restoration techniques knowing what effect climate change will have on flows
Spot gauging	Hydrology	Provides a **snapshot of flow information**, and can be used to create accretion profiles. Spot gaugings can also be used to calibrate rainfall-runoff models in ungauged catchments. Knowing the flow regime is vital to determining the appropriate river restoration techniques to apply
Stilling well and level logger	Hydrology	Use in flood models. Can be used to record high **river and floodplain water levels**. Range of instrumentation available depending on resources
Trash lines	Hydrology	**Physical measurement** of flood height. Useful for calibration models.
Velocity	Hydrology	In –channel measurement in conjunction with cross sections to get an estimate of flow. Useful for **invertebrate habitat preference** and **potential to move sediment**
Water level (e.g. gauge board monthly	Hydrology	**Physical Surveys** can be used to record when a river overspills onto the flood plain
Community Involvement (simple key macrophyte species assessment)	Macrophytes	Can include photographs, mapping and identification. Will provide high level information about the **presence or absents of fauna and flora in the river and on the floodplain.**
Expert observation	Macrophytes	Can include photographs, mapping and identification. Will provide high level information about the **presence or absents of fauna and flora in the river and on the floodplain.** Potentially more detailed than above but data likely to be less frequent.
JNCC survey	Macrophytes	P**resence, absence, and percentage cover** along reaches.
LEAFPACS survey	Macrophytes	P**resence, and percentage** of the river channel covered for WFD quality assessment
Quadrat/NVC survey	Macrophytes	Records **percentage of species** at one grid square.

8. Monitoring Timescales

8.1 Adding time to monitoring objectives

Section 4 demonstrates how SMART project objectives should be set. However, it does not identify what level of monitoring is appropriate and over what time period. The following case study from ***Section 4.1.2*** identifies the option to remove a weir thus benefiting salmonid passage and restore natural physical processes.



SMART objectives:

- Increase Brown Trout *spawning* on upstream gravel beds.
- Prevent any *siltation* of identified downstream spawning areas due to released sediment.
- Increase the *number of fish passing* through the reach in November.
- Reduce *channel width* by 30% for 60 m upstream of weir location using locally-sourced, tethered wood.

The period of monitoring of a river restoration project has up to now generally been assumed to be 3 years post-completion, simply because funding has most often been costed over this period. However, by considering the project objective(s), river type and potential sensitivity to change this can help to identify when monitoring should be undertaken both of what number of years and how often within each year. Following the example given setting monitoring targets timescales might be as follows:

Spawning: Measure the increase in numbers of brown trout redds just after spawning season on upstream gravel beds to determine change in numbers from completion of project for a 3 year period initially. If no conclusive results are forthcoming, consider additional impacts and/or increase the period of monitoring. Check redds on downstream gravels to compare current levels of spawning with post-project levels over the same 3 year period.

Siltation: Measure the % of silt deposit in existing downstream spawning areas to check in % increase in fines that may adversely affect spawning following weir removal. Measurement to be taken immediate after weir removal, 3months post, and after a high flow event.

Fish passage: Count the number of brown trout passing through previously impassable reach during November over a 3 year period.

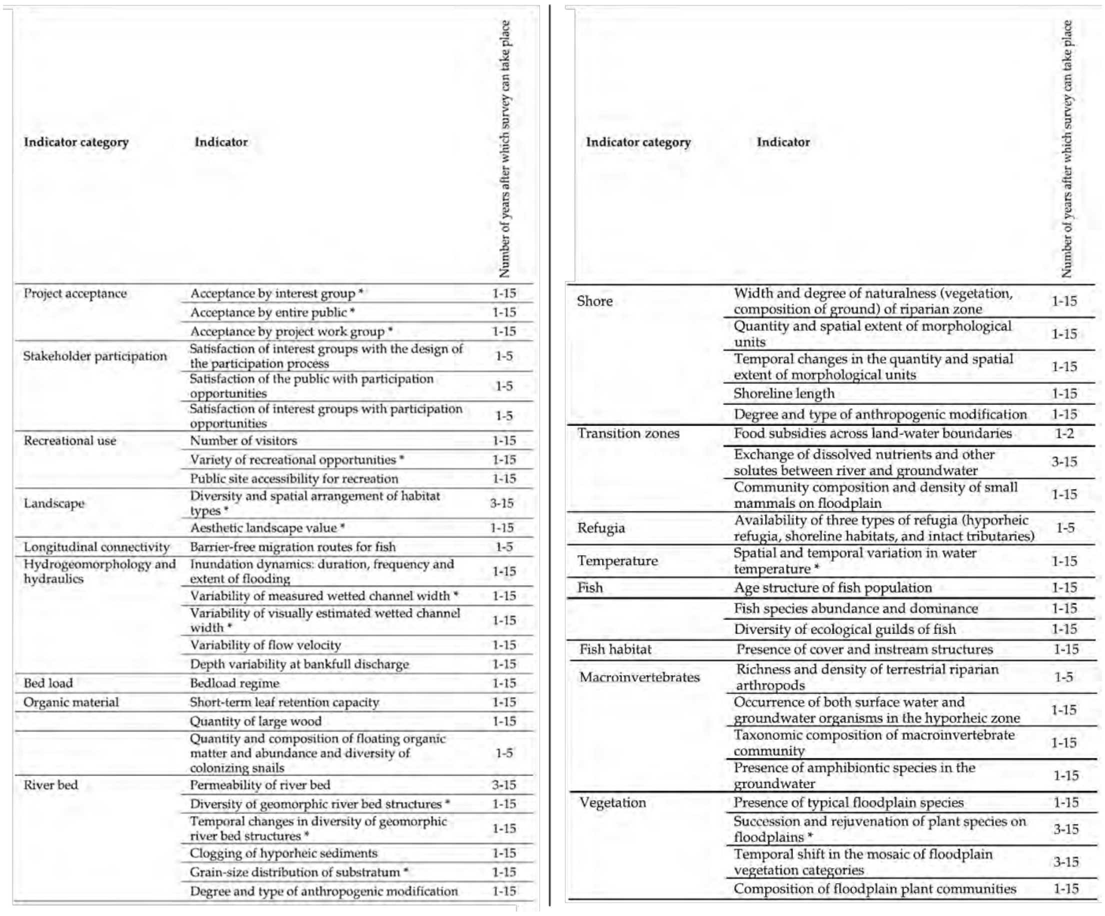
Channel width: Complete cross-sectional surveys throughout narrowed reach immediately post- construction, 1 year on and 3 years on. This may need to be extended beyond this period to include 5 and 10 year assessments. Review at end of 3 years.

8.2 Monitoring – for how long?

Deciding when to complete your monitoring (i.e. which season) and how many times you collect data each year is an essential aspect towards achieving effective monitoring. Each aspect to be monitored must relate back to the project objectives to ensure these will be answered. The detail and frequency of sampling is to some extent, a matter of expert judgement and dependant on questions required to be answered. Flexibility is key to good monitoring; not all elements need to be monitored during the same year and timing may vary depending on specific weather conditions. It must be considered, however, that many methods must be carried out at a particular time of year.

The table shown in ***Table 8.1*** designed by Woolsey et al. (2007) highlight the need to consider the overall length of monitoring; in some case change may still be detectably up to 15years after project completion.

Table 8.1: Relevant timescales for monitoring indicators of river restoration success, from Woolsey et al., 2007.



Indicator category	Indicator	Number of years after which survey can take place
Project acceptance	Acceptance by interest group *	1-15
	Acceptance by entire public *	1-15
	Acceptance by project work group *	1-15
Stakeholder participation	Satisfaction of interest groups with the design of the participation process	1-5
	Satisfaction of the public with participation opportunities	1-5
	Satisfaction of interest groups with participation opportunities	1-5
Recreational use	Number of visitors	1-15
	Variety of recreational opportunities *	1-15
	Public site accessibility for recreation	1-15
Landscape	Diversity and spatial arrangement of habitat types *	3-15
	Aesthetic landscape value *	1-15
Longitudinal connectivity	Barrier-free migration routes for fish	1-5
Hydrogeomorphology and hydraulics	Inundation dynamics: duration, frequency and extent of flooding	1-15
	Variability of measured wetted channel width *	1-15
	Variability of visually estimated wetted channel width *	1-15
	Variability of flow velocity	1-15
	Depth variability at bankfull discharge	1-15
Bed load	Bedload regime	1-15
Organic material	Short-term leaf retention capacity	1-15
	Quantity of large wood	1-15
	Quantity and composition of floating organic matter and abundance and diversity of colonizing snails	1-5
River bed	Permeability of river bed	3-15
	Diversity of geomorphic river bed structures *	1-15
	Temporal changes in diversity of geomorphic river bed structures *	1-15
	Clogging of hyporheic sediments	1-15
	Grain-size distribution of substratum *	1-15
	Degree and type of anthropogenic modification	1-15
Shore	Width and degree of naturalness (vegetation, composition of ground) of riparian zone	1-15
	Quantity and spatial extent of morphological units	1-15
	Temporal changes in the quantity and spatial extent of morphological units	1-15
	Shoreline length	1-15
	Degree and type of anthropogenic modification	1-15
Transition zones	Food subsidies across land-water boundaries	1-2
	Exchange of dissolved nutrients and other solutes between river and groundwater	3-15
	Community composition and density of small mammals on floodplain	1-15
Refugia	Availability of three types of refugia (hyporheic refugia, shoreline habitats, and intact tributaries)	1-5
Temperature	Spatial and temporal variation in water temperature *	1-15
Fish	Age structure of fish population	1-15
	Fish species abundance and dominance	1-15
	Diversity of ecological guilds of fish	1-15
Fish habitat	Presence of cover and instream structures	1-15
Macroinvertebrates	Richness and density of terrestrial riparian arthropods	1-5
	Occurrence of both surface water and groundwater organisms in the hyporheic zone	1-15
	Taxonomic composition of macroinvertebrate community	1-15
	Presence of amphibiontic species in the groundwater	1-15
Vegetation	Presence of typical floodplain species	1-15
	Succession and rejuvenation of plant species on floodplains *	3-15
	Temporal shift in the mosaic of floodplain vegetation categories	3-15
	Composition of floodplain plant communities	1-15

8.3 Monitoring – which season to collect data?

Table 8.2 provides a summary of when is the optimum time (A) and possible time (B) to carry out surveys for rivers and wetlands/floodplains for a range of functional groups and where important for different parts of the life cycle. Whether you then decide to move you morphological measures to optimise you ecological interests of vice versa depends very much on you initial objectives (i.e. do you need to assess the degree of morphological change and generic habitats that are forming or are you more interested in what species are present and how where they are colonising?).

Table 8.2 Timescales for different sampling types

		Ecology	Fisheries (salmonids)	Fisheries (Cyprinids)	Geomorphology/ sedimentology	Hydrology	Macrohytes	
Year 1	Spring	A - Rivers	A - eggs/fry			A		
	Summer	A – Wetlands and still waters	B - eggs/fry	A -fry/Adults	A	A	A	
	Autumn	A - Rivers	A - juveniles	A -Adults		A	B	
	Winter		A - Adult/spawning		B	A		
Year2	Spring		A - eggs/fry		B	A	A	
	Summer		B - eggs/fry		A	A	B	
	Autumn		A - juveniles			A		
	Winter		A - Adult/spawning			A		
Year 3	Spring	A - Rivers	A - eggs/fry			A		
	Summer	A – Wetlands and still waters	B - eggs/fry		A	A	A	
	Autumn	A - Rivers	A - juveniles			A	B	
	Winter		A - Adult/spawning			A		
Year 4	Spring					A		
	Summer					A		
	Autumn				B	A		
	Winter					A		

		Ecology	Fisheries (salmonids)	Fisheries (Cyprinids)	Geomorphology/ sedimentology	Hydrology	Macrohytes	
Year 5	Spring	A - Rivers	A eggs/fry			A		
	Summer	A – Wetlands and still waters	B eggs/fry			A	A	
	Autumn	A - Rivers	A juveniles			A	B	
	Winter		A Adult/spawning			A		
Year 6	Spring		A eggs/fry	B		A		
	Summer		B eggs/fry	A		A		
	Autumn		A juveniles	B		A		
	Winter		A Adult/spawning			A		
Year 7	Spring	A - Rivers	A eggs/fry			A		
	Summer	A – Wetlands and still waters	B eggs/fry			A	A	
	Autumn	A - Rivers	A juveniles			A	B	
	Winter		A Adult/spawning			A		
Year 8	Spring					A		
	Summer					A		
	Autumn					A		
	Winter				B	A		
Year 9	Spring		A eggs/fry		B	A		
	Summer		B eggs/fry	B	A	A		A

		Ecology	Fisheries (salmonids)	Fisheries (Cyprinids)	Geomorphology/ sedimentology	Hydrology	Macrohytes	
	Autumn		A juveniles	A		A		B
	Winter		A Adult/spawning			A		
Year 10	Spring	A - Rivers				A		
	Summer	A – Wetlands and still waters				A		
	Autumn	A - Rivers				A		
	Winter					A		

Notes:

A = optimum time B = possible time

Geomorphology may need flexibility to account for high and low flows depending on objectives set.

Invertebrates can be flexible to be timed after geomorphology has adjusted

8.4 Key timescale considerations

It is important to note the following:

- Not all aspects of river restoration record success at the same period of time (i.e. recovery period may vary between species, river types and geographical location). Both limitations on movement of sediment and abundance and diversity of species can have significant effects on both ecological and physical recovery rates.
- The rate of recovery will vary depending on the local weather conditions; a year of drought may limit invertebrate or macrophyte recovery as shown in the STREAM case study (see ***Section 11.4***); conversely, an extreme flood event may result in a more rapid than predicted change in plan and cross sectional form the predicted.
- The time at which it is most appropriate to monitor varies depending on species, life cycle aspect required to capture and flow event variability.

Aim to design your monitoring strategy to be flexible in terms of detail collected and frequency. This will depend initial objectives, fluctuations in seasonal conditions from year to year, your river type, its hydrological regime and the ecological communities present.

9. Estimating Monitoring Costs

These will always be difficult to predict. Nonetheless, it is essential that sufficient resources are planned within the project budget. By planning-in monitoring at project conception there is more chance that this will be achieved.

9.1 Breaking down the cost elements

9.1.1 Planning

Planning the monitoring – particularly setting well-defined objectives – is absolutely critical to saving money, time and effort in the latter stages. As such, one should explicitly budget sufficient resources to this phase. The cost of effective monitoring should not be underestimated and in some cases a budget of around of 10-20% of the full project should be considered as appropriate for detailed monitoring but this will vary significantly depending on the input and interest from local groups.

9.1.2 Data collection

Unless large amounts of data can be collected remotely, or early assessments of risk and scale indicate that only minimal monitoring is required, the actual on-the-ground data collection activities are likely to take up most of the monitoring budget.

Table 9.1, on the following pages, gives some indications of costs for a range of methods and scales of projects. Note also the potential savings of data collection in partnership with wider interest groups, as mentioned in ***Section 10.2*** (Who should be involved in monitoring and why).

9.1.3 Interpretation and reporting

Ideally data should only be collected for the purpose of specific planned analyses which will relate directly to the monitoring objectives. In this way, the costs of interpretation can be limited.

Cost of interpretation can quickly escalate. For example:

- Where data collection is inconsistent since not initial clearly defined (see Shopham Loop case study)
- Where dissemination is necessary for a number of audiences which may require multiple outputs.
- Where detailed scientific analysis is required.

9.1.4 Estimating costs for data collection and analysis

Table 9.1 provides some outline costings related to different monitoring techniques. These are based on information collected from a range of sources. These are aimed to give some generic ideas of costs and are only here to provide some initial project estimates. More research and investigation will be necessary to provide detailed costs.

For the purpose of ***Table 9.1*** it is assumed that your river is less than 10m wide; larger than this can significantly affect cost estimates. Costs include data analysis and reporting but do not include equipment costs.

Table 9.1 Costings – based on river less the 10m in width and does not include equipment costs.

Method	Length (km)	Cost	Notes
Fixed Point Photography	1	£200- £1000	
RRC Rapid Assessment	0.5	£200	
Habitat Mapping (biotope)	0.5	£200	
Habitat Mapping (RCS)	0.5	£200	
Community collection of macro-invertebrates	5	£100-£300	
Unit-time Invertebrate Survey	1	£2,000	
Unit-area Invertebrate Survey	1	£2,000	
River Habitat Survey (RHS)	0.5	£170	
Urban River Survey (URS)	0.5	£150	
Expert Observation (fisheries)	Up to 5	£500	
Angler Catch	2	£150	
Electro-fishing	Up to 0.2	£750 per day	Equipment costs can amount to approx £5k.
Netting	0.05-0.2	£750 per day	Equipment costs can amount to approx £2k.
Trapping	Up to 10s of km	£10k per year	A fixed position fish trap will only occupy a few metres of river channel length and width, but effectively monitors upstream fish migration into whatever length of river exists upstream of that position. Cost of equipment can be inexpensive for temporary traps (£100s) or considerable for permanent traps (10s of thousands of pounds). Fyke nets inexpensive (£100s of pounds).
Hydro-acoustics	Up to 10	£750 per survey	Equipment costs can easily amount to 10s of thousands of pounds
Fish Counter	Up to 10s of km	£3-5K per year	A fixed position fish counter will only occupy a few metres of river channel, but effectively monitors upstream fish migration into whatever length of river exists upstream of that position. Does not include equipment costs which can easily amount to 10s of thousands of pounds.

Method	Length (km)	Cost	Notes
Tagging	Up to 1 (In the context of assessing habitat use in restoration schemes)	£200 per day	Equipment costs can easily amount to 10s of thousands of pounds.
Macrophyte Survey (LEAFPACS)	1	£400	
JNCC Survey	1	£400	
Quadrat/NVC	0.01	£20	
Aerial Photography	.001 to 5	£2,000	
GeoRHS	5	£130	
Topographic survey	5 – 10 ha	£2000-£4500	Based on easily accessible floodplain area
Repeat Cross Section	1	£2000-£4500	Approx. 20 cross-sections
Geomorphological Mapping	1	£3,000	
Fluvial Audit	5	£1,000	Typically requires 2 people
LiDAR	20	£6,000	
Trash Lines	1	£250	
Water levels		£595	
Spot Gauging		£30-£50	per gauge
Velocities		£30-£50	per gauge
Rainfall-runoff modelling		£5000 - £10000	per site

Note costs and lengths initially collated from questionnaires completed at the first monitoring workshop

10. Above and beyond existing data

It has been highlighted in this document that there are many well-established monitoring protocols and schemes already in place, but also that these have specific drivers which do not necessarily relate directly to river restoration. More importantly, data collection sites rarely coincide with specific river restoration project reaches. In the language of the Water Framework Directive, this is termed „surveillance‟ monitoring, as distinct from the more „investigative‟ and „operational‟ monitoring required for projects.

However, thinking more creatively about possible data sources can very often be extremely valuable, and this section highlights what is already available from existing schemes, as well as how engaging a cross-section of society can be of mutual benefit.

10.1 Existing data resources and monitoring schemes

The very first port of call for many people looking for a general overview of a site is Google Earth. This and other open access resources (such as are available online from the Ordnance Survey) may be invaluable for the most basic level of investigation. Indeed, over the long term, Google Earth may be useful for tracking changes with its historic imagery function. At a coarser spatial resolution but with images captured more frequently, LANDSAT images (via the US Geological Survey) may be of some use on much larger rivers. All these resources are subject to specific use license terms, however, and one should be careful not to breach these.

Figure 10.1 An example of LiDAR data, showing fine details of a derelict water meadow system on the River Nar SSSI in Norfolk (© Environment Agency copyright 2010 and the River Restoration Centre).

A second type of existing dataset may be those collected by large agencies for the purposes of large technical projects. Typically we are talking about remote sensing and aerial surveys, and most frequently Light Detection And Ranging (LiDAR – ***Figure 10.1***), which produces a high resolution elevation map of a flown site. Though such data often represents only a snapshot of a very defined area at a single point in time, this can be invaluable for reference in some cases. LiDAR data may be available from the EA, who have their own specialist remote sensing business unit – Geomatics Group.

Further to the above examples, there are on-going surveillance monitoring campaigns run by the EA and other groups for various purposes. It is extremely important that these data sets and collection are recognised since they may, in some cases, be extremely useful and reduce the need for some monitoring or at least help focus on the areas that need complimentary monitoring. In essence, always ensure you are aware of existing data collection programmes when developing your monitoring strategy. ***Appendix 14*** outlines and provides links to data sets, and examples of many of the existing monitoring methods are found in ***Appendices 8-13***.

Table 10.1 provides a list of some of the EA databases and the information they hold; the level of detail (both spatially and temporally varies significantly between these datasets. That said, more river and floodplain data has been collected continuously in England and Wales than in Northern Ireland, or Scotland, where data is sparse and primarily the domain of academic institutions. More details of additional data sets can be found in Bellamy and Rivas-Casado (2009), especially ***Section 2.***

Table 10.1 EA databases (Bellamy and Rivas-Casado (2009)

Database	Full name and brief description
WISKI	Hydrometric archive: river data such as water levels, river flow velocity, gauging stations, naturalised flows, surface water abstractions and consented discharge (effluent returns).
BIOSYS	Biological Monitoring Data. Database with information on invertebrates, macrophytes and diatoms.
BIBER	Database with spot gauging data and Acoustic Doppler Current Profiler (ADCP) site data. For the ADCP sites the database holds the contact details of the person in charge of each data set.
RHS	River Habitat Survey: database with information regarding the river habitat quality and degree of modification.
WIMS	Surface water and monitoring discharge: discharge and chemical data. The database holds all the surface water quality data.
NFPDB	National Fish Population Database. Fisheries monitoring data.
NFCD	National Flood Coastal Defence Data: The database contains data on flood mapping data (GIS format) and asset data (defences and structures such as dams, river channels…).
DRN	Detailed River Network: GIS metadatabase with the entire UK river network.

10.2 Who should be involved in monitoring and why

A key aspect of this document is to enable a wider audience to be involved with river and floodplain monitoring. With full, open and clear engagement of volunteers and other, wider interest groups in monitoring of river restoration schemes, there are potential cost savings for the practitioner and tangible benefits for those brought in from outside the project. Additionally, the passion and local knowledge which such groups often bring dramatically increase the chances of a successful scheme.

Note that there is likely to be an even greater need for simple, robust monitoring design and fool-proof protocol definition when working in partnership with more people.

10.2.1 Types of groups to approach

The following groups may be receptive to being approached to collect monitoring data. Note that there is a need for these organizations to be able to commit to involvement over most, if not all of the monitoring period:

- Angling clubs
- Educational institutions
  - Local schools
  - Universities and research institutions (likely also to be interested in monitoring planning and development)
- Local conservation volunteer groups
- Rivers Trusts
- Wildlife Trusts

10.2.2 Benefits of engaging a wider section of society

A summary of the benefits to both the practitioner and the outside parties involved is presented below:

Benefits to practitioners:	**Benefits to wider stakeholders:**
Cost savings – if carefully planned	Improved community cohesion
Local knowledge	Knowledge, education and training
Increased advocacy and public interest in the local and global river restoration cause	Opportunities to visit the site and work in the fresh air
Passion and enthusiasm	Case studies for researchers
Filled knowledge gaps	Filled knowledge gaps

11. Case studies

11.1 Mayes Brook

11.1.1 The project

Mayesbrook Park, located in Barking, North-East London (***Figure 1***), is an area of 45 hectares of parkland which prior to restoration was degraded and under appreciated by the community. The Mayes Brook runs from north to south alongside the west boundary of Mayesbrook Park where in the past it has been engineered to protect against flooding; it is culverted along much of its length and no water quality monitoring is currently undertaken. It was publically inaccessible and hidden by high metal fencing. There are historical water quality issues in the Mayes Brook, which have resulted from a series of mis-connections originating from properties and drains that connects to the Mayes Brook. Thames Water is currently dealing this with in two stages.

Restoration will realign the river through Mayesbrook Park, creating more natural bank profiles and introducing river meanders, backwaters and ponds. Through this Mayes Brook will become a feature of the park, public interest and use will increase and it could contribute to local regeneration.

Figure 1: Mayes Brook location map

Key themes outlined within the scheme were:

- Sustainable urban regeneration
- Recreational amenity (access to nature)
- Sustainable flood risk management
- Biodiversity/Conservation
- Climate change adaptation (*demonstration site for this driver in particular)*
- BAP targets for wetland related species and habitats
- Environment Agency duties to promote the conservation and enhancement of inland waters (Environment Act 1995)
- Implementation of WFD on the ground in an urban area

11.1.2 Pre-restoration Monitoring design

A baseline survey assessing ecological and hydromorphological aspects was carried out prior to restoration to help develop an evidence base for the Mayes Brook whereby the success of the project may be assessed in future. Environment Agency (2008) outlines this in detail. This baseline survey included;

- *River Habitat Survey (RHS)* focusing on natural features recorded; channel and riparian vegetation types; habitat quality assessment (HQA) and habitat modification scores (HMS).
- *River Corridor Survey (RCS)* investigating plant communities, species and geomorphological features of the channel, banks and corridor to within 50 metres of bankfull to create a 500 metre visual representation of the section. A biotope map overlay aimed to highlight the different in-stream functional habitat and link in with natural processes.
- *Invertebrate survey*. 3 minute kick samples taken at upstream, midpoint and downstream sites following standard Environment Agency methodology. This was analysed using BMWP (Biological Monitoring Working Party), ASPT (average score per taxon) and Environmental Quality Indices (EQI). Using a 100m representative section, 5 Surber-samples were collected from each of the functional habitats present, determined using the habitat map and personal observation. Unit-area samples were collected to enable densities and individuals per m^2 to be calculated. Physical parameters including substrate, flow and plants were also recorded for each sub-sample. Photographs of these methods are shown in ***Figure 2***.
- *Fisheries Survey.* Undertaken using point abundance sampling techniques. Battery powered backpack electric fishing equipment was used and habitat variables were recorded at each point. A small anode ring (20cm in diameter) was used to reduce field size and increase survey efficiency for small species. On a representative section of the channel, 43 point samples were taken at approximately 5 metre intervals. Starting at the downstream end, each point was exposed for 5 seconds and stunned fish were removed by dip net, identified, measured (fork length) and returned.

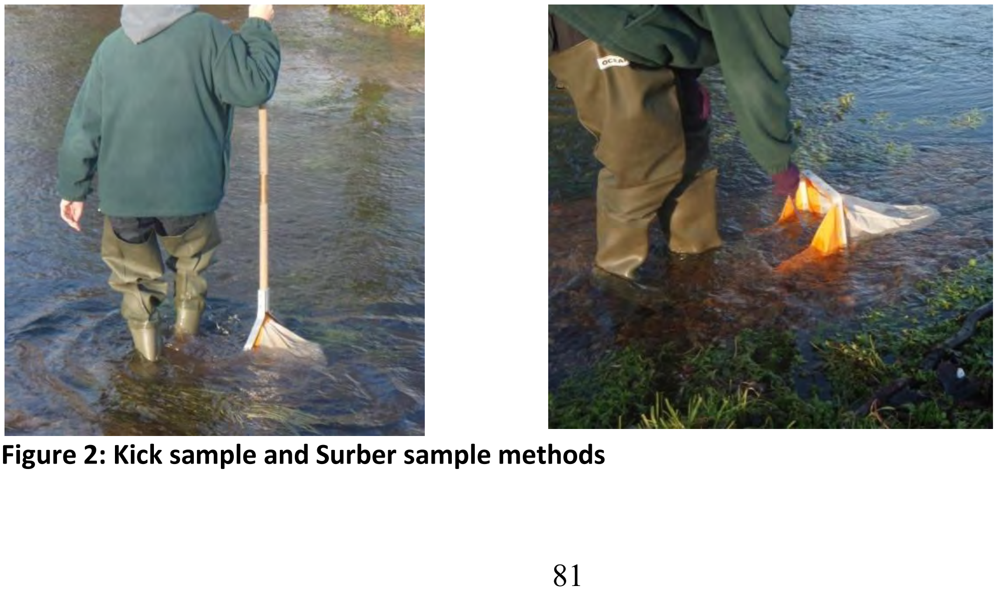


Figure 2: Kick sample and Surber sample methods

11.1.3 Pre-restoration Outcomes

Pre-monitoring results led to the following basic conclusions:

1. RHS and RCS highlighted that the channel was over deep, had been greatly modified and lacked any natural features or habitat structures. The banks were very high, steep and reinforced in places with no connection to the floodplain.
2. HQA scores revealed in terms of habitat quality, that it was ranked in the bottom 40% of the 150 most similar rivers while HMS scored the Mayes Brook in the class of severely modified rivers. The calculated EQI scores for the number of taxa and ASPT put the Mayes Brook into the general quality grade of D (fair quality); considerably different from the grade expected for an unpolluted river of this size, type and location.
3. The biotope map highlighted only three functional habitats: emergent plant, riffle and run habitats; however emergents were found throughout the channel, and were not just confined to the margins where they would be expected to occur. Surber-samples showed that riffle and run habitats had similar invertebrate compositions (***Figure 3***).
4. Pollution tolerant taxa ranging from BMWP score 1 to 3 dominate (snails, leech, hoglice, midges and worms) typical of a modified channel. A low number of pollution sensitive caseless caddis (BMWP 8) indicates that the habitat quality and possibly water quality issues limit invertebrate diversity.
5. BWMP and ASPT scores indicated that the upstream site had a more varied in-stream habitat suffering least from any organic pollution entering the watercourse.
6. Roach were dominant in terms of fish abundance and their biomass accounted for 63% of the total catch. Other species included 3-Spined Stickleback (22%), Chub, Dace, European Eel and Perch, so although there is a diversity of species present, the fish community is limited.
7. Age samples for Roach revealed that the majority were 5 years old and these had above average growth rates compared to the average for Roach in southern rivers; this was linked to low levels of competition and an abundance of pollution tolerant invertebrates providing good food resources.
8. No juvenile Roach were present suggesting that suitable spawning habitat is limited.

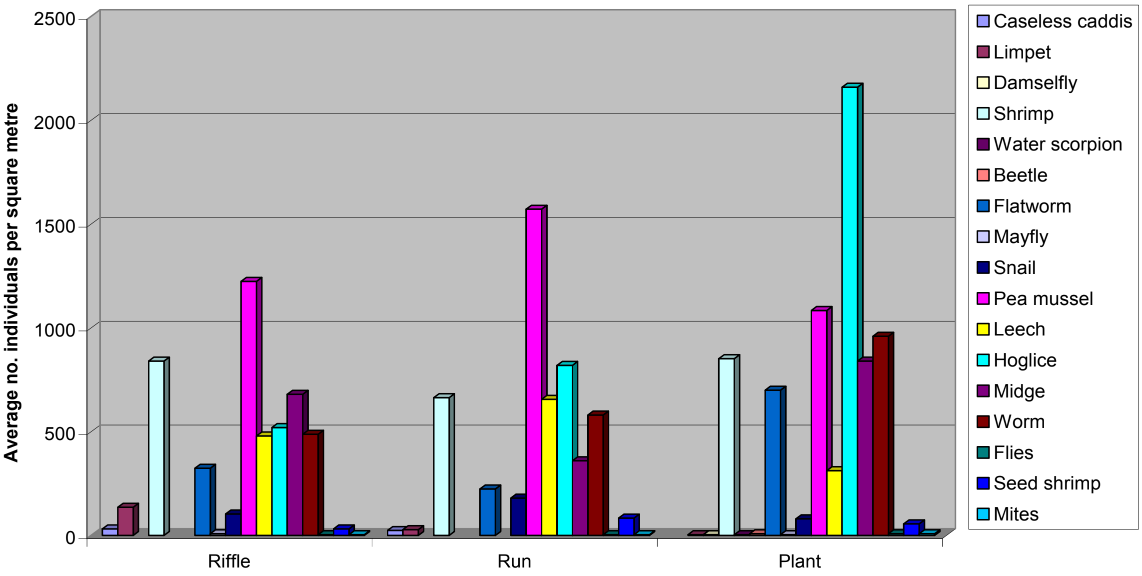


Figure 3: Taxa composition and number of individuals for each functional habitat

11.1.4 Current stance and Future intentions

The July 2010 launch of the Mayesbrook Park Landscape Master plan: The UK"s first Climate Change Adaptation Public Park signalled the progress that is being made on the ground – and now presents an important time to identify whether short-term improvements have been made, simply as a result of restoration activities. As the monitoring guidance suggests however, a long-term perspective is just as key to assessing whether the project has been a success for the ecology and the people of the area. A formal monitoring strategy is in the process of being delivered to monitor the restoration project from a physico-chemical, morphological, ecological and social perspective throughout the duration of the project.

Input into the strategy was the first example of using the PRAGMO guidance in regards setting detailed project objectives, and S.M.A.R.T. project monitoring objectives. Four working groups were organised by theme with specialists in each sector (aquatic environment; terrestrial environment; people; climate change) contributing to the overall document. Once all of the desired objectives had been devised and prioritised by the working groups, a decision was taken by other members of the Steering Group to prioritise all four inputs in the context of the wider project, where possible looking to combine or amalgamate objectives with a similar focus or aspiring goals. This has been very successful so far in giving the Mayes Brook Park project a clear vision in regards to;

- The objectives it would like to achieve;
- The monitoring strategy to use in this project;
- The costs and benefits of the monitoring strategy;

- Who will co-ordinate the monitoring strategy on behalf of the project partners;
- When, and in what format, data will be available to convey messages to the partners, funders and the public about the success of the project.

11.1.5 Project Partners

The Environment Agency, Natural England, Greater London Authority, London Wildlife Trust, Design for London and the Thames River Restoration Trust (TRRT). The project lead is LB Barking & Dagenham.

11.1.6 References

Environment Agency (2008) Mayes Brook Restoration Scheme: baseline ecological survey. 27pp

11.1.7 Further Information

For more information on the Mayes Brook Project see the London Rivers Action Plan interactive map on the River Restoration Website http://www.therrc.co.uk/lrap.php

11.2 River Cole

The River Cole at Colehill restoration scheme was one of three chosen for an EU LIFE funded project, "River restoration: benefits for integrated catchment management" as a demonstration site of innovative techniques and best practice. Prior to restoration, the river course was almost entirely artificial having been straightened and deepened over a period of 400 years. In 1997, restoration works involve re-profiling the bed and banks of two sections of the river creating approximately 1.3km of channel in addition to the restoration of a further 1.2km. Further works in 2008 involved the input of gravel and anchoring of large woody debris across the river.

11.2.1 Monitoring design

A monitoring rationale was designed to assess the benefits of the project and evaluate whether the project delivered a low-cost solution. Extensive monitoring addressed physical, chemical, biological and social aspects.

Possible benefits identified at the start of the project included:

- flood storage and flood alleviation
- nutrient reduction or storage
- river maintenance costs
- conservation
- recreation and amenity.

Surveys to assess geomorphological change were carried out throughout the EU LIFE+ project"s duration. In terms of pre-project data, a morphological survey, a topographic survey and a fluvial audit were undertaken and post-construction; a geomorphic survey was completed in the second and third year; while a follow-up topographic survey was also carried out in the final year of the project. The final report (RRP, 1999) illustrates the effects. An MSc study (Molloy, 2009) assessed hydromorphological change twelve years on. This also reviewed the 2008 works, which aimed to increase the coarseness of sediment to encourage the formation of permanent depositional features such as bars, which increase flow diversity.

Physical and chemical	
Water quality, including nutrient pollution	Special study
*Geomorphological change	✓
Hydrological regime/hydraulics (Q, surface & groundwater levels)	✓
Biological	
Aquatic invertebrate ecology	Special study
Aquatic plant communities	Special study
Floodplain plant communities	✓
Birds	✓
Fish	✓
Public perception	
Landscape assessment	✓
Public perception assessment	✓
Catchment management	
Cost-benefit analysis	Special study

Monitored aspects of the River Cole restoration at Coleshill. Note that more detailed studies were conducted for water quality, invertebrates, plants and cost-benefit analysis.

11.2.2 Outcomes

Geomorphology

Two main aspects of morphology were considered:

- Large-scale channel morphology (i.e. channel planform and cross-section)
- The frequency of small-scale morphological features (e.g. riffles and pools, point-bars, eroding cliffs).

Fluvial auditing was undertaken to describe the development of channel features following restoration. The River Cole demonstration site is split into two sections, upstream and downstream of Coleshill Bridge. These showed different morphological characteristics, and as such are described separately below.

A control site (upstream of the restoration demonstration site area) is channelised and ponded, and it had no riffles, runs, point bars or mid-channel bars. Over the course of the study, the control section showed little change over the course of the project, while in comparison the newly restored channel upstream of Coleshill Bridge changed dramatically. There was an observed increase in the number of riffles, pools, point-bars, actively eroding banks and overbank deposits.

In the restored section downstream of Coleshill Bridge, erosional channel features all increased and features which increased in abundance were riffles, pools, point-bars, mid-channel bars and overbank deposits. Actively eroding banks were numerous immediately after restoration but these had returned to pre-restoration levels by March 1998. There was also evidence on the River Cole of extensive sedimentation downstream of the restoration site which led to the local raising of bed levels, and a small increase in the number of berms.

Overall, the monitoring indicates that the 1997 restoration works increased channel morphology diversity improving river habitat conditions. This has increased channel length by 10%, reduced the channel width on average about 60% and bed levels have been raised by up to a metre. Molloy (2009) found that the input of coarse gravels also had a positive impact on redistributing sediment throughout the stretch and the thalweg had become more sinuous. The large woody debris had also seen to have increased flow diversity, and alter the morphology causing the formation of new habitats such as a shallow glide over a deposited gravel bar.

Figure 11.1 Pre, post and following restoration

Hydrology

Catchment modelling techniques revealed that should restoration be undertaken at the catchment scale, it would have a significant effect on peak discharge. The most effective theoretical alteration to channel structure was to reduce cross-sectional area to 20% of the existing value. This was predicted to reduce the 1 in a 100 year flood peak by about 10% at the bottom of the catchment, and the more frequent return period floods were reduced by proportionately greater amounts, the 1 in 2 year flood peak for example being reduced by 35% (RRP, 1999).

Biological

Macrophytes

There was no evidence that released sediment or other potentially damaging impacts of the restoration work had any adverse impact on the downstream plant communities. The number of wetland species (aquatic and emergent plants) quickly reached pre-restoration levels in the newly created channels, stimulated following the rapid colonisation of new muddy banks by marginal wetland ruderals such as pink water-speedwell and celery-leaved buttercup.

Interestingly however in the existing channel sections, there was a difference between emergents and aquatic response rates. Emergent plant species demonstrated a rapid recovery while the number of aquatic plant species downstream of Coleshill Bridge appeared to have been little affected by restoration (RRP, 1999) Molloy (2009) similarly reaffirms a lack of marginal bank-side vegetation years later.

Invertebrates

In the restored channels, the process of re-meandering eliminated most of the original river channel (which was backfilled with spoil from the newly created sinuous channels). Colonisation therefore began following the completion of the works with no pre-existing invertebrate assemblages.

Aquatic macro-invertebrates recolonisation was rapid and one year following restoration, species richness was only slightly below pre-restoration values. However, the average species rarity of macro-invertebrates recolonising the restored channel was significantly lower than the pre-existing channel data. Prior to restoration, the channel had thirteen local or Nationally Scarce species recorded. Statistically overall, there was a significant interaction between time (before vs. after) and location (control vs. restored), while the two upstream control sites showed similar species richness values to each other throughout the project.

Fish

Following restoration, fish biomass and density quickly returned to pre-restoration levels, with the highest values found in areas of gravelly eroding substrate. Surprisingly however, these values were recorded in the downstream impact reach below the restoration scheme itself. It is suggested that the improvement is however more than likely a reflection of the improved habitat in the restored section, as fish may be expected to rest in the downstream areas before moving into the faster flowing shallower water of the restored area to spawn.

Fish species richness generally remained unchanged both in the restoration site and the control and impact reaches. Twelve years on, it was determined that it may take much longer to see fish populations change (Molloy, 2009) and that factors other than geomorphic change may be limiting the establishment of fish at varying scales of the life cycle.

Social appraisal

- 42% of Coleshill residents thought that the restoration scheme was of „good" or „quite good" value, with many at the time wising to determine the cost-benefit of the project at a much later date following re-establishment of the river environment, and in-particular ecology.
- Overall the view of the scheme was consistently favourable. 53% broadly approved the restoration work; perhaps a reflection that the River Cole in part did not appear too degraded at the beginning of the project.

11.2.3 Lessons Learnt

While it was hoped that the restoration features would act as in-stream nutrient concentrations, the absence of any clear reduction (RRP, 1999) should not be unexpected. In the medium to longer term, effective buffering and nutrient removal processes may lead to an improvement in water quality, but it is likely that should releases of nutrients still occur elsewhere in the catchment, the water quality may remain at a similar level to pre-project.

11.2.4 References

- Molloy, H. (2009). Hydromorphological changes to the River Cole over a twelve year period following restoration. Submitted in partial fulfilment of the requirements for the degree of MSc Water Management (Environmental option). 65pp.
- RRP (1999). The effects of river restoration on the R. Cole and R. Skerne demonstration sites. Final report. 60pp plus appendices. River Restoration Project, Huntingdon.

11.3 River Quaggy

11.3.1 The Project

For years the River Quaggy at Sutcliffe Park was lost underground in a culvert. Local residents only became aware that a river was there when their homes flooded more frequently as development increased. Rather than further deepening and widening the hidden channel, a decision was made to combine flood risk management with a strategy for river restoration that would benefit the local community.

The Sutcliffe Park restoration scheme was part of a series of flood alleviation schemes along the River Quaggy, and provided a floodwater storage area upstream of Lewisham town centre, which has suffered from severe flooding in the past. Since restoration, Sutcliffe Park has won two awards, the Living Wetlands Award 2007 and the Natural Environment Category of the 2007 Waterways Renaissance Awards.

A new 'low-flow' meandering channel was cut through the park, following its original alignment. The previous culvert was retained, enabling it to take excess water in times of extreme flood events. Flow is now regulated between the two watercourses by a sluice. To provide further flood water storage, the park itself was lowered and re-shaped to create a floodplain capable of storing a maximum of 85,000 cubic metres of flood water. A network of boardwalks, pathways and viewing points were designed to encourage access to the river and ponds, all of which were an integral part of the scheme for community and wildlife enhancements.

11.3.2 Monitoring design

The monitoring objectives were;

- To determine the post restoration adjustments in the reach‟s geomorphology;
- To determine the physical habitat diversity of the restored reach;
- To assess the riverbed and floodplain sediment quality and;
- To assess the water quality of the restored reach
- To assess the ecology of the restores reach

11.3.3 Methods Used

Geomorphological appraisal

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- Surveys of river level and bankfull dimensions (i.e. width and depth);
- Calculation of Manning‟s „n‟, hydraulic radius, wetted perimeter;
- Measurement of flow velocity and discharge;
- Completion of a River Habitat Survey.

Sediment quality appraisal

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- Particle size analysis of riverbed and floodplain sediment;
- Measurement of organic matter content of riverbed and floodplain sediments;
- Measurement of trace heavy metals within riverbed and floodplain sediments.

Water quality appraisal;

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- Measurement of trace heavy metals within river water;
- Measurement of dissolved oxygen and pH;
- Measurement of Nitrate, Phosphate, Nitrite and Chloride.

Ecological appraisal;

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- Surveys of instream macrophytes and riparian plant species;
- Surveys of macroinvertebrate species, calculation of BMWP, ASPT and number of taxa.

11.3.4 Outcomes

Comparison of the channel design specifications from 2004 and the measured channel geometry from 2006 found that the reach had a more diverse form after restoration and that the mean bankfull width and depth had increased. The presence of instream aquatic plants (macrophytes) had a major impact on water velocities, and was responsible for the creation of extensive slackwater areas. The sediment assessments showed that traces heavy metal in both the riverbed and floodplain sediments exceeded a number of sediment quality guidelines, although they were within the „nomal‟ range for UK urban rivers based on limited published data. This highlighted the need for a comprehensive set of sediment quality guidelines for assessment of UK urban rivers. Ecological appraisal based the classification of Holmes et al. (1998), found that instream and marginal plant species composition was characteristic of both lowland rivers with minimal gradients and rivers with impoverished ditch floras in lowland England Mean Trophic Rank results suggested that in future the monitoring of nitrate and phosphate levels would be required. Macroinvertebrate surveys indicated that the watercourse was populated by mainly pollution-tolerant taxa.

11.3.5 Lesson Learnt

Results from the appraisal of the Sutcliffe Park reach of the River Quaggy highlighted a number of implications and recommendations for monitoring river restoration projects in of urban rivers;

- If on-site geomorphological input is not available at the construction phase, then geomorphological monitoring should take place as soon as the channel is constructed to obtain accurate as-built data which can be confidently used in future geomorphological assessment of the restoration scheme.
- The results from appraisal post restoration need to be validated with results from annual monitoring. For example, assessment of macroinvertebrates in the Sutcliffe Park reach showed limited abundance and diversity of high BMWP scoring species, but research has suggested that a restricted taxa range after restoration is not uncommon, and changes in macroinvertebrate assemblages may be subtle within the first few years, particularly in urban areas.
- The requirement for a standard set of guidelines to assess the quality of urban river sediments. The comparative guidelines used to assess riverbed sediments were Canadian (OPSQG) guidelines and were not ideal for assessing the quality of UK river sediments. Furthermore, the guidelines used for floodplain sediment quality assessment were for use in assessing trace heavy metals in soils rather than fluvial sediments.

11.4 Seven Hatches

11.4.1 The project

The STREAM project **was** a £1 million four-year conservation project centred on the River Avon and the Avon Valley in Wiltshire and Hampshire. The River Avon and its main tributaries are designated as a Special Area of Conservation (SAC), and the Avon Valley is designated as a Special Protection Area (SPA) for birds. The STREAM project has undertaken strategic river restoration activities and linked management of the river and valley to benefit the river habitat including water crowfoot and populations of Atlantic salmon, brook and sea lamprey, bullhead, Desmoulin's whorl snail, gadwall and Bewick's swan.

A Conservation Strategy for the River Avon Special Area on Conservation (2003) identified the main issues affecting the ecological health of the River Avon *SAC*, and agreed on a range of actions required to address them. It also highlighted the complex relationship between the river and the Avon valley. In December 2002, work began on securing substantial new funding to do the following:

- Restore, to favourable condition, the River Avon Special Area of Conservation/Special Site of Scientific Interest (SSSI) and the Avon Valley Special Protection Area/SSSI.
- Tackle wider biodiversity issues outside the European protected sites including additional priority species and associated habitats, and
- Improve public access, awareness and support for the natural heritage importance of the river and valley.

The project identified six sites where conservation-led restoration of the watercourse habitat may be used to demonstrate techniques and disseminate knowledge and experience of this work.

11.4.2 The River Wylye at Seven Hatches

Just upstream of Wilton, „Seven Hatches" was one of the six sites within STREAM. It had historically been over widened and over deepened, and sluices prevented fish migration and caused a backwater effect on flows upstream of the structure.

The project objectives aimed to;

- Modify the operation of Seven Hatches sluices, reducing height by an average of 0.15 metres, therefore increasing ecological connectivity between reaches and improving upstream habitat quality;
- Restore the historic bed level and increase the heterogeneity of bed morphology in previously dredged reaches, by the reclamation and re-introduction of excavated gravel/stone bed material;
- Narrow over wide channels where necessary in order to re-establish a sinuous channel of appropriate cross-sectional area with respect to present day hydrograph data;
- Increase the amount of large woody debris in the channel in order to increase both the availability of this habitat type and morphological diversity of the channel;
- Break out and remove the tractor bridge footings and replace with a single span bridge.
- Remove the impounding effect of the structure;
- Enhance the availability and quality of habitat for SAC species (and habitats);

  Bullhead (increase the number of hard bed pools, insert large flints in new riffles/fast glides and increase shading/ large woody debris for juveniles);

  Salmon (improve migration routes, source viable spawning sites, and more appropriate habitat for fry and parr);

Brook lamprey (increase the availability of well sorted, fine sediment in shaded, marginal areas with large woody debris for ammocoetes and gravel/sand dominated shallows <40cm deep for spawning adults);

Desmoulin‟s whorl snail (marginal zone enhancement of all channels);

Ranunculus (increase heterogeneity in velocity and bed morphology).

11.4.3 Monitoring design

Detailed monitoring was carried out at Seven Hatches, with a control site with comparable physical characteristics. Field mapping was converted into a suitable digital GIS format to allow calculation of the area of habitats within the two sites to monitor change following repeat surveys. The GIS recorded physical and ecological features, sample and cross-section locations and any other spatial data collected in the field.

Pre-restoration surveys intended to establish a record of biological and physical conditions at the site prior to restoration. The post-restoration surveys recorded modifications to the channel after restoration. It should be recognised that there is a limitation to the comparisons that could be made over this still relatively short duration. The relationship between physical and biological conditions was assessed, taking into account other factors and processes that might have influenced these.

The following datasets were collected:

	Pre (2006)	Pre (2007)	During (2007)	As built (2007)	Post (2008)
Physical Biotope Mapping	+[1]				+[1]
River Corridor Survey (RCS)	+[1]				+[1]
Macrophyte Survey	+[1]	+[3]			+[13]
Fish Survey	+[1]				+[1]
Fixed Point Photography		+[12]	+[2]	+[2]	
Rapid Appraisal Survey*		+[2]	+[2]	+[2]	

[1] Royal Haskoning
[2] River Restoration Centre
[3]Wessex Water

* Included different aspects including visual and social elements; physical characteristics; vegetation; fish and aquatic invertebrates and; mammals, terrestrial invertebrates and birds.

Note that this was probably more comprehensive than is necessary for a typical individual UK restoration project. Please note that further data has been collected post 2008 by Royal Haskoning.

11.4.4 Outcomes

Hydro-geomorphology

The introduction of gravels and the creation of riffles were largely successful as heterogeneity in flow types was achieved. Additionally, large woody debris pinned into the substrate increased the flow variability locally and there was evidence of scour on the downstream side of the structures. In the long term it is predicted that the turbulence at moderate to high flows generated by the woody debris will help to ensure that the riffles remain free of excessive siltation.

Appraisal of overall effectiveness is limited by the apparent lack of direct response to restoration measures; as while there has been an observed increase in variation of channel width, depth and flow velocities, there has also been natural variation in an increase of water level and processes within the catchment. Significant geomorphic change is likely to occur over much a longer timescale as the river naturally readjusts (Royal Haskoning, 2010).

Biological

Macrophytes

Channel narrowing techniques (berms) were successful in terms of providing marginal vegetation features. The system of brashings and log deflectors upstream of the hatches trapped silt and sediment. Deflectors have improved heterogeneity of the habitat, providing shallow well vegetated margins close to the existing deeper water. Larger structures would have had a more significant narrowing effect; however this would likely have had an adverse impact on flood flow conveyance.

The narrowing above the hatches could have been bolder than was actually carried out. The log deflectors could have protruded much further into the channel and the brushwood infill and log staked wet ledge could have then been wider. However, what was installed is developing well. The result of the planting scheme was not as varied as was originally planned because many of the plants did not survive as a result of water levels being higher than expected due to wet winters and wet summers. It could be a number of years before the ledge vegetation reaches its full potential.

Post monitoring statistics revealed that macrophyte cover increased, the proportion of macrophyte species preferring swift flows increased and the proportion of macrophyte species preferring slow flows decreased. However in comparison to the control reach, these were insignificant to demonstrate an attributable direct response to restoration measures. Macrophyte composition remained the same.

Invertebrates

Assemblages at the restoration site does not appear to have changed significantly more than that observed in the control site however with high taxonomic richness observed at both sites prior to restoration; there was unlikely to have been an significant increase.

Fish

Initially measures appear to have improved salmon and trout populations in the first year following restoration – species that prefer swift flows – and this was not replicated at the control site. Grayling populations may also have been positively impacted however further catchment scale analysis is required. However, salmon numbers decreased the following later, and while restoration has been successful in altering the age composition of bullheads with an increase in juveniles; overall bullhead and lamprey populations appear to have declined following restoration.

11.4.5 Lessons Learnt

- Prior to implementing a restoration scheme, **SMART objectives** should be set following the approach outlined in RRC (2009). The subsequent monitoring protocol should then aim to assess if these SMART objectives have been met ensuring that it is linked directly to the objectives of the restoration scheme and the Water Framework Directive.
- It is recommended that a **10 year monitoring** programme is undertaken to include sufficient replicates to enable detailed statistical analysis. For example, the majority of the river remains over-deep and over-wide and it is recognised that it may take some time for the channel to gradually adjust through year-on-year sediment deposition and vegetation growth.
- Monitoring should be undertaken throughout the **entire reach** rather than specific sections. This will enable holistic conclusions to be drawn on the effectiveness of the scheme.
- Cross sections, macrophytes, invertebrates and fish were monitored in detail however it is apparent that measurements **over a longer timeframe** are required to enable statistically robust analysis to be undertaken. Macrophyte and invertebrate sampling should continue for at least 5 years to determine what direct effect the restoration work is having. Though macrophytes and invertebrates are not the designated interest, they often provide a more reliable indication of river health than more mobile fish populations.
- Monitoring of velocities and substrate was not effective in producing data of sufficient quality and resolution. Velocity measurements should be undertaken in a **variety of flow conditions** and **repeated when water levels are similar**. Substrate measurements should be taken using a sediment sieve to collect grain sizes and enable a detailed analysis of sediment distribution.
- Monitoring approaches are going to **require more 'vision'** in terms of immediate works versus long term results.
- Change was limited by sub-optimal operation of hatches with restoration potential constrained by their existence as structures. Planned changes to the hatch operation were not carried out because of the concerns about reduced flows and the potential effect on salmon in Butchers Stream and flooding downstream in Wilton. The project demonstrated the impact that in-stream structures can have, and a **hatch operating protocol** developed through this four year project.

11.4.6 References

Royal Haskoning (2010). Seven Hatches Case Study Draft Report: Appraisal of River Restoration Effectiveness.

RRC (2009). Post works assessment of the STREAM restoration project sites at Seven Hatches (R. Wylye).

11.5 Kissimmee River Restoration Project, Florida

11.5.1 The project

The Kissimmee River is located in south Florida, arising from the Kissimmee Lake headwater streams just south of Orlando before flowing in a southerly direction into Lake Okeechobee, which is the second largest lake in the USA. The river once meandered for 103 miles through Central Florida and inundation of its floodplain as a result of for long periods by heavy seasonal rains, meant that wetland plants, wading birds and fish thrived. This was up to two miles in width. However, prolonged flooding was seen to cause severe impacts to humans, and the U.S Army Corps of Engineers cut and dredged a large 30-foot deep straightway canal cut between 1962 and 1971. While it achieved flood reduction benefits, it detrimentally impacted upon the river-floodplain ecosystem.

When restoration is complete in 2015, more than 40 square miles of river-floodplain ecosystem will be restored, including almost 20,000 acres of wetlands and 44 miles of historic river channel. Phase 1 in the lower Kissimmee basin began in 1999 and was completed in 2001, while Phase 2 was completed in 2009 respectively, together restoring continuous flow to 19 miles of the Kissimmee River. The third phase involves backfilling to the canal cut and restoring flow to a further eight miles of river. About 98% of the land required to complete the River Restoration has now been acquired – a total of 102,061 acres; and the only sections that will remain untouched are those that are still required to quickly drain floodwaters. The total project cost is anticipated to be in the region of $620 million.


Tom Palmer, The Ledger

11.5.2 Monitoring design

Extensive monitoring is an integral component of the scheme, and since the project aims to restore the entire Kissimmee ecosystem, studies have and continue to be undertaken not only the river itself but also on the wetlands, and the hydrology, hydraulics, water chemistry, algae, plants and macro invertebrates of the environment, looking in terms of the diversity, productivity and functional processes. The driving force behind this is a set of „61 expectations‟ which considers not only the desired end point, but also the natural processes upon which they depend. This is based on a variety of data whereby inferences can be made including historical records, professional expert judgement and empirical/computational models.

A key element of the monitoring design is the Kissimmee River Restoration Evaluation Program (KRREP), a comprehensive monitoring and assessment program designed to evaluate ecosystem-scale responses to the restoration program. This involves the collection of baseline datasets, after construction and following re-establishment and if an expectation is not met; adaptive management strategies may have to be adopted. KRREP will:

- *Assess achievement of the project goal of ecological integrity.*
- *Identify linkages between restoration project and observed changes.*
- *Support adaptive management as construction proceeds and after project completion.*

11.5.3 Outcomes

Phase 1:

This involved the removal of a water control structure, the creation of a new river channel and the infilling of an eight mile flood control canal. The measured improvements have been compared with the condition before restoration began and the results are extremely encouraging (SMWFD, 2008):

- *Continuous flow of water since 2001 has improved biodiversity value of the river its floodplains and surrounding wetlands, and the biological community composition.*
- *Organic deposits on the riverbed decreased by 71%, which has helped re-establish sand bars, providing new habitat for invertebrates and shorebirds.*
- *Emergent plants native to the historic river, to replace undesirable plants, are developing.*
- *Dissolved oxygen concentrations, critical for the survival of fish and other aquatic organisms, have increased to levels similar to those in relatively pristine rivers in South Florida.*
- *Aquatic invertebrates are more characteristic of free-flowing water (e.g. caddis and mayflies)*

Phase 2:

Works were undertaken upstream of Phase 1 towards Lake Kissimmee and below the Avon Park Bombing Range in a similar vein to those completed in 2001. It is still only recently that these works have been completed but the initial signs remain promising.

- *The restored river‟s water quality is better, which is reflected in the fish populations. Native Largemouth bass and sunfish populations have increased significantly.*

- *The length of river channel through the restored section has increased from 13 miles to 25 miles, and Mike Cheek, an environmental scientist with the South Florida Water Management District, has compared the old canalised cut to "an interstate highway", whilst the new channel, is a "two-lane country road; much more scenic and biologically diverse" (Palmer, 2010).*
- *Bird species which were historically lost have returned, and the mixture is now relatively rich, consisting of more than 300 species; largely as a result of the wetlands rebounding. At least six species of shorebirds, which are smaller and harder to spot in aerial surveys used to monitor trends in bird populations, have been documented.*

11.5.4 Lessons Learnt

- While efforts to coordinate and integrate wildlife research projects have been widespread, and largely successful, there is a continuing drive to share and collect even more data to allow scientists a ***more complete picture*** of the extent of ecological ecosystem restoration.

- It is apparent that with in addition to a diverse range of datasets, there are also hydrologic modelling studies and wider regional studies, that this case study in particular of all of those within this monitoring guidance, presents an example of the ***archetypal "all-singing, all dancing" example of appraisal in river restoration***.

- While this project is perhaps an exceptional case in terms of the scale, cost and ambitious „expectations" set, much will still be learnt about the ecosystem-scale impact of undertaking not only river, but also floodplain and wetland restoration on their associated biotopes and species. With ***very little data available at this scale***, following the completion of headwater projects to increase water storage capacity in the Upper Chain of Lakes by 2013, restoration evaluation of ecosystem recovery will continue through to 2018, creating a monitoring record of almost two decades, ***probably the longest river monitoring record worldwide***.

11.5.5 Bibliography

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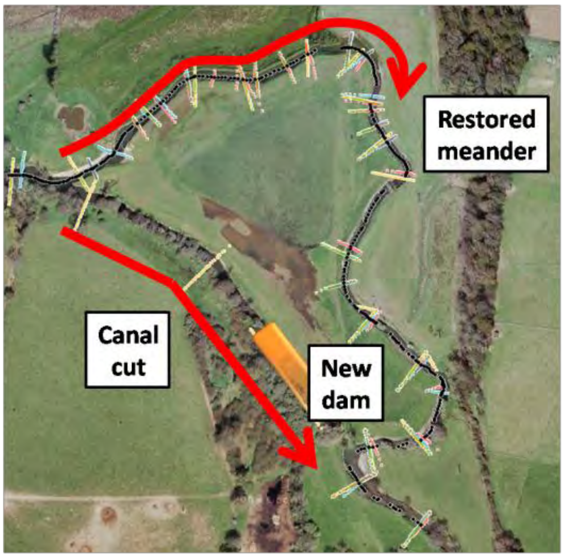
South Florida Water Management District (2008) Below the surface an in-depth look at…Kissimmee River Restoration Phase 1: Environmental Recovery is Under Way.

http://my.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/belowthesurface.krr20081020.pdf accessed on 21st October 2010.

Palmer, T. (2010) “Birds Flock to Restored Wetlands Along Kissimmee River”, The Ledger.com. http://www.theledger.com/article/20100223/NEWS/2235028/1338 accessed on 21st October

11.6 Shopham Loop

11.6.1 The project



In 2004, on the Western River Rother in West Sussex, an 18th century canal which cut off approximately 850 m of meander loop was blocked with a dam, forcing the flow back round the loop. Previously, remnant flow in the loop had caused excessive sedimentation, and so this sandy material had to be removed. At the same time, parts of the floodplain were lowered and a levee augmented to encourage flooding on the inside of the loop; a scrape was excavated; and cobble and shingle fixed beds were installed just inside the up- and downstream confluences with the old canal. The inset figure shows the general layout of the site, as well as surveyed cross-sections.

11.6.2 Monitoring design

Monitoring of the project aimed to be a comprehensive programme sensitive to:

1. Changes in *geomorphology*, looking at the evolution of physical habitat features.
2. Changes in the *hydrology and hydraulics* of restored and adjacent reaches, to identify the impact on flood levels and enable analysis of in-channel hydraulic conditions within the restored reach.
3. The *ecological response* within restored and adjacent reaches, to document how the biota adjust to the changing physical habitat and, via habitat suitability models, identify driving mechanisms.
4. The ecological response of the surrounding landscape, particularly species in the floodplain.
5. The *drivers of changes* in channel morphology, substrate composition and the establishment of flora and fauna, to compare the restored physical habitat with design aspirations.

The following datasets were collected:

	Before	As built	2005	2006	2007	2008	2009
Topographic survey	+	+	+	+			+
Fixed-point photography	+	+	+++	+++	+++	+	
15-minutely water levels			+	+	+	+	+
Invertebrate kick samples	+		+	+	+		+
Electro-fishing			+	+	+		+
Macrophyte survey			+	+	+		+

Note that this was partly an experimental programme, designed to investigate the best approaches to monitoring by attempting to understand interactions between monitored aspects. It is probably more comprehensive than is necessary for a typical individual UK restoration project.

11.6.3 Outcomes

Monitoring results led to the following basic conclusions, grouped according to the aims above:

1. Survey detected small changes in channel shape in some areas, and that the greatest changes happened very quickly (< 1 yr). This confirmed the loop was evolving greater complexity of form.
2. Cross-sections and flow data from downstream allowed modelling of hydraulic habitat, which was increasing in diversity in concert with increasing complexity in the cross-sections.
3. Fish numbers and diversity appear to have increased post-construction, when controlled for trends up- and downstream. The scrape is being well colonized, suggesting more flooding.
   Macrophyte cover has increased steadily, but species number peaked soon after construction.
   Invertebrate data show no clear trends except a peak in diversity and numbers in 2006 (as fish).
4. Coarse-scale changes in floodplain vegetation can be detected via the fixed-point photography.
5. The fixed cobble beds appear to be responsible for the greatest morphological changes.

11.6.4 Main lessons learnt

The project suffered from a lack of **clear objectives** and a **formal protocol** for reference. Though there are monitoring „aims‟ (listed above), the project objectives did not meet SMART specifications and were in fact decided upon after the work had started, for the purpose of the monitoring. Consequently, it is difficult to appraise the success, or otherwise, of the project with hard evidence. The fact that methods to be employed were not explicitly detailed meant that this ambitious monitoring programme, in the absence of a consistent project manager, was greatly limited by apparently minor mistakes, misinterpretations and inconsistencies resulting from the involvement of many different members of staff. A significant amount of data had to be discounted from analyses as they were not comparable with previous and/or subsequent years.

The fact that this was a rather experimental exercise in monitoring dictated that the programme did evolve over time, with gradually more sampling introduced. However, this is to be avoided, owing to inconsistencies between years and the fact that newly collected data will lack baseline (or „before‟) **control data**. It is by far preferable to begin by sampling more points than can be sustained (ensuring a comprehensive baseline), and then eliminating those which may prove difficult to access in future, for example, or appear to be of less value or cannot be used with great confidence. The

Shopham programme was not designed before works started, and so the baseline is incomplete. As such, most conclusions relate to changes after construction, rather than any improvements over the pre-project situation. The collection of data to control for effects outside the reach was fairly good, aided by the convenient location of standard surveillance monitoring stations for invertebrates and fish not far up- and downstream. Beyond these datasets, however, there was little indication of typical background dynamics of geomorphology or seasonal and successional progression of vegetation on nearby un-impacted parts of this river.

Finally, the **selected methodologies** were not capable of meeting *all* of the programme aims. No firm conclusions could be made about the evolution of specific features such as banks, bars and berms (mentioned in the full version of Aim 1). The ecological response of the floodplain and surrounding landscape was neglected (Aim 4), and there was insufficient information to meet all aspects of Aim 5, particularly with regard to substrate composition and the original design aspirations. Lack of baseline data prohibited firm conclusions as to the impact on flooding.

In summary:

- Primarily, a lack of SMART **objectives** meant…
- **methods** selected were not always appropriate for evaluating „success", and…
- insufficient **control data** were collected.
- Also, a lack of **formal protocol** definition and planning …
- led to mistakes in **data collection** and abandonment of many data.

11.6.5 An improved protocol

With the benefit of hindsight, taking on the lessons above and more specific issues relating to each dataset, the following outlines a suggested revised protocol to meet the (somewhat „woolly") aims stated earlier for Shopham.

1. Geomorphology

Cross-sections should be surveyed **only at key areas** of expert-predicted channel adjustment in the design (including immediate down- and upstream reaches and where change may be a particular problem) and defined by clearly visible, fixed and surveyed-in **markers** well up on the bank (e.g. painted 2 m stakes driven into the ground). An evenly horizontally distributed number of elevation measurements should be taken before works begin, immediately after construction (i.e. before any flow is allowed in the loop) and in the 1st, 2nd, 4th and 10th years after completion, or more or less frequently, as appears necessary. Measurements should be taken when vegetation is limited but flows are not too great to prohibit access. It is also suggested that the surveys extend to the canal cut, which remains as a backwater and assumed sediment sink. It is key that the surveys are done **in exactly the same way** each time. *See also point 5, below*

Physical biotope (habitat) mapping based on the RCS methodology is a more direct way to achieve Aim 1. It is suggested that this is done at the same times as the topographic survey, or in conjunction with channel ecology data collection if this is done more frequently, so that interactions can be investigated as part of Aim 5, and that the maps are **digitized** to enable further analysis. *See also point 5, below*

2. Hydrology & hydraulics

The **water level recording** set-up (one sensor in the loop and two more a few hundred metres up- and downstream) was sufficient, in conjunction with floodplain surveys, for determining impacts on flood levels and frequency. The sensors (pressure transducers) must be properly protected from peak flow events and vandalism, as well as their elevation accurately surveyed-in at installation, however (which these were not). A simpler design might be to have one or two pressure sensors at points of interest **in the floodplain**, giving a more clear-cut definition of flooding and flood depth, and not necessarily requiring surveying-in. In-channel measurements aid the verification of hydraulic modelling, however *(see below)*.

Hydraulic conditions and how they change may largely be inferred from interpretation of the geomorphological monitoring, but **modelling** based on the topographic survey will be informative. Data requirements for modelled sections or more intensively surveyed reaches *(see point 5, below)* are likely to include **flow data** (from nearby gauging stations, perhaps adjusted in light of locally recorded water levels or velocity measurements) and observations of the **channel vegetation and substrate**, all recorded at the same time as the surveys.

3. Channel ecology

The **sampling area** of all ecological monitoring should be **extended** to include the canal cut backwater, which represents an entirely novel set of habitats and another area of great change due to the project.

Sampling times of invertebrates and fish should be **matched to up- and/or downstream** surveillance monitoring as closely as possible, to control for wider patterns of natural variation.

Kick sampling should be performed using a **standard method** to facilitate analysis, but specifically where and when **depends on monitoring objectives** and available resources. If a representation of the whole loop is required, and many samples may be taken, a randomly distributed design may be suitable. If fewer samples may be taken, it is advisable to take these at fixed points. It is suggested that sampling should again be contemporaneous with the geomorphological surveys, though to account for high variability in invertebrate communities, sampling should be more frequent if possible. In any case, if nearby surveillance monitoring data are not available for any sampling period, further **control data** should be collected. Furthermore, one should be aware that the limited spatial extent of surveillance monitoring may not make it comparable with the more extensive loop monitoring. If interested in the colonization of the new habitats, this may be rapid and so sampling frequency should be increased in the first year. *See also point 5, below*

Electro-fishing should again be contemporaneous and standardized with wider surveillance monitoring. It‟s not essential that this sampling is performed at the same time as other data are collected, but the frequency of the topographic surveys may be a good guide (minus the „as-built‟). Main known spawning periods should be avoided. One of the few specific project objectives was fishery enhancement, and so it is recommended that **size (or weight) data** be collected, and **larval fish** be explicitly included, to capture population dynamics.

Macrophyte data collection actually implemented (species and total percentage cover) was fairly fit for purpose, but cover estimates for individual taxa would be informative, and **pre-project data** for the original course of the river (i.e. the canal, but also the loop if possible) should be collected. Only staff capable of identifying confidently to species level should collect these data, as apparent mis- or incomplete identification were an issue in the actual implementation. *See also point 5, below*

4. Landscape and floodplain

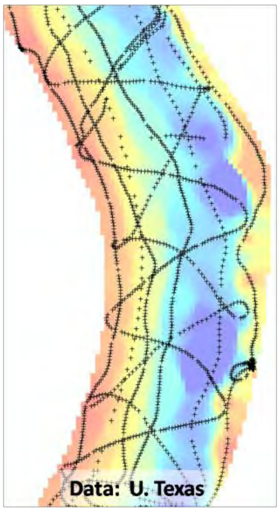
Fixed point photography should aim to cover the full site, particularly focusing on predicted areas of change. Many points should initially be established, and if necessary, some may be discarded at a later date. These points should be clearly marked with stakes, in a similar way to those demarcating cross-sections, and additionally marked with a direction for the central point in the image. Ideally the **same digital camera and lens settings** should be used year on year, to facilitate any digital image processing and overlaying (35 mm slide film was used in reality here). Certainly, data about the focal length (usually recorded automatically as file metadata with most digital cameras) and field of view should be noted to allow for later correction if necessary. Pre-project photos absolutely must be taken, as should „as-built‟. Photos should be taken at least once during winter, and preferably not during high flows (so that the channel is most visible), and once during summer (when the vegetation is most visible). As succession of vegetation is ongoing, sampling should occur every year for the first 5 years, and then perhaps every 3-5 years. Coverage of other river sites is advised.

Quadrat surveys of the floodplain will capture changes in plant species present and relative cover. A campaign of 10 – 20 x 1 m^2 quadrats, randomly distributed, pre-construction and then conducted towards the end of spring in each year photographed should be sufficient.

Pre-project **bird surveys** are already available for the immediate upstream reach. It is suggested that increased flooding and vegetation change is likely to affect the avian community at this site, and that these are followed up, perhaps in years 1, 2, 4, 7 and 10. Care should be taken to ensure that the same sampling effort and methods are employed. Ideally, pre-project data should be collected for the exact restoration site, but owing to inter-annual variability, these might have to be collected for several years to get a clear picture of the species present. Involvement of community groups or local ornithological societies in these surveys is a good way of proceeding.

Pit-fall traps would also be valuable for detecting changes in the floodplain invertebrate and small mammal communities. Around 20 of these, well distributed around the site, could be installed semi-permanently and sealed with lids when not actively sampling. Species and abundance data could be collected, over a period of a week or so, pre-project and once or twice (not during winter) yearly at the same frequency as suggested for the bird surveys. It is important that traps are opened at the same times each year, and that they are checked daily to minimize trapped organisms predating each other.

5. Process drivers



The rather ambitious goal of investigating the drivers of changes would require a large dataset for statistical analysis, and thus considerable further monitoring.

The **topographic survey** approach could be modified in this case.

Still focusing just on key areas where change is expected or important, channel elevation (bathymetry) data could be collected, distributed either evenly (gridded) or in a properly randomized manner in the x and y directions. This represents a **more intensive, smaller-scale** and more evenly distributed version of the approach illustrated in the inset figure, and would allow more powerful statistical and modelling analyses and importantly, reliable interpolation (kriging) between the measured points, building a 3D surface model of the channel (coloured layer in the figure). Simple cross-sections may be extracted from anywhere on this surface. Even in the sparsely distributed, large-scale example illustrated, it‟s clear that this approach also aids identification of morphological features such as pools and meander bars.

During **biotope mapping**, special attention should be given to recording the **substrate** present. Dependent on specific details of objectives, samples may be taken for particle size analysis.

Point velocity measurements across surveyed sections or reaches would help validate the modelling mentioned in point 2, but also allow more detailed interpretation of how hydraulic factors are influencing or associated with physical habitat development and the establishment of vegetation and other organisms.

Kick samples stratified by physical habitat, will allow the investigation of associated or causative factors in biota establishment. For a complete picture, at least some of these biotopes should have their bathymetry surveyed. This stratification was actually done, though without **formal biotope definitions** there was little comparability between different sampling personnel‟s interpretations of the meso-habitats.

Macrophyte mapping would also facilitate investigation of the mechanisms of morphological change, as channel plants are obvious candidates as both drivers and responders. It is recommended that these data are **recorded digitally as areas** of coverage to facilitate integration with other datasets.

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Appendices

Appendix 1
Water Framework Directive

The Water Framework Directive (WFD) is the most substantial piece of water legislation ever produced by the European Commission, and provides the major driver for achieving sustainable management of water in the UK and other EU Member States for many years to come

It requires that all inland and coastal waters bodies are within defined river basin districts must reach at least „*Good Ecological Status (GES)*" by 2015 and defines how this should be achieved through the establishment of environmental objectives and ecological targets for surface waters. For water bodies that have been designated as Heavily Modified (HMWB) or Artificial, they must reach at least „*Good Ecological potential (GEP)*", and that „ no deterioration" should occur in any water body.

In summary, the Directive requires that all surface waters and groundwaters within defined river basin districts must reach at least „good" status by 2015. It will do this for each river basin district by;

Defining what is meant by „good" status by setting environmental quality objectives for surface waters and groundwaters;

Identifying in detail the characteristics of the river basin district, including the environmental impact of human activity;

Assessing the present water quality in the river basin district;

Undertaking an analysis of the significant water quality management issues;

Identifying the pollution control measures required to achieve the environmental objectives;

Consulting with interested parties about the pollution control measures, the costs involved and the benefits arising.

A1.1 WFD Monitoring

Implementing the agreed control measures, monitoring the improvements in water quality and reviewing progress and revising water management plans to achieve the quality objectives.

The WFD requires that an integrated monitoring programme be established within each river basin districts. These monitoring programmes will in many cases be extensions of modifications of existing monitoring programmes and will collect and collate chemical, physical and biological data necessary to assess the status of surface water and groundwater bodies in each river basin district.

There are three types of monitoring under the WFD, these are:

- *Surveillance monitoring* which will be used to validate risk assessments and determine long-term changes.
- *Operational monitoring,* to determine the status of *water bodies* identified as being at risk and how this changes as result of the *programme of measures.*
- *Investigative monitoring,* which will be used to establish reasons for failure.

It is envisaged that the river restoration monitoring may well differ from the standard WFD monitoring but may fall under the WFD investigative monitoring category. However, river restoration monitoring may be totally independent of the WFD, though many of its outputs may still be utilised in assessing river basin catchments if only with respect to gaining more knowledge about the catchment and how it operates.

The main reasons for undertaking monitoring for the WFD are to:

- Establish an overview of the water status of each river basin district
- Classify individual water bodies as to their water status

For each surface waterbody, the Competent Authorities will assess as appropriate:

- Biology (plankton/phytobenthos, macrophytes, invertebrates and fish);
- Hydromorphology;
- Physico-chemical (including organic pollutants);
- Priority and priority-hazardous substances.

For groundwaters the monitoring requirements cover:

- Groundwater *resources* through a water level monitoring network;
- Surveillance and operational monitoring of *chemical status* (Common Implementation Strategy, 2003a)

For more information see the Environment Agency WFD website http://www.environment-agency.gov.uk/research/planning/33106.aspx , the DEFRA website http://www.legislation.gov.uk/uksi/2003/3242/contents/made , or the UKTAG website http://www.wfduk.org/

A1.2 Determining which pressure is causing biological failure

The following information was circulated to members of the Defra Water Stakeholders Forum in October 2011, and gives an overview of how staff in the Environment Agency determine which pressures cause biological failure. While their ecologists use standard methods and data tools, the interpretation of ecological data is an exploratory process. The procedure described below is not prescriptive but is an overview of current practice.

Environment Agency Practice

The following text is written with reference to ***Figure A1.1*** which gives an overview of the current practice used to determine which pressure is causing a biological failure.

When considering the causes of biological failure at a water body (Box 1), we generally take four things into account:

- Our professional knowledge of the response of biology to pressures
- The existing pressures in the water body and wider catchment taking local knowledge into account
- The tools and methods that we use to diagnose the causes of biological pressure (examples in ***Appendix 1)***
- Existing biological data (including external data), its trends and its statistical associations with pressures

Taking these into account we may be able to infer the causes of the failure, or not (Box 2).

If we can infer the likely cause, then we assess if the level of evidence linking the pressure with the biological failure is sufficient to support action (Box 3) as set out in the guidance on 'Levels of evidence for completing investigations and selecting measures'. Where there is sufficient evidence, the next steps, for example an investigation to determine the source of the pressure and/or implementing measures, can proceed. However, if the level of evidence does not support action, i.e. there is insufficient evidence linking the pressure to the biological impact to justify action, then we conclude that we can‟t infer the cause of the failure with sufficient confidence (Box 6).

If we can‟t infer the likely cause of failure based on the initial assessment (Box 2), then we need to judge if the current data is adequate for the application of the diagnostic tools or to apply professional judgement (Box 4). Where the data is inadequate, we then gather more or different data (Box 5). If the data is sufficient to apply the tools but we can‟t infer what causes the failure (Box 6) our next step depends on the level of certainty associated with the cause of failure.

Where we are uncertain about what causes the failure then we need to explore the situation by gathering and assessing more extensive data (Box 7). This might include increasing the number of biological elements sampled at the water body; it may include collecting more data on pressures.

Where we have a good idea what causes the failure (Box 8) then we would normally intensify monitoring focussing on the biological elements most likely to be affected by the pressure in question (Box 9). For example, where the suspected pressure is flow, invertebrate analysis might be taken to species rather than family level to improve the level of evidence linking pressure to failure. Occasionally, we might undertake an experimental application of a measure to reduce the pressure to demonstrate if this improves the biology (ie "Adaptive Management") (Box 10).

Our knowledge of biological responses to pressures and our diagnostic toolkit will improve further as we repeat this process through time and at multiple water bodies.

Example guidance on the analysis of biological data in rivers

This appendix contains extracts of guidance given to Environment Agency Ecologists analysing data from rivers. It demonstrates the wide range of diagnostic tools available for a selection of biological elements (invertebrates, macrophytes and diatoms). Habitat assessment tools are also included as an example of supporting information used for investigations.

Introduction to ecological data

Overview

We collect a range of different ecological data from our rivers using a variety of different techniques. These data on biological quality elements (BQEs) will show responses to a variety of different pressures and are good indicators of environmental change and anthropogenic stresses.

How to look at data

Ecological data can be looked at in a number of forms:

Raw data

Most ecological data are in the form of taxa lists with an associated measure of abundance. Large amounts of information can be obtained from looking at these by looking at the ecological preferences of those taxa present. This can give an immediate indication of what pressures may be acting on the ecological communities.

Biotic indices

Most of the ecological data we collect can be summarised by biotic indices. They are designed to take a large amount of information and combine it into one number called an index or metric. They are very useful for summarising and presenting data but can overlook the extra information that can be gained from looking at the raw data. These indices are often targeted and describe the impact of specific environmental pressures.

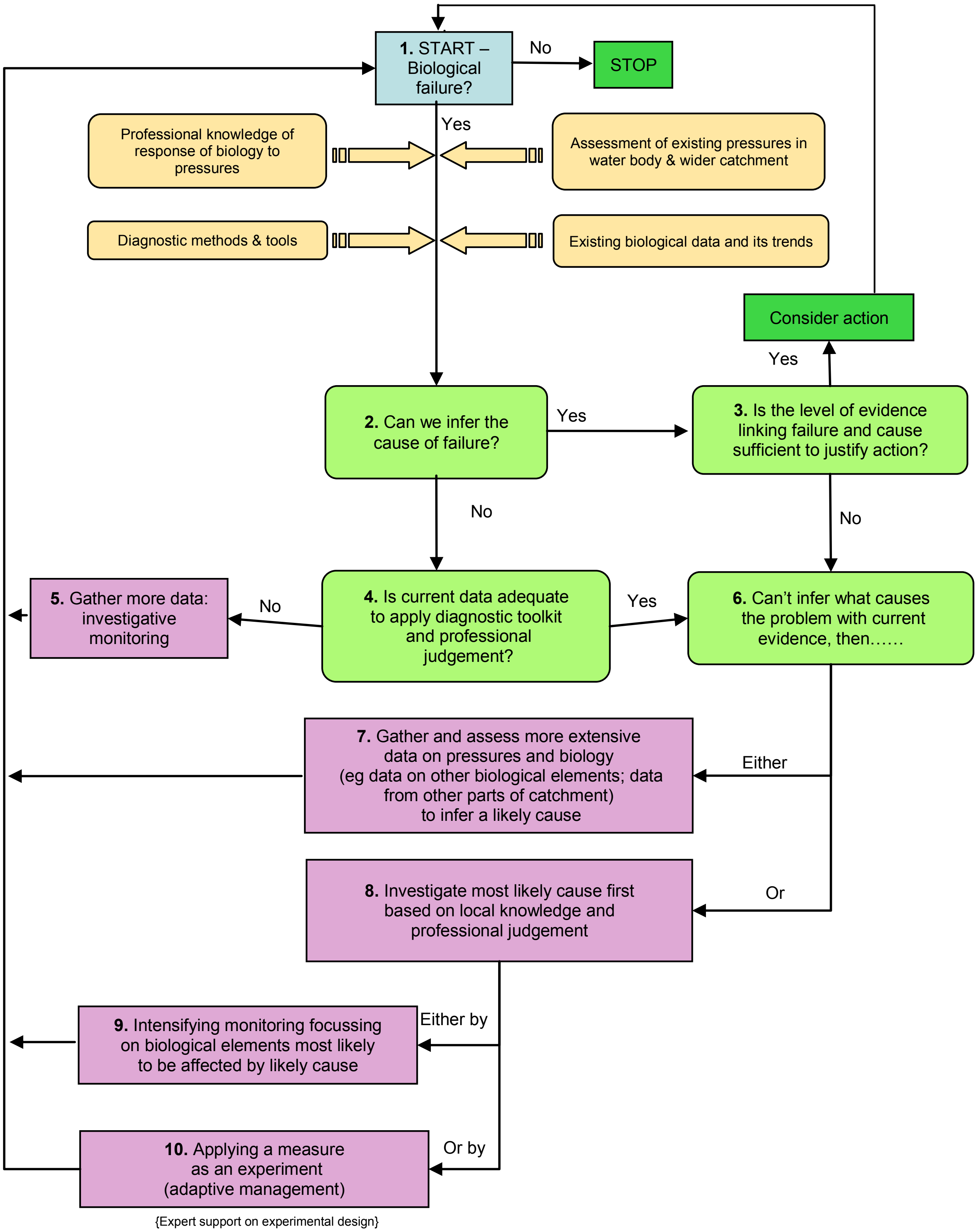

Figure A1.1 An overview of the current practice used to determine which pressure is causing a biological failure

Classification tools

Classification tools are generally designed to process biotic indices to make them comparable across river type, habitat and index type. The outputs from these tools are standardised and are in a format that makes them easy to understand, even by people with no experience of ecology. They are extremely useful for summarising data and presenting it in a regional or national context. The tools describe the quality of ecology against a standardised scale.

WFD biological classification tools

The classification tools referred to in this document are used by the Environment Agency, the Scottish Environment Protection Agency and Northern Ireland Environment Agency to carry out WFD reporting.

Environmental quality ratios (EQR)

The WFD classification tools are designed to calculate the current condition of a particular biological quality element (BQE). They do this by calculating an environmental quality ratio (EQR). This is achieved by comparing the observed value of the metric calculated from samples with the value of the same metric expected at WFD reference state. This is expressed as a decimal fraction of the observed value against the reference value.

Macroinvertebrate data

Overview

Macroinvertebrates have historically been used as indicators of organic pollution. More recently they have proved useful for assessing the impact of many other anthropogenic stresses. There are a variety of quantitative and semi-quantitative techniques used to collect samples from rivers, lakes and canals, but all these techniques have been standardised to make the data collected comparable.

Biotic indices

Macroinvertebrate samples collected using a standard three minute kick/sweep sample or airlift technique can be can be used to calculate the following useful biotic indices or metrics:

- **Biological Monitoring Working Party score (BMWP).** This index is primarily used to monitor the impact of organic water quality, but will also show responses to toxic pollution, siltation, habitat reduction and reduced flows. BMWP scores cannot be directly compared across river types.
- **Average score per taxon (ASPT).** This index is primarily used as an indicator of organic pollution. This index is directly comparable between samples collected from different river types and in different seasons.
- **Lotic Invertebrate Flow Evaluation (LIFE).** This is used to determine the sensitivity of an invertebrates community to changes in flow. LIFE scores can be

calculated from both family level or species level data but will often be more informative when calculated from species data.

- **The number of taxa (N-TAXA).** This is a simple diversity index. It is a non specific index of environmental pressure and is useful when pressure specific indices such as ASPT and LIFE show no response.
- **Proportion of sediment-sensitive Invertebrates (PSI).** This is a biotic index designed to describe an invertebrates communities sensitivity to sedimentation.

Other biotic indices. There are many other biotic indices available for summarising macroinvertebrate data sets. Each index is designed to describe a different reaction by the invertebrate community. The indices described above have either been or will be adopted by the ecology community and the WFD. If you choose to use other biotic indices for a specific purposes, it is important you check their background and validity before using them to make decisions.

Non biotic index information

Macroinvertebrate data collected using other techniques such as grabs, corers or Surber samplers for example, are generally not appropriate for use with biotic indices. However, these data tend to be more suited to quantitative analysis techniques. Possible analysis techniques are mentioned below:

- **Sample composition.** The ecological preferences of dominant taxa and the relative proportions in which each taxon or species occur can give you a very good idea of habitat type and the pressures acting on the ecology community. If you have a number of quantitative samples collected from different sites or over time, then multivariate analysis techniques such as Principal Component Analysis can be very useful to differentiate differences that may be arising between your samples;
- **Indicator species.** Often in depth analysis of full taxa lists are not required. Key indicator species can be used to tell you about what pressures and environmental influences may be impacting your invertebrate communities. The website, www.cies.staffs.ac.uk provides information about the distribution of families in relation to a wide range of chemicals.

Tools for classification

There are a variety of tools available to help interpret and classify macroinvertebrate data and indices. They include:

- **The River Invertebrate Classification Tool (RICT)** RICT calculates what the invertebrate communities would be like at reference state for any given site based on its physical parameters. It then compares the prediction with the actual results recorded from samples taken at the site and produces an environmental quality ratio (EQR) for each site. The EQRs are then used to produce a classification for the site and assign it to an ecological status with an associated confidence of class. This is the principal tool used to produce WFD classifications for invertebrate data.
- **The HydroEcological Validation tool (HEV)** tool can be used to calculate predicted (reference) conditions for LIFE, PSI, ASPT and N-TAXA indices. HEV

uses observed sample data to calculate the ecological quality indices (EQIs) for all four of these indices. EQIs are a measure of how different the observed indices are from reference state. The HEV tool does not produce a WFD classification. The HEV tool is useful for examining the impact of many different pressures/stresses on macroinvertebrates at the same time as they can all be compared side by side.

- **River pressure diagnostic system (RPDS)** and the River pressure Basian belief network (RPBBN). Known collectively as the artificial intelligence (AI) tools, these packages allow you to explore your raw data to identify water quality pressures that may be acting on a site.

Diatoms

Overview

Diatoms are principally used to monitor nutrient enrichment (eutrophication). However, they have also proved useful for monitoring sedimentation, heavy metal pollution and are now being increasingly used to describe the impact of acidification.

Biotic indices

Diatom samples collected using the standard benthic diatom sampling techniques can be used to calculate the following biotic indices:

- **Trophic diatom index (TDI).** This index describes the nutrient preferences of a diatom community. In lake assessments you should use the lake specific TDI (LTDI) for your investigations.
- **Percentage motile taxa (%motile).** This index simply gives a proportion of the taxa identified that are motile. Benthic diatoms can be heavily affected by light limitation. Light limitation can occur from excessive growths of filamentous algae or siltation. Motile diatoms tend to fare better as they are able to migrate to the surface of the smothering substance to reach the light.
- **Percentage planktonic taxa (% planktonic).** This index simply describes the proportion of taxa identified as being planktonic. Higher values mean more of the diatom community are made up of planktonic taxa. This can indicate that flows are reduced or the river impounded.
- **Diatom acidity metric (DAM).** This is a relatively recent index and describes the acidity of the environment within which the diatom community exists.

Non biotic index information

Heavy metals. Some species of diatoms, particularly the Fragilaria groups, have been identified as being particularly sensitive to heavy metal pollution and have growth abnormalities in the cell frustules. No index is available to summarise this pressure, but abnormal cells are recorded during analysis.

Tools for classification

There is just one tool available to help interpret and classify diatom data and biotic indices.

DARLEQ is a data classification tool that calculates what the diatom communities should be like at reference state for any given site based on its physical parameters. It then compares these predictions with the actual results recorded from samples taken at the site to produce an EQR. The tool then produces an ecological status class and associated confidence of class. This is the principal tool used to produce WFD classifications using diatom data.

Macrophytes

Overview

Macrophytes (including aquatic bryophytes) have been used traditionally to monitor for the impacts of eutrophication in rivers. However, like invertebrates they respond to a wide range of pressures which can make the interpretation of macrophyte data less clear cut than with diatom data.

Pressures/ stresses

Macrophytes respond to a number of different pressures. However, different pressures can often have similar effects and so it can be difficult to apportion cause. Pressures that macrophytes show a known response to include:

- **Phosphate** In freshwater environments, plants are principally restricted by the availability of the nutrient phosphorous. Increases in nutrients will often cause a change in the macrophyte community to one dominated by plants with a preference for high nutrient conditions.
- **Flows** can have a significant impact on the macrophyte communities within a reach of river. If flows change then the plant community will often change in response. In lowland systems, flow pressures can often be masked by nutrient pressures.
- **Habitat modification**. Plants respond both directly and indirectly to habitat modification.
- **Siltation**. Siltation pressures tend to cause a decline in the diversity of the macrophyte community, with the silt loving plants becoming dominant.
- **Water level fluctuation**. In lakes, where there are large and or rapid changes in water level, macrophyte communities can show significant response.

Biotic indices

Surveys carried out to using the standard WFD macrophyte survey methodology can be used to generate the following biotic indices:

- **Mean trophic rank (MTR).** The MTR index describes a plant communities preferences to nutrients. The MTR scoring system has now been largely superseded by the RMNI;
- **Mean flow rank (MFR).** The MFR index is very similar to the MTR however it describes a plant communities response to flow conditions. The MFR scoring system has now been superseded by the RMHI;

- **River macrophyte nutrient index.** The RMNI is designed to categorise a macrophyte community"s preferences to nutrient levels
- **River macrophyte hydraulic index (RMHI).** The RMHI describe a plant community"s preferences for flow conditions.
- **Number of aquatic plant functional groups (NFG).** The NFG index is a richness or diversity index and describes the number of functional macrophyte groups existing within a surveyed plant community;
- **Number of aquatic taxa (NTAXA).** The NTAXA index is another richness index and simply describes the number of truly aquatic taxa.

Both the NFG and NTAXA indices are very useful indicators of habitat quality. High quality habitats with good flow regime, habitat heterogeneity, upstream connectivity and low sedimentation pressures will have higher values for both these indices.

Tools for classification

The principal tool available to help interpret the different biotic indices calculated from macrophyte data is called LEAFPACS.

- **LEAFPACS** is a data classification tool that calculates what the macrophyte communities should be like at reference state for any given site based on its physical parameters. It compares these predictions with the actual results recorded from surveys carried out at the site. This enables it to produce a classification of the ecological status of the site and associated confidence of class. This is the principal tool used to produce WFD classifications using macrophyte data.

Habitat

Overview

River habitat survey (RHS) provides an assessment of the morphology of a 500m reach of river, recording both modifications and natural features, and giving an idea of habitat quality and diversity.

Hydromorphology forms part of the overall ecology of a water body by underpinning and supporting the biology. Most aquatic species have certain physical habitat requirements, in addition to those of water quality and hydrology.

RHS and WFD

WFD requires the hydromorphology of a water body to be sufficiently high to support all of the biological quality elements. We assess hydromorphology to:

- investigate reasons for failure of good ecological status or a deterioration in status;
- assess the impacts of any proposed new modifications on ecology;
- plan mitigation or restoration measures where necessary.

Indices

RHS survey data can be summarised using two summary indices.

- **The habitat modification score (HM)** is a scoring system used to assess the degree of modification associated with a river. The HM score is independent of water body type and so can be used to describe artificial modification to physical structure across the board.
- **The habitat quality assessment (HQA)** scoring system offers a broad measure of the diversity and „naturalness" of the physical habitat structure of a site, including both the channel and river corridor.

HM and HQA indices are designed to give only a summary of the habitat over the 500m river length surveyed. For more targeted investigations (such as looking at siltation), using the raw data is recommended.

Appendix 2
Adaptive Management

Applying adaptive management in river restoration projects involves the integration of project/program design, management and monitoring to systematically test assumptions in order to adapt and learn.

Testing assumptions is about systematically trying different actions to achieve a desired objective or outcome. This is not a random trial and error method, rather it uses knowledge about a specific site to select the best available strategy, laying out the assumptions behind how the strategy will work and then collating and assessing monitoring data to determine if the assumptions are true.

The assumptions are then adapted in response to the knowledge gained from the assessment and interpretation of the monitoring data. The implementation process and the successes and failures need to be documented both within the team and in the wider river restoration community in order for all to benefit and learn from these experiences. This enables future restoration schemes to be better designed and manage and to avoid the pitfalls experienced by others.

Adaptive management can be either passive or active. Passive adaptive management uses a predictive model based on present knowledge to inform management decisions. As new knowledge is gained the model is updated and management decisions adapted accordingly. Active adaptive management involves changing management strategies altogether in order to test a new hypothesis. Thus the goal of passive adaptive management is to improve existing management approaches, whilst for active adaptive management it is to learn by experimentation in order to determine the best management strategy. The current river restoration programme within the UK is, in many respects, at the experimental phase so much of the current adaptive management is active.

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Key features of both passive and active adaptive management are;

Interactive decision making whereby results are evaluated and actions adjusted on the basis of what has been learnt;

Feedback between monitoring and decisions, i.e. learning;

Characterisation of systems uncertainty through multi-model inference;

Bayesian inference, i.e. evidence or observations are used to update or newly infer the probability that a hypothesis may be true;

Utilising risk and uncertainty as a way of building understanding.

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Appendix 3
Literature Review

The benefit of river restoration (including floodplain connection) work needs to be assessed over both the short- and long-term to determine the degree of scheme success. As discussed by Roni (2005), Downes et al (2002) and Stewart- Oaten (1986) ideally monitoring should include **B**efore and **A**fter assessment of what is referred to as the **I**mpact reach together, with, where possible, a **C**ontrol site for comparison. This approach is commonly referred to as the **BACI** method. In order to carry out such an assessment a combination of qualitative and or quantitative monitoring needs to be completed but determining the appropriate mix (i.e. where to concentrate effort) requires a clear set of objectives.

A3.1 Evidence and knowledge base

The fact that river restoration and rehabilitation work generally lacks the evidence to demonstrate conservation benefit is widely asserted (Pullin and Knight, 2003; Sutherland et al., 2004; Pullin and Knight, 2009). As a result the proliferation of enhancement projects on the ground in the last few decades (Miller et al., 2010) has meant that the development of technology and techniques has rather outpaced the supporting science.

Of the most widely available literature, studies from the USA predominate. This is perhaps to be expected, however, owing to the fact that stream habitat enhancement was first popularized here, and also the sheer size of the country. Some early published attempts to evaluate the success of these endeavours relate to the durability of log structures in the north-eastern (Tarzwell, 1937) and Pacific states (Ehlers, 1956). The major increase in projects across the Atlantic since the 1990s has since been accompanied by a growing body of evaluation and monitoring literature (e.g., Lepori et al., 2005; Kail et al., 2007; Habersack et al., 2009).

Another bias which is important to note is that towards that discussion of monitoring of physical, rather than biological effects of restoration (Roni et al., 2002; Alexander and Allan, 2007), and within the latter, a strong bias towards the effects on fish (Pretty et al., 2003; McDonald et al., 2007; Baldigo and Warren, 2008). The particular interest in, more specifically, salmonid responses is likely due to the relative ease of collection and handling of the types of data involved and the fact that the motivation behind the majority of projects implemented globally has traditionally been enhancement of these fisheries. Indeed, Roni et al. (2008) cite Parish‟s suggestion (2004) that decline in important food fisheries may be a key driver of watershed and river restoration in developing countries into the future.

A3.2 The big picture

In general, monitoring is not the norm for enhancement and rehabilitation projects, and so there is a very limited pool of information from which authors may draw. In conducting the US National River Restoration Science Synthesis (outputs available at RestoringRivers.org), Bernhardt et al. (2007) found that only 10% of 37,099 projects included in the exercise had any form of assessment or monitoring. This, and the fact that the subject of monitoring is complex and multi-faceted, have led to most literature taking the form of opinion-style papers. The scarcity of controlled experiments has proven a significant obstacle in attempts at meta-analyses (Miller et al., 2010) and drawing conclusions from detailed reviews (Roni et al., 2002; Follstad Shah et al., 2007; Kondolf et al., 2007; Palmer et al., 2007; Roni et al., 2008). The necessary retrospective use of data collected for different purposes is fraught with problems, but usually the only way to proceed with these wider analyses.

A3.3 Objective setting and monitoring design

Alexander and Allan (2007), like many others (e.g., Giller, 2005; Christian-Smith and Merenlender, 2008; Mant and Janes, 2008; O'Donnell and Galat, 2008), assert that, where monitoring is undertaken, appraisal is often hampered by the lack of a fully developed concept of the desired project outcomes. That there are no universal success criteria is widely acknowledged (Wohl et al., 2005) but Palmer et al. (2005) suggest five very generic properties which successful projects share:

> There is a guiding image of the dynamic state to be restored;
> There are measurable improvements in ecosystem properties;
> Resilience is increased;
> The works cause no lasting harm to the system; and
> Some form of ecological assessment is completed.

When considering specific objectives which may be interrogated by monitoring, non-linear ecological responses and the high degree of variability in measurable ecosystem components are widely discussed issues (Heino et al., 2004; Nilsson et al., 2005; Wohl et al., 2005; Alexander and Allan, 2007; Schiemer et al., 2007). Being two of the most frequently monitored elements, the responses of fish (Pretty et al., 2003; Shields Jr. et al., 2003; Baldigo and Warren, 2008) and invertebrates (Harris et al., 1995; Miller et al., 2010) generate particular interest. Opinion on the best approach to objective setting in light of this is well established – to seek suitable reference data from a similar, un-impacted (or less impacted) „control" site.

Wohl et al. (2005) go into detail as to how reference sites might be selected, and propose that projects should aim to restore the „normal" range of measured variables, rather than any fixed endpoint. Furthermore, this focus on processes rather than specific habitats or species represents an increasingly prevalent guiding principle (e.g., Roni et al., 2002; Clarke et al., 2003; Schiemer et al., 2007; Habersack et al., 2009). Indeed, results of studies have often shown little benefit to monitored target organisms unless very specific structural heterogeneity requirements are met (e.g., Pretty et al., 2003; Lepori et al., 2005).

A3.4 A question of scale

The spatial extent and period of monitoring represent the bottom line of requirements for project managers, though the consensus among academics is that these must be determined on a case-by-case basis, and depend on what aspects are being monitored. Where geomorphological effects may be very quickly apparent (Habersack and Nachtnebel, 1995; Clarke et al., 2003; Shields Jr. et al., 2003; Caruso, 2006), ecological responses may take many years to occur (Roni et al., 2002; Shields Jr. et al., 2003; Heino et al., 2004) and, owing to natural variability, decades to detect (Downs and Kondolf, 2002; Klein et al., 2007; Baldigo and Warren, 2008). Florsheim et al. (2006) have looked at flow threshold models to identify when morphological monitoring may be necessary, and authors such as Bryant (1995) have been proponents of a pulsed approach to monitoring, with short periods of more intensive study spread over a longer period.

With regard to the spatial extent of monitoring, again, highly naturally variable systems may require comprehensive monitoring, and details depend on the specific project context, particularly consideration of the reference, or control reach(es) (Wohl et al., 2005). Roni et al. (2002) highlight in their review our poor understanding of the links between wider physical processes and in-stream ecology, making particular reference to landslides, roads and grazing, while Miller et al. (2010) found the strength and consistency of invertebrate responses to be particularly related to watershed-scale conditions. Both of these points, together with the fact that it is usually the aim and effect of rehabilitation projects to increase spatial heterogeneity, suggest that one should perhaps pay more close attention to the wider context when planning monitoring.

A3.5 How to proceed?

River restoration can be an expensive enterprise – Bernhardt et al. (2007) estimate an annual expenditure of over $1 billion in the US – and financial restrictions which lead to the neglect of monitoring, despite the fact that there is little doubt as to its value, are widely acknowledged (e.g., (Alexander and Allan, 2007; England et al., 2008)). Beyond practical requirements for adaptive management and feedback to the design of projects and techniques, funding mechanisms and policy drivers increasingly require demonstration of success. This will be welcomed by authors such as Bash and Ryan who, in 2002, found that only 18% of projects they studied explicitly required any monitoring (Bash and Ryan, 2002); Wohl et al. (2005); and Gillilan et al., who advocated that sponsors make project appraisal a requirement (Gillilan et al., 2005). Furthermore, Palmer et al. (2007) argue that, for the success of future projects, dissemination of such information should be obligatory.

Despite there being a significant body of available academic literature (note especially Vol 15(3) of *Restoration Ecology*, and the forthcoming special issue of *Hydrology and Earth System Sciences*), guidance on the monitoring of river restoration is very rare (Woolsey et al., 2007). Phil Roni‟s book „*Monitoring Stream and Watershed Restoration*‟ (2005) is perhaps the only comprehensive document available, though „*Monitoring ecological impacts: concepts and practice in flowing waters*‟, edited by Barbara Downes et al. (2002) is also of note. „*River Restoration: Managing the*

Uncertainty in Restoring Physical Habitat", edited by Darby and Sear (2008) sets the context well and explores the concepts and manifestation of „success" in river restoration, but without detailing methods and procedures. The current document (PRAGMO) therefore, building on the frameworks developed in Mant and Janes (2008) and England et al. (2008), represents a significant step forwards, in addressing this need and keeping practitioners in close contact with the wide-ranging expertise related to this necessarily interdisciplinary business of river restoration.

A3.6 River Restoration Design and Appraisal Process

Figure 3.2 (adapted from Bruce-Burgess 2004) outlines a 3 phased process which should be followed for any restoration project; others have also made excellent attempts to outline a pragmatic approach to the river restoration process with Holl and Cairns (1996) with adaptations by Woolsey et al (2007) and in particular stating 5 phases name: strategic planning, a preliminary phase where objectives are set, project planning, project execution and utilisation which includes project assessment. What is general missing from these approaches is a detailed explanation of how the appraisal process should be clearly shaped to ensure answer to specific questions can be answered.

A3.7 Indirect Literature

There are a number of scientific papers which refer indirectly to river restoration monitoring. This indirect or „grey" literature is listed in the ***Reference Section*** under a separate heading.

Appendix 4
SMART Objectives

Specific

Specific means that the objective is concise, clear, detailed, focused and well defined. That is the objective is straightforward, emphasises action and the required outcome. Objectives need to communicate what you would like to see happen. To aid in the setting of specific objectives it helps to ask the following questions:

Diagnostic Questions

What exactly are we going to do, with or for whom?

What strategies will be used?

Is the objective well understood?

Is the objective described with action verbs?

Is it clear who is involved?

Is it clear where this will happen?

Is it clear what needs to happen?

Is the outcome clear?

Measurable

If the objective is measurable, it means that the measurement source is identified and it is possible to track the results of our actions, as progress is made towards achieving the objective. Measurement is the standard used for comparison and enables us to know when we have achieved our objective.

Diagnostic Questions

How will I know that the change has occurred?

Can these measurements be obtained?

What will be measured?

Achievable

Objectives need to be achievable, if the objective is too far in the future, it will be difficult to keep motivated and to strive towards it's attainment. Objectives, unlike aspirations and visions, need to be achievable to keep motivation going. Whilst being obtainable, objectives still need to stretch you, but not so far that you become frustrated and lose motivation.

Diagnostic Questions

Can we get it done in the proposed timeframe?

Do I understand the limitations and constraints?

Can we do this with the resources we have?

Has anyone else done this successfully?

Realistic

Objectives that are achievable, may not be realistic, however, realistic does not mean easy. Realistic means that you have the resources to get it done. The achievement of an objective requires resources, such as, skills, money, equipment, etc. to support the tasks required to achieve the objective. Most objectives are achievable but, may require a change in your priorities to make them happen

Diagnostic Questions

Do I have the resources available to achieve this objective?

Do I need to revisit priorities in my life to make this happen?

Is it possible to achieve this objective?

Time-bound

Time-bound means setting deadlines for the achievement of the objective. Deadlines create the all important sense of urgency. If you don't set a deadline, you will reduce the motivation and urgency required to execute the tasks. Deadlines create the necessary urgency and prompts action.

Diagnostic Questions

When will this objective be accomplished?

Is there a stated deadline?

A4.1 Examples of SMART objectives

	Specific	**Measurable**	**Achievable**	**Realistic**	**Time-bound**
Re-meandering	Fixed point photography at indicative sites.	Number of specific sites selected to illustrate how the new river channel is developing	1 set of photos taken before the work commences, 1 set during works, 1 set just after and 1 set three years after works completed	Fixed point photography will only take 1 day at the most to complete so only requires 4 days filed work over a three year period, plus 0.5 days towards a report on monitoring of the whole scheme	4 fieldwork days and 0.5 days write up
Planting up the Floodplain	Fixed point photography (can be done at same time as the other fixed point photography requirements see Re-meandering)	Number of specific sites determined to demonstrate the growth progress of the trees and give a qualitative indication of how many have been planted and how many have survived three years after planting	See Re-meandering	See Re-meandering	See Re-meandering
	Assessment of Number of trees surviving after 3 years	Count of number of trees (can be done at the same time as the fixed point photography	Assessing the percentage of trees that have survived after 3 years is straightforward	Time required to do this is not excessive	Less than half a day to do this assessment
	Assessing the diversity of wet meadow plants 1 year after and 3 years after the wet meadow created	Quadrat survey – assess the change in wetland plant diversity over a 3 year period	Quadrat surveys at three separate locations within the wet meadow area to be carried out 1 year and again 3 years after the wet meadow created	This is a straightforward tried and tested method which should only take half a day to complete	Two half days over a three year period, plus half a day to write up results
Protecting properties from flooding	Determine if properties have been flooded during high flow events	Set up a group of local volunteers who will take photographs at specific	Engaging local volunteers	Simple cost effective method of monitoring which involves community involvement	Community group engagement would need to be on a long term basis

	Specific	**Measurable**	**Achievable**	**Realistic**	**Time-bound**
		locations during flood events			in order to record significant flood events
Re-connecting the river to the floodplain	The river bed will be raised to allow high flows to overtop the banks and inundate parts of the floodplain	Level loggers can be installed to record water levels. These would need to be surveyed in and calibrated to record water levels above Ordnance datum. Local residents could also be co-opted to record water levels by reading a gauge board (levelled in to ordnance datum)	It would take half a day to install the logger, and the data would need to be downloaded every 4 to 6 weeks. The collecting of the logger data could be incorporated into an existing hydrometric data collection round.	Data collection on an existing hydrometric collection round is entirely feasible. Similarly local residents reading levels from a gauge board is possible, however this relies on the local volunteers remaining interested in the project and being available to go and read the gaugeboard during a flood event which may occur during the night. As a surrogate locals could photograph trash lines to show the extent of the flooding. Both logger and gauge board risk being vandalised in urban areas or areas where public access is available.	The logger would need to reamin in place for several years to enable it to record waterlevels for significant flood events

Appendix 5
Hydrology

A5.1 Definition of Common Hydrological Terms

Gauging Stations

Many catchments have a permanent gauging station usually located towards the bottom of the catchment which records flows. The station generally records a water level which is then converted to a flow using a specific equation unique to that particular gauging station. Some gauging stations, such as ultrasonics, records flow directly (see ***Figure A5.1***). The flows/levels are recorded every 15 minutes with the start of day being 09:00 hours. From the 15 minute time series a mean daily flow time series is calculated by taking an average of all the 15 minute flows between 09:00 on one day and 08:45 on the next day. Plate I illustrates some examples of different types of gauging station. The flow and level data is stored in the Agency‟s WISKI archive both as 15 minute levels and flows and mean daily flows.

Crump Weir

Flat V Weir

Essex Weir

Ultrasonic

Figure A5.1 Examples of Different Gauging Station Types

Spot Gauging

Spot gaugings (also know as current meter gaugings) are individual flow measurements taken at sites along a river (See ***Figure A5.2***). Generally this type of monitoring is done at sites in a catchment where there are no gauging stations set up. Often a series of spot gaugings are done along the length of a catchment on the same day and this information is plotted up as an accretion diagram (see ***Figures A5.3*** and ***A5.4***) which shows how a river gains and loses water along its length. This example is from a Chilterns chalk stream (the River Misbourne)

Figure A5.2 Examples of Spot Gaugings Being Carried Out

Figure A5.3 shows that the river starts to gain water from its source at Mobwell down to Shardeloes Lake, then it starts to lose water, being dry from Chalfont St Giles to Chalfont St Peter. It the gains again from downstream of Chalfont St Peter to the gauging station at Denham Lodge. ***Figure A5.4*** shows that in 2003 the river is flowing along its full length, though it still loses water between Lower Bottom Farm and Waterhall.

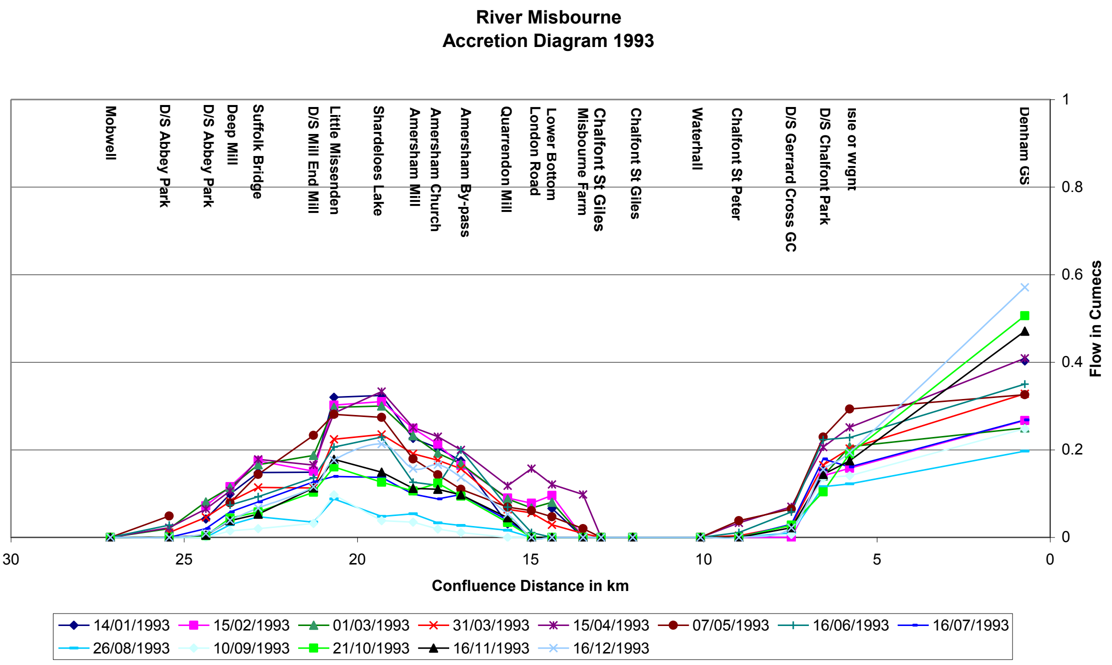
River Misbourne
Accretion Diagram 1993

Figure A5.3 Accretion Diagram Misbourne 1993

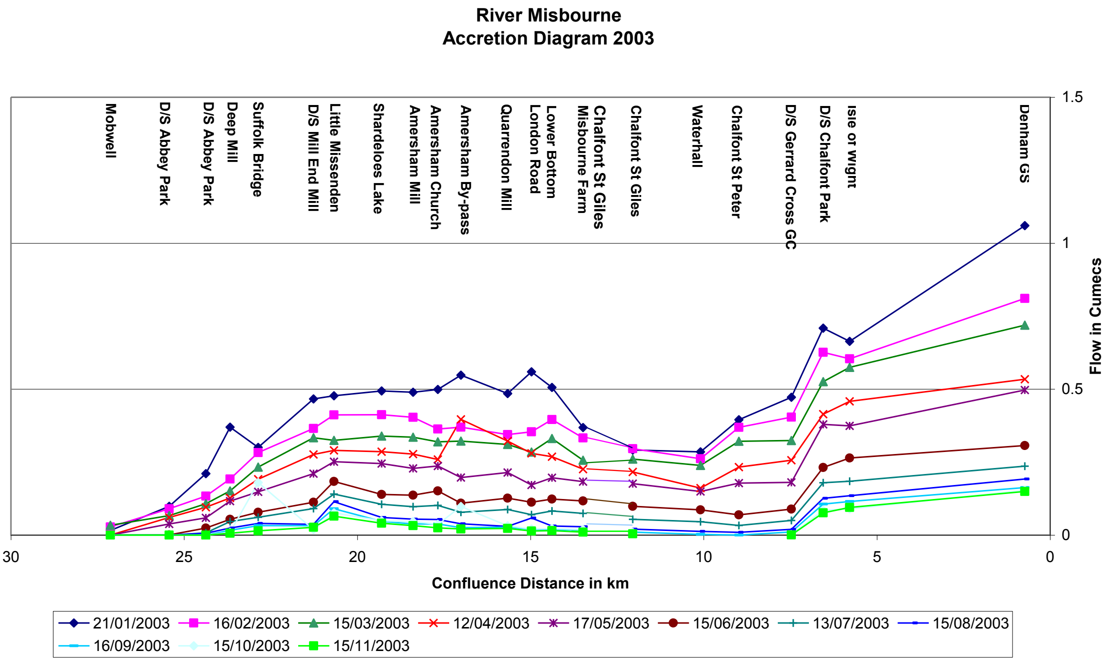
River Misbourne
Accretion Diagram 2003

Figure A5.4 Accretion Diagram River Misbourne 2003

Mean Daily Flows

As explained above the 15 minute flow or level data recorded at gauging stations is converted to mean daily flows and stored on WISKI. The mean daily flows are the average flows between 09:00 on one day and 08:45 on the next, i.e. the average over a 24 hour period which starts at 9 o‟clock in the morning. ***Figures A5.5*** to ***A5.7*** show the mean daily values plotted up as hydrographs. ***Figure A5.5*** shows a hydrograph for a groundwater dominated catchment with flows increasing through the winter months generally reaching a maximum in March/April.

This hydrograph can be compared to the illustrated in ***Figure A5.6*** where the graph is very spiky and there is not a great deal of difference between summer and winter baseflows. The spikes (usually termed flashy) nature of the hydrograph shows the rapid response to rainfall events whereby the water flows over the ground or within the soil layer and is delivered to the watercourses shortly after the rainfall has occurred. Thus the flows increase rapidly soon after the rainfall event and fall away relatively quickly once the rainfall has ceased. This shows as a spike on the hydrograph. With groundwater dominated catchments, rainfall percolates through to the aquifer once the catchment is saturated in winter. As the aquifer fills and groundwater (the water table) levels rise, spring flow outputs increase and the flows gradually rise over the winter reaching a peak in early spring. Once the warmer weather arrives the saturated soils begin to dry out, thus summer rainfall is held within the soil layer rather than percolating through to the aquifer. With the cessation of this movement of water downwards, the aquifer stores begin to deplete and groundwater levels start to fall over the summer months reaching a minima in September/October and it is not until the soils are saturated again by autumn and winter rains that recharge can start and the groundwater stores start to replenish. ***Figure A5.7*** shows hydrograph with both groundwater and clay component.

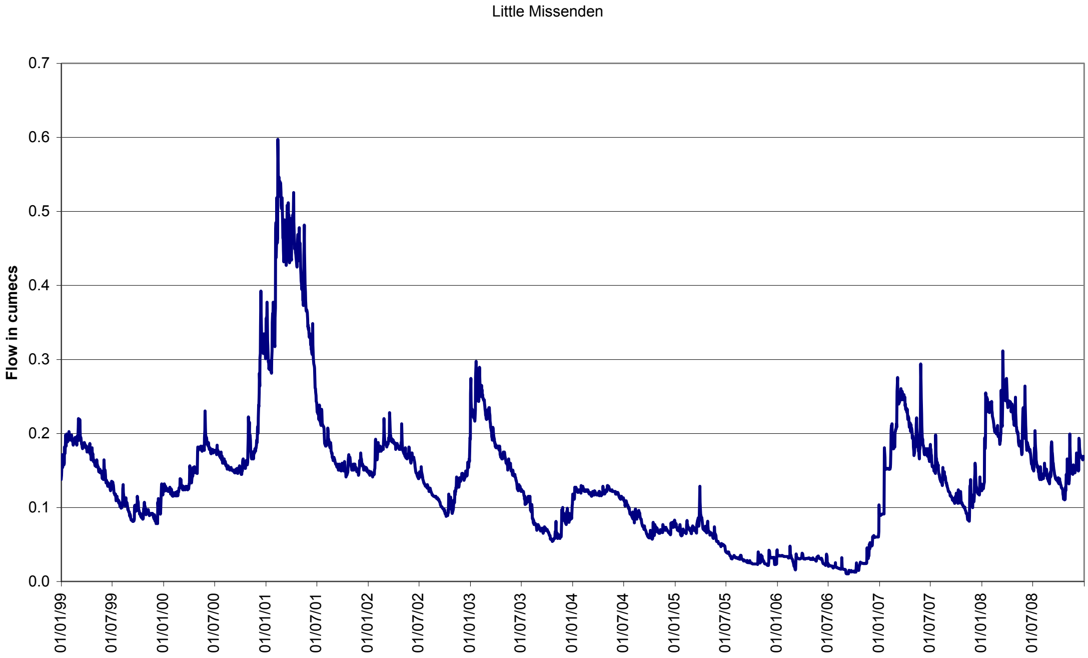

Figure A5.5 Groundwater Dominated Catchment (Chalk)

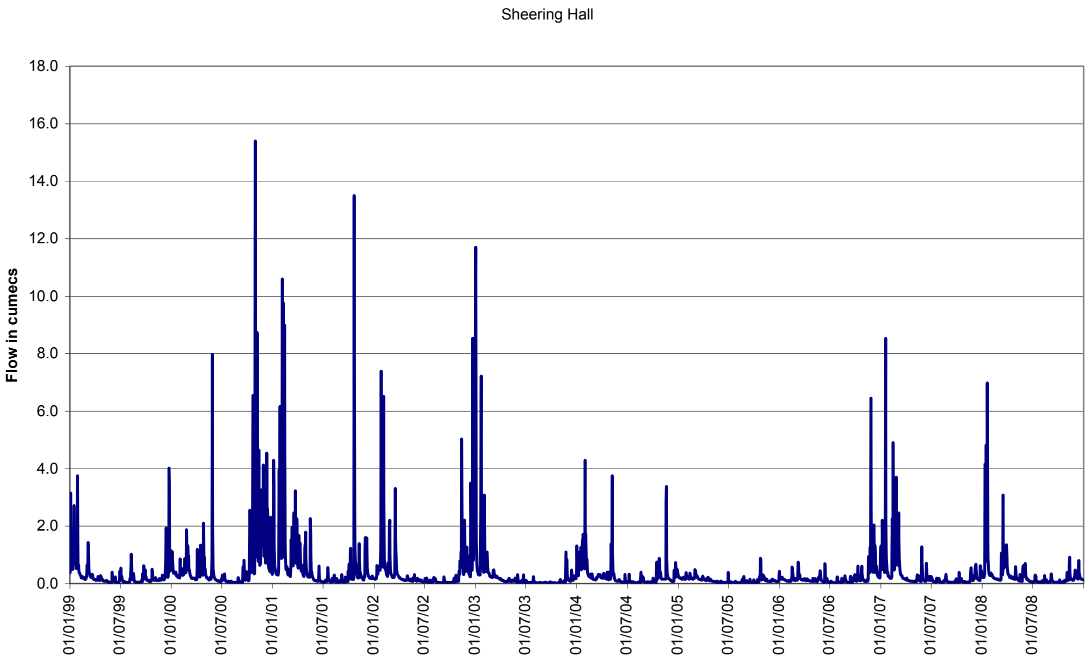

Figure A5.6 Runoff Dominated Catchment (Clay)

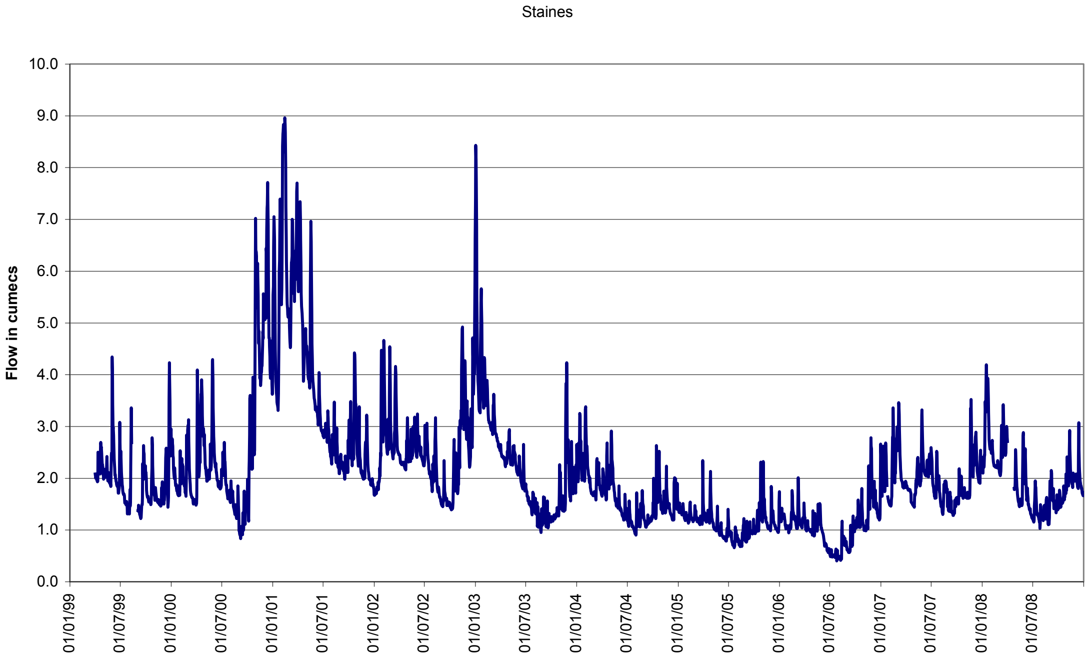

Figure A5.7 Catchment Characterised by Groundwater, Clay and Urban Runoff flows

Percentiles and Flow Duration Curves

Flow time series are often represented at flow duration curves (FDCs) which is demonstrated in ***Figure A5.8***. The FDC is a graphical representation of a flow time series which has been converted to percentiles. The flows are converted to percentiles by ranking the flow data in descending order and assigning a rank number to each flow. The equation;

Perc = rank/ (total+1)*100

Where *rank* is the rank number assigned to the flow time series which has been sorted in descending order, and *total* is the total number of flows in the time series. ***Table A5.1*** shows the first 18 percentile calculations for a flow time series. The percentile calculation is done automatically in the Excel spreadsheet provided with this report.

Then the percentiles is calculated using ***Figure A5.8*** shows the Q5, Q50 and Q95 percentiles position as blue vertical lines. The Q95 for the observed (gauged) flows is 0.22 cumecs, this means that for this given example, within the given time series of flows which ranged from 1992 to 2007, 95% of the time the flow was 0.22 cumecs or greater. In other words Q95 is a representation of low flows. Similarly the Q50 percentile means that 50 percent of the time flows are 0.119 cumecs or greater. Q50 is similar to, but not identical to the mean (average) flow. The Q5 percentile represents the high flow end of the time series range.

Table A5.1 Example of Percentile Calculation for a Flow Series

Rank	percentile	Flows
1	0.05	1.428
2	0.10	1.418
3	0.14	1.409
4	0.19	1.407
5	0.24	1.391
6	0.29	1.388
7	0.33	1.381
8	0.38	1.373
9	0.43	1.369
10	0.48	1.369
11	0.52	1.368
12	0.57	1.365
13	0.62	1.361
14	0.67	1.357
15	0.71	1.357
16	0.76	1.357
17	0.81	1.356
18	0.86	1.355

The ***Figure A5.8*** also shows a naturalised time series (the green line) and the 90%, 80% and 50% of natural are also illustrated. The current actual glows are plotted in dark blue and a direct comparison can be made between the flows which actually occur in a river and those which would naturally occur if there was no abstraction or discharge going on the catchment. In this example it can be seen that at low flow the actual is less than half of what should be occurring naturally and even at high flows (Q5), the flow is well below what would naturally be occurring. Thus it can be demonstrated that the flow duration curves area good way of comparing what actually happens in a river with what the flows would be naturally and in the example it is clear that flows are significantly impacted by abstraction.

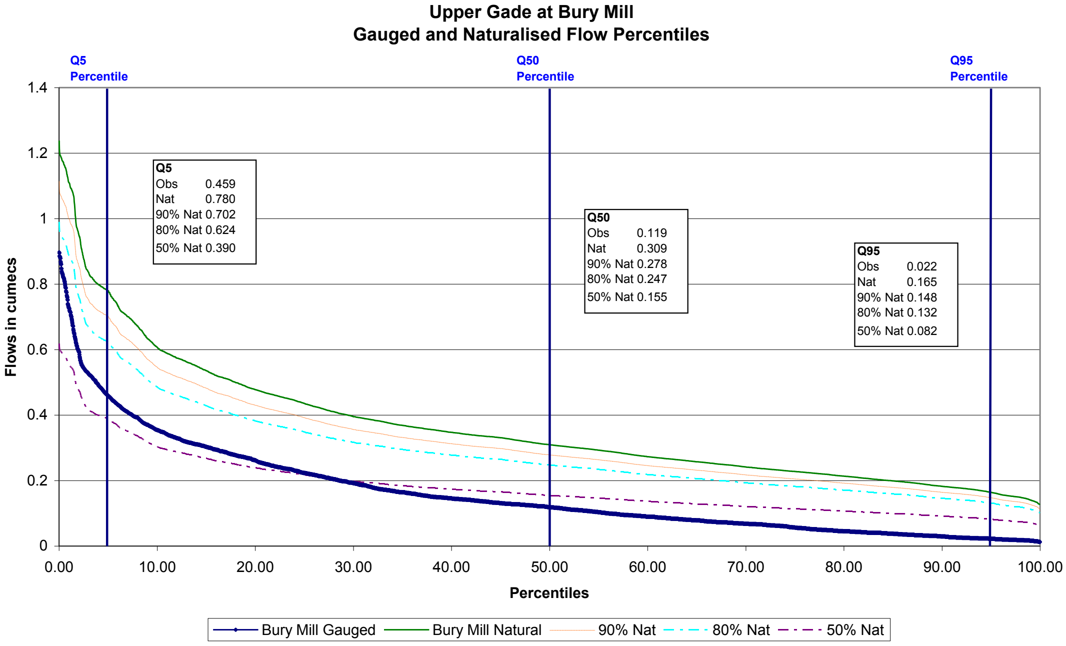

Figure A5.8 Example of a Flow Duration Curve

Volumetric descriptions of Flow

There are a range of different descriptions of flow. Commonly hydrologists use cubic metres per second (cumecs). Hydrogeologists generally use megalitres per day (Ml/d), but can also describe flows in terms of thousands of cubic metres (TCMD). Flows can also be described in litres per second. ***Table A5.2*** sets out all the common volumetric flow descriptors and gives the conversion rates for each. It should be noted that there are 1000 litres in a cubic metre, there are 1 million litres in a megalitre and 1000 cubic metres in a megalitre.

Table A5.2 Common Volumetric Flow Descriptors

Volumetric measure			Multiply by
Cumecs	to	Ml/d	0.11574
Ml/d	to	Cumecs	86.4
Ml/d	to	TCMD	1
Ml/d	To	Cubic metres	1000
Litres	To	Cubic metres	.001
Litres	To	Ml/d	.000001
Gallons	To	Cubic metres	0.0045461

Naturalised flows

Most rivers in England and Wales are not natural. They are influenced by a number of factors including abstractions, treated effluent discharges (in terms of both quality and flow), structures (weirs and online reservoirs) and management (dredging, weir operation, weed cutting etc).

Naturalised flows in terms of the amount or water flows in rivers can be calculated by using a rainfall-runoff model which has been calibrated for the current measured flow conditions and the abstraction and discharge files, which are part of the input time series, can be switched off to produce a naturalised series. Alternatively gauged flows can be naturalised by subtracting known discharge quantities and adding back known abstraction quantities. This is a slightly simpler method of naturalisation compared to the rainfall-runoff model, but can often be quite effective and gives a reasonable approximation.

Figure A5.9 shows the results of a calibrated rainfall-runoff model. The gauged flows recorded at a gauging station are in grey and the dashed line is the simulated flows from the model. The modelled flows are a good representation of the gauged flows. By running the model again with the abstraction and discharge files switched off the naturalised flows are then simulated. ***Figure A5.10*** shows an example of the same model illustrated in ***Figure A5.9***, but with naturalised flows. From the naturalised results (dashed line) it is clear that the catchment is significantly influenced by abstraction (comparing the dashed line with the grey infilled curve).

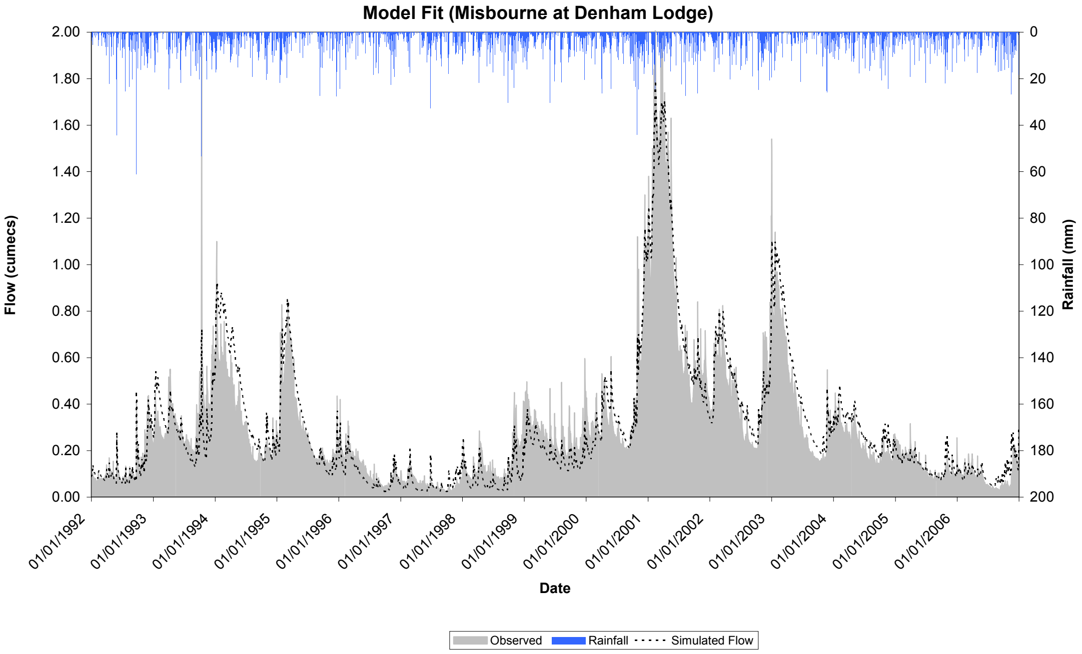

Figure A5.9 Example of a Rainfall-Runoff Calibration

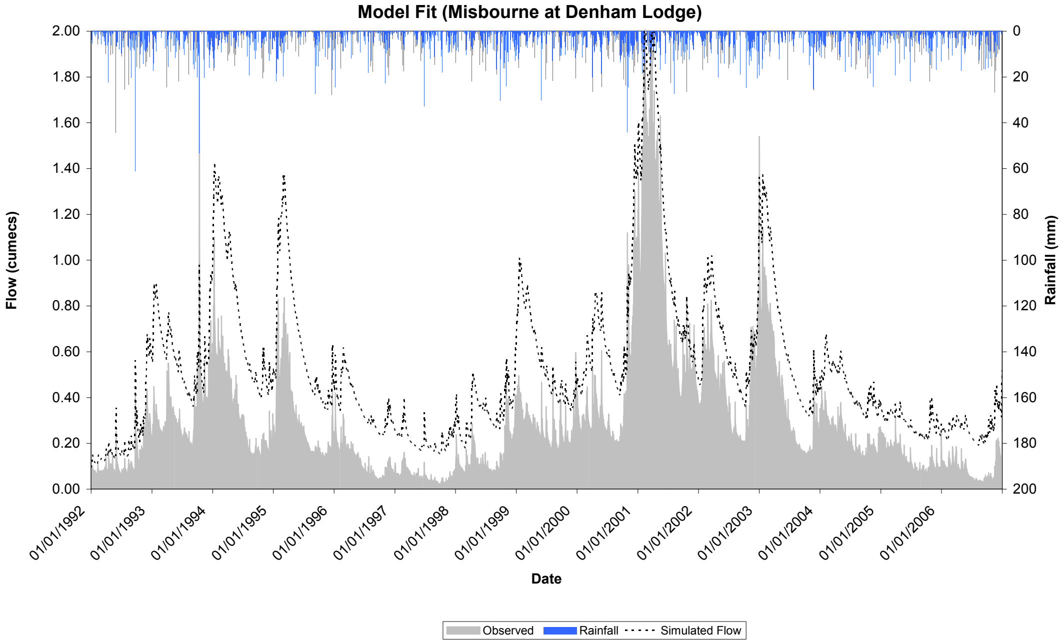

Figure A5.10 Naturalised Flows Simulated by a Rainfall-runoff Model

A5.2 Available Hydrological data and its uses

It is recommended that the ecologists ask the EA/SEPA/NIEA area hydrology team to produce these time series for them. A good deal of data is also available for download from the National River Flow Archive (http://www.ceh.ac.uk/data/nrfa). The flows should be presented in an excel spreadsheet with date in column A and the flow time series in cumecs (cubic metres per second) in column B. The hydrology team should be asked to infill any missing data and to calculate any derived flows at ungauged sites. If derived flow are required (i.e. a flow time series at a site where there is no gauging station), discuss with the hydrologist where you would like the time series to be and how good, i.e. how accurate the time series should be. The hydrologist should also be able to calculate a percentage error of the derived time series and give a description of the accuracy of the gauging station from which the derived series will be calculated.

It should be noted that a hydrological assessment tool is available within the Environment Agency in the form of an Excel spreadsheet called Flow Statistics.xls in which flow data can be input and monthly Q95 and monthly mean statistics can be calculated.

Deriving Flows at Ungauged Sites Using Spot Gaugings

In both hydrology and ecology it is often very useful to have a flow time series at sites other than just at sites where there is a permanent gauging station. If there are sufficient spot gaugings at the site of interest then a regression assessment can be carried out (see ***Figure A5.11***). In this example gauged flows are regressed against spot gauging flows from a site upstream of the gauging station and a regression equation derived. The equation ($y = 0.6106x – 0.0368$) can then be used to determine a time series at the target site (in this case the spot gauging site). So for each mean daily flow from the gauging station the flow in cumecs is substituted into the equation (x) to derive a flow at the spot gauging site. The R^2 value in Figure A5.11 gives an indication as to how well the equation can reproduce the spot gauging values when the gauging station flows are substituted into it. A perfect fit would give an R^2 of 1. Preferably your R^2 value should be 0.8 or greater to give reasonable result.

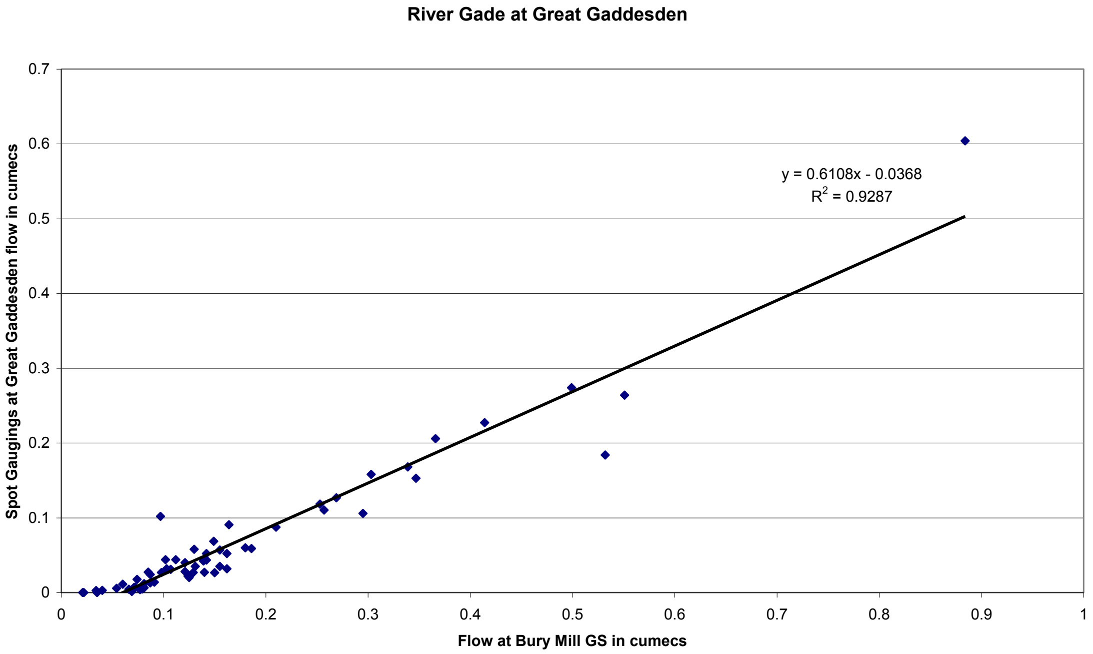

Figure A5.11 Regression of Gauging Station Flows against Spot Gaugings

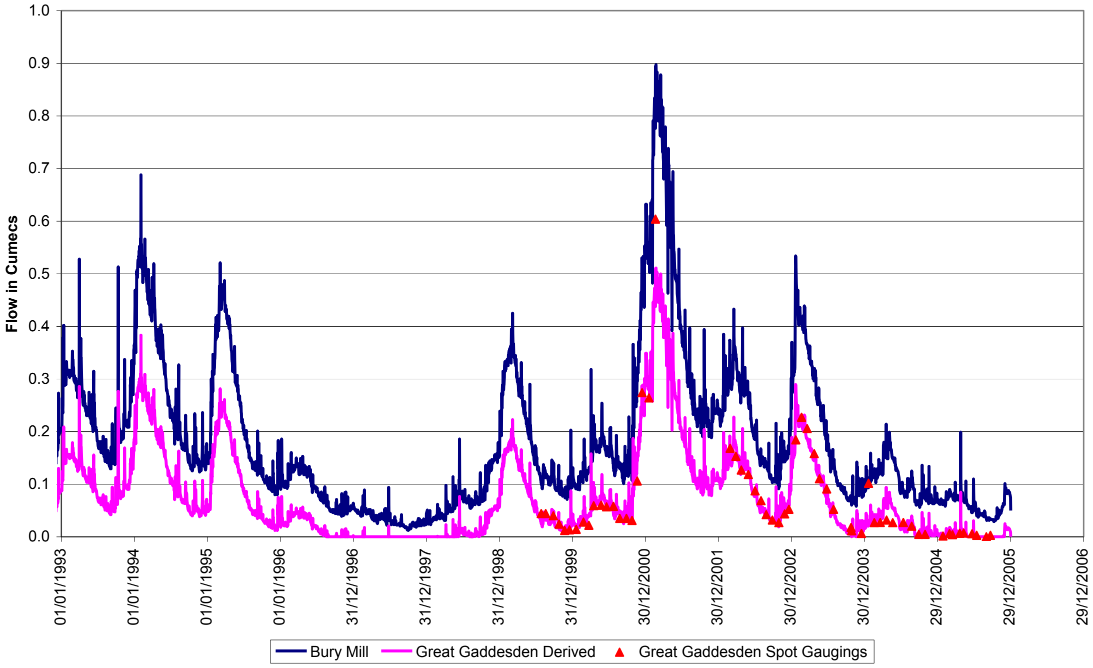

Figure A5.12 Flows Derived from Regression Equation

Figure A5.12 shows the flow time series derived from substituting the gauging station flows into the regression equation. The spot gaugings are also plotted up and it illustrates that they fit on top of the derived flows (pink line) very well with only two significant outliers on 19/2/2001 and 20/1/2004.

Appendix 6
Water Quality

The WFD water quality standards for rivers covered by the above report include Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), Ammonia, pH and Phosphorus.

Ecological status class is recorded on the scale of high, good, moderate, poor or bad. „High“ denotes largely undisturbed conditions and the other classes represent increasing deviation from this undisturbed, or reference, condition. The ecological status classification for the water body is determined by the worst scoring quality element.

Table A6.1 Basic Typology for Rivers

	Alkalinity (as mg/l CaCO3) Site Altitude				
Site Altitude	Less than 10	10 to 50	50 to 100	100 to 200	Over 200
Under 80 metres	Type 1	Type 2	Type 3	Type 5	Type 5
Over 80 metres			Type 4	Type 6	

Where the resulting standards for types turned out to be similar, the types were amalgamated. In each case the standards for combined types were then produced by combining their sets of data and performing the analysis on the combined set. This process allowed the simplification of the typology into two types, as shown in ***Table A6.2*** for dissolved oxygen and ammonia.

Table A6.2 Typology for Oxygen and Ammonia for rivers

Upland and low alkalinity	Types (1 + 2), 4 and 6
Lowland and high alkalinity	Types 3,5 and 7

Table A6.3 Water Quality Standards for Dissolved oxygen and Biochemical Oxygen Demand

	High	Good	Moderate	Poor
Dissolved Oxygen (percent saturation) **10-percentile**				
Upland and low alkalinity	80	75	64	50
Lowland and high alkalinity	70	60	54	45
Biochemical Oxygen Demand (mg/l) **90-percentile**				
Upland and low alkalinity	3	4	6	7.5
Lowland and high alkalinity	4	5	6.5	9

There are a number of other quality standards. ***Tables A6.3*** and ***A6.4*** show the EC Freshwater Fisheries Directive Standards.

Table A6.4 Imperative standards for freshwater fisheries Directive

parameter	Imperative Standards			notes
	Units	**Salmonid**	**Cyprinid**	
Temperature	° C	1.5	3.0	Increase due to thermal discharge
	° C	21.5	28.0	Maximum at monitoring site
	° C	10.0	10.0	Maximum for breeding season
Dissolved Oxygen	mg/l	50% > 9	50% >7	When oxygen concentration fall below 6 mg/l, member States shall implement the provisions of Article 7(3)
pH		6 to 9	6 to 9	
Phenols		No odour	No odour	
Hydrocarbon oil		Non visible	Non visible	
Non-ionised ammonia	mg/l	0.025	0.025	
Total ammonium	mg/l	1.0	1.0	
Total residual chlorine	mg/l	0.005	0.005	
Total zinc (dependent on the	mg/l	0.03	0.3	Hardness <= 10 milligrammes $CaCO_3$ / litre

average hardness	mg/l	0.2	0.7	Hardness <= 50 & > 10 milligrammes $CaCO_3$ / litre
	mg/l	0.3	1.0	Hardness <= 100 & > 50 milligrammes $CaCO_3$ / litre
	mg/l	0.5	2.0	Hardness > 100 milligrammes $CaCO_3$ / litre

Table A6.5 Guideline Standards for Freshwater Fisheries Directive

Parameter	**Guideline standards**			**Notes**
	Units	**Salmonid**	**Cyprinid**	
Dissolved oxygen	mg/l	50% >9	50% >8	
	< TD>	100%>7	100% >5	
Suspended solids	mg/l	25	25	
BOD	mg/l	3	6	
Nitrites	mg/l	0.01	0.03	
Non-ionised ammonia	mg/l	0.005	0.005	
Total ammonium	mg/l	0.04	0.2	
Dissolved copper (standard is dependent on the average yearly hardness)	mg/l	0.005	0.005	Hardness <= 10 milligrammes $CaCO_3$ / litre
	mg/l	0.022	0.002	Hardness <= 50 & > 10 milligrammes $CaCO_3$ / litre
	mg/l	0.04	0.04	Hardness <= 100 & > 50 milligrammes $CaCO_3$ / litre
	mg/l	0.112	0.112	Hardness > 100 milligrammes $CaCO_3$ / litre

Organic micro-pollutants may also need to be considered in some cases. These substances, often derived from pharmaceuticals and hormone analogues, have been found to produce effects in aquatic species even when at extremely low concentrations. They require specialist methods to detect, but may be worth investigating in cases where no other water quality elements monitored as standard would appear to be responsible for limiting ecological status or producing strange pathological phenomena, particularly in vertebrates.

Appendix 7
Sedimentation

There are complex interactions at both the reach and catchment scale that affect the movement of sediment and the creation of habitat types in watercourses. Channel shape and flow dynamics can influence the movement of sediment and the composition and form of the river bed and banks. In a natural river the channel adjusts its morphological features depending on the sediment and water discharges. Hence the amount of water and sediment present to move through the system is essential to understand when delivering a river restoration project since both can significantly affect the range of habitats that can be achieved.

In essence the composition of the sediment and the shape of the habitats they create, determines what wildlife will be supported. In addition many fish species require contrasting types of sediment for spawning and adults need different conditions to juveniles. Salmon and trout need clean, well aerated, gravel (free from silt) habitats for successful spawning and in lowland rivers for example, these may be present where locally narrowing of the river increase water velocity with the resultant cleansing of the bed of silt and exposure of gravel.

In terms of river restoration principles the most important aspect is to determine the sediment dynamics of a river and how much it has been interfered with by human intervention. For example, if banks have been significantly affected by bank protection this may have a major influence on the river‟s ability to restore specific river features even if there are changes in river management or narrowing interventions etc.

There are whole set of issues that can trigger changes in the sediment dynamics of a catchment. These can include mining influence, the construction of reservoirs that store sediment, gravel extraction within the river, tree clearance and conversely inappropriate afforestation, and perhaps most significantly in urban areas, over-widening of rivers and heavy engineering of banks and beds.

The critical influence of these activities in terms of sediment transport, erosion, and/or deposition at particular locations is dictated to by a number of interrelated processes. Significantly, the river discharge will affect the flow velocity distribution in the river. This in turn will have an impact on the forces acting on the river (depending on the specific channel form) which will, in part, determine whether or not sediment is transported or eroded. The limits to sediment movement will depend on the capacity of the discharge energy which will be set by sediment size, how much material is available (i.e. how much human intervention) and natural vegetation characteristics which can increase the force needed to move sediment .

Understanding sediment movement is complex and requires a mixture of expert judgement and physical principles related to critical shear stress, sediment density, sediment size, the extent of sediment „packing‟ and the lift and drag forces acting on a particle to determine the extent of likely erosion, sediment transport or sedimentation associated with a river restoration project.

There are range of equations that can be applied to rivers to determine sediment movement in terms of what stress or size of flow is necessary to transport a specified load. However, there are extremely variable in terms of both their data collection requirements and their estimates since they have often been determined through assessment of specific river systems and hence are affected by a certain set of environmental characteristics. Examples of these are:

- Hjulstrom (1936), that that looks at erosion, depositon and transport rates as a function of velocity and grain size.
- Miller et al (1977) that uses an empirically derived entrainment function.
- Williams (1983) that compares bed shear stress with grain size.

If movement of sediment is a key concern as part of your project it may be better to call for expert advice.

However, the key aspects you will need to consider are as follows

- Your flow dynamics in terms of its magnitude, changes in discharge and how often this happens and how the velocity is distributed across you river: these will determine where the main force is available hence where sediment is likely to be deposited or eroded.
- Material composition – size, type and cohesiveness
- Channel geometry – understanding the cross-sectional profile will help to explain where sediment might be deposited (i.e. very wide will tend to be an area of deposition whilst overly narrow, relative to its average water discharge will increase force and hence potential for erosion.
- The type and extent of vegetation – the presence of vegetation including its root system will increase the shear stress on the river banks and beds and hence increase force will be necessary to move sediment; strong vegetation structure is often synonymous with stable river banks.
- Urbanisation – here there are a whole range of issues that can affect sediment characteristics of a river and significantly affect a river‟s ability to support a range of habitats. Stabilisation of banks through some kind of liner (e.g. sheet piling, walls, etc etc) will have an impact on sediment loads as will land drainage directly into the river.

Most importantly:

You need to think about the function of your river in the context of the catchment rather than just the reach you are going to restore.

Appendix 8
Multidisciplinary Monitoring

A8.1 Fixed point Photography

This is a very simple method whereby photographs are taken prior to any restoration work being carried out at a number of locations along the river upstream of the proposed works, within the reach or reaches where restoration work is to be carried out in the reach downstream of the lower limit of the restoration work.

Ideally at least four sets of photographs should be taken, one before any works have been carried our (pre works), one when the restoration work is under construction (during works), one immediately after the works are completed (as built) and one at least a year and up to three years later (post works) as can be seen in ***Figure A8.1***.

Pre Works During works

As Built Post works

Figure A8.1 Repeat photographs

Figure A8.2 shows a map detailing the locations of the fixed point photography, the location for the photograph should ideally be fixed using a GPS or at least accurately located on a large scale map (i.e.1:10,000 to 1:1000). ***Figure A8.1*** shows a set of four photographs for a fixed point photography location. It clearly shows how the installation of wood deflectors infilled between with brushwood and pre planted coir mats has allowed marginal vegetation to grow up and narrowed the river.

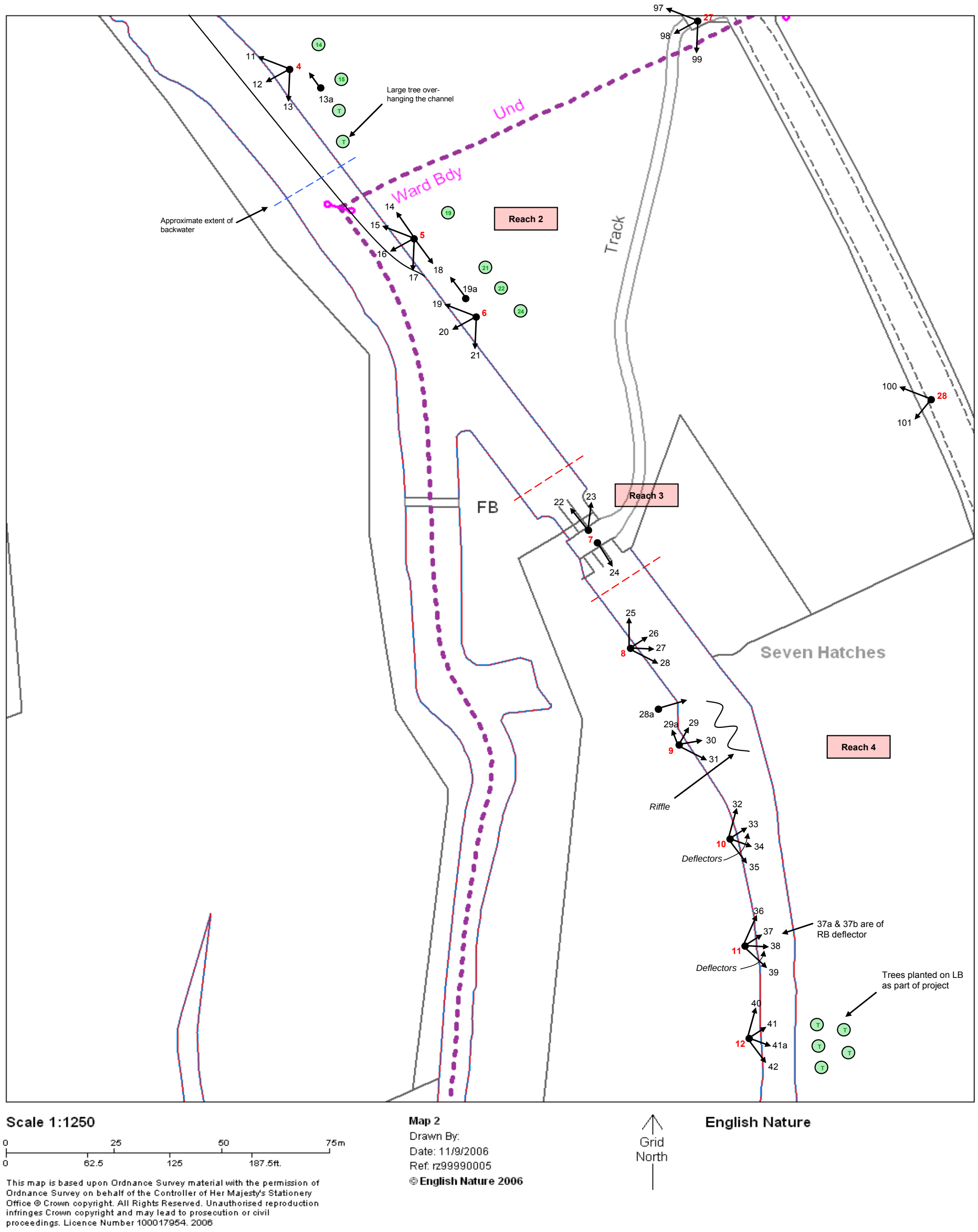

Figure A8.2 Map Detailing Fixed Point Photography locations

A8.2 RRC Rapid Assessment

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Project Assessment Form – Pre works Section 1: Project Objectives and Background information

NOTES: This Project Assessment should be completed in conjunction with photographic monitoring through fixed point photography, the location and orientation of each fixed point photograph should be marked on a site map.

This section (page 1) of the assessment form should be completed prior to going on site.

Objectives

Please outline each of the project objectives for this site and state the category into which they fall:
HG – Hydro geomorphology; V – Vegetation; FA - Fish & Aquatic Invertebrates; M – Mammals; T- Terrestrial Invertebrates; B - Birds; VS – Visual & Social

Objective category	Objective

Background information

	Any survey information?	Any indicator species present? - specify	Any species specific objectives? - specify
Hydro geomorphology			
Vegetation			
Fish			
Aquatic invertebrates			
Mammals			
Terrestrial invertebrates			
Birds			

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Project Assessment Form – Pre works Section 2:
Unit description, reach, vegetation and landuse characteristics[1]

NOTE: An assessment needs to be completed for each 'assessment unit' - identified according to geomorphological features, changes in riparian landuse, vegetation & floodplain characteristics. The location of each unit must be marked on a site map.

Date: Surveyor: GPS point:
River name: Assessment Unit: Weather conditions:

Unit description

Reach Characteristics

Code: LB - Left Bank; RB-Right Bank; Cl – Clay; H-High; M-Medium; L-Low; NF-No perceivable Flow; Y-Yes; N-No

Bankful width (m) Bankful depth (m) Bank slope range (°) LB RB

Av. riffle water depth (m) Av. pool water depth (m) Av. water depth (m) - no pool/riffle sequence

Bank Material (LB) – D= dominant, tick others:	☐ Cobble	☐ Gravel	☐ Cl	☐ Sand	☐ Silt	☐ Artificial
Bank Material (RB) – D= dominant, tick others:	☐ Cobble	☐ Gravel	☐ Cl	☐ Sand	☐ Silt	☐ Artificial
Bed Material– 'D'= dominant, tick others:	☐ Cobble	☐ Gravel	☐ Cl	☐ Sand	☐ Silt	☐ Artificial

If there is any artificial bank or bed material please state the % and provide brief details:

☐ % LB ☐ % RB ☐ % Bed Details:

Has it got any geomorphological features? Please note, and estimate spacing for pool / riffle sequence.

☐ Sinuosity (H/M/L) ☐ Bars (Y/N) ☐ Bed variation (Y/N) ☐ Width variation (Y/N)
☐ Deposition (Y/N) ☐ Bank Erosion (Y/N) ☐ Pools / riffles (Y/N) Approx. spacing (m):

Is there any variation in flow? (Y/N) What is the average stream power? (H/M/L/NF)

Please sketch the typical reach X-section, labelling LB and RB. Include main features, floodplain characteristics & flow conditions.

Vegetation

Av. in-channel cover (%): Av. Marginal cover (%): Av. Bank cover (%): LB RB

Av. tree cover (%): LB RB Is the vegetation typical / native to the river? (Y/N):

Are there any invasive species present (Y/N) Specify……………………………………………………………

Landuse

Please tick main type of landuse – for 'Farmland' please delete arable or grazing as appropriate

LB	RB		LB	RB		LB	RB		LB	RB	
☐	☐	Urban	☐	☐	Industrial	☐	☐	Parkland	☐	☐	Farmland: arable/grazing
☐	☐	Private garden	☐	☐	Wetland	☐	☐	Woodland	☐	☐	Other………………

---

[1] 'Reach Characteristics', 'Vegetation' & 'Landuse' have been adapted from 'Geomorphological Sensitivity Assessment Sheet', *Detailed Catchment Baseline Review*, Environment Agency & University of Southampton, 2000.

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Project Assessment Form – Pre works Section 3: Assessments of ecological habitats & Section 4: Potential Impacts of restoration works

Please comment on the quality of the ecological habitat:

Vegetation: Is there diversity in veg. types - In-channel: emergent, marginal, floating & submerged; Bankside: bryophytes, herbs or grasses, scrubs or shrubs & trees; and Riparian?

Fish & Aquatic Invertebrates: Is there sufficient flow & diversity in flow types? Is there a diverse river bed (substrate and structure)? Is there adequate cover, shelter & shading? Is there clear fish passage? Is there lateral diversity between the river & floodplain? Are there food sources?

Mammals: Is there cover & shelter? Is there sufficient flow & diversity of flow? Is there lateral diversity between river & floodplain? Are there food sources?

Terrestrial Invertebrates: Is there suitable diversity in emergent, bankside & riparian vegetation? Is there lateral diversity between the river & floodplain?

Birds: Is there adequate cover, shelter & shading? Is there lateral diversity between the river & floodplain? Are there food sources?

Project Assessment Form – Pre works Section 4: Potential Impacts of restoration works

Comment on potential impacts of restoration works & identify perceived degree of impact – High, Medium, Low, Negligible.

Short Term

	+ve	H/M/L/N	-ve	H/M/L/N
Hydro geomorphology				
Vegetation				
Fish & Aquatic Invert's.				
Mammals				
Terrestrial Invertebrates				
Birds				
Visual & Social				

Long Term

	+ve	H/M/L/N	-ve	H/M/L/N
Hydro geomorphology				
Vegetation				
Fish & Aquatic Invert's.				
Mammals				
Terrestrial Invertebrates				
Birds				
Visual & Social				

Additional notes:

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Project Assessment Form – During construction Section 1:
Contractor's information, Budget, Site plans and Summary of Predicted Impacts

NOTES: This Project Assessment should be completed in conjunction with photographic monitoring through fixed point photography, the location and orientation of each fixed point photograph should match those taken as part of the 'Pre works assessment'. Any additional fixed point photographs considered to be necessary should be marked on a site map.

This section (page 1) of the assessment form should be completed prior to going on site.

Contractor

Company name

Name of Foreman:

Contact details:

Budget

What is the budget for this project?

Technical site plans

Have sites plans been supplied? (Y/N)

Any other technical specification details:

Summary of Predicted Impacts (from 'Pre works' assessment)

Short Term

	+ve	H/M/L/N	-ve	H/M/L/N
Hydro geomorphology				
Vegetation				
Fish & Aquatic Invert's.				
Mammals				
Terrestrial Invertebrates				
Birds				
Visual & Social				

Long Term

	+ve	H/M/L/N	-ve	H/M/L/N
Hydro geomorphology				
Vegetation				
Fish & Aquatic Invert's.				
Mammals				
Terrestrial Invertebrates				
Birds				
Visual & Social				

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Project Assessment Form – During construction Section 2: Project implementation

Project implementation – site overview

Weather conditions:

Is the project running to the predicted time schedule? (Y/N) ☐

If no, what are the reasons for the changes?

Is the project running to budget? (Y/N) ☐ If no is it expected to be: ☐ Under ☐ Over By how much? ☐

What are the reasons for the changes to the expenditure?

Have there been any problems encountered whilst implementing the project – please provide details?

If any problems have been encountered how have they been overcome? Have there been any changes made to the original design?

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Project Assessment Form – During works Section 3:
Unit description and Potential Impacts of restoration works

NOTE: An assessment needs to be completed for each 'assessment unit' - identified in the 'Pre works assessment' according to geomorphological features, changes in riparian landuse, vegetation & floodplain characteristics. The location of each unit must be marked on a site map.

Date: Surveyor: GPS point:

River name: Assessment Unit:

Unit description

Potential Impacts of restoration works

Refer to predicted impacts from 'Pre Works assessment' (summarised on page 1 of this document) and comment on any changes to these predictions that have occurred as a result of the on-site works, for each identify the perceived degree of impact – High, Medium, Low, Negligible.

Short Term

	+ve	H/M/L/N	-ve	H/M/L/N
Hydro geomorphology				
Vegetation				
Fish & Aquatic Invert's.				
Mammals				
Terrestrial Invertebrates				
Birds				
Visual & Social				

Long Term

	+ve	H/M/L/N	-ve	H/M/L/N
Hydro geomorphology				
Vegetation				
Fish & Aquatic Invert's.				
Mammals				
Terrestrial Invertebrates				
Birds				
Visual & Social				

Additional notes:

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Project Assessment Form[1] – Post works section 1:
Basic Project details, Project Objectives, Background information and Inventory of River Restoration Techniques used

NOTES: This section (pages 1 and 2) of the assessment form should be completed prior to going on site.

Basic Project details

Project name:

Start date: Finish date: Length (km):

Catchment type: Urban / Rural, Upland / Lowland (delete as applicable) Catchment Geology:

Objectives

Please outline each of the project objectives for this site and state the category into which they fall:
HG – Hydro geomorphology; V – Vegetation; FA - Fish & Aquatic Invertebrates; M – Mammals; T- Terrestrial Invertebrates; B - Birds; VS – Visual & Social

Objective category	Objective

Background: Pre and post project information

	Any survey information? (Yes/No)		Any indicator species present? - specify		Any fixed point photography? (Yes/No)	
	Pre	Post	Pre	Post	Pre	Post
Hydro geomorphology						
Vegetation						
Fish						
Aquatic invertebrates						
Mammals						
Terrestrial invertebrates						
Birds						

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[1] Sections 1, 2 and 4 of this Project Assessment form were adapted from L. de Smith, Post-River Restoration Assessment (PRRA), ***The development of the 'post river restoration assessment' for evaluating river restoration projects***, 2005.

Inventory of River Restoration Techniques

Which of the following river restoration techniques were implemented within the project - please tick.
* (MAJOR: the main/primary focus of the project; MINOR: secondary consideration/incidental)

		MAJOR*	MINOR*
	Rehabilitation of watercourse features		
1	Reach re-meandered (>500m)		
2	Reach re-meandered (<500m)		
3	Culverted reach re-opened (state approximate length)		
4	X-sectional habitat enhancement (>500m) – two–stage channel profiles etc		
5	Long section habitat enhancement (>500m) – pool/riffle sequences etc. restored		
6	River narrowing due to depleted flows or previous over-widening		
7	Backwaters and pools established/reconnected with watercourse		
8	Bank re-profiling to restore lost habitat type and structure/armouring removed		
9	Boulder etc. imported for habitat enhancement		
10	Gravel and other sediments imported/managed for habitat enhancement		
11	Fish cover established by other means		
12	Current deflectors/concentrators to create habitat and flow diversity		
13	Sand, gravel and other sediment traps to benefit wildlife		
14	Tree/shrub planting along bankside (only if covers >500m of bank or >0.5ha)		
15	Artificial bed/bank removal and replaced by softer material (>100m)		
16	Establishment of vegetation for structure/revetment (e.g. use of willows)		
17	Eradication of alien species		
18	Provision of habitat especially for individual species – otter, kingfisher etc		
19	Fencing along river banks; fencing floodplain habitats for management		
20	Aquatic/marginal planting		
21	Removal of floodbanks		
22	Other (please specify)		
	Restoration of free passage between reaches		
23	Obstructing structure replaced by riffle		
24	Obstructing structure replaced by meander		
25	Obstructing structure modified/removed to enable fish migration		
26	Obstructing structure retained, but riffle/meander structure established alongside		
27	Culverted reach re-opened/daylightened		
28	Obstruction within culvert (e.g. lack of depth, vertical fall) redresses		
29	Dried river reach has flow restored		
30	Other measures taken to restore free animal passage		
31	Other (please specify)		
	River floodplain restoration		
32	Water table levels raised or increased flooding achieved by		
33	Unspecified means/rationalised control		
34	Watercourse re-meandering		
35	Raised river bed level		
36	Weirs established specifically to increase floodplain flooding/water-table		
37	Termination of field drains to watercourse		
38	Feeding floodplain with water (Sluice feeds, water meadow restoration)		
39	Narrowing watercourse specifically to increase floodplain wetting		
40	Lakes, ponds, wetlands established (maybe flood storage areas)		
41	Lakes, ponds, wetlands, old river channels restored/revitalised)		
42	Vegetation management in floodplain		
43	Riparian zone removed from cultivation		
44	Substantial floodplain tree/shrub planting		
45	Other (please specify)		

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Project Assessment Form[1] – Post works Section 2: Assessment of visual elements and social value, physical characteristics and ecological characteristics

NOTE: An assessment needs to be completed for each 'assessment unit' - identified according to geomorphological features, changes in riparian landuse, vegetation & floodplain characteristics. The location of each unit must be marked on a site map.

Date: ☐ Surveyor: ☐ GPS point: ☐

River name: ☐ Assessment Unit: ☐ Weather conditions: ☐

Unit description

☐

Part 1: Assessment of visual elements and social value in this unit

Landuse 'Landuse' assessment table adapted from Geomorphological Sensitivity Assessment, *Detailed Catchment Baseline Review* Environment Agency & University of Southampton, 2000

Code: LB - Left Bank; RB-Right Bank

Please tick main type of landuse – for 'Farmland' please delete arable or grazing as appropriate

LB	RB		LB	RB		LB	RB		LB	RB	
☐	☐	Urban	☐	☐	Industrial	☐	☐	Parkland	☐	☐	Farmland: arable/grazing
☐	☐	Private garden	☐	☐	Wetland	☐	☐	Woodland	☐	☐	Other………………

Please also consider the following questions:

	Y/N
Is the visual appearance of the river harmonizing with the locations surroundings?(e.g. urban/rural)	
Are the river restoration techniques or practices still visible?	
If Yes, do they blend in with the natural environment?	
Is there a need for monitoring?	
Is there visual evidence of the following:	
Unnatural features to the river or bankside? (e.g. sudden changes in bank slope, sharp corners etc.)	
Hard engineering/man made materials? (e.g. concrete, steel, etc.)	
Litter or unsightly objects? (e.g. trolleys, tyres, sewage pipes etc.)	
Vandalism or graffiti?	
Is there sufficient public access to the river site? (e.g. footpaths, bridges, gates etc.)	
Is there any evidence of public use? (e.g. dog walkers, cyclists etc.)	
Has the project incorporated recreational opportunities & educational interest? (e.g. playground, paths, display boards, maps)	
Are there any safety considerations or health hazards, which have not been identified? (e.g. steep bank sides, hard material)	

Any other comments on the visual elements and social value:

Overall score of Section 2 Part 1:	**1 - Poor**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 - Excellent**

Level of confidence in Answers for Section 2 Part 1:	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100 %**

Part 2: Assessment of physical characteristics in this unit

Reach Characteristics ‘Reach Characteristics’ assessment tables adapted from Geomorphological Sensitivity Assessment, *Detailed Catchment Baseline Review* Environment Agency & University of Southampton, 2000

Code: LB - Left Bank; RB-Right Bank; Cl – Clay; H-High; M-Medium; L-Low; NF-No perceivable Flow; Y-Yes; N-No

Bankful width (m) ☐ Bankful depth (m) ☐ Bank slope range (^{o}) ☐ LB ☐ RB

Av. riffle water depth (m) ☐ Av. pool water depth (m) ☐ Av. water depth (m) - no pool/riffle sequence ☐

Bank Material (LB) – D= dominant, tick others:	☐ Cobble	☐ Gravel	☐ Cl	☐ Sand	☐ Silt	☐ Artificial
Bank Material (RB) – D= dominant, tick others:	☐ Cobble	☐ Gravel	☐ Cl	☐ Sand	☐ Silt	☐ Artificial
Bed Material– ‘D’= dominant, tick others:	☐ Cobble	☐ Gravel	☐ Cl	☐ Sand	☐ Silt	☐ Artificial

If there is any artificial bank or bed material please state the % and provide brief details:

☐ % LB ☐ % RB ☐ % Bed Details:

Has it got any geomorphological features? Please note, and estimate spacing for pool / riffle sequence.

☐ Sinuosity (H/M/L) ☐ Bars (Y/N) ☐ Bed variation (Y/N) ☐ Width variation (Y/N)

☐ Deposition (Y/N) ☐ Bank Erosion (Y/N) ☐ Pools / riffles (Y/N) Approx. spacing (m): ☐

Is there any variation in flow? (Y/N) ☐ What is the average stream power? (H/M/L/NF) ☐

Please sketch the typical reach X-section, labelling LB and RB. Include main features, floodplain characteristics & flow conditions.

Please also consider the following questions:

	Y/N
Does the river experience High flows?	
If Yes, does the river channel pose a flood risk? (e.g. low flood banks, close proximity to housing, choked channel etc.)	
Does the river experience Low/Depleted flows?	
If Yes, does the river have a distinct low flow channel?	
Are the bank profiles structurally diverse?	
Are the bank profiles performing naturally as accustomed to the river catchment type? (compared to u/s and d/s river reaches of same order in the same ecoregion)	
Is the substrate conventional to the river catchment type?	
Is there diversity of in-channel features?	

Any other comments on the physical characteristics:

Overall score of Section 2 Part 2:	**1 - Poor**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 - Excellent**

Level of confidence in Answers for Section 2 Part 2:	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100 %**

Part 3a: Assessment of ecological characteristics in this unit - Vegetation

Vegetation ‘Vegetation’ assessment tables adapted from Geomorphological Sensitivity Assessment Sheet, *Detailed Catchment Baseline Review* Environment Agency & University of Southampton, 2000

Av. in-channel cover (%): ☐ Av. Marginal cover (%): ☐ Av. Bank cover (%): ☐ LB ☐ RB
Av. tree cover (%): ☐ LB ☐ RB Are there any invasive species present (Y/N) ☐ Specify…………..

Please also consider the following questions:

	Y/N
Is there diversity of vegetation types:	
In-channel? (e.g. emergent, marginal, floating and submerged)	
Bankside? (e.g. bryophytes, short herbs, tall herbs or grasses, scrubs or shrubs and trees)	
Riparian? (e.g. mixed woodland, coniferous plantation, orchard, heath, scrub, pasture, wetland and urban development)	
Is the vegetation native/natural/? (compared to u/s and d/s or river reaches of same order in the same ecoregion)	
Is there a need for monitoring/maintenance?	
Has there been any planting or seeding?	
If Yes, has it taken well?	

Any other comments on the ecological vegetation characteristics:

Overall score of Section 2 Part 3a:	**1 - Poor**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 - Excellent**

Level of confidence in Answers for Section 2 Part 3a:	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100 %**

Part 3b: Assessment of ecological characteristics in this unit - Fish & Aquatic Invertebrates

Please consider the following questions:

	Y/N
Are the following habitat characteristics present:	
Diversity of flow types?	
Diverse river bed? (substrate and structure)	
Stream cover, shelter and shading?	
Resting places and refuge?	
Clear fish passage and habitat connectivity between u/s and d/s?	
Lateral diversity between the river and floodplain?	
Food sources? (e.g. bankside trees, bushes and scrub – a source of terrestrial invertebrates)	
Was an improvement in fisheries part of the initial aim of the river restoration project?	
If No, has the river restoration project been beneficial to fisheries?	
Is there any evidence of fish using the habitat?	

Any other comments on the ecological Fish and Aquatic Invertebrate habitat:

Overall score of Section 2 Part 3b:	**1 - Poor**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 - Excellent**

Level of confidence in Answers for Section 2 Part 3b:	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100 %**

Project Assessment Form[1] – Post works Section 2 continued, & Section 3: Identification of Potential Impacts

Part 3c: Assessment of ecological characteristics in this unit – Mammals, Terrestrial invertebrates, Birds

Please consider the following questions:

	Y/N
Was an improvement in a particular mammal habitat part of the main objectives of the river restoration project?	
Was an improvement in a particular terrestrial invertebrate habitat part of the main objectives of the river restoration project?	
Was an improvement in a particular mammal bird part of the main objectives of the river restoration project?	
Are the following habitat characteristics present:	
Shelter and cover? (e.g. bankside trees, bushes and scrub)	
Diversity in emergent, bankside & riparian vegetation?	
Lateral diversity between the river and floodplain?	

Any other comments on the ecological habitat for mammals, terrestrial invertebrates and birds:

Overall score of Section 2 Part 3c:	**1 - Poor**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 - Excellent**

Level of confidence in Answers for Section 2 Part 3c:	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100 %**

Project Assessment Form – Post works Section 3: Identification of Potential Impacts of the restoration works

Comment on potential impacts of works on this unit & identify perceived degree of impact (High, Medium, Low, Negligible)

Short Term

	+ve	**H/M/L/N**	**-ve**	**H/M/L/N**
Hydro geomorphology				
Vegetation				
Fish & Aquatic Invert's.				
Mammals				
Terrestrial Invertebrates				
Birds				
Visual & Social				

Long Term

	+ve	**H/M/L/N**	**-ve**	**H/M/L/N**
Hydro geomorphology				
Vegetation				
Fish & Aquatic Invert's.				
Mammals				
Terrestrial Invertebrates				
Birds				
Visual & Social				

Level of confidence in Answers for Section 3:	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100 %**

Project Assessment Form[1] – Post works Section 4: Appraisal of Techniques and Overall evaluation of the project

Appraisal of Techniques

Please take a photograph of each technique or change implemented, wherever possible; and for each of the 'ticked' practices, please consider the following questions on-site:

	Technique number - taken from table on page 2												
Is the technique: (Y/N)													
Still in place?													
Functioning as intended/producing the desired effect?													
Working with natural processes?													
Appropriate to the river type?													
Score 1-10 (1 = Poor, 10 = Excellent)													

With hindsight, were any of the techniques unnecessary or avoidable? In your view, are there any alternative techniques, which should have been implemented? Please comment:

Overall evaluation of the project

Please consider the following questions for evaluating the project on the basis of your evaluations in Sections 2 & 3:

Overall, is the river restoration project proceeding in the right direction to achieve its objectives?

Is there any evidence of unexpected negative outcomes of the project?

Has the project gained any other benefits?

Are there any areas of the project where further work or regular maintenance may be required?

Overall score for the project[2]:	**1 - Poor**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 - Excellent**

Level of confidence in Answers for Section 4:	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100 %**

---

[2] Please consider scores awarded in Section 2 of this assessment when deciding upon the overall score of the project

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Project Assessment Form – Post works Section 5:
Future improvements and management

Please tick all the issues that still apply to this site:

- Artificial banks ☐
- Artificial bed ☐
- Choked channel – urban and natural debris ☐
- Culvert blockage ☐
- CSO or drains present/water quality issue ☐
- No amenity value – river cut off from urban area ☐
- No in channel features ☐
- No in channel vegetation ☐
- No tree cover ☐
- Over wide ☐
- Over deep ☐
- Overgrown riparian trees – too much shade ☐
- Straightened ☐
- Unacceptable bank erosion ☐
- Unacceptable siltation ☐
- Urban debris ☐
- In-channel obstruction (e.g. weir) ☐
- Other – specify or use to expand on key issues ☐

Does the river pose a serious flood risk in this location? (Y/N) ☐ If Yes provide details:……………………
……...

Potential for adaptive management and future restoration

Please tick all that apply, if you wish to expand on the key potential 'technique' please do so in Additional Comments box

- Artificial bank removal – LB ☐
- Artificial bank removal – RB ☐
- Artificial bed removal ☐
- Fencing ☐
- In channel feature enhancement – pools / riffles ☐
- Increased in-channel sinuosity (current location) ☐
- Local community gain[3] - specify in 'other' box ☐
- Narrow ☐
- 'Natural' bank protection ☐
- Plant marginal vegetation ☐
- Plant riparian vegetation ☐
- Raise bed level e.g. substrate enhancement, woody debris ☐
- Re-meander ☐
- Riparian vegetation management ☐
- Re-profile banks ☐
- SUDS or further investigation re. water quality ☐
- Urban debris management (local community) ☐
- Weir removal/lowering ☐
- Flood storage e.g. floodplain re-connection ☐
- Other – specify ☐

Additional Comments ☐

Level of confidence in Answers for Section 5:	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100 %**

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[3] Such restoration techniques might include improving access by installing bridges and dipping platforms, removing bankside vegetation etc. many of these 'techniques' can be specified under already identified 'techniques', additional suggestions should be specified in the 'Other' box

A8.3 Habitat Mapping (biotope)

Methodology

Biotopes, functional or mesohabitat assessment is a technique used to map a watercourse, stillwater or wetland by breaking it down into components. Biotopes are defined as an area with uniform environmental conditions that provide a habitat for a specific assemblage of plants and animals. Functional habitats (see Harper and Smith, 1995 and Kemp et al, 1999) are areas where hydrological and physical processed for distinct habitats which support distinct invertebrate assemblages. Functional habitats in rivers are called 'mesohabitats' by other researchers e.g. Pardo and Armitage, 1997. Some workers map the physical biotopes rather than the functional habitats that they provide. Their inter-relationship and visualised within the picture below.

Biotopes or functional habitats may be mapped directly or highlighted on other maps produced as part of a study such as a River Corridor Survey.

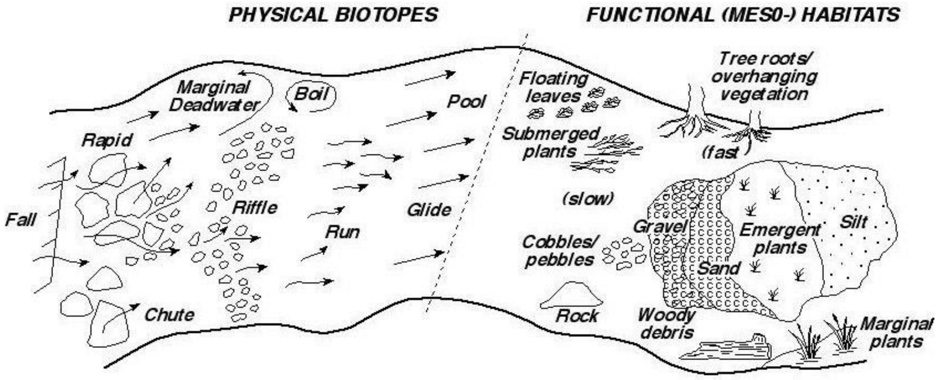


Figure A8.3 Biotope Map Extract from River Corridor Survey (Source: Newson and Newson, 2002, Referenced from the Applied Guidebook of Fluvial Geomorphology, Sear et.al., 2003)

Figure A8.4 An Example of Function habitat overlain on a RCS map

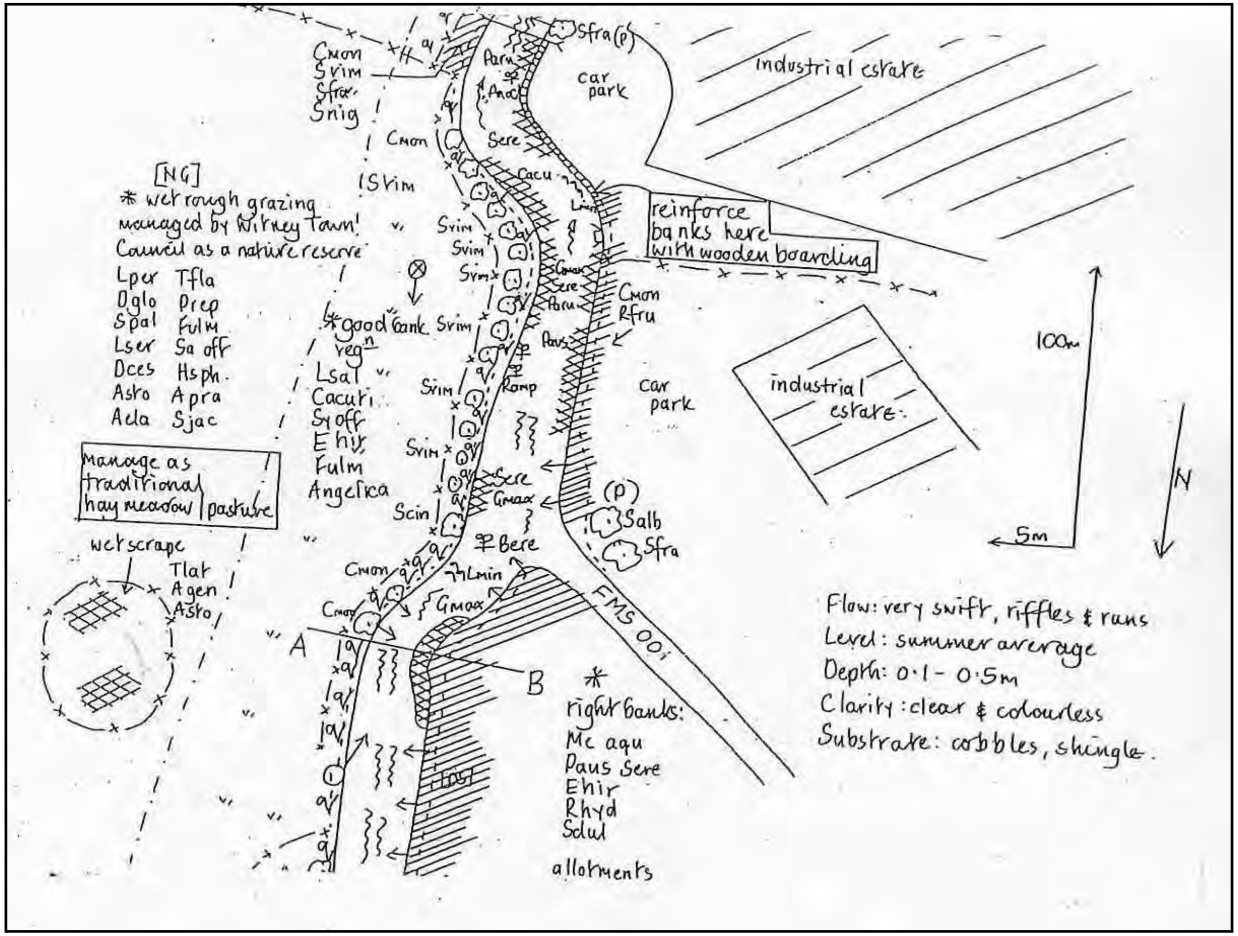
Application

Mapping of biotopes is a relatively simple method of assessing and recording what habitats present within a study section. The composition of habitats present within the section to be restored can be compared with a reference section to help identify what habitats need to be created and the restoration measures needed. Undertaking pre and post surveys and comparing the restoration section with the reference or control section will enable the success of the scheme in re-creating the required habitat to be reviewed. By sampling invertebrates associated with each of the functional habitats the habitat information can be extrapolated into ecological change.

A8.4 Habitat Mapping (RCS)

Methodology

A River Corridor Survey (RCS) is a survey technique described within National Rivers Authority (1992). It produces standardised maps of vegetation structure along a stretch of a watercourse and provides a detailed outline of the physical habitat available for aquatic animals and a botanical survey.



[NG]
* wet rough grazing managed by Witney Town Council as a nature reserve

*good bank veg^n

Manage as traditional hay meadow / pasture

reinforce banks here with wooden boarding

*
right banks:
Mc aqu
Paus Sere
Ehir
Rhyd
Sdul

Flow: very swift, riffles & runs
Level: summer average
Depth: 0·1 - 0·5m
Clarity: clear & colourless
Substrate: cobbles, shingle.

Figure A8.5 River Corridor Survey Map

Application

River Corridor Surveys are a widely accepted way of mapping of vegetation and habitats within a watercourse – it can be used in conjunction with biotope assessments (see below). The comparison of plant structure and composition can inform the selection of restoration measures within scheme.

Appendix 9
Ecology Monitoring

A9.1 Community Involvement (simple invertebrate assessment)

Methodology

Community involvement could take many different forms. The most common is the use of The Riverfly Partnership Anglers‟ Monitoring Initiative (AMI), The Riverfly Partnership interest focuses on three key groups of riverflies: the up-wing flies or mayflies (Ephemeroptera), caddisflies or sedges (Trichoptera) and stoneflies (Plecoptera).

The AMI, endorsed by the statutory agencies, is a simple robust assessment of the biological water quality of rivers based on the presence and abundance of pollution sensitive invertebrates, primarily these riverfly groups. It is designed to enable trained volunteer groups to monitor their local rivers and detect any major changes in water quality. Invertebrate communities are affected by habitat and flow in addition to water quality and the AMI is a useful tool to monitor pre and post river restoration schemes, to both help ensure good water quality and to assess the impact of schemes on invertebrate communities and test if significant changes expected in the community are achieved.

Application

Once trained the AMI Group undertake monthly sampling at their chosen sites using the kick sampling technique (see following section). For each sample the number and abundance of caddisflies, mayflies, stoneflies and freshwater shrimps (*Gammarus* sp.) are recorded. A „trigger level‟ is set for each AMI site by the statutory agencies responsible for the river (the Environment Agency (EA), Scottish Environment Protection Agency (SEPA) or Northern Ireland Environment Agency (NIEA)) through calibration against their routine monitoring data. If the AMI results fall below the „trigger level‟ the relevant statutory agency is alerted and early action taken. Falls in water quality identified by AMI Groups have led to successful statutory agency prosecutions of the parties responsible. The collaboration helps to ensure the good water quality of our rivers.

The Riverfly Partnership runs one-day workshops, for interested groups to join the AMI, covering the methodology, macroinvertebrate identification and recording. See www.riverflies.org.

A9.2 Unit Area Invertebrate Sampling – Surber or Cylinder Samplers:

Methodology

The types of samplers discussed here enable samples to be taken from a given area and allow results to be calculated for a spatial area.

The Surber sampler (Surber, 1937) consists of a quadrat on a hinged frame that can be pushed into the riverbed substrate and a net with side wings to help reduce the loss of invertebrates. The quadrat frame used within this survey encloses an area of 0.05 m2. Its use is demonstrated in ***Figure A9.1***. The sediment within the quadrat is disturbed to dislodge the invertebrates present, larger stones are washed individually to remove any invertebrates attached to the surface. Cylinder samplers operates in a similar way by enclosing a given area which is disturbed so that invertebrates are washed into a net attached to its side.

Application

Replicate samples are needed to represent the invertebrate assemblages at any given site. There are various formulae for calculating the number of samples required see Elliott (1977), Sokal & Rohlf (1981) Resh and McElravy (1993) and Merritt and Cummins, 1996). Samples may be collected randomly from a site or following a stratified approach - e.g replicated sampling randomly within specific habitats.

Once the location of each sample has been determined such as by the generation of randomly selected co-ordinates samples should be collected from the downstream limit of the site first then moving progressively upstream to avoid disrupting the sampling area. Surber samples are best suited for sampling shallow gravel substrate in flowing water conditions.

Unit-area sampling is much more intensive and time consuming then kick sampling but has the benefit of providing results that can be analysed statically to provide densities, abundance, diversity and evenness. As for the kick sample technique when applied to a single restoration scheme it is important to follow the – BACI principles (Before, After, Control, Impact) (Underwood, 1994).

Figure A9.1 Surber Sampling

A9.3 Unit-Time Invertebrate Survey

Methodology

A three minute kick sample is the standard methodology utilised by the Statutory Agencies and adopted by UKTAG to assess ecological status for the WFD details are out-lined in, Murray-Bligh et al 1997. The sampling technique involves actively disturbing the bed of the watercourse with a foot dislodging the invertebrates and collecting them as they are swept into a standard pond net. This is supplemented by a one-minute hand search of stones and other moveable objects. Each habitat present within the site is sampled in proportion to its occurrence. Although invertebrates can be collected at any time of year due to the seasonality of many insects which have an aerial life stage, it is important to ensure surveys are undertaken at the same time of year to ensure comparable results. It is standard practice is to sample the macro-invertebrates over two seasons – spring (March - May) and autumn (September – November). The application of the two season sampling regime has formed the basis of the Environment Agency‟s General Quality Assessment (GQA) and is now accepted by the UK TAG as the monitoring methodology for the WFD.

Where possible data from existing monitoring sites should be used to provide either baseline data or context to the scheme – for this information contact the Environment Agency for England and Wales – 0800 08 770 60 or the Scottish Environment Protection Agency. Samples can be used to establish both temporal and spatial changes. When applied to a single restoration scheme it is important to follow the – BACI principles (Before, After, Control, Impact) (Underwood, 1994) to avoid issues of pseudoreplication.

Figure A9.2 Three Minute kick sampling

Sample analysis

Depending upon the sampling design it is possible to perform a number of different statistical techniques upon the data including times series, trend analysis, modified ANOVA or biotic indices. There are many sources of information that can help such as Sokal and Rohlf (1969), Resh and McElravy (1993) Ennos A.R. & Bailey S. E. R., (1995) Watt, T.A. (1997) Waite, S. (2000) Henderson P. A. (2003) Henderson and Seaby (2008) and Van Emden, H. (2008).

There are a number of biotic indices that can be applied to invertebrate data which include the Biological Monitoring Working Party (BMWP) Score (Chesters *et al.* 1980), system which is used to give an indication of the impact of organic pollution. The Lotic-invertebrate Index for Flow Evaluation - LIFE (Extence *et al.* 1999) can be used to assess flow and velocity and the Community Conservation Index – CCI (Chadd and Extence 2004) the conservation status. These indices can be used to help assess the background conditions of a restoration scheme prior to implementation. Although none of these indices give a measure of habitat quality they are all influenced by habitat and may show a response to a river restoration scheme.

The River Invertebrate Classification Tool (RICT) (see the following web link

http://www.sniffer.org.uk/Resources/WFD72c/Layout_Default/0.aspx?backurl=http://www.sniffer.org.uk:80/project-search-results.aspx&selectedtab=active) which can be used to obtain a list of taxa that might be expected at a site if it was unpolluted and unmodified, based upon its physical parameters. The observed taxa collected within a sample can then be compared with the taxa expected at a site to give the Environmental Quality Indices (EQIs).

The EQIs for two elements of the BMWP score system - the Average Score Per Taxa (ASPT) and the number of scoring taxa collected over two seasons (Spring and Autumn) are used as the basis of the WFD classification system http://www.environment-agency.gov.uk/research/planning/33260.aspx

Three minute pond net sampling method

Selecting a net

Use a standard FBA-pattern long handled pond net for kick and sweep sampling.

Nets and frames vary slightly between manufacturers but their basic features should not differ from those described below:

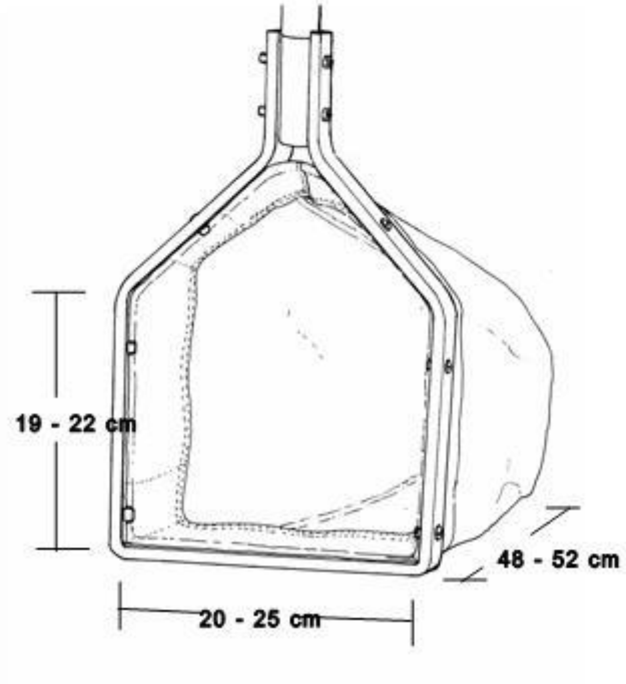
- the frame must have a straight lower edge of 20 - 25 cm and straight, vertical sides of 19 - 22 cm;
- regularly check that the bottom edge of the frame is not bent, because this reduces its sampling efficiency;

  Thin gauge aluminium frames are prone to this type of damage.
- use nets 50 cm deep;

  They are less easily blocked because of their greater mesh surface.
- the pond net handle should be about 1.5 metres long;
- you can use a longer handle in deep waters, for example for collecting sweep samples from deep rivers, but they are not recommended for general use.

Figure 5

The diagram below shows the dimensions of a pond net.



Using a pond net

The pond net can be used in different ways, depending on the nature of the sampling area. You may sample different habitats at the same site by using a combination of the methods described below.

Step	Action
1	Total sampling time is three minutes. The three minutes only covers the time spent actively sampling. It excludes time spent emptying the net or moving around the site. Ideally, sample in short bursts of 15 - 20 seconds, allowing 9 to 12 bursts in a three minute sample. Remember this when apportioning sampling effort to different habitats.
2	If a site includes discrete habitats, weight your sampling effort according to their proportion in the sampling area overall. If a site appears homogeneous in character, use continuous diagonal transects.
3	Always move upstream and diagonally across the stream a number of times while sampling. Do not move straight upstream. This ensures a greater number of habitats are sampled, even if they are not apparent, and, therefore, a higher proportion of the taxa present at the site are collected (see Woodiwiss, 1980).
4	Use a stopwatch to ensure that the cumulative time spent actively sampling is precisely three minutes.

In gravel or cobbles

The table below and Figure 6 describe how to kick sample from gravel or cobbles.

Step	Action
1	Hold the net vertically with the frame at right-angles to the current, downstream from your feet and resting on the stream bed. Disturb the stream bed vigorously by kicking and rotating the heel of your boot to dislodge the substratum and the fauna within it to a depth of about 10 cm.
2	Lifting and disturbing the substratum with your heel and toe by rotating your foot is particularly effective. There is no need to kick-up a froth!
3	Hold the net: ▪ close enough for the invertebrates to flow into the net with the current; ▪ but far enough away for most of the sand and gravel to drop before entering the net. See Figure 6 for a photo of someone doing this. Hold the net further away when the substratum is finer or the current swifter, to prevent it clogging. Move large stones by hand if they cannot be shifted by foot. Sample any finer sediment collected beneath them.

Figure 6

Kick sampling from a shallow, fast flowing stream.

The sampler is facing at right angles to the current and is moving diagonally to the right and towards the photographer. He is dislodging the substratum with his left foot and holding the net close in the plume of disturbed sediment to catch the animals that are dislodged.

In soft sediments

Where the stream bed is soft silt or clay, kick sampling is ineffective because the net will become blocked rapidly. The table below describes how to sample from soft sediments.

Step	Action
1	Skim the bottom edge of the net gently through the top few centimetres of the substratum, which is where most of the animals will be found.
2	Alternatively, stir up the surface of the sediment by foot or with the back of the net. Pass the open net through the clouded water.
3	Rinse the silt away through the net frequently, by agitating the net in the current or at the water surface.

From boulders

It is not easy, and sometimes impossible, to take a kick sample amongst boulders. Most of the invertebrates will be in the finer deposits that accumulate under the boulders. To reach them, boulders may have to be moved by hand, though small ones may be prised away with your foot.

The table below describes how to do this.

Step	Action
1	Move boulders away at right-angles to the current, or upstream and **away from your feet**, so that the net can be held downstream from the area disturbed. Sample the exposed river bed by kicking in the normal way. Waders with steel toe caps must always be worn when sampling in areas dominated by boulders.
2	Where the whole survey area is dominated by large boulders, particularly near waterfalls or where the gradient is steep, it may be impossible to sample effectively. Replace the site by one more amenable to sampling.

From vegetation

Different types of vegetation will require slightly different techniques to dislodge the animals.

The table below describes what to do.

Step	Action
1	The best general technique is to push the net into them with a variety of forward, upward and lateral movements.
2	Dislodge animals from dense tangles of tree roots by kicking.
3	Sample the sediment that accumulates beneath plants by kicking or skimming the surface of the sediment.

Water over gravel or cobbles

When sampling from still or slowly flowing water, a different procedure is necessary, because there is no current to carry dislodged animals into the net.

The table below describes what to do.

Step	Action
1	Disturb the substratum with your feet. Catch the dislodged animals by sweeping the net through the water immediately above the disturbed area. Be careful to keep the net moving or organisms already trapped may float out.
2	Use this technique wherever the current is weak, to supplement the methods described above.

In deep waters

If the watercourse is too deep for a conventional kick sample, you may take a pond net sweep sample from the marginal vegetation and shoreline, using an extension handle if necessary. This is preferable to using a dredge or airlift. Both those methods are less easily controlled and are inefficient on very soft or detrital stream beds.

The table below describes what to do.

Step	Action
1	Some of the sample **must** come from the river bed in the main channel. If it is not possible to get any material from the main channel with a long handled pond net, you must collect a dredge or airlift sample instead.
2	Sample all habitats. If possible, use a combination of sweeping and kicking and, if practicable, collect the sample from both banks. Although each habitat should be sampled in proportion to its cover, this is unlikely to be possible in the main channel. Sample discrete habitats in proportion to their linear predominance along the river.
3	In fenland rivers, it is recommended that you choose sites supporting some emergent vegetation, as these are in a more natural state. Do not extend the sampling area to include stands of different species if this causes a gap in the sampling area. It must be a single discrete area but remember that it covers both banks.
4	There is an increased level of risk with this type of sampling. You have to get close to the water's edge and many slow flowing watercourses have steep, soft banks. It is easy to fall in and hard to climb back out. You must read the 426_05 Generic Risk Assessment on working in or near water and should generally take two people to these sites. Much of the health and safety advice given in the 116_04 Safe system of work for using dredges is applicable to this type of sampling.

Collecting freshwater macroinvertebrate samples

There are a number of methods that can be used to sample macroinvertebrates in freshwaters. The most appropriate depends upon the purpose of the sampling. Individual recorders also tend to develop their own styles which are tailored for specific organisms. Detailed below are two generalised sampling methods that are used for small, shallow flowing and still waters, and enable the capture of a diverse range of freshwater macroinvertebrates. These methods are qualitative but are standardised enough to allow comparisons between samples.

Stream sampling method (kick-sampling)

The typical sampling method for streams and rivers involves a three minute kick/sweep sample using a standard 1 mm mesh pond (hand) net. It is important to move around the site during this time to sample the different habitats in the stream, such as fast moving riffles, shallow water, slow water, weeds and tree roots. This should ensure that the full complement of animals at the site is represented in the sample.

Once the different habitats have been identified, divide the total sampling time (three minutes) proportionally according to the relative habitat areas. Place the pond net on the riverbed and disturb (with foot, kicking motion) the area just upstream of the net for the time allocated to that habitat type. The animals will then be carried downstream by the current into the net. For the weeds and tree roots, sweep the net through the area for the allocated time. It is also advisable to carry out an additional one minute hand search of large stones by gently rubbing the stones in the water letting any animals be carried downstream into the net. Be careful as there may be glass, metal or other sharp objects on the riverbed.

Fill your white tray with river water to a depth of a couple of centimetres and then lower the net into the water in the tray, carefully turn inside out, and shake gently, to release the contents for examination. If you have collected a large sample or lots of debris, it may be necessary to examine the contents by taking sub-samples. To do this you will need to empty the contents of the net into a bucket half filled with water. Remove a sample from that bucket using a kitchen sieve or similar, and empty the contents into your tray. When you have finished examining the sample, empty the contents into a second bucket or put it back into the river. Continue taking sub-samples until your first bucket is empty.

Pond sampling method

As with sampling streams and rivers, the macroinvertebrate sampling method for ponds involves a three minute net sample plus an additional one minute search for animals which may otherwise be missed in the three minute sample. It is advisable to carry out the one minute search before the net sample as the water will be disturbed during the net search. Areas to search for the additional one minute sample include the water surface and under stones and logs.

As with to the stream sampling method, divide the sampling time equally between the different habitat types. Each habitat type should be netted vigorously for the allocated time. You should lightly kick stony or sandy substrates to dislodge the macroinvertebrates.

Try and avoid netting deep accumulations of soft sediment, large accumulations of plant material and root masses, as it makes subsequent sorting difficult. The netted sample should be as debris and silt-free as possible.

As above, the net should then be lowered into the water in the tray, carefully turned inside out and shaken gently, to release the contents.

The environment Agency also have a document entitled "***Freshwater macro-invertebrate sampling in rivers***" which gives detailed descriptions of how, when and where to take macroinvertebrate samples.

A9.4 River Habitat Survey (RHS)

Methodology

The River Habitat Survey (RHS) (Environment Agency, 2003) is a standard field survey of a 500m stretch of river where physical habitat and geomorphological features are recorded in a replicable manner. At 50m intervals „spot-checks" are undertaken to record details of bank and channel physical attributes, man-made modifications, land uses and vegetation structure. A „sweep-up" section is used to record additional information where features and modifications are recorded as absent, present or extensive. Habitat components such as trees and associated features, invasive species, and bank profiles are also recorded. River Habitat Survey (RHS) is the chosen tool for monitoring hydromorphology for the Water Framework Directive (WFD).

Application

The data collected within the survey can be used to calculate the Habitat Quality Class and Habitat Modification Scores which provide a broad assessment of habitat quality and naturalness. The survey also records the presence of invasive plants, types of channel modification and the location of physical barriers to fish migration.

Sites can be compared to the national reference network of sites held on the Environment Agency"s ECOSYS database. The database can holds a national inventory of features and provides a statistically valid basis for the classification of river types. Any site in the country can be surveyed using RHS and categorised based upon river type and observed features compared with a national or regional 'norm'. The technique can also be used to assess changes in the characteristics of a site over time and as the result of a restoration scheme. For more information contact: rhs@environment-agency.gov.uk.

A9.5 Urban Habitat Survey

Methodology

The Urban River Survey (URS, Davenport *et al*, 2004) is a modification of the RHS methodology designed especially for urban or highly modified (HM) rivers and streams. The URS is suitable for the assessment of 500m stretches of urban rivers (including HM reaches) which are defined by their engineering type in terms of planform, cross-section and reinforcement level. Where only shorter stretches are available, URS results can be adapted down to a minimum length of 250m. The URS includes all RHS components and follows the same protocol as the RHS with 50m „spot checks" to record key physical (geomorphological) and vegetation habitat features; plus the cumulative or „sweep-up" data which record enhanced counts and proportional details of physical habitat features and modifications within the channel and riparian corridor. The URS also captures additional data for pollution sources and indicators plus extra urban land use categories.

Application

A higher level of quantification of physical and vegetation habitat features in the URS methodology allows the calculation of >40 indices which describe a broad range of environmental characteristics for urban river stretches, making comparison between stretches straightforward. The URS indices allow stretches to be classified according to channel materials, physical habitat or vegetation structure. Multivariate analysis of URS data has revealed key environmental gradients, against which urban river stretches can be assessed and compared. These gradients also form the basis of the URS matrix. URS data provide information for rehabilitation planning through (i) classification of stretches and (ii) high level assessment of stretches using the URS matrix. These also provide the basis for high-level scenario modelling of the consequences of changed engineering / management.

Appendix 10
Fisheries Surveys

A10.1 Electrofishing

Method

At its most basic, electrofishing can be described as the application of an electric field into water in order to incapacitate fish; thus rendering them easier to catch. Basically the fish are stunned and float to the surface where they can easily be captured. There are two schools of thought as to what causes the fish to react to the electric current. One suggestion is that it causes a reaction to electro-stimulation of both the central nervous system (CNS) and autonomic nervous system (ANS), and the direct response of the muscles of the fish. The other hypothesis is that the fish response is basically that of electrically induced epilepsy (i.e. stimulation of the CNS only). In reality both theories have much to commend them and there are probably elements of truth in both. The advantage of this method is that a much greater proportion of the fish population can be caught and weighed. However, there is a risk of fish mortality – particularly small fry – so the timing of electro-fishing needs to be carefully assessed. Furthermore, the risks involved dictate that this should not be undertaken without complete training, and permission must be sought from the responsible authorities (environmental agencies).

Application

There are a number of different sampling methods which can be used these include quantitative methods such as **depletion sampling** where fish are removed from a reach in a series of successive elcetrofishing runs. The estimate of total population is based on the rate at which the catches on successive electrofishing runs drop off and the total number of fish caught.

The simplest form of semi-quantitative methods is where a single electrofishing run and the fish catch is used to derive a minimum estimate of the fish population. i.e a minimum density of the fish caught at the site. Another semi-quantitative method is to get an estimate of the population based on a theoretical depletion rate. A single survey is conducted and the results calibrated against the initial run of a previous multiple-run survey.

Time delineated surveys involve electrofishing for a given length of time and the number of fish caught is used as an index of abundance. This gives an indication of overall trends in species and year class distribution over time of space rather than exact fish numbers.

These and further methods are described in the electrofishing team leader Training manual Scottish Fisheries Co-ordination Centre Inverness College http://www.sfcc.co.uk/pdfs/SFCC%20Team%20Leader%20Electrofishing%20Training%20Manual%20(Level%20III)%20(1).pdf

Monitoring methods for specific fish species are also described in the Life in UK Rivers Project series at http://webarchive.nationalarchives.gov.uk/20080612154553/http://www.english-nature.org.uk/lifeinukrivers/publications/publications.html

A10.2 Netting

Seine Netting Method

Seine netting uses a small mesh size, the upper edge has floats which keeps the net vertical and the lower edge is weighted keeping the net on the channel bottom. The net is used to surround the fish and as it is drawn in the fish are trapped.

There are a number of different techniques which include;

- Wrap-around;
- Netting between stop-nets
- Isolated area netting
- Netting for fish fry
- Sampling marginal communities
- The wraparound technique uses two pairs of seine nets which are pulled across upstream and downstream of the sampling reach. The downstream nets need to be at least three times the width of the river. Once set in place across the river the excess of the inner downstream net should be laid along the river bank. The inner upstream net is then pulled slowly downstream till almost reaches the inner net of the downstream pair. At this point the excess part of the inner downstream net which was previously laid on the bank is then wrapped around the net which has just been pulled down from the upstream location. Once completely surrounded this net is removed. The seine net can then be pulled in and the captured fish, weighed, measured and counted. The fish are also marked (for example with a Panjet inoculator) and are released back into the reach. The process is repeated, the number of fish re-caught in the second trawl gives an indication of netting efficiency.
- Seine netting between stop-nets is similar to the wraparound technique and is used on rivers wider than 40m where pulling in long nets may be difficult. It can also be used on rivers less than 40m wide.

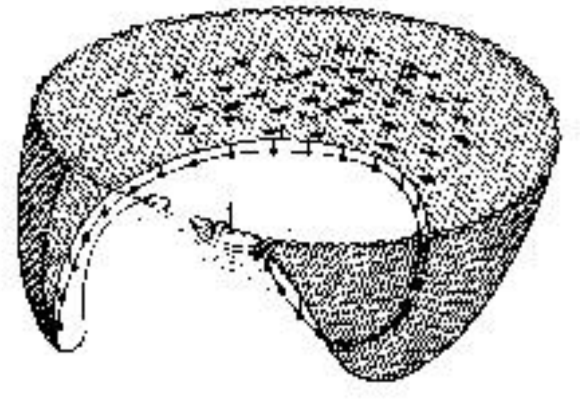


Figure A10.1Seine net

The isolated area method is used on river greater than 90m wide with moderate to low flows. The fish are encircled with the seine net. A pair of seine nets are laid out in a circle from a boat, the inner net is drawn in the normal way and the captured fish removed, the outer net is then drawn in too and any further captured fish removed.

For netting of fry the choice of sampling location is very important. Fry are normally found in the margins and different species often inhabit specific microhabitats. The mesh size should be 3-5mm (knotless). The net is set in a semicircle from the bank and drawn in. Submerged vegetations may lift the net and allow the fish to escape so in weed covered location electrofishing may be more suitable.

For sampling marginal fish communities a semi-quantitative technique is used which is designed to capture adult fish from the margins of transitional waters

Fyke Netting Method

Fyke nets (with leaders or wings) are conical nets with inscales and a circular or D-shaped opening held open by metal rings. There is a series of interconnecting nets with one-way entry to trap fish.

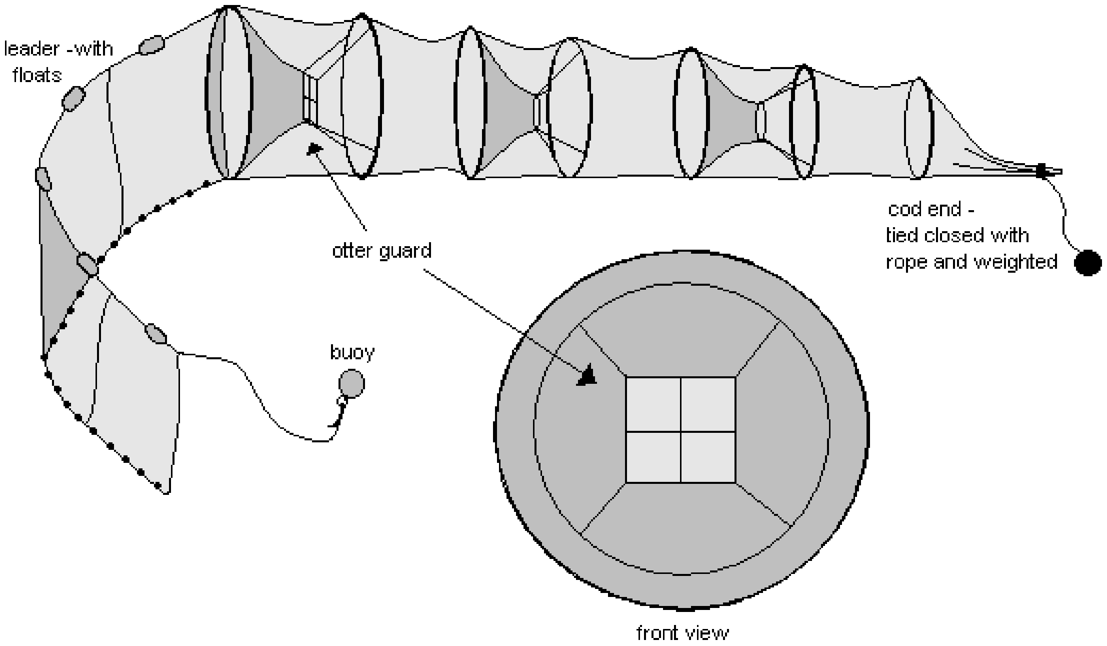


Figure A10.2 Fyke Net

Fyke nets can be set by hand or from a boat. When sampling for migrating fish the nets can be placed across the flow. To sample a large area a number of nets can be tied together on a line. The nets are commonly left in position for 24 hours depending on the objective of the survey`. In transitional waters the nets should be deployed over a full tidal cycle.

The lengths and numbers of all captured fish should be recorded. Freshwater fish are measured in fork length and marine fish in total length. Fish scales may also be taken to determine age and growth.

A10.3 Trapping

Trapping is typically carried out to intercept upstream or downstream migrating fish in rivers – most typically salmonids or eel, although the fyke-netting technique described above (using winged or single-leadered nets), can also be applied to the capture of other fish species, and also in stillwaters. Essentially, the trapping technique involves funnelling the migrating fish into a defined trap that they cannot escape from. As such, the trap itself should be sited and designed appropriately for the target fish species, and should be suitable for the likely size and number of fish expected to be caught.

Trapping method – Upstream migrants

Upstream migrating fish are encouraged into the trap by a combination of: the relative flow of water through the trap; and the ease of upstream passage via the trap compared to alternative routes. Trap are usually sited alongside an existing barrier to migration (for example, a weir) or by creating a barrier (for example, from fencing or netting).

The entrance to the trap normally has a V-shaped inscale or similar structure that funnels fish into the main body of the trap through a narrow opening. Sometimes, the opening is set above the floor of the trap. This arrangement, as well as the size of the opening and the instinct of fish to face upstream against the flow, helps ensure that fish are retained in the trap.

The trap construction usually has steel bars or grid work spaced to retain the target species while allowing sufficient flow of water to serve as an attractant to the fish. The selectivity of the trap is determined by the bar/grid spacing or net mesh size and the size of the inscale opening. Smaller spacings or mesh sizes are required to catch smaller fish.

Trapping method – downstream migrants

Fixed downstream traps normally operate by creating a vertical barrier to downstream migrants, forcing fish to move, via a bypass channel, into a retaining box or pool.

The barrier is usually narrow-spaced bars or grid work designed to retain most or all migrants while allowing through-flow of water. Some traps may also incorporate a horizontal screen set over a natural or manmade fall in the river (for example, a weir) to allow a downward flow of water.

Rotary Screw Traps (RSTs) comprise a pontoon-mounted, cone-shaped drum of up to 2.5m diameter and holding box. Water flowing into the drum mouth causes it to rotate by acting on an internal, helical vane. Downstream migrating fish are carried with the water into the drum and through to a rear holding box.

The drum is constructed of perforated sheet or mesh to allow some through-flow of water, but the design is such that water is always present to carry fish into the holding box, so fish are not damaged by being left dry on the drum walls.

Figure A10.3 Fish trap (by kind permission of the Tweed Foundation)

A10.4 Hydroacoustics

Method

Hydro acoustic surveys use sound waves emitted from a "transducer" to estimate the density fish shoals. The survey vessel tows the transducer under water, which is linked to an echo sounder in the vessel which records the shoals of fish as "marks" on a screen or paper trace. The survey indicates fish densities and shows where the fish are gathering.

Application

Acoustic surveys can give an indication of overall density estimates and general size distribution. Repeated surveys over different season will indicate seasonal variations in terms of densities, size distribution and fish migration.

A10.5 Fish Counters

Fish counters are generally installed on fish passes where the fish are concentrated in a restricted section of flow. One method is to use traps which are usually installed in the fish pass itself or at its exit. The trap generally consists of a mesh cage or chamber fitted with a non-return system. The entrance to the trap also needs to be fitted with an otter excluder to make sure that otters do not get entrained and drowned in the trap. The dimensions of the trap must allow for the maximum number of fish likely to be present in the installation at any one time. So the size will depend on the daily migration peaks of the various species and of the frequency of operation of the pass. The volume of the trap is calculated by allowing a minimum volume of approximately 15 litres per kg of fish trapped. Counting operations should take place at regular intervals to ensure that the fish are not in the trap for any length of time. Typically this takes place one or more time a day.

Resistivity counters are also used to count fish. This method relies on the fact that there is a difference between the conductivity of fish compared with that of water. The fish are forced to swim passed a series of submerged electrodes. The resistance between the electrodes is constantly monitored and changes in conductivity indicate that a fish has swum through. The direction of movement of the fish and its size can be determined. The counter is generally linked to a data logger so that fish movement in terms of time can be recorded as well as direction and size.

A third method of counting is by visual observation or by videoing. The fish are guided through a narrow channel where there is sufficient visibility for them to be identified and counted

A10.6 Tagging

Method

In this method small tags are attached to the fish‟s fin. The tags, which emit ultrasonic „pings‟, can last up to 20 months. They transmit signals to fixed receivers along the length of the river and in some of the side channels and can monitor fish movements 24 hours a day, seven days a week. Receivers log the date, time and tag number when activated by a passing fish. Data is downloaded every couple of months and enables movements of individual fish to be monitored.

Application

The tagging data we obtain is studied to try and understand the temporal and spatial movements, as well as growth rates and condition of fish.

Appendix 11
Macrophyte Surveys

A11.1 Environment Agency Macrophyte Survey Methodology (LEAFPACS)

Macrophyte surveys are done in 100m river lengths and uses a nine point cover scale. There are 4 main drivers for carrying out these macrophyte surveys which include WFD, urban waster water treatment directive (UWWTD), environmental change network (ECN) and water resources planning.

Macrophyte surveys should be carried out between June and September. Sampling should be carried out in average to low flow conditions. Heavily shaded areas should be avoided when selecting the survey reach and consider whether any river maintenance works (e.g. weed cutting or dredging) might have been carried out in the reach recently which may affect your results.

Surveying for river restoration would come under the WFD investigational monitoring type in that you are looking to collate biological evidence that a river restoration project has improved macrophyte cover/variability thus reducing or eliminating a pressure acting on the water body being investigated.

For the survey all macrophytes within the channel should be part of the survey including plants that are submerged or partly submerged in the river at low flow and plants at the side of the river which are attached or rooted to parts of the substrate which are likely to be submerged for 85% of the year. Plants in the bank should be excluded and plants that are submerged or partly submerged at average flows.

Form SD01 contains a list of taxa (approx 184) and defines the taxonomic level to which you should work. The list includes vascular plants and a number of widely recorded and easily identifiable bryophytes and macroalgae that grow in conditions of near permanent saturation or submergence.

Things to remember when surveying include looking at small niche areas (<25cm^2), these can cause inter survey differences if missed. Do not record detached floating macrophyte material except for actual floating species such as *Lemna* sp. Do not record macrophytes that are stranded above the water line. Ensure that *Ranunculus* species are correctly identified as misidentification of these is a common source of survey errors. Take representative samples of bryophytes and algae to the laboratory to confirm their identity. Only record terrestrial taxa if they are found in the channel.

From the survey species percentage cover and Taxon Cover values (TCVs) for each macrophyte taxon can be calculated. Two methods are available, the width method and the square method.

Width Method

Imagine a rectangle that goes along the bank for 1m and stretches from bank to bank. This rectangle is 1% of the channel area (because the reach length is 100m). Now estimate the number of 1% rectangles each macrophyte taxon occupies. This gives you the taxon percentage cover. Then use the table below to calculate the TCV.

Table A11.1

TCV	Percentage cover of the macrophyte species	Corresponding length of bank for 100m survey length
C1	<0.1%	<0.1m
C2	0.1 to 1%	0.1 to 1m
C3	1 to 2.5%	1 to 2.5m
C4	2.5 to 5 %	2.5 to 5m
C5	5 to 10%	5 to 10m
C6	10 to 25%	10 to 25m
C7	25 to 50%	25 to 50m
C8	50 to 75%	50 to 75m
C9	>75%	>75m

Square Method

For this method you need to estimate the number of square metres that each taxa occupies. Then use the tables below to assign a TCV value.

Table A11.2

TCV	% cover	Average River width (m)							
		1	2	3	4	5	6	7	8
C1	,0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
C2	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
C3	1-2.5	1-2.5	2-5	3-7.5	4-10	5-12.5	6-15	7-17.5	8-20
C4	2.5-5	2.5-5	5-10	7.5-15	10-20	12.5-25	15-30	17.5-35	20-40
C5	5-10	5-10	10-20	15-30	20-40	25-50	30-60	35-70	40-80
C6	10-25	10-25	20-50	30-75	40-100	50-125	60-150	70-175	80-200
C7	25-50	25-50	50-100	75-150	100-200	125-250	150-300	175-350	200-400
C8	50-75	50-75	100-150	150-225	200-300	250-375	300-450	350-525	400-600
C9	>75	>75	>150	>225	>300	>375	>450	>525	>600

Table A11.3

TCV	**% cover**	**Average River width (m)**						
		9	**10**	**11**	**12**	**15**	**20**	**25**
C1	,0.1	0.9	1	1.1	1.2	1.5	2	2.5
C2	0.1 – 1	0.9-9	1-10	1.1-11	1.2-12	1.5-15	2-20	2.5-25
C3	1-2.5	9-22.5	10-25	11-27.5	12-30	15-37.5	20-50	25-62.5
C4	2.5-5	22.5-45	25-50	27.5-55	30-60	37.5-75	50-100	62.5-125
C5	5-10	45-90	50-100	55-110	60-120	75-150	100-200	125-250
C6	10-25	90-225	100-250	110-275	120-300	150-375	200-500	250-625
C7	25-50	225-450	250-500	275-550	300-600	375-750	500-1000	625-1250
C8	50-75	450-675	500-750	550-825	600-900	750-1125	1000-1500	1250-1675
C9	>75	>675	>750	>825	>900	>1125	>1500	>1675

With each sample reach a number of physical variable should be recorded including;

- Location
- Width
- Depth
- Substrate
- Habitat
- Shading
- Water clarity
- Bed stability
- JNCC Methodology

The full document can be found at the following link,
http://www.wfduk.org/bio_assessment/rivers_macrophytes_leafpacs

Below is the Environment Agency operational instructions for carrying out macrophytes surveys:-

Environment Agency
Asiantaeth yr Amgylchedd

Surveying freshwater macrophytes in rivers

Operational instruction 131_07 **Issued** 17/05/2010

This document is for staff at level 2 of the data and information management capability in the Environmental Monitoring technical development framework.

What's it about? Describes how to survey freshwater macrophytes in rivers.

Replaces the Mean Trophic Rank (MTR) manual.

Who does it apply to?

- Environmental Monitoring Analysis and Reporting teams.
- contractors who carry out macrophyte surveys for the Environment Agency.

Contents

Note: changes since last issue highlighted in yellow

Document details

Related documents

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Introduction

Reason for macrophyte surveys

The composition and abundance of taxa within river macrophyte communities reflect the nutrient status and hydrology of the river. Large sets of data have been analysed and scores assigned to different macrophyte taxa. The scores reflect the nutrient and hydrological conditions in which the taxa are most likely to occur.

Macrophyte surveys measure the abundance of macrophytes in the river. We combine the scores and abundance data to indicate the condition of the river by comparing the results with pre-determined reference conditions, or less impacted sites.

The composition of river macrophyte communities can also be influenced by substrate and the level of shading from bank-side vegetation.

Definitions

For the purpose of these surveys a macrophyte is classed as

-any plant observable with the naked eye and nearly always identifiable when observed” (Holmes and Whitton, 1977)

This includes all higher aquatic plants and bryophytes, together with groups of algae which can be seen to be composed predominately of a single taxon.

Drivers of macrophyte surveys

We monitor the macrophytes in rivers for the following drivers:

- Water Framework Directive (WFD);
- Urban Wastewater Treatment Directive (UWWTD);
- Environmental Change Network (ECN);
- Water resource planning drivers.

Surveys for WFD

Macrophyte surveys for the WFD assess the ecological status of a river water body as a whole.

We compare macrophyte communities with a reference condition. The reference condition is determined by the river's physical type (such as its geology, size and flow). The results of the comparison indicate the water body's ecological status, which is allocated to one of 5 classes ranging from **high** to **bad**.

Surveys for UWWTD

Macrophyte surveys for UWWTD investigate the impact of point-source nutrient discharges on the macrophyte community in a river.

Locate one survey upstream of the discharge and another downstream of the discharge, and then compare the two surveys. Changes in the plant community reflect the impact of the discharge on the river's trophic status.

Locate these surveys so that other influencing factors (such as substrate or flow) are similar in both upstream and downstream survey.

Surveys for ECN

Macrophyte surveys for the Environmental Change Network follow the existing protocol, which requires you to record all macrophytes in 10m sections of a 100m survey length.

Surveys for water resource planning

Macrophyte surveys for water resource planning usually consist of one survey per assessment point. This survey is located:

- at the lower end of the assessment point reach;
- in a typical part of the river.

We may also use survey data that we collected for other drivers.

About the survey method

Each survey follows a method that uses:

- 100m lengths of river (known as the **survey length**);
- a nine point cover scale (made up of 9 **Taxon Cover Value (TCV)**).

We use one survey method for all drivers (with the exception of ECN, as described above). Any differences in methodology between drivers are clearly indicated in the sections below.

The number and location of the surveys depend on the driver that requires the data. The survey locations are also determined by the driver.

In each survey, we record macrophytes against the same taxa list and on the same recording forms:

- SD01 Survey form.

Changes to the survey method

Until 2006, we based our survey method on the Mean Trophic Rank (MTR) method. In 2007, we revised our method for all drivers to meet the needs of the WFD. The new method described in this instruction differs from MTR in the:

- location of the survey lengths (for WFD only);
- number of surveys per water body (for WFD only);
- list of scoring taxa (all drivers except ECN);
- way that we analyse the data (for WFD).

Preparing for macrophyte surveys

Overview

Contents

This chapter describes how to prepare staff and equipment for macrophyte surveys. It comprises the following topics:

Health and safety

Risks and hazards

You must be familiar with the risks and hazards associated with sampling in or near water. Read the following before surveying for macrophytes:

- generic risk assessments:
  - 426_05 Working In or near water;
  - 37_04 Generic Risk Assessment for Fieldwork.
- dynamic risk assessments;
- local site risk assessments.

Personal protective equipment

Wear a life jacket and any other appropriate personal protective equipment, such as gloves.

Working with boats

If you need to carry out the survey from a boat, make sure you are familiar with the generic risk assessments:

- 32_04 Generic Risk Assessment: boatwork;
- 83_04 Generic Risk Assessment: sampling by boat.

Capabilities of the surveyors

Number of surveyors

We generally assume that surveys require two people. The number depends on the location, equipment and health and safety requirements.

Requirements of the macrophyte surveyor

Surveys must be carried out by at least one accredited macrophyte surveyor. Any member of staff can accompany the accredited surveyor on a survey. Ideally, they should be trainee surveyors who are developing their macrophyte survey skills and being mentored by the accredited surveyor.

Requirements of the accredited macrophyte surveyor

An accredited macrophyte surveyor is a person who has been trained in macrophyte taxonomy and field survey methods. They must have either:

- passed an appropriate accreditation test such as T337: Freshwater macrophyte survey training and accreditation.;
- (or in exceptional circumstances) demonstrated appropriate levels of experience in macrophyte surveying.

The accredited surveyor is responsible for the data entered into BIOSYS.

Equipment required

Equipment required

You need the following equipment when conducting a macrophyte survey:

- life jacket;
- mobile phone (check the charge and likely reception);
- maps — 1:50,000 Ordnance Survey;
- GPS (check batteries);
- SD01 Survey form;
- pencil, pen, all-weather writer or clipboard in a large plastic bag (to protect sheets from damp);
- grapnel with depth markings on rope;
- wading stick with depth markings;
- plastic bags, labels and paper towels;
- tape measure;
- ranging pole;
- ten metre rope;
- identification guides and keys;
- digital camera (check batteries);
- hand lens with x10 and x20 lenses;
- underwater viewing aid (such as a glass-bottomed bucket or underwater camera);
- polarising sunglasses (optional);
- optical range finder;
- boat and additional safety equipment as required;
- protective gloves / gauntlets;
- waders;
- copies of previous survey sheets (if they exist).

Checking equipment

Before conducting the survey, check your equipment as follows:

- check batteries in your mobile phone, GPS and digital camera;
- check your mobile phone's likely reception at the survey sites.

Surveys by boat

Check whether you need to conduct any surveys from a boat. If a boat is required, make sure the boat is fit for purpose. Boats must be:

- used in accordance with the stability test classification;
- provide a suitable platform from which to use drop cameras, glass bottom buckets and grapnels;
- operated by trained personal. The boat handler should not be the only accredited surveyor present on that survey.

You must ensure all survey staff are familiar with 32_04 Generic Risk Assessment for Boat work and 767_06 Carrying out boat work safely.

Deciding when, where, what and how to survey

Overview

Contents

This chapter describes when to conduct surveys and where to locate survey sites. It comprises the following topics:

When to survey

Time of year

Survey between the beginning of June and the end of September. This is the period of maximum plant growth in rivers. Other seasons are unsuitable because:

- plants die back in the winter;
- other seasons have high flows, which can wash away macrophytes.

River flow

Survey after several days of low flow or low-normal flow (as opposed to high flow or spate conditions). To achieve this, you may need to be flexible with your survey dates and your schedule.

River management

Check with colleagues whether river management is carried out on the water bodies you need to survey. River management may affect if and when you can survey a specific water body.

Where to survey (all drivers)

Health and safety

Take account of health and safety in selecting the location of survey lengths. If you intend to survey within the channel ensure you can get in and out safely. If this is not possible, survey the channel from the bank, but only if you can clearly and safely see into the channel. If it is not safe to survey either in the channel or from the banks edge, relocate the survey stretch to a safer location.

Water clarity

Try to avoid locating survey lengths where you have difficulty seeing the river bed because the water is too deep or too turbid.

If the survey length is usually too turbid or too deep to see the bottom, consider using sampling aids or finding a more appropriate location.

Shade

Avoid heavily shaded areas when selecting survey lengths.

Water flow and velocity

Do not survey where water flows or the speed of the current compromise your safety.

River maintenance

Consider the frequency and timing of maintenance activities when selecting survey lengths, and take the effects of the maintenance into account when interpreting results.

Reason

Cutting weeds, dredging and other maintenance activities often have a major effect on the cover and biomass of plant communities. Over time, maintenance activities may alter the taxa that live in the river - the dominant plant taxa may become different to those naturally present.

Artificial structures

Avoid survey lengths that contain structures such as bridges, gauging or syphon weirs, locks and concrete-lined channels.

Where structures cause change in the flow of the river, situate the survey length at a location that is most typical of the rest of the river.

Reason

Avoid survey lengths that contain structures because structures may affect the substrate type, marginal area type and flow pattern. In addition, people or animals may trample vegetation near structures, which may mean the pattern of vegetation is not typical.

In addition, any structure is potentially dangerous to the surveyors.

How to survey (for UWWTD drivers)

Overview

Locate two 100m survey lengths, one upstream and the other downstream of the discharge that you are assessing.

The survey lengths must monitor the effect of the discharge but be far enough downstream to avoid very localised effects of the effluent.

Distance from discharge

The survey lengths should not be more than 500m from the discharge unless there are over-riding factors, such as an additional effluent, storm overflow or a tributary joining the river.

Physical characteristics

The survey lengths should have comparable physical characteristics both upstream and downstream of the discharge. Take into account the position of any storm water or emergency overflows, then position the survey length to avoid these.

If survey lengths with comparable physical characteristics are not present within 500m of the discharge but are present within 1000m, choose these survey lengths in preference to closer survey lengths. Make a record of this. However, do not space survey lengths so far apart if it means there are additional inflows (for example combined sewer outfalls) between the two survey lengths.

Do not use sites with tributaries entering as these will not be comparable.

Multiple downstream surveys

You may wish to survey more than one length downstream of a discharge so you can combine the results to ensure that the survey detects any impacts of the discharge.

Discharges with large flow

Where the flow from a point-discharge creates significantly more flow downstream of the discharge than upstream, the results may be affected more by the water's speed than the water's chemistry.

Give careful consideration before surveying in these conditions.

How to survey (for WFD drivers)

Definition of a water body

For the purpose of the WFD, a water body is the part of the river that the River Basin Characterisation Project defines as a WFD water body. Each WFD water body has a unique identification code.

Terminology

A macrophyte **survey** consists of a single survey of the macrophyte community in a 100 metre length of river channel

A water body **macrophyte status assessment** consists of a minimum of 3 individual macrophyte surveys.

Number of surveys

The number of individual macrophyte surveys required to complete a macrophyte status assessment and so classify a water body confidently, varies depending on the following:

- water body size;
- water body physical type;
- degree of physical variation within the water body.

Confidence

Increasing the number of surveys reduces the risk of misclassifying the water body. Increasing the number of surveys beyond an optimum amount however only gives a minor improvement to the confidence of your classification.

To ensure that the classification of a given water body is at least 75% confident or in WFD terms ‗quite certain‘ you must undertake **a minimum of three** individual macrophyte surveys to complete a macrophyte status assessment of a water body. This ensures that the natural spatial variability in water bodies is accounted for in the final classification.

Large or variable water bodies

Some very large or variable water bodies may need more than three macrophyte surveys to achieve the desired level of confidence in the macrophyte status assessment. Use the ROMANSE tool to inform the decision on how many individual surveys should make up a complete macrophyte status assessment that will give a ‗quite certain‘ confidence in the final classification.

The number of surveys required for WFD monitoring purposes is laid out in following sections:

- WFD surveillance monitoring
- WFD operational monitoring;
- WFD investigational monitoring .

ROMANSE

Risk Of Miscalculation And Number of Samples Estimator (ROMANSE) is an analytical tool that can support informed decisions about the number of surveys required to make up a macrophyte status assessment that will appropriately classify a water body.

You should use the tool to assist your development of an optimum assessment design to effectively investigate water bodies in your area.

More information about the tool and a copy of it can be obtained from EnvMon Help.

WFD surveillance monitoring

In order to achieve a sufficient level of confidence in the classification of surveillance water bodies, each surveillance water body must have at least two macrophyte status assessments completed between 2009 and 2015. Each status assessment must:

- be made up of a minimum of three individual surveys each at different sites carried out in the same year. If the ROMANSE tool identifies that more surveys are required to achieve a 75% confidence in the classification, then complete that number of surveys;
- be made up of surveys that are as far as practical, evenly space through the water body;
- be carried out where possible at three yearly intervals.

For example if a surveillance water body was last assessed in 2008 it should be re-assessed in 2011 and then again in 2014.

! Important In addition, **one surveillance water body in each area must have a full macrophyte status assessment carried out every year.** Areas must choose the surveillance water body to monitor annually and inform EnvMonHelp. This will enable classification results to be adjusted for ‗natural‘ temporal variation.

WFD operational monitoring

Between 2010 and 2012 operational water bodies that require macrophyte monitoring must have one macrophyte status assessment completed during this period. Each status assessment must:

- be made up of a minimum of three individual surveys each at different sites carried out in the same year. If the ROMANSE tool identifies that more surveys are required to achieve a 75% confidence in the classification, then complete that number of surveys;
- be made up of surveys that are as far as practical, evenly space through the water body.

WFD investigational monitoring

For area prioritised investigations, area staff are responsible for developing their own monitoring programmes with the resources allocated to them.

Which WFD investigation?	What to do?
Investigations that aim to use macrophyte surveys to pinpoint pressure types and locations	Use targeted macrophyte surveys in the areas of concern in a similar fashion to monitoring for the UWWT directive.
Investigations that aim to use macrophyte surveys to provide biological evidence as a result of a failing pressure or Investigations that aim to use macrophyte surveys to improve the classification of a particular water body	Carry out a full macrophyte status assessment comprising of a minimum of three individual macrophyte surveys, each at a different site all surveyed within the same year. Spread the three individual sites as evenly through the water body as possible. The number of surveys needed to achieve the required level of confidence in your classification may vary. Use the ROMANSE tool to identify if more than three surveys are required.

Example: For a three year investigation on a 12km long water body where a 25% risk of misclassification of being less than good ecological status is required, put in place an investigation following theses guidelines:

- number of surveys required to achieve confidence of classification is three (based on calculations performed in ROMANSE);
- distribution of surveys should be at three separate sites spaced evenly along the water body, starting from the source;
- surveys should be carried out in the same year to eliminate temporal influences from your classification.

! Important. The time and resources available for each investigation will influence how you design your programme. Areas must make the decision on whether their chosen survey design is appropriate. **However, to achieve an acceptable confidence in the classification of your water body you must have a minimum of three individual surveys per macrophyte status assessment**.

For further advice on practical survey design please contact EnvMon Help.

Survey resource

We consider that it takes 8.1 double-manned hours to conduct one survey of a water body.

Representing the river

The survey lengths chosen should:

- represent the conditions and flora in the water body;
- reflect the pressures (defined by the WFD) from the catchment.

To achieve this, select survey lengths that are, as far as possible, typical of the water body as a whole. When choosing survey lengths, consider:

- flow;
- substrate;
- use of land;
- man-made modifications to the river;
- presence of point source inputs;
- the flora that is typical of the water body.

Using data from other surveys

If your area is surveying macrophytes in a water body for other purposes, during the same season, (such as water resource planning) and the surveys fulfil the WFD criteria, you may use the data from these surveys instead of conducting an additional survey. Use spare resource to conduct additional surveys at other sites and in other water bodies.

! Important Where possible **don't** use macrophyte surveys conducted below sewage treatment works for the UWWT as they will not reflect the trophic status of the water body as a whole.

Survey lengths with severely impaired visibility

If, when you get to a survey length, you have great difficulty in seeing macrophytes under the water, use a survey length at an alternative site, if possible.

Otherwise:

- ensure the same surveyor conducts the survey at all survey lengths that you will compare to this survey length;
- treat comparisons of the overall percentage cover at different sites with extreme caution, if you use them at all - see calculating percentage cover;
- similarly, treat comparisons of the Taxon Cover Values with extreme caution, if you use them at all.

Changes to information

The information above is subject to review in future years. Reviews will happen as:

- more information becomes available from ongoing research and development projects;
- we review the results of the WFD monitoring programme.

What to include in the survey

What to include

Survey the river macrophytes that are in the channel area.

Generally, survey the full channel. There are certain exceptions to this rule:

- when the river is deep or turbid;
- when assessing a discharge that tracks a bank;
- when assessing a discharge at mature islands;
- when a survey is difficult to navigate.

Channel area

Include all macrophytes that are in the **channel area**. This includes plants that are:

- submerged or partly submerged in the river at low flow levels;
- at the sides of the river and are attached or rooted to parts of the substrata that are likely to be submerged for more than 85% of the year.

You mustn‘t include plants that overhang the channel but are **not rooted** in the channel area (for instance have roots not submerged for greater than 85% of the year) in the survey.

If a taxon is only recorded from the waterline, make a note of this to inform an audit when water levels may be different.

Bank area

Do not include macrophytes that are in the **bank area**. This includes plants that are:

- at the side of the river (or islands);
- submerged for less than 85% of the time;
- submerged (or partly submerged) during average flow periods.

Macrophytes in the bank area are above the limit of the channel area.

Deep or turbid rivers

Survey a strip down one side of the channel instead of the whole channel if you cannot accurately record the vegetation in the central part of the channel due to its depth or turbidity (even using an underwater camera).

The strip must be at least 5m wide and should ideally have little shading from trees.

Assessing a discharge that tracks a bank

Where you are assessing the impact of a discharge (such as for UWWTD) and the effluent tracks along one bank for at least 500m downstream, you may not require a survey of the full width of the river:

- if you are the first person to do a survey at the site, then survey the full width of the river,
- if you are conducting a subsequent survey, then you can survey a strip with a minimum width of 5m. Your downstream survey length must always be on the side of the river into which the effluent discharges.

Assessing a discharge at mature islands

Where you are assessing the impact of a discharge (such as for UWWTD) and there is a mature island within the survey length, only survey the side on which the discharge enters.

Surveys that are difficult to navigate

Do not leave gaps in a survey length unless all of the following apply:

- you can survey the majority (>80%) of a survey length by wading;
- the remainder of the survey length is to deep or rapid to carry out safely;
- a boat, camera or glass-bottomed bucket are not practical.

If you include gaps:

- map the gaps clearly;
- discount them from this survey and all future surveys;
- do not include estimations of plant cover or physical attributes (except for width).

Conducting macrophyte surveys

Process of surveying for macrophytes

Process

Follow the stages below to conduct a macrophyte survey. Each stage is described in more detail below.

Stage	Description
1	Establishing a new monitoring site
2	Measuring and marking the survey length.
3	Navigating the survey length.
4	Recording the macrophytes.
5	Calculating percentage cover. This stage is in two sections: a. calculate overall percentage cover; b. calculating the taxon percentage cover and the taxon cover values.
6	Measuring your confidence in the survey.
7	Recording the physical variables.
8	Comparing upstream and downstream survey lengths for UWWTD drivers. (not needed for non UWWT surveys.)
9	Drawing a sketch map.
10	Recording the results and storing the photographs.

Stage 1 - Establishing a new monitoring site.

Overview

When you set up a new macrophyte monitoring site, you must consider the needs of the survey. The section Where to survey, explains how you should locate your surveys for different work drivers.

Once a you have established where your new will be, you must make sure that it is named and stored on BIOSYS so that any data collected from surveys at the site can be correctly stored.

In addition to naming the site there are a number of other date you must collate and store on BIOSYS called predictor variables.

Predictor variables

When you set up a new monitoring site, you need to calculate or record a number of physical parameters. We store these parameters on BIOSYS along with other site information, such as water body and site name.

What predictor variable you need

The WFD classification tools use physical typology parameters known as predictor variables to predict different biotic indices for any given site. The predictions made assume the river is in pristine or reference condition (no anthropogenic influences). We can then compare these predictions or expected values with actual or observed values calculated from survey data we collect at the site. This gives us an indication of the level of impact, anthropogenic activities are having on the ecology at the site.

We need to store these predictor variables in the ‗Maintain Freshwater Sites' form in BIOSYS, so we can use them when running the classification tools.

When establishing a new ecology monitoring site, you must ensure you collect all the predictor variables, and store them on BIOSYS. This will ensure the correct predictor variables are available for all biological quality elements in the future. The predictor variables you need to collect are:

- National Grid Reference;
- Source National Grid Reference;
- distance from source (km);
- altitude of source (m);
- site altitude (m);
- discharge category;
- alkalinity (mg/l CaCo0);
- slope (m/km).

! Important You must collect and record these parameters accurately, as the classification tools are very sensitive to certain predictor elements.

Site National Grid Reference

You can determine the site National Grid References (NGRs), by using one of the following:

- a field based GPS;
- a computer based GIS programme.

Wherever possible, you should use a GPS in the field and record the full grid reference.

You must record NGRs to 10 figures (SU XXXXX XXXXX) and store the information in BIOSYS in the ‗Map Ref' box on the ‗Maintain Freshwater Details' tab on the Maintain Freshwater Sites page.

Source National Grid Reference

You must ensure you correctly identify the source of the river you are surveying, as we use it to calculate other predictor variables. Therefore, you must record the NGR of the source in BIOSYS for future reference.

! Important We use different definitions of ‗river source‘ for RICT and LEAFPCAS. Therefore, you need to identify both types of river source. The definitions are described below and illustrated in figure 1 a.

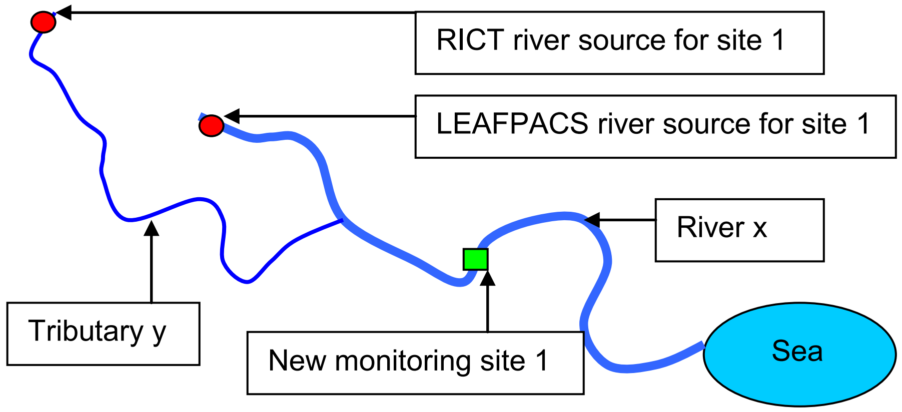
RICT river source

This is the furthest point on the **river catchment** from the sea. This could mean the source of the river is at the top of a tributary as opposed to the traditional source of the main river.

LEAFPACS river source

This is the furthest point along the path of the **main river** from the sea, If the source of tributary is further from the sea it must not be identified as the river source

Figure 1.a – Identifying river source



Determine National Grid References (NGRs), for both RICT river source and LEAFPACS river source, using a computer based GIS system based on 1:50,000 scale ordinance survey maps.

Note: In some cases both the RICT and LEAFPACS river sources may be the same source.

You must record a ten figure NGR (SU XXXXX, XXXXX) and store this information on BIOSYS in the Maintain Freshwater sites page as follows:

Source type	Where to store in BIOSYS
RICT definition	‗Freshwater Site Detail‘ tab, in the Source Map Ref field.
LEAFPACS definition	‗Reason/Comment‘ tab in the ‗Comment‘ field. Select ‗LEAFPACS Source NGR in the ‗Type‘ menu.

! Important This is an interim measure. We are currently addressing this issue, so that a consistent river source will be identified and used for all classification tools in the future. Until this approach is finalised, you must use the method listed here to identify the river source.

Distance from source

This is the distance along the watercourse between the monitoring site and the river source. You need to calculate the distance from source twice based on both the RICT and LEAFPACS definitions. For details on how to identify the river source see Source National grid reference.

Underground reaches

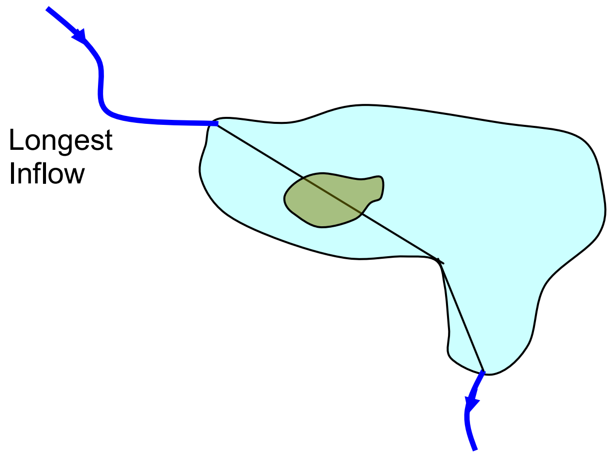
Treat an underground reach as if it was marked on the map. Assume it follows a straight line, unless the watercourse obviously follows a valley.

Reservoirs and other impoundments

Treat reservoirs and other impoundments as part of the watercourse.

Measure the shortest distance within the water body (straight lines), from inflow to outflow. Ignoring any islands but not promontories Figure 1b, below, illustrates this.

Figure 1b. – How to measure distance from source across a lake.



The table below describes how to calculate the distance.

Step	Action
1	Measure the distance by following the line of the river on a 1:50,000 map using an accurate curvimeter, planimeter or GIS measuring tool.
2	Record this distance in kilometres to the nearest 0.1km.

You must store this information on BIOSYS in the Maintain Freshwater sites page as follows:

Source type	Where to store in BIOSYS
RICT definition	‗Freshwater Site Detail‘ tab, in the ‗Distance From Source (km)‘ field.
LEAFPACS definition	‗Reason/Comment‘ tab in the ‗Comment‘ field. Select ‗LEAFPACS Distance From Source‘ in the ‗Type‘ menu.

Source altitude

The source altitude is the height of the river source above sea level in metres. We only require source altitude as a predictor variable for LEAFPACS. Therefore, you only need to record the altitude of the LEAFPACS river source. For details on how to determine LEAFPACS source see Source National Grid Reference.

Measure the source altitude from Ordnance Survey 1:50,000 scale maps, in metres above sea level to the nearest five metres. In mountainous areas, the estimates may only be possible to 10 metres.

You must store this information on BIOSYS in the Maintain Freshwater sites page as follows

Source type	Where to store in BIOSYS
RICT definition	Information not needed
LEAFPACS definition	‗Reason/Comment' tab in the ‗Comment' field. Select ‗LEAFPACS Source altitude' in the ‗Type' menu.

Site altitude

Measure the altitude from Ordnance Survey 1:50,000 scale maps in metres above sea level to the nearest five metres.

Note: There is an exception in mountainous areas, where the estimates may only be possible to 10 metres.

! Important You must not use non differential GPS units for altitude readings, as these can be highly inaccurate.

You must record the measurement in the ‗Altitude' box on the ‗Maintain Freshwater Site Detail' tab on the Maintain Freshwater Site page in BIOSYS.

Discharge category

You must estimate the mean annual discharge at each site using the categories in the table below. Hydrometry staff can provide estimates of the discharge. You should ask them for the **naturalised mean annual discharge**.

Discharge category	Mean annual discharge (m^3/s)		
1		<0.31	
2	0.31	to	0.62
3	0.62	to	1.25
4	1.25	to	2.50
5	2.50	to	5.00
6	5.00	to	10.00
7	10.00	to	20.00
8	20.00	to	40.00
9	40.00	to	80.00
10		>80.00	

You must record the measurement in the ‗Discharge Cat‘ box on the ‗Maintain Freshwater Site Detail‘ tab on the ‗Maintain Freshwater Site‘ page in BIOSYS.

Alkalinity

You can derive alkalinity measurements locally using appropriate water sampling, or taking them from appropriate sites on WIMS.

You must store this information, in the ‗Annual Variables‘ section on the ‗GQA / Annual Data‘ tab on the Maintain Freshwater Sites page in BISOYS. Alkalinity should be measured and recorded in mg / l $CaCO^3$

We are currently running a nation project to produce alkalinity data for all rivers across the country. In the interim, if you need alkalinity measurements to run any of the classification tools for local monitoring reasons, please contact EnvMonHelp. We can also provide further advice on how to calculate appropriate the alkalinity measurements you need.

Slope

The slope of the river is the rate at which the river looses altitude as it travels from source to sea. This recorded as the number of metres of altitude lost per kilometre of distance travelled. Figure 1c gives examples of how you can calculate slope in different situations. You should use a GIS measuring tool on a 1:50,000 OS map to measure the distance along the river between the contour lines. You can then calculate the slop to the nearest 0.1 m/km·

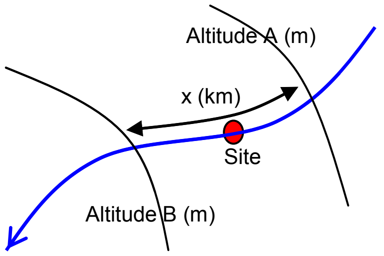
You must Record the slope in the ‘Slope (m/km)‘ box on the ‗Maintain Freshwater Site‘ page on the ‗Maintain Site Detail‘ tab

Figure 1c **How to calculate the slope in different conditions.**

Site is between contours

$$\text{Slope} = \frac{A - B}{x}$$

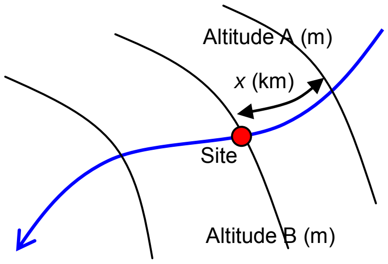
More than one site may lie between the contour lines A and B. They would both have the same slope.



Site situated on a contour

$$\text{Slope} = \frac{A - B}{x}$$

The distance between contours is measured between the contour intersected (B) and the next contour upstream (A). The slope upstream from a site is more likely to affect it than the slope downstream.

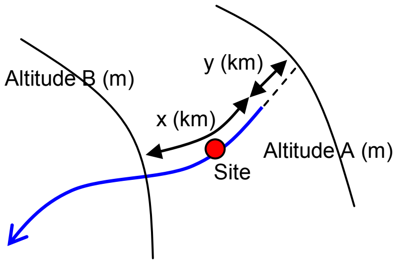


Upstream limit is the source

$$\text{Slope} = \frac{A - B}{x + y}$$

x is the distance between the downstream contour and the source

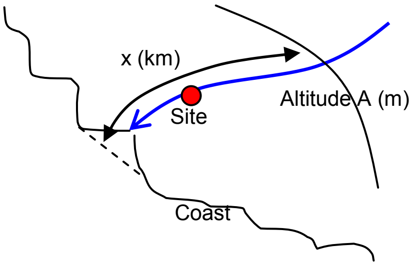
y is the shortest distance between the source and the next highest contour (A).



Downstream limit is the coast

$$\text{Slope} = \frac{A}{x}$$

The altitude at the coast is zero. Distance x is measured from contour A to the theoretical line that extends the natural line of the coast across the estuary.



Stage 2 - measuring and marking the survey length

Measuring

Measure or pace out 100m at your survey site. This is the **survey length**.

The first time you conduct a survey, measure with a tape measure or 10m rope. Then you can see how many paces you need to measure 100m.

Be careful when using paces to measure a survey length. If in any doubt (such as where there are obstructions along the survey length or you can only measure by getting into the channel) measure with a tape measure or a 10m rope.

Marking

Mark each end of the survey length so it is clearly visible from the river channel.

Revisiting a survey length

When revisiting a survey length check the re-location details and ensure that markers for the survey are 100m apart.

Stage 3 - navigating the survey length

Navigating the channel

Decide whether you can wade along the channel. If the channel is too deep to wade:

- you can use a boat, although a boat may be impractical in narrow channels;
- you can survey from the bank providing the channel is narrow (about 5m or less) and you can see the macrophytes by walking along both banks and collecting specimens with a grapnel;
- if you can wade more than 80% of the survey length, then you do not need a boat and can complete the remaining part of the survey from the bank;
- if after applying a dynamic risk assessment, none of the above are viable survey options, red card the site and relocate the survey site to a new, safer stretch.

Choosing sampling aids

The bed of channel must be clearly visible to accurately assess the taxa present and their abundance.

Decide whether you need sampling aids, such as a grapnel, glass-bottomed bucket or underwater camera. A glass-bottomed bucket is strongly recommended. You can retrieve submerged macrophytes from small areas of deep water with a grapnel.

Traversing the channel

Aim to traverse the channel at least four times in every 10m length of river by wading or by boat, frequently inspecting all the habitats. On wide rivers you may not need to cross the channel as often.

Direction of travel

Wade in an upstream direction so disturbed substrate does not obscure the visibility of the survey length.

Stage 4 - recording the macrophytes

About the taxa list

The SD01 Survey form contains a list of taxa. The list defines the taxonomic level to which you must work. When you record macrophytes, record them against the taxa on the list. It is generally expected that you will record all the taxa you find during a survey.

The taxa list contains approximately 184 taxa. This list is based on a database of 6500 surveys of river macrophytes in UK rivers.

The list include vascular plants (and a number of widely recorded and readily recognisable bryophytes and macroalgae) that regularly grow and flower under conditions of nearly permanent saturation or submergence of their basal parts. The list also includes a few taxa of a more terrestrial nature.

Changes to the taxa list

The taxa list contains a significant number of additions to the original MTR list, mainly of amphibious or emergent taxa that we must include so that we can assess hydromorphological pressures.

Scope of the taxa list

The taxa list covers macrophytes occurring in all geographic locations and river types across the UK. Therefore, on any one survey, do not expect to find the full range of taxa.

Experienced surveyors may prefer to use a blank recording sheet while referring to the taxa list for guidance, or to create their own survey list to reflect the taxa most likely to be found in their geographic region. In this case care must be taken to ensure that rare or previously unrecorded taxa are not missed.

Splitting taxa list into species

The taxa list splits certain taxonomic groups (such as *Chara* spp.) into individual species. The reason for the split is that different charophyte species occur in a wide range of nutrient and hydromorphological conditions, and so grouping them together provides very little information that is ecologically relevant to the classification tool.

Forms for recording macrophytes

Record macrophytes in the fields on the SD01 Survey form.

Features and criteria

The table below shows features to look for and criteria to check when recording macrophytes.

Feature or criteria	How to record
small niches	Examine all small niches in the survey length for small (less than or equal to 25cm^2) patches of taxa. These niches are easy to miss but can cause inter-surveyor differences and an erroneous final result.
floating material	Do not record detached macrophyte material, except for actual floating macrophyte taxa such as *Lemna* sp.
stranded macrophytes	Do not record macrophytes that are stranded above the water (such as in low flow conditions). Instead, make a note of the taxa, the amount present, and suggest why it is stranded.
Ranunculus taxa	Take care with *Ranunculus* taxa. Misidentification of *Ranunculus* taxa is a common cause of survey errors. If in doubt, take a sample to the laboratory to confirm the identity.
algae and bryophytes	Take representative samples of all algae and bryophytes to the laboratory to confirm their identity.
specimens attached to artificial structures	Where you are comparing survey lengths (such as in UWWTD monitoring), only record specimens attached to artificial structures (including ‗natural' bank reinforcement) when a similar structure is present in all the survey lengths in the comparison. Always note which specimens are attached to artificial structures.
terrestrial taxa	The taxa list contains some terrestrial taxa. Only record these taxa if they occur in the channel area.

Using results from previous surveys

Do not use results from previous surveys to inform your current surveys because:

- the macrophyte community may have changed;
- the previous survey may contain errors.

You can compare results from previous surveys to your own survey, which can:

- help you spot identification errors;
- ensure you do not overlook sparsely-distributed plants.

Taxa that are not in the list

If you find taxa that are not on the list, make a note of them and record them on BIOSYS. They can still be of interest but they are not used in data analysis for classification.

Species that you cannot identify

You can only identify some taxa when fruiting bodies or flowering parts are present. In addition, the SD01 Survey form contains information telling you which species can only be reliably identified in the laboratory. If you cannot identify a specimen:

- record the specimen to the level you are confident (such as its genus), even if this recording level is not on the taxa list;
- take a representative sample back to the laboratory, if you can. See collecting samples.

Collecting samples

Follow this procedure to collect a sample:

Step	Action
1	Dry plants with paper towel.
2	Place in a polythene bag (one plant per bag).
3	Seal the bag leaving air in the bag. To do this, blow air into the bag before sealing it. Do not add extra water unless collecting filamentous algae. **Reason** The air helps maintain a healthy specimen and prevents crushing. By not adding water you ensure the specimen does not become waterlogged and so remains identifiable.
4	Label the bag with the same name as that used to label the survey form so there can be no confusion in the laboratory. This is important when more than one macrophyte from the same survey needs further investigation.

Collecting filamentous algae

Place samples of filamentous algae with a small amount of water into a labelled tube. Ensure there is a large air space above the water. This is the only exception to the procedure in collecting samples above.

Stage 5 - calculating percentage cover

Overview

When you have recorded all macrophyte taxa, go back along the survey length to record:

- the overall percentage cover;

  (This is an estimate of the total percentage of the channel area that is covered by macrophytes.)
- the **species percentage cover** and the **Taxon Cover Values (TCVs)** for each macrophyte taxon.

  (These are estimates of the percentage of the channel area that is covered by each macrophyte taxa.)

Under some circumstances, you may also need to assess the biomass. See assessing biomass.

The importance of percentage cover

Differences in percentage cover values are the most common source of differences between primary and audit surveys of the same survey length. Do not guess the percentage cover; make reasoned estimates consistent with observation.

Calculating a square metre as a percentage

Before recording percentage cover and TCVs, you may find it useful to calculate what a one metre square patch of macrophyte represents as a percentage of the channel area. For example, one square metre might represent 0.01% or 0.5% of the channel area.

Filamentous algae

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

Stage 5a - calculating overall percentage cover

Procedure

Picture the survey area from above in two dimensions (that is, the length and breadth). Use one of the options below to estimate the percentage cover.

Option 1

Imagine moving all the macrophytes to one end of the survey length. The area covered is the overall percentage cover. For example, in a 100m survey length, an area of macrophytes that completely covers a 25m section covers 25% of the survey length.

Option 2

If the majority of the vegetation is confined to strips along the margins of the river, estimate the overall percentage cover as:

- marginal area covered $[m^2]$ = length of marginal vegetation cover[m] x □□□□width of marginal vegetation [m];
- total area covered $[m^2]$ = marginal area$[m^2]$ + other areas$[m^2]$;
- total survey area$[m^2]$ = 100[m] x average width of channel [m];
  overall % cover = (total area covered$[m^2]$ / total survey area$[m^2]$) / 100.

Checking the overall percentage cover

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

Stage 5b - calculating the taxon percentage cover and the taxon cover values (TCV)

Procedure

Follow this procedure to calculate the taxon percentage cover and the TCV:

Step	Action
1	Estimate the taxon percentage cover and TCV for each macrophyte species by following either the width method or the square method.
2	Once you have calculated the TCV for each species, add up all the percentage cover values for every taxa. Is the sum of individual percentages different to the overall percentage cover for the survey length? **Yes:** go to step 3. **No:** you have finished calculating TCVs.
3	If the sum of the every taxon percentage cover is greater than overall percentage cover, can the difference be explained by overlapping vegetation (see the note below)? **Yes:** you have finished calculating TCVs. **No:** go to step 4. **Overlapping vegetation** It is possible for the sum of the individual percentages to be greater than the overall percentage cover where macrophytes overlie each other. It is also possible for the sum of the individual percentages to be more than 100% where the channel is choked with vegetation.
4	Recalculate the species percentage cover and TCVs. Do this at the survey site - never recalculate percentages after leaving a site.

Width method

The table below contains the width method for estimating the taxon percentage cover and the TCV of a macrophyte taxon:

Step	Action
1	Imagine a rectangle that goes 1m along the banks and stretches from one bank to the other. This rectangle is 1% of the channel area (because the survey length is 100m).
2	Estimate the number of 1% rectangles each macrophyte taxon occupies. This is the taxon percentage cover.

Table continues on next page.

<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>3</td><td>Using the table below, work out the TCV based on the amount of 1% rectangles that the species occupies.
Example: a species that fills six 1m rectangles, represents 6% of the channel area and so has a TCV of C5.
<table>
<tr><th>TCV</th><th>Percentage cover of the macrophyte species</th><th>Corresponding length of bank for 100m survey length</th></tr>
<tr><td>C1</td><td><0.1%</td><td>< 0.1 m</td></tr>
<tr><td>C2</td><td>0.1 to 1%</td><td>0.1 – 1 m</td></tr>
<tr><td>C3</td><td>1 to 2.5%</td><td>1 - 2.5 m</td></tr>
<tr><td>C4</td><td>2.5 to 5%</td><td>2.5 – 5 m</td></tr>
<tr><td>C5</td><td>5 to 10%</td><td>5 – 10 m</td></tr>
<tr><td>C6</td><td>10 to 25%</td><td>10 – 25 m</td></tr>
<tr><td>C7</td><td>25 to 50%</td><td>25 – 50 m</td></tr>
<tr><td>C8</td><td>50 to 75%</td><td>50 – 75 m</td></tr>
<tr><td>C9</td><td>>75%</td><td>> 75 m</td></tr>
</table>
Values between two TCV categories
In the rare event that a percentage cover is estimated between two categories, record a value for the upper category.</td></tr>
</table>

Width method advantages

This method has the advantage that the lengths on the bank are constant, regardless of the channel's width.

Square method

The table below contains the square method for estimating the taxon percentage cover and TCV of a macrophyte species:

Step	Action
1	Estimate the number of square meters that each macrophyte taxon occupies. **Conversion factors** You may find the conversion factors (below) useful.
2	Assign a taxon percentage cover and TCV based on the tables below. **Example:** if a river has a channel width of 5m and a macrophyte taxon fills 6m^2, then the taxon has a TCV of C3. **Values between two TCV categories** In the rare event that a percentage cover is estimated between two categories, record a value for the upper category.

Tables for square method

The following tables convert the actual area of plant growth [m^2] into the correct TCV and taxon percentage cover depending on a rivers width. For example 8 m^2 of *Sparganium erectum* in a 2 metre wide river represents 4% cover and a TCV of C4.

TCV	% cover	Average river width (m)							
		1	2	3	4	5	6	7	8
C1	<0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
C2	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
C3	1-2.5	1-2.5	2-5	3-7.5	4-10	5-12.5	6-15	7-17.5	8-20
C4	2.5-5	2.5-5	5-10	7.5-15	10-20	12.5-25	15-30	17.5-35	20-40
C5	5-10	5-10	10-20	15-30	20-40	25-50	30-60	35-70	40-80
C6	10-25	10-25	20-50	30-75	40-100	50-125	60-150	70-175	80-200
C7	25-50	25-50	50-100	75-150	100-200	125-250	150-300	175-350	200-400
C8	50-75	50-75	100-150	150-225	200-300	250-375	300-450	350-525	400-600
C9	> 75	>75	>150	>225	>300	>375	>450	>525	>600

TCV	% cover	Average river width (m)						
		9	10	11	12	15	20	25
C1	<0.1	0.9	1	1.1	1.2	1.5	2	2.5
C2	0.1-1	0.9-9	1-10	1.1-11	1.2-12	1.5-15	2-20	2.5-25
C3	1-2.5	9-22.5	10-25	11-27.5	12-30	15-37.5	20-50	25-62.5
C4	2.5-5	22.5-45	25-50	27.5-55	30-60	37.5-75	50-100	62.5-125
C5	5-10	45-90	50-100	55-110	60-120	75-150	100-200	125-250
C6	10-25	90-225	100-250	110-275	120-300	150-375	200-500	250-625
C7	25-50	225-450	250-500	275-550	300-600	375-750	500-100	625-1250
C8	50-75	450-675	500-750	550-825	600-900	750-1125	1000-1500	1250 - 1675
C9	> 75	>675	>750	>825	>900	>1125	>1500	>1675

Useful conversion factors

You may find the following conversions useful when following the square method to estimate the amount of plant cover present in square metres;

0.1 m^2 = 32cm × 32cm	2 m^2 ≈ 1.4m × 1.4m	30 m^2 ≈ 5.5m × 5.5m
0.2 m^2 = 45cm × 45cm	5 m^2 ≈ 2.2m × 2.2m	50 m^2 ≈ 7.1m × 7.1m
0.5 m^2 = 71cm × 71cm	9 m^2 = 3m × 3m	75 m^2 ≈ 8.7m × 8.7m
0.8 m^2 = 90cm × 90cm	20 m^2 ≈ 4.5m × 4.5m	90 m^2 ≈ 9.5m × 9.5m

Recording channels choked with vegetation

When the channel is choked with vegetation:

- use option 1 to calculate the overall percentage cover of macrophytes.
- You must also search for submerged macrophytes that live under other macrophytes using a grapnel and either an underwater TV camera or glass-bottomed bucket. Record taxa found from these searches and estimate their abundance.

Assessing biomass

Do not routinely make a quantitative or semi-quantitative assessment of biomass. However, if you compare two sites (such as for UWWTD) and find that:

- a macrophyte species has the same TCV at both sites;
- the biomass is obviously greater at one site because the depth of the macrophyte ‗stand‘ is greater;

then:

- make a comment in the **notes** section of the SD01 Survey form;
- take photographs of the macrophytes at the two sites.

Stage 6 - measuring your confidence in the survey

Procedure

You must assign a level of confidence to each survey. To do this, decide how accurately your results reflect the trophic and hydrological situation at the site, given the constraints of water chemistry, weather and impacts such as the effects of weed cutting or site management.

To do this, follow the procedure below:

Step	Action

1	Decide if your survey has been hampered and perhaps rendered meaningless by one or more of the following factors:
	▪ recent river management, such as:
	  ▪ dredging;
	  ▪ weed cutting;
	  ▪ herbicides;
	▪ disturbance due to flood defence works such as bank reinforcements;
	▪ recent extreme flooding events;
	▪ poor survey conditions, such as;
	  ▪ turbidity;
	  ▪ high discharge due to recent rain;
	  ▪ very wet or windy conditions.
	▪ excessive blanketing of algae or floating vegetation growth obscuring the view or smothering other vegetation.

<table>
<tr><td>2</td><td>Score on a scale of A to C the degree to which the factors above may have distorted your findings:
<table>
<tr><th>Score</th><th>Description</th></tr>
<tr><td>A</td><td>Your survey length is not affected by the factors above, or any effects are limited to less than 25% of the survey length.</td></tr>
<tr><td>B</td><td>25 to 50% of your survey length is are influenced to a considerable degree by the factors above.</td></tr>
<tr><td>C</td><td>>50% of your survey length is influenced to a considerable degree by the factors above.</td></tr>
</table></td></tr>
<tr><td>3</td><td>Record the factors that potentially distort the accuracy of the survey. It is strongly recommended that you do not use surveys with a score of 'C'. For these surveys, you may record that:
there is sufficient cause for concern that the results do not represent the prevailing trophic status at the site.</td></tr>
</table>

Stage 7 - recording the physical variables

Method

After recording the macrophytes, re-traverse the survey length and record the physical variables in the physical variables section of the SD01 Survey form. Note the following conditions:

- fill out **all** data entry spaces and boxes in the form;
- record physical variables as percentages where appropriate. Record to the nearest 1%. If a feature is absent record it as 0%;
- where there are two or more surveyors, one accredited surveyor is the principal surveyor and takes responsibility for the survey - put their initials first on the survey sheet followed by those of the co-surveyors.

Which are the left and right banks?

Left and right banks are determined by the direction of flow. When you face downstream, the left bank is on your left and the right bank is on your right.

What to record

Record each of the following physical variables. Each one is described in more detail below.

- location;
- width;
- depth;
- substrate;
- habitats;
- shading;
- water clarity;
- bed stability.

In addition:

- take photographs of the site;
- make notes about the site.

Location

With your GPS, take an accurate National Grid Reference (NGR) reading at the survey length's top, bottom and mid-point.

Record the NGR at top and bottom of the survey length so that you can relocate the survey length at a later date.

Width

What to measure

Measure the width of the channel at several points along the 100m survey length. Your measurements must include any area of substratum that are above the water.

The SD01 Survey form , physical variables section, contains several width categories. Record the percentage of the survey section that falls into each width category.

How to measure

Measure the width with one of:

- a tape measure;
- a rope with 0.5m divisions;
- an optical range finder.
- a ranging pole

Depth

What to measure

Measure the depth at various points along the survey length. Take measurements that represent the range of depths in the survey length. You will probably gather a feel for the depths along your survey length as you record the macrophyte species.

The SD01 Survey form , physical variables section contains several depth categories. Record the percentage of the channel area that falls into each depth category.

How to measure

Measure the depth to the nearest centimetre using:

- a marked bank stick;
- ranging pole;
- metre rule;
- grapnel with depth divisions marked on the rope.

In deeper water, use a grapnel rope with depth divisions at 0.1m intervals. Lower it vertically.

When measuring with a grapnel, remember to include the height of the grapnel in your measurement.

Substrate

What to measure

Record the substrate composition throughout the survey length. Record the percentage of substrate that falls into each of the following substrate types:

For example, a site may comprise 60% bedrock and 40% sand.

Substrate	Description
bedrock	exposed underlying rock that is not covered by alluvial deposit
boulders and cobbles	>64mm — the size of half a fist or larger (while a distinction is not required between boulders and cobbles, a boulder has one or more sides greater than 256mm)
pebbles and gravel	between 2 and 64 mm — the size of half a fist to the size of instant coffee granules (!)
sand	between 0.0625 and 2mm — smaller than coffee granules and abrasive to the hands (unlike silt and clay)
silt and clay	<0.0625mm — has a soft texture when rubbed between fingers
peat	dead vegetation undergoing bacterial decay in stagnant, deoxygenated water (strictly pure peat) Do not include fine, peaty deposits that lie over more substantial substrate.

How to measure

If possible, use a birds-eye view to estimate the substrate, ensuring that you are in a safe position at all times.

Only include particles that 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, record the larger particles. However, if the shapes of underlying particles are not distinct, record the fine particles.

If you cannot see the channel bed, identify the substrate type with the grapnel, bank stick, ranging pole and underwater camera or glass-bottomed bucket.

Habitats

Record (as a percentage) how much of the channel area is made up of each of the following habitats. For example, the channel area may comprise 60% pool and 40% riffle.

Note that these habitat types are not the definitions used for the River Habitat Survey method.

Habitat	Description
pool	Pools are either: ▪ a discrete area of slow-flowing water (usually relatively deeper than surrounding water); ▪ an area between faster flowing stretches, as in a sequence of riffle-pool-riffle. Pools are deep and often turbulent. They are scoured during spate flows.
riffle	Riffles are fast-flowing, shallow water whose surface is distinctly disturbed. Riffles do not include water whose surface is disturbed only by macrophyte growth.
run	Runs flow quickly or at a moderate pace. They are often deep and have surfaces that are rarely broken or disturbed except for occasional swirls and eddies.
slack	Slacks are areas of deep, slow-flowing water that are uniform in character.

Shading

What to measure

Record (as a percentage) how much of the channel area is affected by each of the shade categories in the table below. Do not record the percentage of the bank on which stands vegetation that causes shade.

Shade category	Description
none	no shade
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.

Continues on next page.

Shading, continued

How to measure

Estimate the percentage of the whole channel area shaded by vegetation or structures from the left bank when the sun is directly overhead (that is, at 12 noon). Then do the same for the right bank.

If you need the total shading of the channel, add the two figures. In theory this value can be >100%.

What to record

In addition to recording the percentages (see what to measure above), show the estimate of shading on the sketch map (see drawing a sketch map).

Water clarity

Record (as a percentage) how much of the channel area is in each of the following categories of water clarity. A channel area may contain water in more than one category.

Water clarity category	Description
Clear	Both the channel's substrate and macrophyte species are clearly visible at all depths.
Cloudy	The water: ▪ is slightly discoloured; ▪ contains a moderate load of suspended solids; ▪ has partially reduced light penetration. You can locate all clumps of macrophyte species on the substrate of the river channel but the view of them is partially distorted. You may miss a small piece or a single shoot of a macrophyte species.
Turbid	The water: ▪ is strongly discoloured; ▪ contains a heavy load of suspended solids; ▪ has greatly restricted light penetration. The channel bed is obscured. You cannot distinguish submerged macrophyte species from substrate and water. **Effects on the survey** Turbid water reduces the accuracy and efficiency of the survey. You should reschedule the survey if the turbidity is a temporary occurrence (such as following heavy rain fall).

Bed stability

Record (as a percentage) how much of the channel area is in each of the following categories of bed stability.

Bed stability category	Description
solid or firmly bedded	bedrock or compacted clay - increased flow has little effect on the bed
stable	boulders, pebbles and gravel - increased flow is unlikely to significantly alter the bed
unstable	gravel, sand, silt and mud - increased flow is likely to dislodge the bed
soft or sinking	deep silt and mud - you cannot wade in the channel and the bank stick penetrates easily into the substrate

Photographs

Take a digital colour photograph of the survey length to record its general character. To do this, follow the procedure below.

Size of photographs
Photographs must be a maximum of 1Mb in size (Biosys restriction).

Reducing reflections
A polarising filter can reduce surface reflection.

Step	Action
1	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.
2	Place a feature into the photo for scale, such as a ranging pole.
3	With the sun behind you (if possible), stand at one end of the survey length and take a photograph along the length of the river to gain a representative impression.
4	Record the identifying code on the record sheet.
5	Take extra photos to show changes in vegetation between sites. **Indicating scale** Include a reference object to indicate scale, as in step 2 above.
6	Catalogue and store digital photographs on BIOSYS in **Maintain Freshwater Sites**. Enter the date of the survey and a description of the photograph into the **details** field.

Notes

Record:

- any unusual features of the survey length, such as:
  - excessive growth of a particular macrophyte.
  - lack of macrophytes with no obvious cause.
- any problems encountered while surveying;
- distinguishing features of the survey length so that you can relocate it at a later date.

Stage 8 - comparing upstream and downstream survey lengths for UWWTD drivers

Procedure

To assess the changes in trophic status caused by a discharge, you need to know how physically comparable survey lengths are.

The following procedure assigns a measure of confidence in the comparability of upstream and downstream survey lengths. The measure of confidence ranges from **I** (similar) to **III** (dissimilar).

<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>1</td><td>Compare the following physical variables at the upstream and downstream survey lengths:
▪ width;
▪ depth;
▪ substrate;
▪ habitats;
▪ shading;
▪ water clarity;
▪ bed stability.</td></tr>
<tr><td>2</td><td>Record on a scale of I to III how comparable the survey lengths are. Use the following criteria:
<table>
<tr><th>Measure of confidence</th><th>Criteria</th></tr>
<tr><td>I</td><td>five or more of the variables listed in step 1 are similar for more than 75% of both the upstream and downstream survey lengths.</td></tr>
<tr><td>II</td><td>three or four of the variables listed in step 1 are similar for more than 75% of both the upstream and downstream survey lengths.</td></tr>
<tr><td>III</td><td>two or less of the variables listed in step 1 are similar for more than 75% of both the upstream and downstream survey lengths.</td></tr>
</table></td></tr>
<tr><td>3</td><td>On the SD01 Survey form in the physical variables section, record I to III in the appropriate box. In addition, record which surveys the comparability score related too. Do not calculate confidence scores after leaving the survey site.</td></tr>
</table>

Surveys with measure of III

It is strongly recommended that you do not interpret trophic status using surveys that have a measure of confidence of **III**.

Stage 9 - drawing a sketch map

Purpose of the sketch map

Create a sketch map so you can relocate the survey length next time you visit. You do not need to create a detailed plan of the survey.

Procedure

Follow the procedure below to create a sketch map of a survey length.

Step	Action
1	In the SD01 Survey form, there is a specific page to assist with the drawing of a sketch map.
2	Draw a sketch of the survey length. The sketch must show the survey length's general physical character. Include the following features: ▪ location of river and its pathway; ▪ national grid reference for the start and end of the survey length; ▪ width of the channel; ▪ depth of water in metres across the channel width; ▪ relocation features (for both ends of the survey length, if possible); ▪ shading position and type — broken or dense (see indicating shade and macrophyte stands); ▪ grid north (found on OS map); ▪ dominant macrophyte stands (see indicating shade and macrophyte stands); ▪ use of land adjacent to the channel — for example tilled land, industrial, improved pasture, suburban/urban development; ▪ extent of riverbanks — for the sketch map, a riverbank is defined as the area before the start of the 'use of land adjacent to the channel', above. **Layout of the map** Ideally, start at the downstream end of the survey length and work upstream. In this situation: ▪ the direction of flow must be from the top of the paper to the bottom; ▪ the left bank is on the right side of the paper, and the right bank is on the left side of the paper. If starting from the upstream end, turn the map upside down.
3	Pace out 10m lengths and check that any features on your sketch map are in the correct location.
4	When back in the office, you may need to re-draw the sketch map so that text (such as labels) is legible. Do not use personal shorthand in the final map because others cannot correctly translate it.

Table continues on next page.

Step	Action
5	File all sketch maps with their corresponding field records.
6	On a printed map (preferably one with a scale of 1:10 000): ▪ show the location of the survey lengths; ▪ attach a short description of each survey length location, which must include notes on access.
7	File the printed map with your sketch map.

Indicating shade and macrophyte stands

Indicate broken shade by: ||||||||||||||||||||||||||

Indicate dense shade by: . . . .

Indicate macrophyte stands by: ▨▨▨▨▨▨▨▨▨▨

Stage 10 - recording the results and storing photographs

Recording results

Record your field results on BIOSYS as soon as possible after the survey.

Storing photographs

Store all the photographs in BIOSYS.

Add the survey date to the photograph's details.

Assistance

Contact Alice Hiley if you have any problems entering your data.

Sampling aids

Introduction

You may not be able to clearly see the river bed due to deep or turbid water, or due to reflections from the water surface. This can cause errors in your survey. You can reduce these errors by using the following sampling aids:

- glass-bottomed bucket;
- underwater TV camera;
- grapnel;
- binoculars.

When to use sampling aids

Use the sampling aids in the following situations:

Situation	Sampling aid
wade-able survey lengths	It is strongly recommended you use a **glass-bottomed bucket** to help observe macrophytes. You may use a **grapnel** to retrieve submerged macrophytes for identification from small areas of deep water, if necessary.
deep-water sites where you cannot see the river bed unaided	Use an **underwater TV camera** or a **glass-bottomed bucket** to locate the position and to assess the abundance of any macrophytes that you cannot see from the surface. Use a **grapnel** to retrieve submerged macrophytes for identification. You may find **binoculars** useful to scan the margins of the survey length so that you do not miss species present in small quantities. (particularly if the species are amongst a large stand of other macrophytes).
surveys by boat	

Estimates in deep or turbid water

In deep and or turbid water, you may need to estimate the percentage cover for submerged taxa entirely by taking observations from an underwater camera or glass-bottomed bucket.

Submerged taxa present in very small amounts may still be missed if the water is turbid. Take extra care not to miss less abundant taxa in these conditions

Surveying multiple sites

If you use an underwater camera or glass-bottomed bucket for a survey at a particular site, then you must also use it at any other sites that you will compare with this site.

Example: for UWWTD, you may compare two sites, one upstream and one downstream of a discharge. If you use an underwater camera or glass-bottomed bucket at one site then you must also use it at the other site.

Survey lengths with severely impaired visibility

If, when you get to a survey length, you find that you have great difficulty in seeing macrophytes under the water, use a survey length at an alternative site, if possible.

Otherwise:

- ensure the same surveyor conducts the survey at all survey lengths that you will compare with this survey length;
- treat comparisons of overall percentage cover and submerged species percentage cover with extreme caution, if you use them at all. (See recording percentage cover.)

Using an 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.

Step	Section
1	During the survey, use the camera every few metres across the deep section of the river channel, as necessary. Row the boat very slowly to ensure that the camera is stable and that you can accurately identify submerged species. **Determining when to lower and rotate the camera** The clarity of the water determines the number of times that you must lower and rotate the camera lens so that you can observe 360 degrees.
2	Estimate the abundance of each species for each traverse of the river.
3	Combine your estimates to give a total estimate of percentage cover in the whole survey area.

Using cameras with light sources

The camera unit incorporates a light source that can help visibility in deep or turbid sites. However, use this with care because it uses much more power and so reduces the battery time.

Stabilising the camera

If necessary, attach a small weight (see manufacturers guidelines) to the base of the camera to stabilise it and keep it upright.

Filming in silty or muddy waters

In silty or muddy waters, avoid contact with the base of the river channel because disturbing the river bed reduces visibility.

When to use a grapnel

Use a grapnel to retrieve submerged macrophytes from areas of deep water for identification. Do not use it to search for macrophytes instead of visual observation because:

- a grapnel does not snag fine-leaved or deeply rooted macrophytes effectively, which means these macrophytes will be under-represented or missed entirely;
- bushy species (such as *Elodea*) are easily collected by grapnel and therefore you may over-estimate their abundance.

As a result of the above points, using only a grapnel leads to inaccurate records of submerged species and inaccurate estimates of overall percentage cover.

Grapnel hauls should only be used when necessary to retrieve macrophytes for identification or determine if macrophytes are present.

Take extra care in areas with high conservation or aesthetic value because grapnels can damage or uproot macrophytes.

Identifying macrophytes in the laboratory

Introduction

You may need to bring plant material back to the laboratory to confirm its identity.

Equipment

You need the following equipment in the laboratory:

- binocular microscope;
- identification keys;
- microscope slides;
- plant press;
- hand lens x10;
- mounting paper and glue;
- white tray;
- forceps;
- dissecting needle;
- refrigerator.

Collecting samples

Collect samples as described in collecting samples above.

Storing samples

Macrophyte specimens collected in the field will keep in good condition for several days if placed in plastic bags or lidded tubes **without** additional water.

Store the bag or tube in a refrigerator on return to the laboratory.

If you need to extend the period of storage for identification:

- a few drops of ethanol may extend the period for identification but may extract the chlorophyll;
- alternatively, use Lugol's iodine to preserve the sample (Jones 1979);
- **! Important** do not add formalin.

Identifying samples

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

In a filamentous algae sample, record the dominant species. For example, a filamentous algae mass consisting mainly of *Cladophora* will also contain small amounts of other species, but you only need to record the *Cladophora*.

Specialist advice

If you cannot identify the species or you are not absolutely certain, ask other accredited surveyors locally or other in-house experts. If you still need verification contact:

Dr Nigel Holmes
Alconbury Environmental Consultants
The Almonds, 57 Ramsey Road
Warboys
Huntingdon, PE28 2RW
n.holmes3@btinternet.com
Telephone 01487 822020

A high quality photo of the diagnostic parts of the plant is often sufficient to confirm the identification of many taxa.

Preserving macrophytes

Most macrophytes can be pressed, including charophytes. To do this:

Step	Action
1	Float the specimen in a shallow tray containing water.
2	Place a piece of smooth, shiny, drying paper or good quality cartridge paper under the macrophyte and then lift it from the tray. **Mucilaginous taxa** For mucilaginous taxa, cover the drying sheet with a piece of waxed paper or polythene so the specimen does not stick to the drying paper in the plant press.
3	Make fine adjustments of the macrophyte position so that you can see all attributes. A pipette and brush may help.
4	Label a piece of drying paper with a waterproof marker or pencil.
5	Place the second piece of drying paper on top of the macrophyte. **Using a corrugate** If a corrugate is available, use it between layers. The corrugate allows air to circular and so aids drying. **Mucilaginous species** For mucilaginous species, cover the drying sheet with a piece of waxed paper or polythene so the specimen does not stick to the drying paper in the plant press.
6	Sandwich the macrophyte between layers of newspaper or other absorbent paper. If a corrugate is available, use it between layers.
7	Place the whole thing in a flower press and close while applying even pressure. Keep the press size small unless using corrugates.
8	Store the press in a dry atmosphere.
9	Change the absorbent paper after 24 hours.
10	Change the absorbent paper after a further 48 hours. (That is, 72 hours after you first pressed the specimen.)
11	Continue to regularly change the absorbent paper until the macrophyte specimen is completely dry.

Building a reference collection (herbarium)

About the reference collection (herbarium)

Compile a reference collection of dried or pressed macrophyte specimens and add to it as new species are found in the area.

Include fruiting and flowering parts. In addition, slides of macrophytes can be useful.

Adding and indexing specimens

After you have pressed the specimen, label it and list its main identification features.

Index the reference collection using an index card box file.

Group the cards, but have a separate card for each species, with identification features and information.

Storing specimens

The reference collection is best kept in a cabinet with many shallow draws to avoid crushing the dried specimens.

Special treatment

The following specimens require special treatment in the reference collection:

Specimen	Treatment
dried specimens	Dried specimens are fairly brittle so take care when handling them.
rare species	Do not include rare species in the collection but use photographs and annotated field drawings instead.
species that are difficult to identify	Compile a collection of specimens that are difficult to identify (to which reference may need to be made for quality assurance purposes) as an integral part of the reference collection or as a supplementary collection in its own right.

Related documents

Supporting documents

- SD01 Survey form

Links

- 426_05 Working In or near water
- 37_04 Generic Risk Assessment for Fieldwork
- 32_04 Generic Risk Assessment for Boat work
- 83_04 Generic Risk Assessment: sampling by boat
- Environment Agency (1999) R & D Report E38 Mean Trophic Rank: a users guide
- A LEAFPACS R&D Report (contact Jo-Anne Pitt)
- SC070051/R1 - River macrophyte sampling: methodologies and variability
- SC070051/R2 - Variability components for macrophyte communities in rivers
- SC070051/R3 - Variability components for macrophyte communities in rivers: 2008 survey
- SC070051/R4 - Variability components for macrophyte communities in rivers: summary report
- SC070051?R4 – Report of the macrophyte surveying and variability workshop 4-5 June 2009.

Useful keys and guides

- Laminated field identification guides (contact Katharine Pilcher)
- S. Haslam et al — (1975) British Water Plants
- Environment Agency guide for identifying British river higher plants, algae and bryophytes (contact Katharine Pilcher)
- Standing Committee of Analysts (1987) — Methods for the Use of Aquatic Macrophytes for Assessing Water Quality. HMSO
- E.V. Watson (1981) — British Mosses and Liverworts
- Lansdown R.V. (2007) — A field guide to the riverine plants of Britain and Northern Ireland. Including selected vascular plants, bryophytes, lichens and algae. Environment Agency Thames Region.
- BSBI publications – pondweeds, charophytes

References

Holmes, N. T. H. and Whitton, B. A. (1977) Macrophyte vegetation of the River Swale, Yorkshire. *Freshwater Biology*, 7: 545-558

A11.2 JNCC Standard method for river macrophyte survey and for determining River Community Type (Edited extract from SERCON 2 User's Guide)

Field survey

Ideally, survey sites are located every 5 to 7 km along a river, but this will vary depending upon the size of the river and ease of access. For most rivers it has been found that sites 5 km apart reflect accurately the character of small streams whilst distances greater than 10 km apart may suffice for large rivers. The macrophytes in each 0.5 km survey site are surveyed using a check-list of species (***Table A11.4***).

Where possible, recording is done by wading in the channel, but for deep and wide rivers it is necessary to walk the banks using a grapnel for sampling, or to use a boat. The survey at each site includes the entire channel and immediate banksides, with separate records being made for those macrophytes found in the river and those found on the bank. This is an attempt to distinguish between species which occur more or less permanently submerged (if only their basal parts), and those that are subjected only to periodic submergence. The former are referred to as „river‟ records and the latter as „bank‟ records. To make the separation of these records objective, the following guidelines should be observed when defining the limits of the river being surveyed.

At the sides of the river all parts of the substratum are included which are likely to be submerged for more than 85% of the year. The „bank‟ can be usefully defined as that part of the side of the river (or islands) which are submerged for more than 50% but less than 85% of the time. In general terms, therefore, „river‟ records are reserved for those macrophytes occurring 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 year. „Bank‟ records are for 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 partially so, during mean flow periods. The upper limit of the „bank‟ excludes all the areas which are submerged during the 150 days of each year when river flows are at their highest. Such estimates have to involve guesswork, but estimates of submergence levels do allow better interpretation of the data and clearer insights into the ecology of individual species and communities at different sites.

The macrophyte survey concentrates on recording the presence or absence of species on the check-list and limits itself to the channel and base of the banks. Additional species of interest are noted but not used in the classification. Survey results are tabulated, with any species present within a 0.5 km site denoted by a double set of numbers, either under „River‟ or „Bank‟ (***Table A11.5***). (Note that in the case of marginal plants it is not uncommon for the species to be recorded in both habitats.) The two numbers are essentially estimates of abundance.

The first number in each column (r), refers to the relative abundance of one species against the other species present, but does not indicate how much of the site it covers. Assessment is made on a scale of 1-3 which roughly accords to a simplified DAFOR scale.

1 = Rare

2 = Occasional or Frequent

3 = Abundant or Dominant

The second number (a) refers to absolute abundance or percentage cover and is a semi-objective assessment based on the percentage of the river bed or bank covered by each macrophyte species. Again assessment is on a scale of 1-3.

1 = <0.1% cover of the channel (river) or at its wetted margins (bank)

2 = 0.1 - 5.0% cover

3 = >5% cover

Visualizing the relative abundance of one species compared with all the others present in a 0.5 km length of river is relatively straightforward but estimating the actual cover value is more difficult. As a general guide it is valuable to envisage a dense stand of vegetation which stretches from bank to bank, and extends for 5 m downstream as covering 1% of the 500 m stretch. Similarly, an unbroken stand of 25 m represents 5%. Bank cover is best recorded from one bank in very wide rivers. In such cases a continuous fringe of a single species stretching 5 m represents 1%. If both banks are clearly visible and being recorded, then a continuous stand of 10 m represents 1% cover. A species with cover value 3 means, for instance, that it completely covers the stream bed for 25 m, or it covers half the bed for 50 m, a quarter of the bed for 100 m or it occurs throughout the whole 500 m, but more sparsely. For a score of 3 to be given, bank taxa must:

i) be similarly abundant along both banks with a continuous fringe of 50 m, or

ii) form a co-dominant fringe of 100 m, or

iii) occur as 50 plants or colonies each covering 1 m

Table A11.5 gives an example of how data should be recorded. This is interpreted as:

> Species A is co-dominant in the river channel with Sp. E; it covers >5% of the river channel but does not occur on the banks.
> Species B is rare; it is present in both river and bank habitats but at a cover value of <0.1%.
> Species C is present only in the upstream length. It is co-dominant with Species D on the banks by covering >5%, is frequent relative to other species within the river channel but covers <0.1%.

Species D is co-dominant with Sp. C on the banks. In the river channel it is frequent compared with other species and covers 0.1-5%.

Species E is co-dominant in the river channel with Sp. A; it covers >5% of the river channel but does not occur on the banks.

Table A11.4. Macrophyte species listed on the standard river survey (RMS) field card.

*non-native taxa and „dumping ground" categories

Scientific Name	Common Name
ALGAE	
Batrachospermum sp(p).	Frogspawn alga
Chara sp(p).	Stonewort
Cladophora aegagropila	Carpet blanketweed
*Cladophora / Rhizoclonium agg.	Blanketweed
*Enteromorpha sp(p).	Tubeweed
*Filamentous green algae (other)	-
Hildenbrandia rivularis	-
Hydrodictyon reticulatum	Netweed
Lemanea fluviatilis	-
Nitella sp(p).	Stonewort
*Vaucheria sp.	Mole-pelt alga
LICHENS	
Collema dichotomum	River Jelly-lichen
Encrusting lichen(s)	-
Foliose lichen(s)	-
LIVERWORTS	
Chiloscyphus polyanthos	-
Conocephalum conicum	-
Jungermannia sp(p).	-
Lunularia cruciata	-
Marchantia polymorpha	-

Scientific Name	Common Name
Marsupella sp(p).	-
Nardia sp(p).	-
Pellia endiviifolia	-
Pellia epiphylla	-
Porella sp(p).	-
Riccardia sp(p).	-
Scapania sp(p).	-
MOSSES	
Amblystegium fluviatile -	-
Blindia acuta -	-
Brachythecium plumosum -	-
Brachythecium rivulare -	-
Brachythecium rutabulum -	-
Bryum pseudotriquetrum -	-
Calliergon cuspidatum -	-
Cinclidotus fontinaloides -	-
Cratoneuron filicinum -	-
Dichodontium pellucidum / flavescens -	-
Dicranella palustris -	-
Fissidens crassipes / curnovii / rufulus -	-
Fontinalis antipyretica -	-
Fontinalis squamosa -	-
Hygrohypnum luridum / ochraceum -	-
Hyocomium armoricum -	-
Isothecium holtii -	-
Leptodictyum riparium -	-
Octodiceras fontanum -	-
Orthotrichum sp(p). -	-

Scientific Name	Common Name
Philonotis fontana -	-
Polytrichum commune -	-
Racomitrium aciculare -	-
Rhynchostegium riparioides -	-
Schistidium agassizii -	-
Schistidium rivulare -	-
Sphagnum sp(p). -	-
Thamnobryum alopecurum -	-
PTERIDOPHYTES	
*Azolla filiculoides	Water fern
Equisetum fluviatile	Water horsetail
Equisetum palustre	Marsh horsetail
Hymenophyllum sp(p).	Filmy ferns
Osmunda regalis	Royal fern
Other ferns	-
DICOTYLEDONS	
Achillea ptarmica	Sneezewort
Angelica sylvestris	Wild angelica
Apium inundatum	Lesser marshwort
Apium nodiflorum	Fool"s watercress
Berula erecta	Lesser water-parsnip
Bidens cernua	Nodding bur-marigold
Bidens tripartita	Tripartite bur-marigold
Callitriche hamulata / brutia	Intermediate water-starwort
Callitriche hermaphroditica	Autumnal water-starwort
Callitriche obtusangula	Blunt-fruited water-starwort
Callitriche platycarpa	Various-leaved water-starwort
Callitriche sp(p). indeterminate	Water-starwort (species not identifiable)

Scientific Name	Common Name
Callitriche stagnalis	Common water-starwort
Caltha palustris	Kingcup, Marsh marigold
Cardamine amara	Large bitter-cress
Ceratophyllum demersum	Rigid hornwort
*Crassula helmsii	Australian swamp stonecrop, New Zealand water stonecrop
Dipsacus fullonum	Teasel
Epilobium hirsutum	Great willowherb
Eupatorium cannabinum	Hemp-agrimony
*Fallopia japonica	Japanese knotweed
Filipendula ulmaria	Meadowsweet
Galium palustre	Marsh bedstraw
*Heracleum mantegazzianum	Giant hogweed
Hippuris vulgaris	Mare‟s-tail
*Hydrocotyle ranunculoides	Floating pennywort
Hydrocotyle vulgaris	Marsh pennywort
*Impatiens capensis	Orange balsam
*Impatiens glandulifera	Indian balsam, Himalayan balsam
Littorella uniflora	Shoreweed
Lotus pedunculatus	Greater bird‟s-foot-trefoil
Lycopus europaeus	Gypsywort
Lysimachia vulgaris	Yellow loosetrife
Lythrum salicaria	Purple loosetrife
Mentha aquatica	Water mint
Menyanthes trifoliata	Bogbean
*Mimulus sp(p).	Monkeyflowers
Montia fontana	Blinks
*Montia sibirica	Pink purslane

Scientific Name	Common Name
Myosotis scorpioides	Water forget-me-not
Myosoton aquaticum	Water chickweed
Myrica gale	Bog myrtle
Myriophyllum alterniflorum	Alternate water-milfoil
*Myriophyllum aquaticum	Parrot‟s-feather
Myriophyllum spicatum	Spiked water-milfoil
Nuphar lutea	Yellow water-lily, brandy-bottle
Nymphaea alba	White water-lily
Oenanthe crocata	Hemlock water-dropwort
Oenanthe fistulosa	Tubular water-dropwort
Oenanthe fluviatilis	River water-dropwort
Persicaria amphibia	Amphibious bistort
Persicaria hydropiper	Water-pepper
Petasites hybridus	Butterbur
Potentilla erecta	Tormentil
Potentilla palustris	Marsh cinquefoil
Pulicaria dysenterica	Common fleabane
Ranunculus aquatilis	Common water-crowfoot
Ranunculus circinatus	Fan-leaved water-crowfoot
Ranunculus flammula	Lesser spearwort
Ranunculus fluitans	River water-crowfoot
Ranunculus hederaceus	Ivy-leaved crowfoot
Ranunculus omiophyllus	Round-leaved crowfoot
Ranunculus peltatus	Pond water-crowfoot
Ranunculus penicillatus ssp. penicillatus	Stream water-crowfoot
Ranunculus penicillatus ssp. pseudofluitans	Stream water-crowfoot
Ranunculus penicillatus ssp. pseudofluitans var. vertumnus	Stream water-crowfoot

Scientific Name	**Common Name**
Ranunculus sceleratus	Celery-leaved buttercup
Ranunculus subgenus *Batrachium* sp(p). indeterminate	Water-crowfoot (species not identifiable)
Ranunculus trichophyllus	Thread-leaved water-crowfoot
Rorippa amphibia	Great yellow-cress
Rorippa nasturtium-aquaticum / microphylla agg	Water-cress
Rorippa palustris	Marsh yellow-cress
Rorippa sylvestris	Creeping yellow-cress
Rumex hydrolapathum	Water dock
Sagina procumbens	Pearlwort
Scrophularia auriculata	Water figwort
Scutellaria galericulata	Skullcap
Senecio aquaticus	Marsh ragwort
Solanum dulcamara	Bittersweet, Woody nightshade
Stachys palustris	Marsh woundwort
Stellaria uliginosa	Bog stitchwort
Symphytum sp(p).	Comfrey
Tussilago farfara	Coltsfoot
Utricularia sp(p).	Bladderwort
Valeriana officinalis	Valerian
Veronica anagallis-aquatica	Blue water-speedwell
Veronica anagallis-aquatica / catenata indeterminate	Water-speedwell (species not identifiable)
Veronica beccabunga	Brooklime
Veronica catenata	Pink water-speedwell
Veronica scutellata	Marsh speedwell
Viola palustris	Marsh violet
*Other non-aquatic dicotyledons	

Scientific Name	**Common Name**
TREES AND SHRUBS	
*Alnus glutinosa	Alder
*Rhododendron ponticum agg.	Rhododendron
**Salix* sp(p).	Willow
*Conifererous Trees	-
*Other Deciduous Trees and Shrubs	-
MONOCOTYLEDONS	
*Acorus calamus	Sweetflag
Alisma lanceolatum	Narrow-leaved water-plantain
Alisma plantago-aquatica	Common water-plantain
Alopecurus geniculatus	Marsh foxtail
Bolboschoenus maritimus	Sea club-rush
Butomus umbellatus	Flowering rush
Carex acuta	Slender tufted-sedge
Carex acutiformis	Lesser pond-sedge
Carex aquatilis	Water sedge
Carex curta	White sedge
Carex disticha	Brown sedge
Carex echinata	Star sedge
Carex elata	Tufted sedge
Carex flacca	Glaucous sedge
Carex hirta	Hairy sedge
Carex nigra	Common sedge
Carex otrubae	False fox-sedge
Carex ovalis	Oval sedge
Carex panicea	Carnation sedge
Carex paniculata	Greater tussock-sedge
Carex pendula	Pendulous sedge

Scientific Name	**Common Name**
Carex pseudocyperus	Cyperus sedge
Carex pulicaris	Flea sedge
Carex remota	Remote sedge
Carex riparia	Great pond-sedge
Carex rostrata	Bottle sedge
Carex vesicaria	Bladder sedge
Carex viridula	Common yellow-sedge
Catabrosa aquatica	Whorl-grass
*Crocosmia sp(p).	Montbretia
Deschampsia cespitosa	Tufted hair-grass
Eleocharis palustris	Common spike-rush
Eleogiton fluitans	Floating club-rush
*Elodea canadensis	Canadian pondweed
*Elodea nuttallii	Nuttall‟s waterweed
Glyceria declinata	Small sweet-grass
Glyceria fluitans	Floating sweet-grass
Glyceria maxima	Reed sweet-grass
Glyceria notata	Plicate sweet-grass
Glyceria sp(p). indeterminate	Sweet-grass (species not identifiable)
Groenlandia densa	Opposite-leaved pondweed
Hydrocharis morsus-ranae	Frogbit
Iris pseudacorus	Yellow iris
Juncus acutiflorus	Sharp-flowered rush
Juncus articulatus	Jointed rush
Juncus bulbosus	Bulbous rush
Juncus effusus	Soft rush
Juncus inflexus	Hard rush
Lemna gibba	Fat duckweed

Scientific Name	**Common Name**
Lemna minor	Common duckweed
*Lemna minuta	Least duckweed
Lemna trisulca	Ivy-leaved duckweed
Luronium natans	Floating water-plantain
Molinia caerulea	Purple moor-grass
Nardus stricta	Mat-grass
Narthecium ossifragum	Bog asphodel
Phalaris arundinacea	Reed canary-grass
Phragmites australis	Common reed
Potamogeton alpinus	Red pondweed
Potamogeton berchtoldii	Small pondweed
Potamogeton broad-leaved spp.indeterminate	Pondweed (species not identifiable)
Potamogeton crispus	Curled pondweed
Potamogeton fine-leaved spp. indeterminate	Pondweed (species not identifiable)
Potamogeton friesii	Flat-stalked pondweed
Potamogeton gramineus	Various-leaved pondweed
Potamogeton lucens	Shining pondweed
Potamogeton natans	Broad-leaved pondweed
Potamogeton nodosus	Loddon pondweed
Potamogeton pectinatus	Fennel pondweed
Potamogeton perfoliatus	Perfoliate pondweed
Potamogeton polygonifolius	Bog pondweed
Potamogeton praelongus	Long-stalked pondweed
Potamogeton pusillus	Lesser pondweed
Potamogeton trichoides	Hairlike pondweed
Potamogeton x olivaceus	Hybrid pondweed
Potamogeton x salicifolius	Willow-leaved pondweed

Scientific Name	Common Name
Sagittaria sagittifolia	Arrowhead
Schoenoplectus lacustris	Common club-rush
Schoenoplectus tabernaemontani	Grey club-rush
Scirpus sylvaticus	Wood club-rush
Sparganium angustifolium	Floating bur-reed
Sparganium emersum	Unbranched bur-reed
Sparganium erectum	Branched bur-reed
Spirodela polyrhiza	Greater duckweed
Typha angustifolia	Lesser bulrush
Typha latifolia	Bulrush
Zannichellia palustris	Horned pondweed
*Other monocotyledons -	

Table A11.5. An example of the way in which macrophyte survey data are tabulated before determination of the River Community Type

	River		Bank	
	r	a	r	a
Species A	3	3		
Species B	1	1	1	1
Species C	2	1	3	3
Species D	2	2	3	3
Species E	3	3		

Determining the River Community Type

The RCT for designated sites is given on the JNCC Rivers Database, copies of which are held

by each of the conservation agencies. Advice on keying out RCTs from the species recorded

during the monitoring process should be sought from the appropriate specialist in SNH, EN, CCW and EHS.

A11.3 Quadrat/NVC methodology

Plant/macrophyte samples are taken using a standard sampling unit or quadrat. Quadrats normally consist of a square frame usually 1 m square in size. The quadrat size can however, vary according to the type of vegetation being surveyed. As a general guideline 0.5 – 1.0m^2 size quadrats are used for short grassland or dwarf heath, taller grassland and shrubby habitat would require 2m^2 quadrats, while qudrats of 20m^2 or larger would be required for woodland habitats.

- The quadrat is used to estimate the percentage cover of a species within it. Species often overlap and there may be several different vertical layers so the percentage cover may therefore add up to more than 100%. The estimation can be improved by subdividing the quadrat into 100 squares whereby each sub square represents 1 %.
- The National Vegetation Classification Users‟ Handbook is available on the JNCC website http://www.jncc.gov.uk/default.aspx?page=3728

Appendix 12
Hydromorphology – Geomorphological Surveys

A12.1 Aerial Photography and Satellite Imagery

Both aerial photographs and satellite images are useful tools to look at original land features such as paleo-channels. Viewing a catchment from above also gives an idea of the drainage network and shows important features such as landuse and the extent of urbanisation within the catchment.

A12.2 Geo-River Habitat Survey (GeoRHS)

Geo-RHS is the geomorphology component bolt on to RHS. It largely targets features and dimensions that relate to the processes of sediment transport in the channel and floodplain. Geomorphology is inherent in RHS surveys but is limited in scope and does not extend to the floodplain or consider the wider catchment features. Updated field survey forms are now available. The information will be used in tandem with RHS data to develop indicators of channel and floodplain status, naturalness, and modification. The full research document can be found at http://publications.environment-agency.gov.uk/pdf/SCHO1205BKBV-e-e.pdf

A12.3 Topographic Survey

Topographic surveys consist of the height of the ground above a datum being recorded at regular (predefined intervals) along a transect. The transect can be down the river bed (i.e. a bed level survey) or across the channel (i.e. a cross section survey). Cross section surveys can include just the channel (i.e. from bank top to bank top) or might also include the floodplain. Topographic survey can also be done in a grid pattern

A12.4 Repeat Cross Sections

Cross section surveys carried out before the restoration work can be compared with surveys taken in exactly the same place, but which are repeated at predefined intervals (for example immediately post restoration, then 1 year after and three years after). The repeat cross sections will then show how much the channel has changed as a result of the restoration work.

A12.5 Geomorphological Mapping

Mapping all the geomorphological features in a catchment highlight areas of erosion and deposition. It also indicates how dynamic the river system is as well as highlighting potential sources of silt. Understanding the dynamicity of a river will assist in selecting the most appropriate restoration methods to use and give an indication of where monitoring sites should be located.

A12.6 Fluvial Audit

The Fluvial Audit (FA) uses contemporary field survey, historical map and documentary information to gain a comprehensive understanding of the river system and its catchment. The river is divided into a series of reaches defined by natural changes in the geomorphological controls of the river system. In addition within each reach information on channel dimensions, bank properties, flow types, anthropogenic controls and catchment influences, the specific location, type and severity of bank erosion processes, bank protection works and inchannel modifications are mapped.

A12.7 LiDAR

LiDAR (**Li**ght **D**etection **A**nd **R**anging) is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target. The prevalent method to determine distance to an object or surface is to use laser pulses. Like the similar radar technology, which uses radio waves, the distance to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal. LiDAR therefore gives you an idea of the height of the ground surface above a given datum. This can then be plotted (see ***Figure A12.1***) and can show old meander channel and other palaeo-features.

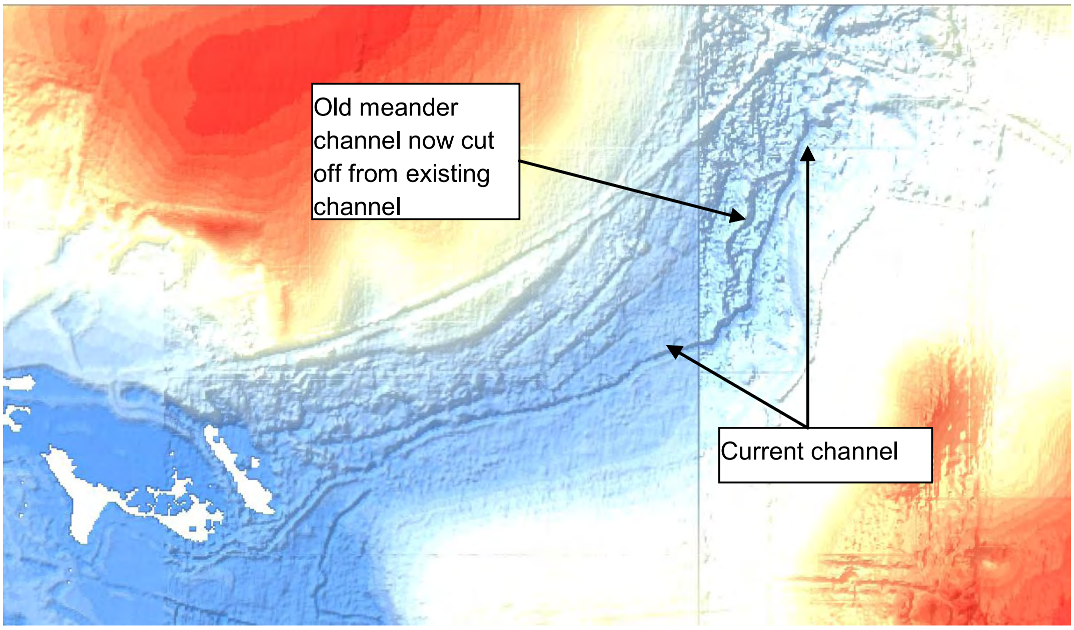


Figure A12.1 Example of LiDAR Data

Appendix 13
Hydromorphology – Hydrological Surveys

A13.1 Trash Lines

After flooding events lines of debris accumulate marking the highest level that the flood waters reached (see ***Figure A13.1***). Knowing the peak flood levels gives the observed some idea of the likelihood of a river going out of bank and into the floodplain and therefore indicates whether the river is connected to the floodplain.

Figure A13.1 Trash lines

A13.2 Water Level

Gauge Boards

Figure A13.2 shows a gauged board fixed to the downstream wing wall of a gauging station. In this instance the gauge board is there to check the water level downstream of the gauging weir. Gauge boards can be fixed in any location, but need to be surveyed in so when they are read the level can be calculated from a standard datum (such as ordnance datum). The boards can then be read at regular intervals (daily, weekly or monthly) by anyone from Agency staff to the Wild Trout Trust volunteers to members of action or interest groups.

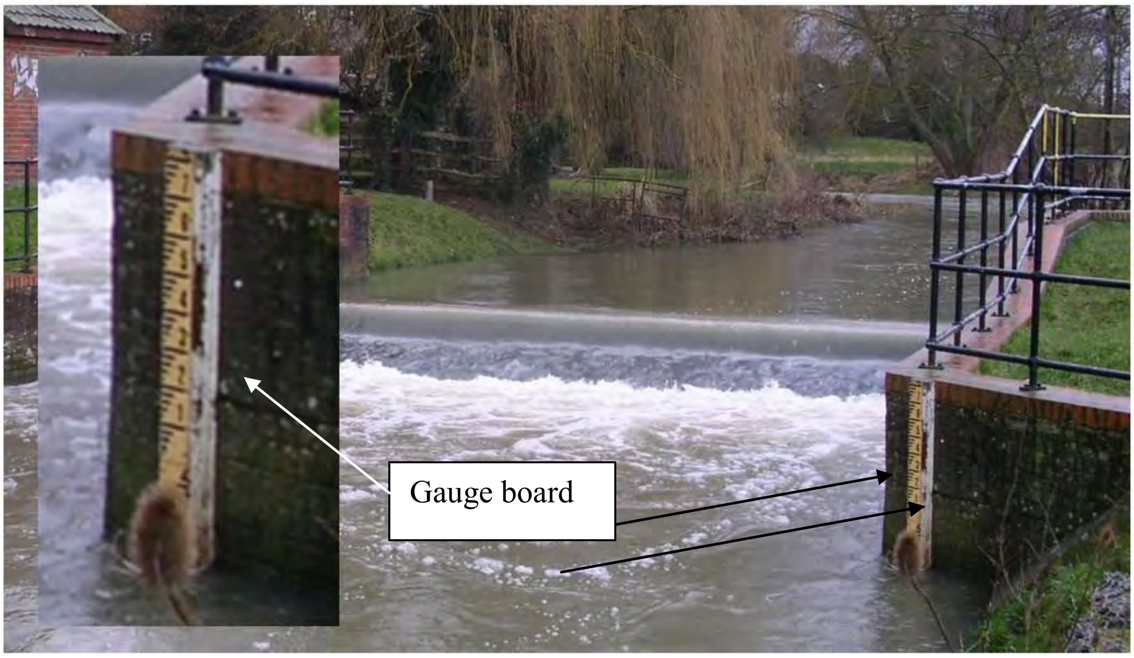


Figure A13.2 Gauge board at gauging station

Stilling Well and Level Logger

A stilling well is a tube or lined well construction in which a float travels up and down according to the vertical movement of the water level of the river. The tube goes directly into the river whilst the well construction is in the bank and is connected to the river via a horizontal pipe. Within the tube or well a transducer can be fixed which record the water level and logs them electronically at a set interval such as every 15 minutes. Water level loggers can also be installed directly in rivers to record water levels.

The levels can be used to determine when a river goes out of banks and spills onto the floodplain. This gives an indication of how well connected a river is to its floodplain.

A13.3 Spot Gauging

Spot gaugings are a series of flow/discharge measurements that are carried out often as part of a set series of flow measurements at predetermined sites. ***Appendix 5*** has an extract from the Environment Agency"s hydrometric handbook which describes spot gauging and acoustic Doppler channel profiling (ADCP) gauging. Both types of flow/discharge measurement give an indication of the amount of water in the channel at the time of measurement. The method of calculating the flow/discharge is to record a series of velocities across the channel in a series of panels. The mean for each panel is then multiplied by the cross sectional area to determine the amount of water flowing in each panel, these are then summed to calculate the total flow/discharge.

These measurements can be used along with macroinvertebrate sample data for example, to assess the relationship , if any, between flow and aquatic invertebrates. A series of spot gauging results taken at the same site can also be used to derive a time series of flows at that site by using regression analysis with a nearby gauging station flow time series.

A13.4 Velocity

The velocity data collated when conducting a spot gauging can be used to assess the velocity pattern across the channel. A velocimeter can be used to take a number of reading both across the channel and at each departure from the bank to build up a more detailed pattern of water movement.

Velocity readings can be compared with biotope maps or macroinvertebrate sampling using a surber sampler to determine which plants or invertebrates are associated with particular velocities, and whether a change in velocity changes the aquatic invertebrates or macrophyte assemblages.

A13.5 Rainfall-runoff Modelling (to determine mean daily flows)

Rainfall-runoff models can be used to model flows/discharges at any location within the catchment provided there is sufficient gauged flow data to calibrate the model. Once calibrated, the models can then be run to produce the flows which might be expected with various climate change scenarios.

Hydrometric manual chapter 4 - instantaneous flow measurement

What's this document about?

This is chapter 4 of the Hydrometric Manual „Instantaneous flow measurement‟ and provides background information and guidance in the measurement of Instantaneous Flow Measurement. It covers all types of spot flow measurement but concentrates on mainly on the use of point velocity meters. The use of Acoustic Doppler Current Profilers calculates discharge using the same velocity area principles as point flow meters and this is covered in detail a separate work instruction.

Note: Some future Work Instructions are planned that will overlap with material in this chapter. Once the future Work Instruction has been produced the relevant sections will be removed from this chapter. A link to the new Work Instruction will be inserted into this chapter. The position of those future hyperlinks are indicated in this document by blue highlighting.

Who does this apply to?

This document will be used by Hydrometry and Telemetry monitoring teams.

Contents

Introduction

Definition

Strictly speaking, most continuous digital flow records consist of a series of „instantaneous‟ readings while flow measurements referred to in this section are „instantaneous‟ in a very loose sense. They may be defined as short-term flow measurements taken at irregular and usually infrequent time intervals. In addition, the methods used to derive flow values are quite distinct from those used for time series data at flow measurement stations.

This type of flow measurement may be taken at any point on any watercourse at any time, although the accuracy and effectiveness of the various methods may differ greatly at any one location. Considerable inaccuracies may also result from variations in the way the chosen measurement is implemented.

Methods

Even though there are a variety of methods available for taking „instantaneous‟ measurements of flow, in practice the vast majority of those carried out by the Environment Agency are velocity area gaugings using rotating element or electromagnetic current meters and the increasing use of ADCPs and ADVs.

Accuracy

Velocity area gauging is necessary, but can be a relatively labour intensive way of collecting flow information. The staff involved in current meter gauging have almost total control over the accuracy and reliability of the final flow figure. Only diligence on their part can ensure that the Environment Agency gets good value from the time and money it spends on this activity. It is important that the procedures and guidelines outlined are followed to ensure that the resulting flows are as accurate as circumstances allow.

Purpose and Use

History

In 1992 it was estimated that the National Rivers Authority (NRA), the predecessor of the Environment Agency, carried out approximately 25,000 velocity area gaugings per year. The distribution between individual regions and summary of main purposes for which they are taken are documented in R&D project report 303/4/S-T, „Review of Hydrometric Field Techniques used in the National Rivers Authority‟.

Instantaneous flow measurements taken by other methods are very few by comparison. The largest single other group are volumetric (direct) measurements. The total of all other methods is insignificant in comparison to velocity area gaugings

Water resources

The information obtained from instantaneous flow measurements has many applications across a range of functions. Hydrometric and hydrological staff use the measurements for establishing and maintaining stage discharge relationships at all rated section and channel controls (see Chapters 5-2 and 5-3), for checking performance of flow measurement structures (see Chapter 5-3) and multi-path ultrasonic river flow gauges (see Chapters 5-4), and calibration of electromagnetic river flow gauges (see Chapters 5-4). „Spot" flow readings are invaluable for assessing yields from ungauged catchments and can be particularly useful when co-ordinated into basin wide surveys that reflect specific catchment conditions (e.g. low flows). They are also used in abstraction assessment, monitoring and enforcement work, and conservation and ecological studies.

Flood defence

Within Flood Defence, high flow gaugings are generally of most interest and a small number of flood levels and flow measurements may have a large influence on the design of expensive flood defence works. Performance of these schemes is frequently assessed by spot level and flow data.

Environmental Quality

Environmental Quality request gaugings to be carried out to assess effluent dilution in connection with the issue of discharge consents. They also frequently require measurements of flow as part of pollution incident investigations.

Summary

The above are major uses, however there are a number of others and together they emphasise how important these measurements are to the work of the Environment Agency. Each individual measurement is normally entered into a database and may then be used for a variety of purposes over time. Therefore, this type of data must be collected and processed to the highest possible standards that conditions allow.

Methods of Measurement

Current meter gauging

For current meter gauging, a meter is used to measure the water velocity which, when combined with the cross-sectional area, produces a measurement of the total flow. In practice, the cross-section is divided up into a number of „panels‟ for each of which a mean velocity is calculated, based on one or more individual point velocities in that panel. The section „Principles of current meter gauging‟ below gives more complete details of the method. As with all instantaneous measurements of flow, water level is normally recorded to enable comparisons to be made between measurements.

See also document: WI Monitoring & Data (hydrometry) – Field Current Meter Gauging

Volumetric gauging

This method involves catching the flow in a container for a measured time. It is normally only appropriate for low flow rates of up to approximately 2 to 3 litres per second (say 0.15-0.25 Mld) but is potentially the most accurate of all methods. As a rule, the longer the time, the more accurate the result. For the level of accuracy to be achieved the container used must be calibrated, normally by filling it with water whist weighing it on calibrated scales. Even on small streams, opportunities to use this method are limited, as suitable sites for catching the flow are rare. It is most frequently used to measure flow from pipes, springs and abstraction from boreholes and when it can be employed it is a cheap and simple method.

See also document: WI Monitoring & Data (hydrometry) – Field Gauging, Volumetric

Dilution gauging

In dilution gauging flow is determined from the diluting effects of the flow volume on the concentration of a „tracer‟ substance. Typically, this would be a chemical, e.g. sodium chloride (common salt), or a radioactive substance such as bromine-82. If the amount put into the river is known, a measurement of the concentration of the tracer at a downstream sampling point can be used to calculate the volume of flow.

Two basic methods are in use, constant-rate injection and „gulp‟ injection. In the former, the tracer is dripped at a constant rate into the watercourse, while in the latter; the whole of the tracer is put into the river at once.

The successful use of the technique is dependent on obtaining good mixing of the tracer throughout the entire flow profile (cross-section) by the time that it reaches the sampling point.

The technique has been used successfully in several countries for many years (e.g. Switzerland) but has tended to have limited application within the Environment Agency‟s domain. Devices are now available which make use of modern sampling technology (e.g. conductivity monitoring) that makes it a more attractive method of monitoring. It may prove a useful adjunct to the more mainstream methods of flow measurement where conditions (e.g. turbulence) prevent the use of current meters and good mixing can occur such as steep mountain rivers and in heavily polluted water courses. However there are environmental concerns about the use of chemical tracers and costs can be relatively high.

Further details of the method can be found in ISO 9555 parts 1 to 4, and for a more readable description, Herschy (2008).

Slope area method

The slope area method is a means of estimating velocity (and thus the discharge) in the measuring section. It is based on several well-known semi-empirical formulae for estimating velocity using surface water slope, channel geometry and a channel roughness (friction) coefficient. The Manning formula is usually preferred. The appropriate roughness coefficients (for channel and flood plain, if appropriate) are normally estimated from experience or by means of other methods of flow measurement. One of the standard pictorial guides may also be used.

Slope area methods for estimating flows are not widely used within the Environment Agency. They can be useful for establishing peak flows, particularly when they are above the rated range at a gauging station, and can provide valuable post flood peak estimation in a simple and relatively low cost way. However it is not as accurate as other methods due to its dependence on selection of roughness coefficient and other physical factors. The method is most accurate when staff gauges are installed specifically for this purpose. Levels based on trash lines and other peak level markers are an acceptable but inferior substitute.

For best results, a straight, or converging and consistent length of river is chosen with uniform flow characteristics, to minimise variations in mean velocity. If these criteria are not satisfied, it may be necessary to calculate and use the energy gradient rather than the water surface slope.

Full details may be found in ISO 1070 (1992) and „Streamflow Measurement‟ by Herschy (2008).

Float gauging

There are a number of types of float that can be used for measuring water movement, although the most relevant to fluvial flow measurement are surface velocity floats. In Britain these are rarely used, as rivers are generally small enough to enable other (more accurate) methods to be used. They may occasionally be useful when it is impossible to use a current meter, e.g. when there is significant material in suspension or when velocities are too high, and in cases of reconnaissance.

Types of float gauging

There are three types of float:

- **surface floats** - used to attain velocity quickly such as during flood events, not to be used when wind could have an effect;
- **subsurface floats** - used to measure velocities in deep rivers, the sub-surface body to be positioned at 0.6 of the depth below the surface;
- **Rod floats** - method of obtaining mean velocity in each segment if the bed profile is regular over the measuring reach.

Float gauged velocities

In the case of surface floats, the measurements relate only to surface velocities, which will normally overestimate the average velocity in the vertical. While at some sites it may be possible to correlate the surface velocity with the average velocity in the vertical, the normal procedure is to apply an estimated factor of between 0.8 and 0.95, depending on channel shape, water depth and type of float.

Float gauging errors

Errors in float gauging may arise when:

- the coefficient from which the mean velocity is obtained from the float velocity is not known accurately;
- too few segments are used to obtain a reasonable determination of the variation of the velocity distribution across the channel;
- if a sub-surface float is used and channel depth is not uniform within the measuring reach;
- the float does not travel in the centre of the panel due to oblique currents;
- if there is wind, although it must be noted that this is negligible in comparison to the above.

Acoustic Doppler current profilers (ADCP)

An ADCP is a device for measuring current velocity and direction throughout the water column in a non-intrusive manner. The ADCP is floated across the river on a raft or boat with the transducer head submerged. The collected data is downloaded onto a PC and analysed back in the office.

How ADCPs measure velocity

The instrument works rather like a police radar gun. It uses the Doppler effect to measure the relative velocities between itself, the riverbed and suspended particles in the water column. Ultrasonic transducers (which form part of the ADCP) emit a pulse of sound into the water column. Suspended particles in the column and the channel bed reflect some of the sound back. The ADCP measures the Doppler shift of the reflected sound and uses this to calculate the relative velocity of the particles and bed to itself. The velocity of the particles is assumed to be the velocity of the current, the channel bed is assumed to be stationary.

Velocity measurements are directly related to the speed of sound in water, this varies with water density, which in turn is dependent on factors such as salinity and temperature. It is believed most ADCP manufacturers monitor water temperature at the sensor head and apply correction factors to allow for temperature related differences in the speed of sound.

How ADCPs calculate discharge

The ADCP divides the water column into horizontal slices. The average velocity of water flowing through each slice is calculated to produce a velocity profile of the water column. As the ADCP is propelled across the river, velocities in many verticals are collected and processed by supporting software to estimate a total discharge. It records direction of flow, produces an instantaneous velocity profile, can be attached to a boat or flotation collar and need not go straight across the river. The benefits of using an ADCP are:

- near instantaneous data collection;
- potential for accurate determinations of a wider range of velocities;
- health and safety risks could be reduced;
- use on larger and navigable rivers where conventional gauging is either not feasible, unsafe or time consuming.

Further details of the method can be found in WI „Monitoring & Data (hydrometry) – Field Gauging, Acoustic Doppler Current Profilers (ACDP)

Principles of current meter gauging

Further reading

This section must be read in conjunction with „Monitoring & Data (hydrometry) – Field Current Meter Gauging‟ Work Instruction**,** for additional information and the Foundation 1 Training Course Notes.

Principle of the method

Velocity-area method

Current meter gauging is based on the velocity area method, described below.

Flow rate or discharge (Q) for a river cross-section can be determined from the mean velocity and area of flow:

Q = V x A

where: Q = Discharge (m^3/s)
V = Mean velocity in cross-section (m/s)
A = Cross-sectional area of flow (m^2)

This is known as the **velocity area method**. Most methods of discharge measurement are based directly or indirectly on this method.

Current meters measure the point velocity at their deployment position. Velocity and depth measurements are made at a number of positions (verticals) across the channel cross-section (see Figure 4.1). The portions encompassed by each pair of these verticals are referred to as panels. The mean velocity (v) in each panel and the related panel area (a) are determined and their product gives the discharge in each panel. The summation of the discharge (q) in each panel gives the total discharge (Q) in the measuring section (area A).

Thus:

- $q_i = v_i \times a_i$

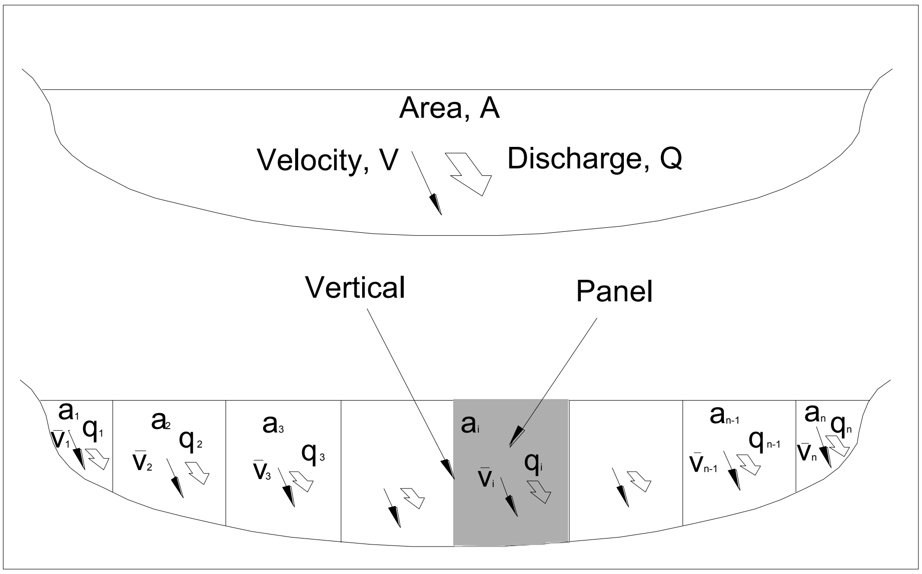
where:

- i = number of the panel (*1 to n*)
- n = the total number of panels

TOTAL DISCHARGE:

(Q) = $q_1 + q_2 + q_3 + \ldots q_n$
= sum of discharges in each panel

Figure 4-1 Diagram illustrating the velocity area method



Selection of site

General

In choosing the site, it must first be established that the flow at the site represents the data required for the purpose.

Where the derived result will be used to check a stage-discharge relationship, hydrometric staff must be satisfied that the flow represents the relationship at the gauging station.

Particular care must be taken about the proximity of any tributary or distributary, discharge or abstraction.

The possibility of flow loss due to bed leakage or accretion of flow from groundwater may (in some areas) also have a bearing on the site selection.

Site characteristics

In practice there is very rarely an “ideal” location for current meter gauging. Hydrometric staff (by necessity) are often required to take measurements in far-from-ideal conditions. The choice of individual measuring sites must endeavour to minimise the amount of effort and time involved, while at the same time minimising measurement uncertainties.

Choice of meter/impeller

Rotating element current meters (REMs)

The REM consists of an impeller (buckets or vanes fixed to a spindle) rotated by moving water. The local flow velocity or point river velocity is proportional to the number of revolutions per second of the rotor.

REMs can be divided into types:

- vertical-axis meters with buckets (cups) or vanes;
- horizontal axis meters with helical screws (impellers) or vanes.

Examples of both types of meter are illustrated in Figure 4.2. The Environment Agency no longer uses the former. Because of this, the remainder of this manual only refers to the horizontal axis impeller type of REM.

Horizontal axis REMs

Some makes of horizontal axis REMs are provided with a selection of associated impellers intended for use under different circumstances. Only the combination of meter and impeller that has undergone a valid calibration must be used. The choice of meter and impeller will depend on factors such as the depth of and velocity of water, as well as whether a means of suspending the meter from a cable is required.

Table 4-1 gives some guidance for the selection of meter and impeller combinations.

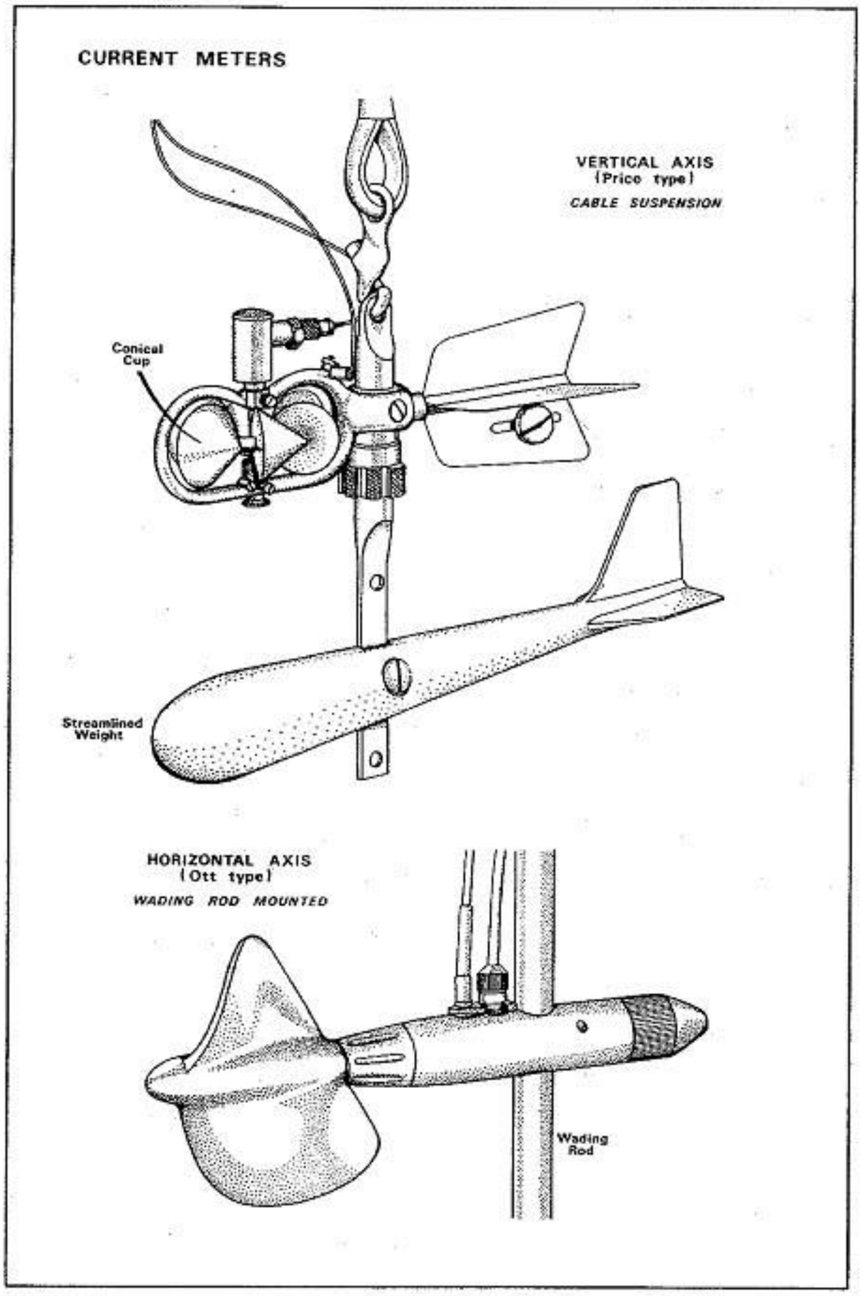
ISO 748 states that “no rotating element current meter shall be selected for use in water where the mean depth is less than four times the diameter of the impeller that is to be used”. In reality, this would preclude many gaugings being carried out on small streams. It is recommended that, providing the impeller is fully immersed, and sufficiently far away from the bed to prevent fouling, then a velocity reading can be taken. The field sheet must be annotated accordingly in order to keep a record of this non-compliance with the standard.

There are three makes of rotating element current meter used by the Environment Agency; these are summarised as follows:

Make	**Types**
Ott	C1; C2; C3.
Seba	F1; M1
Valeport – Braystroke meters	BFM 001; BFM 002; BFM004

The potential uses of these meters are described in the following sections.

Figure 4-2 Examples of Vertical and Horizontal Axis Current Meters (Gregory and Walling (1973), “Drainage Basin Form and Process”)



OTT C31/ Braystoke BFM001/ Seba F1

These are standard current meters, which are suitable for use in all but the smallest rivers and streams. Depths must generally be greater than 0.35m. These meters tend to be fairly rugged and robust in comparison with the smaller meters described in section OTT C1 or C2/Braystoke BFM004/Seba M1 below. The meters are suitable for use with cableways and suspension derricks as well as wading rods. They must be used for all applications provided there is sufficient depth across the cross-section in which to fully immerse the impeller.

OTT C31s and Seba F1s have steel bearings, which require oil lubrication. The Braystoke meters have fibre bearings that are lubricated by the water in the river or stream. The Braystoke meter is provided with only one standard impeller.

OTT C1 or C2/Braystoke BFM004/Seba M1

These current meters are used for wading gaugings in channels with shallow depths.

Their main advantage over the larger meters referred to in section OTT C31/ Braystoke BFM001/ Seba F1 is their smaller diameter impellers. This allows their deployment in shallow water. However, they are not as robust as their larger counterparts. In particular the Ott C1 and the Seba M1 were originally developed mainly for laboratory work. **Care has to be taken not to knock the spindles since these are very susceptible to damage (they bend/go out of alignment very easily) and thus lose calibration**.

The BFM 004 meter is no longer in production but it is still supported to a certain extent by Braystoke. Because only a few were purchased, the model will have limited further application within the Environment Agency.

The Ott C2 and the Seba M1 gauging poles have a 6-7mm offset unless the relocating device is being used. This means the water depth as seen on the pole is overestimating the depth by 6-7mm, so this discrepancy needs to be taken into account. When setting the meter on the rods unlike the other meters you need to align the height required with the top of the body of the meter not the centre.

Note: The Ott C1 meter is an earlier version of the Ott C2.

Braystoke BFM002

The Braystoke BFM 002 is smaller than meters referred to in section OTT C31/ Braystoke BFM001/ Seba F1. Its impeller diameter is similar to the larger impeller sizes available for the small meters referred to in section OTT C1 or C2/Braystoke BFM004/Seba M1. It is more robust than the other small meters so can be used on larger rivers as well as smaller streams and channels. Cableway and suspension derrick deployment is possible with this meter. Arguably, it is sized somewhere between the standard sized meter and the small/mini meters.

Choice of impeller

The choice of meter and impeller will ultimately be dependent on site conditions. As a general rule, the greater the curvature of the impeller (i.e. the smaller the pitch of the helix), the greater the surface area it presents to the water. Therefore, impellers with lower pitch must be used where velocities are lower. **The meter/impeller combination must only be used within its calibrated range and care must be exercised when measuring velocities close to the minimum response speed**. Furthermore, for shallow depths of flow it is important to select an impeller with a diameter that is sufficiently small.

In order to assist with the choice of meter and impeller, Table 4-1 contains dimensions and limits of application for meters to which reference is made in this manual.

Particular caution needs to be exercised when using the Ott C2 meter No. 6 impeller. Although its smaller diameter allows its deployment in very shallow water, its minimum speed of response is typically 0.06m/s compared to 0.04m/s for the No. 3 impeller. Similarly, Braystoke, BFM 002 and 004 have smaller diameter impellers but their minimum response speed is higher than the BFM 001.

Electronic (EM) current meters

Introduction

The EM current meter operating principle is based on Faraday"s law of Electromagnetic Induction, whereby a conductor moving through an electromagnetic field creates an electromotive force (voltage).

The speed of movement of the conductor (in this case water) is proportional to the magnitude of the electromotive force.

For further details on the technique, reference must be made to the following:

- National Rivers Authority (NRA) R&D notes:R&D Note 333: "Calibration of Portable Electromagnetic Current meters - Performance Evaluation";
- R&D Note 410: "Calibration of Portable Electromagnetic Current meters - Field trials".

Two examples of electromagnetic meters are shown in Figure 4.3. EM current meters (like conventional REMs) only sample point velocities. They have the advantage of having no moving parts and thereby eliminate all friction and resistance. They can measure to a very low value and can potentially measure negative velocities. They can operate in silty or weedy water (refer to "When to use an EM meter", below). Although they can measure velocities as accurately as REMs operating within their known calibration range, they can be susceptible to electrical interference effects, which may not be obvious to the field user.

EMs must be check-calibrated throughout the range of velocity for which they are to be used and must meet accuracy requirements similar to those of REMs.

They must not be used outside the range of calibration. Although capable of operation in shallow depths and of detecting and measuring very low velocities (including negative velocities), they must not be selected for use in water whose mean depth is less than three times the vertical dimension of the probe.

When to use an EM meter

In view of their susceptibility to electrical interference, EM meters must only be used at sites or in circumstances where a properly maintained REM cannot deliver the required performance in velocity measurement. This would normally be limited to situations such as:

- weed infested water (see note below);
- water with a high incidence of entrained materials (e.g. raw or screened sewage or water with high sediment concentrations);
- water velocities close to or below the stall speed of the most sensitive mechanical meter available;
- rapidly changing flow, where speed of gauging is important.

Note: Even the use of EM meters must be avoided whenever possible in weed-infested waters. The EM meter is not affected by weed trailing round the sensor, as is the case for an REM meter. The occurrence of weed growth in the cross-section creates abnormal velocity distributions both in the vertical and in the horizontal. For example, in weed infestations, the classical 0.6 of depth positioning of the meter (see section Measurement of depth below) in the vertical might not be applicable. Thus, the EM meter is no substitute for channel clearance.

Figure 4-3 Valeport Electromagnetic Current Meter Sensing Head

Acoustic Doppler Velocimeters (ADVs)

Introduction

ADVs use the Doppler shift principle to measure the velocity of particles in the water. A unit will have a transmitter and from 2 to 4 receivers. They are used in the same way as REM or EM and take a spot velocity reading that can be used to calculate the total flow. See figures 4.4 and 4.5 below that show examples of available ADVs.

When to use an ADV

- ADVs can be used in place of a REM
- As the ADV has no moving parts it can be used in slower flows where the velocity to initiate movement in a REM may not easily be achieved
- Where there is a high silt load in the water column.
- At the time of writing you will need to check with your team leader if the use of ADV"s has been approved.

Figure 4-4

Picture of a Sontek Flowtracker

Figure 4-5 Picture of an OTT ADC

Meter Type	Impeller Type	Impeller diameter/ head depth (m)	Impeller pitch (m)	Minimum depth of water for deployment to comply with ISO 748 (m)	Typical minimum response speed (m/s)	Typical maximum operating speed* (m/s)
REM Meters						
OTT C31	1	0.125	0.25	0.5	0.06	3.00
	2	0.125	0.5	0.5	0.06	3.00
	3	0.125	1.0	0.5	0.055	
	4	0.08	0.125	0.32	0.04	1.50
OTT C2	1	0.05	0.05	0.2	0.03	0.60
	2	0.05	0.1	0.2	0.04	1.20
	3	0.05	0.25	0.2	0.04	2.50
	4	0.05	0.5	0.2	0.08	5.0
	5	0.03	0.05	0.12	0.06	0.60
	6	0.03	0.1	0.12	0.06	1.20
SEBA F1	80/125	0.08	0.125	0.32	0.025	5.0
	80/250	0.08	0.25	0.32	0.025	10.0
	80/500	0.08	0.5	0.32	0.025	10.0
	125/125	0.125	0.125	0.5	0.025	5.0
	125/250	0.125	0.25	0.5	0.025	10.0
	125/500	0.125	0.5	0.5	0.025	10.0
	125/1000	0.125	1.0	0.5	0.025	10.0
SEBA M1	30/50	0.03	0.05	0.12	0.03	0.50
	30/100	0.03	0.1	0.12	0.03	1.0
	50/50	0.05	0.05	0.2	0.025	0.50
	50/100	0.05	0.1	0.2	0.025	1.0
	50/250	0.05	0.25	0.2	0.03	2.50
	50/500	0.05	0.5	0.2	0.05	5.0
Braystroke BFM-001	8011	0.127	0.27	0.508	0.03	5.0
	1178	0.05	0.1	0.2	0.04	2.0
Braystroke BFM-002	911	0.019	0.04	0.076	0.07	1.50
Braystroke BFM-004	912	0.028	0.04	0.112	0.05	1.50

*Current meters must not be used at velocities outside their calibration range.

Meter Type	Impeller Type	Impeller diameter/ head depth (m)	Impeller pitch (m)	Minimum depth of water for deployment to comply with ISO 748 (m)	Typical minimum response speed (m/s)	Typical maximum operating speed* (m/s)
EM meters						
Ott Nautilus C2000	N/A	0.02	N/A	0.08	0	1.50
Marsh-McBirney Flo-Mate	N/A	0.03	N/A	0.12	-0.15	6.00
Aqua Data Sensa-RC2	N/A	0.02	N/A	0.08	0	4.00
Valeport	N/A	0.015	N/A	0.06	-5.0	5.0
ADV meters						
Sontek Flowtracker	N/A	0.13 (width)	N/A	0.08	±0.001	±4.0
OTT ADC	N/A	0.04	N/A	0.16	-0.2	2.5

Table 4-1 Different current meters and impellor types

Measurement of width/horizontal distance

Introduction

Measurement of the width of the channel and of individual segments or the position of a vertical across the river is obtained by measuring the distance from or to a fixed reference point on one of the river banks.

Methods

The method selected depends on the width of the channel and the method of deployment. The methods which can be used include:

- measuring staff or rule;
- surveyor‟s tape;
- calibrated cable, rope or wire;
- surveying techniques such as tachometry, geometric methods (e.g. pivot method), sextants, electronic distance measuring devices;
- differential global Positioning Systems (GPS).

For the majority of gauging work undertaken by the Environment Agency only the first three methods listed above are utilised.

Wadeable channels

For most wadeable channels (<50m) in this country the width can be measured directly by means of a tape or marked tag line fixed across the river section. A metric tape must be used and fixed as taut as possible across the section, at right-angles to the flow. The tape must not stretch and must be waterproof.

Bridge gauging

At bridge gauging sites, a tape can be stretched horizontally across the parapet of the bridge. Provided there are no aesthetic problems in doing so, it is often a good idea at permanent bridge sites to put permanent distance measuring marks on the bridge parapet.

Cableway sites

At cableway sites the current meter is moved across the river using a bank side winch. A distance counter (the calibration of which is based on the diameter of the cable drum and cable) is used to determine the distance traversed from the bank side reference point where the counter is zeroed.

Boat gauging

For boat gauging undertaken by the Environment Agency the width and position of the boat in the horizontal are measured using a calibrated rope, tag-line or cable to which the boat is attached (and thus held steady) while velocity measurements are being made.

Measurement of depth

Introductions

Depths can be measured using the following:

- metric rule;
- graduated gauging rod;
- surveyor"s measuring staff;
- calibrated hand-held suspension line;
- gauging suspension cable winch and gantry with depth counter;
- echo-sounder.

Echo-sounders are not usually used by the Environment Agency for river gauging purposes.

Unless a more detailed cross-section is required, it is sufficient to take a depth measurement for each vertical being used for velocity measurement. Where the depth of the channel allows, this depth measurement must be made directly using the current meter rod, by placing the rod base directly on the riverbed. The current meter rod is usually graduated in centimetres, which is sufficient resolution for most applications. In shallow streams it is necessary to interpolate between centimetre marks to estimate the depth to the nearest millimetre in an attempt to improve accuracy.

Irregular or unstable bed profile

For irregular or unstable bed profiles, it is recommended that two depth measurements are made and the average of these taken in order to reduce the error in measurement. In the case of a soft, silty riverbed it is important that the base of the current meter rod is not allowed to sink into the riverbed thereby giving an erroneous reading.

Boats and bridges

Depth measurements can be made from boats and bridges by the use of either rods or suspension cable. The choice will be dependent on site conditions.

Suspension winches can be used from bridges or boats. The design of the gantry is the only significant difference between the two. A sinker weight (sometimes referred to as a fish-weight or bomb) has to be attached to the suspension line to keep it as vertical as possible. The choice of sinker weight will depend on the equipment used and site conditions. The sinker weight is often attached to the current meter by means of a hanger bar. The distance between the centre-line of the axis of the current meter and the bottom of the sinker weight must be measured and allowance made for this when measuring depth and positioning the meter. Ensure the meter and not the sinker weight is positioned at the required position in the vertical.

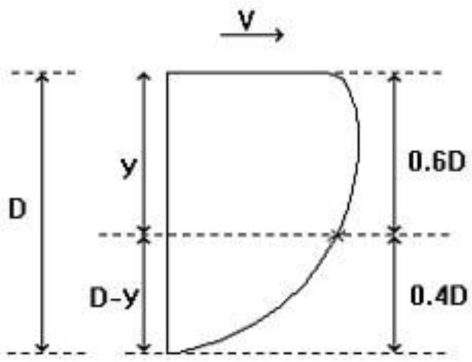
The winch has a calibrated depth-measurement counter. This is zeroed with the fish weight or current meter just touching the water surface. The current meter and sinker weight are then lowered to the bed of the river and the depth can be obtained from the counter when the weight just touches the riverbed. The counter is also used to fix the position of the meter in the vertical.

Measurement of velocity

Velocity profile

Velocity usually varies with depth in a river channel. The classical velocity profile is typically as in figure 4-6.

Figure 4-6 Classical form of the velocity profile



Where:

V = velocity
D = total depth
y = position relative to water surface

Velocity measurement

The measurement of discharge using a current meter requires an estimation of mean velocity in each vertical. Current meters only measure point velocities and a method is therefore required to use point velocity measurements to obtain the mean in the vertical. A number of methods exist which are summarised in Table 4-2 below.

The most accurate method of obtaining the mean velocity in a vertical is through the use of the velocity distribution method. This involves the measurement of velocity at a number of points down each vertical between the water surface and the channel bed, with spacing between them chosen so that the difference in velocity between two adjacent points is not greater than 20%. The mean velocity can be obtained by means of digitising equipment after the velocity observations have been plotted in graphical form. However, this method is time consuming. An alternative method using a reduced number of points in the vertical is usually preferred. Provided the site characteristics are in accordance with those recommended in Section Site characteristics the use of a well-executed, reduced-point method must not result in a significant increase in the uncertainty of the flow measurement in comparison with one undertaken using the integration or velocity distribution method.

In these other methods the meter is positioned relative to the surface. For the standard, single-point method the meter is positioned at 0.6 of the depth (0.6D or $v_{0.6}$) from the surface or 0.4 of the depth from the river bed (see Figure 4.6). For example, if the depth in a vertical is 2.0m the current meter must be positioned at 1.2m from the water surface or 0.8m from the bed. A recognised alternative is to position the meter at 0.5D.

Method	**Measurement (at proportion of depth from surface)**	**Estimation**	**Uses**
One-point method	**0.6**	$v_m = v_{0.6}$	**Standard for D < 1m.**
Alternative one-point method	**0.5**	$v_m = 0.95 \times v_{0.5}$	**Use at shallow depths or for ease of calculation**
Two-point method	**0.2; 0.8**	$v_m = 0.5(v_{0.2} + v_{0.8})$	**Standard for D > 1m.**
Three-point method	0.2; 0.6; 0.8	$v_m = 0.25(v_{0.2} + 2v_{0.6} + v_{0.8})$	Used either when greater accuracy is required than the one- or two- point methods would give or when the classic profile is not present
Five-point method	s; 0.2; 0.6; 0.8; b	$v_m = 0.1(v_s + 3v_{0.2} + 3v_{0.6} + 2v_{0.8} + v_b)$	
Six-point method	s; 0.2; 0.4; 0.6; 0.8; b	$v_m = 0.1(v_s + 2v_{0.2} + 2v_{0.4} + 2v_{0.6} + 2v_{0.8} + v_b)$	
Surface one-point method	s	$v_m = c \times v_s$ (c = variable coefficient)	Use when other methods are not feasible (e.g. in flood conditions).
Velocity Distribution method	A number of velocity measurements are taken in the vertical (points chosen so that the difference between successive velocity readings is less than 20%). These are plotted against decimal fraction of depth from the surface, and the mean velocity is calculated by measuring the area under the curve using digitising equipment.		Used when a very high level of accuracy is required as the method is time consuming. Can be used for research into irregular velocity distributions. Not appropriate for rapidly changing stage.

Table 4-2 Methods of estimating mean velocity in a vertical
NOTE: „s" is a velocity measurement just below the surface and „b" a measurement just above the bed.

Method choice

The one-point (0.5D or 0.6D) and two-point (0.2D & 0.8D) methods are adequate for most routine fieldwork. The one-point method should generally be used for depths of less than 1.0m. The two-point method should generally be used for depths greater than 1.0m.

Factors such as weed growth, obstruction in the channel (e.g. bridge piers) and a rough channel bed can affect the velocity profile. In such cases the reduced-point methods might not accurately represent the mean velocity and the number of points must be increased as time and other constraints allow. For special research investigations and calibration flow measurements at important or difficult sites, consideration must also be given to using more points in the vertical.

Some Environment Agency Regions have adopted a system whereby up to five metres can be mounted on the same rod or suspension device which are linked to a multi-channel revolution counter and timer for gauging at important sites on major rivers, particularly where irregular velocity profiles are known to occur.

General gauging procedure

General

General procedures and more detailed deployment-specific routines have been developed and must be adopted for all current meter gauging work. See document: WI Monitoring & Data (hydrometry) – Field Current Meter Gauging

Health and safety

The instructions and guidelines contained in the Environment Agency‟s Generic Task Risk Assessments and other manuals, safety instructions and regulations in current use must be adhered to at all times. Such documents must be provided to all hydrometric field staff. Because of this, no attempt has been made to reproduce these in this document. Instead the relevant pages of the Environment Agency‟s Generic Task Risk Assessments have been cited for each of the different deployment methods and gauging procedures described in the following sections.

Field tests

REM field spin test

At the start of a gauging (or a set of gaugings) it is important to ascertain whether the meter is operating normally and whether the counter is giving a correct reading. For the oil-lubricated REMs a standard field spin test must be carried out.

Zero stability tests for EMs

As a routine preliminary to using an EM meter at any site it is recommended (and in addition to any still water stability test that a manufacturer may recommend) that a zero stability test must be carried out.

ADCP/ ADV self tests

As a routine preliminary to using an ADCP or ADV the proprietary self test/ fault diagnosis programs should be run.

Number of verticals

General

The number of verticals is determined by the size, shape and regularity of the channel and the velocity profile across the measuring section. If too few verticals are used, this can cause the largest potential error in the current meter discharge estimate.

Number of verticals

The following guidelines for the selection of the number of verticals must be used:

Channel width (m)	Minimum number of verticals*
0 to <0.5	5 to 6
>0.5 to < 1	6 to 7
>1 to < 3	7 to 12
> 3 to < 5	13 to 16
>5	>22

For channel widths >5m, the number of verticals must be chosen so that discharge in each segment is less than 5% of the total insofar as possible and in no case exceed 10%.

Notes:
* **- In addition two of the verticals included in the above are required to be close to each of the two water’s edges** (i.e. at a distance from the edge of slightly greater than half an impeller diameter, if possible).

- depths must be measured at the water‟s edge if the banks are vertical. If the banks are sloping to the water‟s edge, the depth at the edge shall be recorded as zero;
- the velocity at the water‟s edge shall always be recorded as zero;
- the difference in depth between two adjacent verticals must not exceed 50% of the smaller;
- the difference in velocity between non-zero samples taken at the same proportion of depth in adjacent verticals must not exceed 50% of the smaller.

Generally, such standards must be considered as a **minimum requirement**, rather than an upper limit.

Depth measurement – pre-surveyed cross sections

General

The methods of measuring depth are referred to in Section Measurement of depth. The procedure to be adopted is dependent on the specific gauging method to be used. Depth measurement techniques are covered further below.

Pre-surveyed cross sections

Many cableway and some bridge gauging sites in this country are regularly surveyed to give a known cross-section which can be applied when undertaking subsequent current meter gaugings. This has a number of advantages which are highlighted as follows:

- the pre-survey can take place at low flows giving greater accuracy, since at high flows there tends to be a pull on the cable, giving erroneous depth readings;
- the measurements are related to a stage reading and the depths at higher flows can be easily calculated by adding the level difference;
- the pre-surveyed section also leads to a greater consistency between gaugings, allowing for direct comparison between measurements;
- gauging is easier and quicker as the meter only needs to be lowered once at the correct depth setting for each measurement;
- for some sections it may be easier to use a boat to survey depths for a pre-surveyed section;
- levels of known points on the banks can also be surveyed relative to the water surface, to give an estimation during out-of-bank flow.

It must be noted that where there are regular changes in the bed section due to erosion or deposition a pre-surveyed section must not be used for gauging calculation. Where this happens the depths must be measured during each gauging.

When it is not possible to measure depths accurately due to high velocities, and in the absence of a pre-surveyed cross-section, the position of the water level relative to a known datum must be ascertained at the time of gauging. A survey of the cross-section must then be undertaken as soon as possible after the flood has passed. In such circumstances velocities must be measured just below the water surface and multiplied by 0.85 to estimate the mean velocity in the vertical.

Exposure time

General

Exposure time is the time over which the current meter revolutions are counted. The exposure time to be selected will be dependent on the physical characteristics of the river channel being monitored. However, it is important that the time selected is sufficient to minimise errors due to **pulsations**. Conversely, if the discharge is changing rapidly the time selected must not be too long. The following is recommended:

Exposure time

For routine applications it is recommended **that a minimum exposure time of 50 seconds** be adopted. It must be noted that on some very large rivers under certain flow conditions, a longer exposure time might be appropriate; e.g. on the lower Thames at Kingston exposure times of as long as 180 seconds have been used during special investigations.

If the velocities are very low and there are less than 20 counts in 50 seconds in mid-stream, the exposure time must be increased to 100 seconds. Alternatively the time it takes to record 20 revolutions could be measured.

Approximately 10 seconds must be allowed before the start of measurement to allow for settling and to prevent any effect from the movement of the meter into the water. If a suspension cable or hand-line is used this settling period might have to be longer to minimise the effect of cable swing/oscillation.

Timers

Most modern current meter revolution counters have an in-built timer. In some circumstances a separate timing device might be used which is not linked to the counter (e.g. it might not be possible to stop the counter and the timer automatically at the same time). An example of this is a simple on/off counter with a separate stopwatch. **In such situations it is essential that the actual time on the stopwatch is recorded and not the target exposure time**. For example, if an exposure time of 50 seconds is being used and the counter and stopwatch are stopped at 50.5 seconds, then the latter time must be entered on the field sheet.

EMs

For EMs the following must be noted:

Velocity samples must not be integrated over periods of less than 50 seconds. If the meter control electronics unit allows it, an integration period of 100 seconds should be set. Alternatively, pairs of 50-second samples at each meter placement in the gauged cross-section must be taken and the average of the two results must be noted.

If electing for a short period velocity integration (less than 30 seconds), in order specifically to reduce the overall gauging time, expect significant measurement volatility (up to +/- 20%), particularly in turbulent flow regimes.

If using a “continuously reading” form of device display, when moving the EM meter head from one point to another within the cross-section, allow not less than ten seconds for the meter to stabilise before noting a velocity reading.

ADCPs

The equivalent of an exposure time for an ADPC gauging is determined by the amount of time taken per transect and the setup of the instrument. It is recommended that the minimum time to complete a transect of any size channel should be 180 seconds.

Rapidly changing stage

In conditions where the stage is changing rapidly, such as the rising or falling limb of a flood peak, it is possible that the exposure time could be reduced to 30 seconds. Further details of adjustments to standard gauging procedure to reduce the overall time of the gauging are detailed in R & D Report 529, “Current Meter Gauging Methods - Small Streams and Rapidly Changing Stage”.

Electromagnetic and ADV current meters

Application

The procedures outlined in the sections below from „Wading‟ to „Boats‟ mainly apply to REMs. They also apply to EMs and ADVs unless otherwise stated. EMs and ADVs are currently mainly used for wading gauging or bridge gauging by means of rods. However, at least one version can also be used with a suspension kit. Therefore, there is no reason why they cannot be used from cableways, boats and higher bridges.

Wading

Equipment

The standard gauging equipment required for a wading gauging includes:

- a current meter attached to a graduated rod, a connecting cable from the meter to the counter;
- a revolution counter and timer or suitable field computer or control box;
- a metric tape or rule, pegs or stakes for attaching the tape on each bank if no secure fixing is already available;
- any safety equipment necessary.

Reference must also be made to BS3680, Part 3Q – „Guide to safe practice in stream gauging‟.

Current meter

The current meter chosen must be appropriate for the site (see Section Choice of meter/impeller), and must be easily moved up and down the rod. This can either be done directly by tightening a screw on the meter at the appropriate point, or by the use of positioning collars. When a positioning collar is used the current meter is attached to an outer metal sleeve that can be moved up and down the inner rod. Slightly more calculation is required to position the meter but the gauger‟s hands do not have to go into the water. This is useful when working in polluted rivers or for some bridge gauging applications

Modifications to channel

The channel bed must be as even as possible. This may mean that debris and large rocks need to be removed. To ensure that the channel edges are well defined, weed growth or other vegetation at the edges may need to be cut, so that there is flow over the full channel width. Alternatively, the channel edges may need to be reconstructed to narrow the channel width in order to provide a measurable velocity. House bricks or stout wooden planks may be used at an angle to produce a more appropriate channel width. In such cases care must be taken to gauge across a section with parallel sides immediately downstream of any funnelling. In addition, weed growth in the vicinity of the gauging reach may need to be removed to ensure a smooth river approach and to prevent weeds drifting into the impeller path and reducing counts.

Modifications to the channel and/or weed removal may cause unsteady flow conditions to occur. A settling period is required to allow conditions to stabilise before commencing gauging.

Cableways

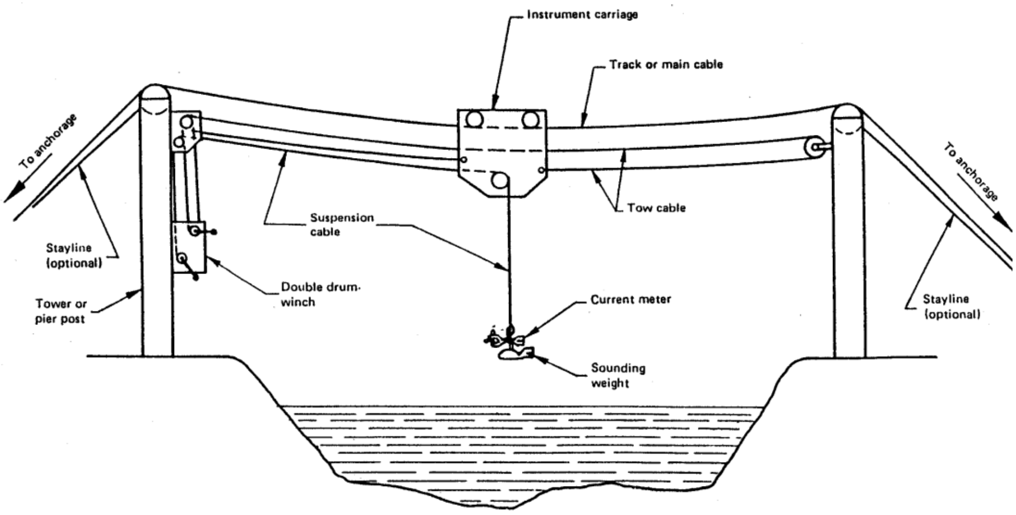
Equipment

Normally a cableway consists of a stanchion on each bank, which support a main cable between the two (See Figure 4.7). An additional traversing cable is used by the observer to move a carriage or trolley across the river from the bank, with the aid of a winch unit. The current meter and sinker weight are attached to the bottom of the trolley by a coaxial cable, which is used to control the vertical position of the meter and also to send signals back to the counter unit on the bank. The current meter is similar to those used for wading gauging, except that it has a tail fin, to give directional stability and keep the meter in line with the flow, and a sinker weight attached to the bottom, to keep the cable in line with the vertical.

Cableways can also be used for ADCP gauging to simply tow the unit across the channel.

Cableways are normally permanent installations. However, portable and semi-portable systems are available for which similar basic principles apply.

Figure 4-7 Cableway system with tow cables in endless circuit and separate suspension system (Source BS EN ISO 4375:2004).

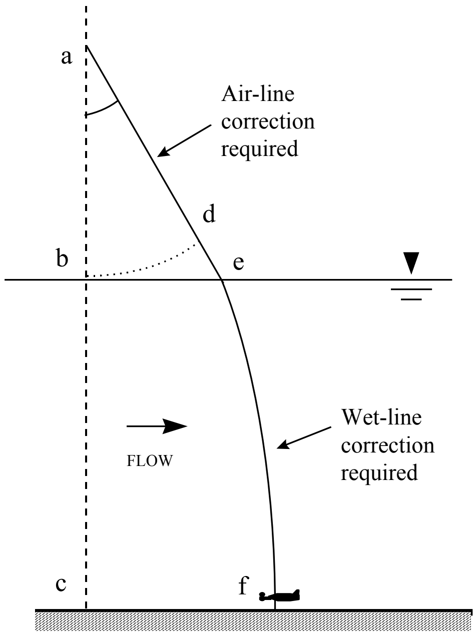


Air/wet line correction

In high flows the current meter and weight assembly has a tendency to move downstream with the current of the water. This causes depth overestimation when gauging from cableways. It is also difficult to set the meter in the correct position, particularly when calculating the depth setting from a pre-surveyed cross-section. The action of the river current results in the meter being set higher than the desired position. In order to overcome the problems two correction factors are used. The air-line correction factor accounts for the extra cable above the water and the wet-line correction factor is used to take account of the extra length in the arc of the line below the water surface (see Figure 4.8). Both correction factors can be read from tables, when the figure corresponding to the angle θ from the vertical and either the vertical height (above the water) or the vertical depth (below the water) are recorded. Air line and wet line correction tables are contained in ISO 9209:1989.

For some cableway installations, the angle of the current meter cable can be measured using pre-drawn angles on engraved glass on the window between the winch operator and the cableway. This cuts out some of the error inherent in estimation of the angle.

Figure 4-8 Sketch illustrating the concept of air line and wet line corrections



Air line correction = de = ae - ab

Wet line correction = ef – bc

Bridges

General

Where wading or cableway gauging is not possible, bridge gauging is an alternative even though conditions are not always ideal e.g. skew flow conditions being created by the bridge piers. Single or limited span rectangular cross-section bridges, which do not cause a constriction to flow, are the best type of section.

The current meter is usually suspended from the bridge by means of a hand-line or suspension derrick and winch. Rods may be used from lower bridges such as footbridges.

There must be a free drop from the bridge parapet to the river. Suspension bridge stanchions and cables can cause problems since they cause obstructions thus preventing the easy, smooth movement of equipment across the measuring section. For example, the current meter has to be raised completely to the top of the bridge and manoeuvred round obstructions to gain access to the water at each vertical.

Upstream of bridge

For gauging, the option may be available of using the upstream or downstream side. The downstream side is more frequently used but this is not invariably the best side. The advantages of using the upstream side are:

- hydraulic characteristics at the upstream side of the bridge openings are often more favourable;
- approaching floating debris can be seen with less difficulty;
- the streambed at the upstream side of the bridge is not likely to scour as badly as at the downstream side but there may be afflux if the bridge waterway is tight.

When gauging from the upstream side of a bridge care must be taken to ensure that the cable hangs free from the face of the bridge structure, particularly in high velocity situations where the meter moves downstream under the bridge i.e. it is not suspended vertically below the suspension point.

Downstream of bridge

The advantages of using the downstream side of the bridge are:

- vertical angles are more easily measured because the sounding line will move away from the bridge;
- the flow lines of the river may be straightened out by passing through a bridge opening with piers;
- the downstream side is less likely to be affected by accumulation of debris against piers.

Equipment and procedure

There are three main methods of bridge gauging:

- the rod method can be used in situations where there are lower bridges, moderate water depths and lower velocities;
- otherwise the derrick winch/A Frame method, or
- the manual handline method can be used depending on conditions.

Rod suspension

Low footbridges can sometimes be used on a small stream with **rod suspension** with extension rods. The procedure in low velocities is the same as for a wading measurement, but the procedure for obtaining the depth in higher velocities must be modified to eliminate errors in depth measurement caused by the water piling up on the upstream face of the rod as follows:

- for each selected vertical, an index point is established on the bridge;
- the distance from this point to the water surface is measured by lowering the rod until the base plate just touches the water;
- the rod is then lowered to the bed and the reading again noted at the index point.

The difference in these readings is the depth of water in the vertical.

Gauging from a bridge with rods is easier if a positioning collar and sleeve is used.

Handline method

The **handline method** involves the use of a suspension rope, which has distance measuring marks or a separating measuring tape. The current meter to counter connection cable is usually attached separately. The handline is used to manually lower and lift the current meter and sinker weight. The equipment is portable but there are a number of drawbacks. It can involve considerable physical exertion and imposes a limit on the sinker weight and therefore the river velocity that can be measured using this method. Often two people are required in order to lift the weight and to mark reference points on the cable, in order to minimise the errors involved due to movement of the cable. The method is usually appropriate where it is too deep to wade, where it is not possible to use rods or where there is insufficient room for a winch derrick/A Frame.

Derrick winch or A frame

Using the **derrick winch or A Frame** is a very similar methodology. However, heavier sinker weights can be lifted, so this may be more appropriate for faster flowing, larger rivers, and also from higher bridges. The current meter equipment can be more easily wound up and down, but the winch is bulky and heavy and requires transport. As some types of A frame need to lean against the bridge, they may not be suitable for all bridges and a self-supporting version mounted on a trolley may be required. It is important not to use a sinker weight heavier than that recommended by the manufacturer of the derrick. In most cases the equipment will need counter-balancing to prevent the derrick toppling over.

Note: A-Frames are often unstable so care must be taken to ensure they do not move, slip or tilt suddenly. Such sudden movement could cause injury to the operative(s) and/or damage to the equipment.

The procedure for measuring depths and positioning the current meter using a bridge suspension outfit or handline **is similar to that undertaken for a cableway**.

Bridge piers

Bridge piers can have a significant effect on the accuracy of the gauging, as they can create turbulence and thus affect flowlines. They often cause variations in velocity, angular flow and in some cases scour and deposition. Where using a bridge with piers is unavoidable, sufficient measurements must be taken to ensure that the effect of the piers can be assessed. If the gauging can be carried out between the bridge piers it may be best to treat each arch as a separate gauging. The flow estimates for each bridge section i.e. between each pair of bridge piers must then be summed to obtain the total flow.

Correction factors

As for cableway gauging, air line and wet line correction factors will be required if the cable is not vertical. A further correction factor may be required for skewed flow if the bridge is not normal to the flow of the river. A simple factor can be used equal to the ratio of the width of the river to the length of the bridge.

ADCPs

An ADCP can be deployed from a bridge. The unit must first be carefully lowered from the bridge into the water. The gauging can then be done by towing the unit on a single line or preferably two lines, one line from each side of the unit, for maximum stability.

In some cases the bridge may be used purely as a suitable point to deploy a rope across the channel to carry out an ADCP gauging up or down stream of the bridge.

Boats

General

Boat gauging tends to be one of the last methods of current meter gauging considered, due to the greater number of staff required to comply with safety procedures and its more hazardous nature.

One of the largest problems experienced with boat gauging is the positioning of the boat. The boat can either be held in place under its own power against the current of the river (in this case someone very experienced in boat handling will be needed) or by means of a tag-line, but the rigging of this can also require some skill.

Procedure and equipment

Boat gauging within the Environment Agency is usually undertaken by stretching a cable or rope, sometimes referred to as a tag-line, across the measuring section to which the boat is attached. The cable is marked off in distance measuring units e.g. 1m intervals in order to ascertain the boat‟s position across the cross-section. A separate tape or measuring line can be used. Suspension of the current meter and measurement of depth can either be by gauging rods or by means of suspension winch and portable derrick.

The basic procedure is similar to the other methods of gauging.

- depths can be measured using gauging rods or a suspension cable system with portable winch and derrick or a handline. When using rods care has to be taken to ensure that they remain vertical;
- once the boat is in position it is important to let the boat and current meter settle before undertaking the velocity measurement. The up and down movement of the boat can cause vertical velocity components. A well designed, horizontal axis impeller meter must be able to compensate for this;
- the distance marks on tag-lines, ropes or cables must be checked on a regular basis since stretch and/or mis-positioning of the markers can occur.

Correction factors required

As for bridge and cableway gauging, when a cable is used an air-line/wet-line correction factor may need to be applied to the depth measurements.

ADCPs

An ADCP can be deployed from a boat, though it takes a skilled boat handler to control the boat to insure a perpendicular path is taken across the channel. It is also imperative that the ADCP sensor remains under a constant level of water, which is hard to achieve when using a boat.

This method would only be used if a tag line system could not be, for example on a navigable stretch of river. Another alternative to this would be to use a remote controlled boat for the ADCP.

Calculation of discharge

Introduction

There are two methods of arithmetic calculation of discharge from current meter gauging data. These are the mean section method and the mid section method.

Mean-section method

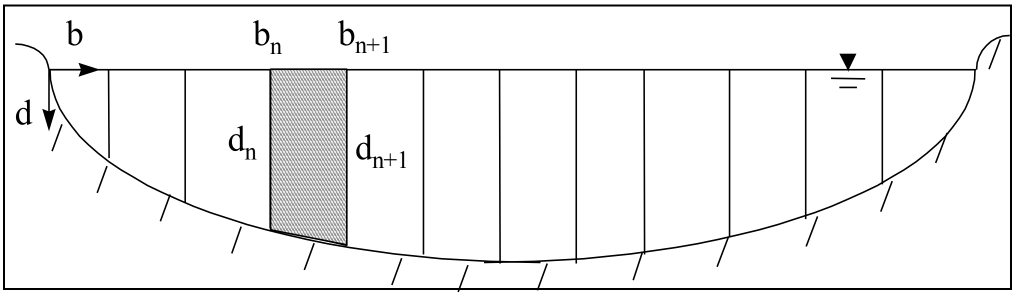


Figure 4.9 Diagram illustrating the mean section method

The flow in the shaded panel is calculated as follows:

$$Q = \left(b_{n+1} - b_n\right)\left(\frac{d_{n+1} + d_n}{2}\right)\left(\frac{\bar{v}_{n+1} + \bar{v}_n}{2}\right)$$

where $\bar{v}$ is the average velocity in each vertical.

In this method the end panels can be treated similarly to the other panels. The total flow is equal to the sum of the discharge in each panel.

Mid-section method

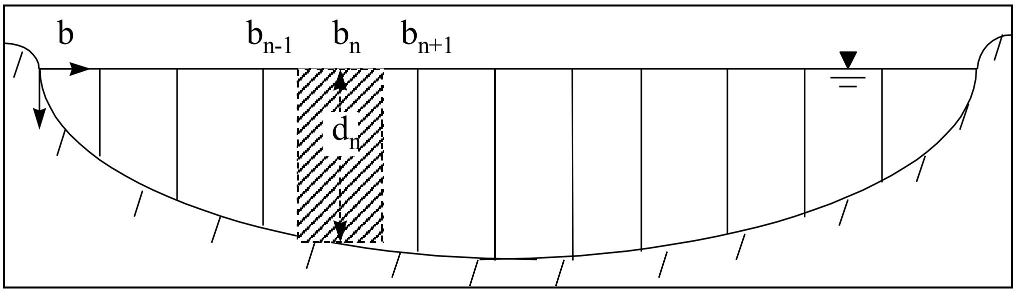


Figure 4.10 Diagram illustrating the mid section method

For this method the flow in each panel is calculated as shown below:

$$Q = \bar{v}_n . d_n \left(\frac{b_{n+1} - b_{n-1}}{2}\right)$$

where again $\bar{v}$ is the average velocity in the vertical.

The total flow is again the sum of the flow in all the panels. In this method some flow is omitted at the edges of the cross-section and therefore when gauging it is important to position the first and last verticals as close to the banks as possible. For this reason, this method is not as widely used as the mean-section method.

Skew Flow

Skew or oblique flow

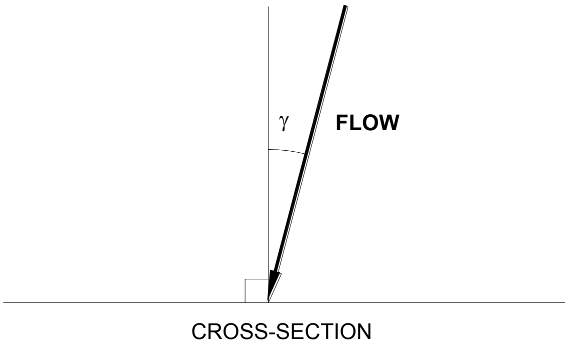
Wherever possible sections with skew or oblique flow must be avoided. Most impeller meters are designed to account for flow that is not normal to the measuring section. The error is relatively small for skew flows up to 10° from the perpendicular to the section. Therefore, in most cases the effects of skewed flow are usually ignored. When an impeller meter is suspended from a cable rather than rod mounted it will tend to measure the maximum velocity and so a velocity correction factor may be required. This must be applied to the measured velocity in order to calculate the actual velocity. This is related to the angle of the direction of the flow. Where measuring equipment is not available, in most cases it can be assumed that the angle of flow at the measuring point is equal to that at the surface. The corrected velocity is calculated as follows:

$$v_{corrected} = v_{measured} \cos\gamma$$

where γ is the measured angle to the perpendicular i.e. the oblique angle of flow (see Figure 4.11).

Figure 4-11

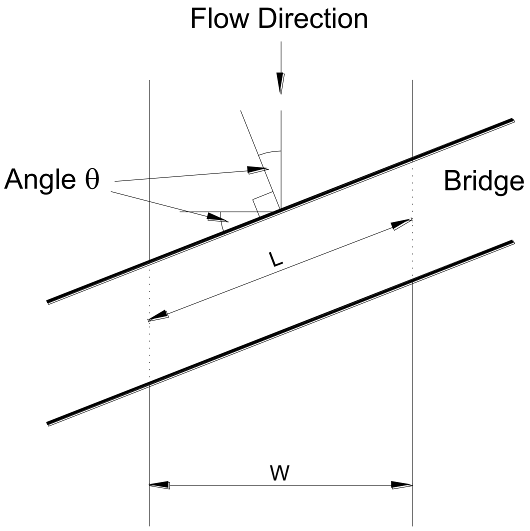
Diagram illustrating the skew flow correction



Skew flow with bridge gauging

There are occasions when it is necessary to gauge from bridges that are not at right angles to the direction of flow i.e. they cross the river at an angle. In such circumstances the measured velocities must be multiplied by the cosine of the angle (θ) made by the perpendicular to the direction of flow (line of banks) and the line of the axis of the bridge. This is illustrated in the sketch below (Figure 4.12). A simple correction factor can be obtained by dividing the actual width of the river (W) by the length of the bridge (L) i.e. correction factor = W/L which equals cosine of the angle (θ). The estimated/adjusted discharge is then obtained by computing the discharge in the normal way using the actual measured data and multiplying this initial value by the correction factor.

Figure 4-12 Sketch illustrating a bridge with its axis skew to the direction of flow



Computation of discharge

General Most discharge computations are now undertaken in the office using desktop or laptop PCs or directly in the field using hand-held computers which also contain revolution counters. The ADV current meters currently available to the Environment Agency have the flow calculation software in the inbuilt proprietary control unit/ handheld computer. In certain circumstances, it might be necessary to obtain an immediate estimate of flow in the field when no computer is available. This is why it is useful if field staff are familiar with the method of calculation so that in emergencies they can estimate the discharge from the gauging results, with only the aid of a hand-held calculator.

Rotating Element Meters (REMs)

Introduction

The rotating element current meter operates on the proportionality between local flow velocity and the local angular velocity of the meter rotor. The relationship between velocity and rotor speed is usually established experimentally by towing the meter, at various velocities, through still water and recording the revolutions of the rotor, the distance travelled and the timing of each. The speed of the towing carriage is assumed to be equivalent to water velocity.

Calibration usually takes place in rectangular tanks about 100m in length, 2m wide and 2m deep. The meters are generally suspended from a rod or cable and attached to a trolley, which tows them through the water. The method of suspension used for calibration purposes must be the same as that to be used in the field. If a meter could be deployed in the field from either a wading rod or a suspension cable, then two separate calibrations must be derived for each method of deployment. During the calibration runs it is important that the supporting structure does not vibrate more than it would for the same velocity when deployed in the field.

Calibration relationship

The calibration relationship is usually of the form:

$$v = a + b \times n$$

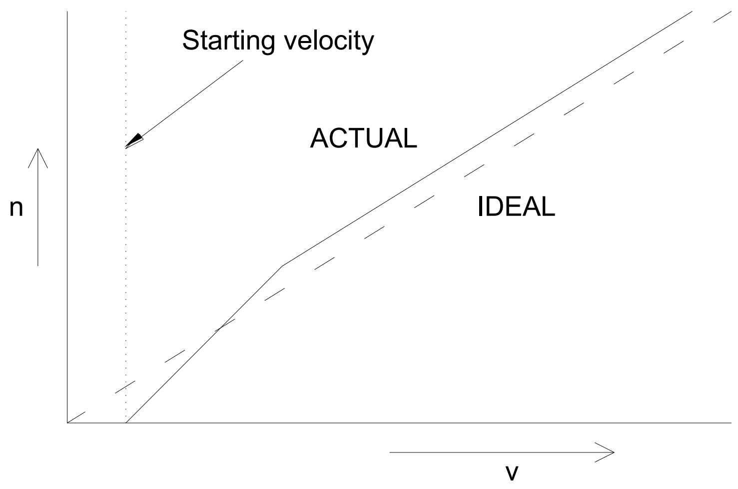
Where v = water velocity (m/s)

n = speed of impeller (revs/s)

a & b are constants

Normally the current meter calibration consists of at least two equations of the above form. This is because there is a minimum response speed below which the meter will not turn and as such the straight line relationship between velocity and rotor speed does not pass through the origin. This is illustrated in Figure 4.13. Usually no more than four equations are required to define the relationship between velocity and rotor speed over the full calibration range.

Figure 4-13 Diagram illustrating the form of a current meter calibration relationship



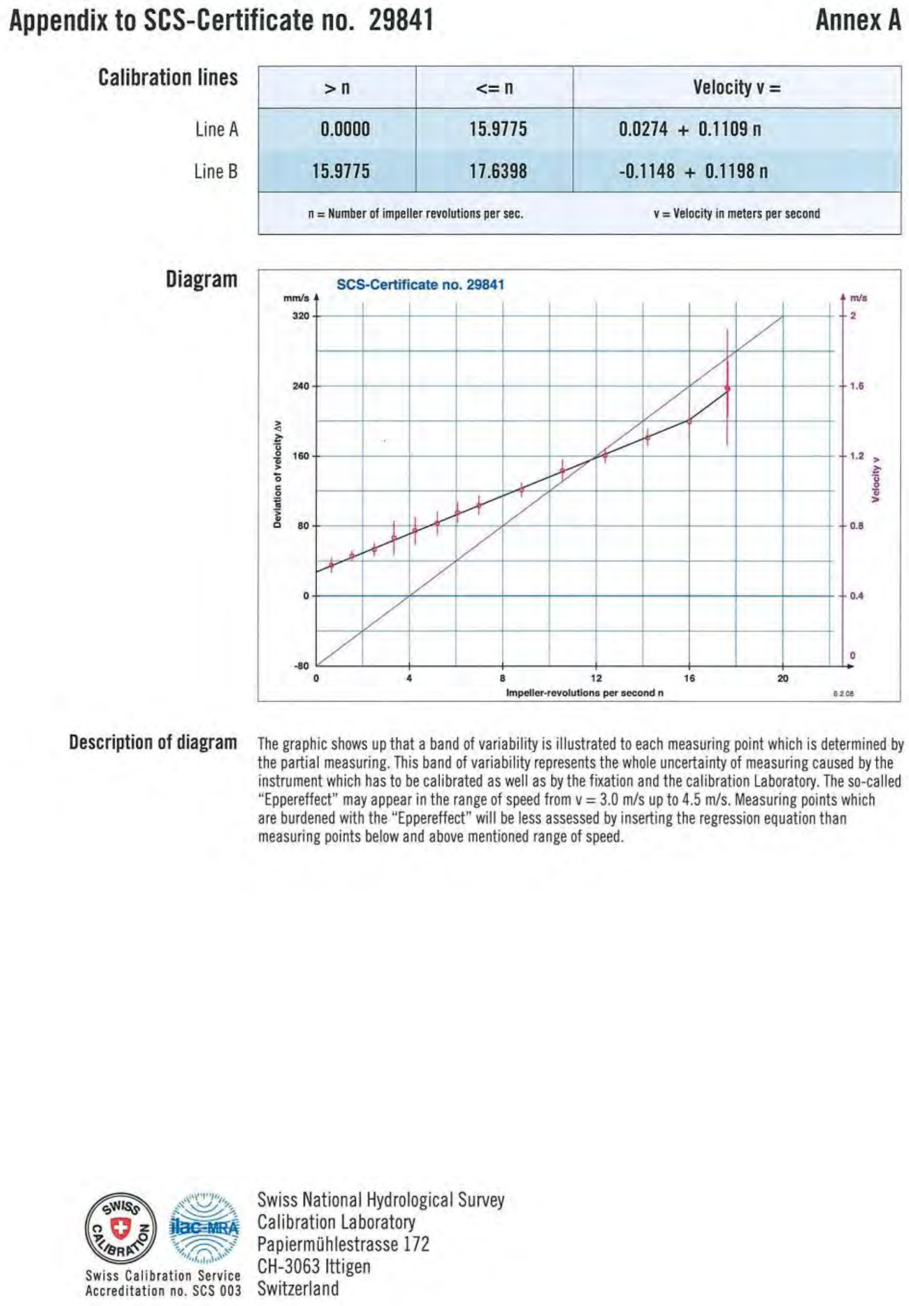
Changes to current meter

Over a period of time the current meter rating may change as a result of damage to impeller shafts or wear and tear to bearings, particularly during harsh flood conditions. These changes might be quite small at higher velocities but may significantly effect low velocity measurement. It is essential that current meters are calibrated and serviced regularly. The British Standard currently recommends that calibration of REMs must be carried out either at yearly intervals, after 300 hours of use, or whenever their performance is suspect, whichever is the shorter. However, this is not always logistically possible. The Environment Agency has adopted the following minimum standard:

- current meters must be calibrated at least once every two years;
- they must not be used for more than 400 gaugings since the last calibration;
- they must be calibrated whenever their performance is suspect, or after repair or replacement of bearings, impellers and other key parts.

Whichever comes first of conditions 1 - 3 above must apply. An extract from a typical current meter calibration certificate is shown below in Figure 4.14.

Figure 4-14 Extract from a current meter calibration certificate



Appendix to SCS-Certificate no. 29841

Annex A

Calibration lines

	> n	<= n	Velocity v =
Line A	0.0000	15.9775	0.0274 + 0.1109 n
Line B	15.9775	17.6398	-0.1148 + 0.1198 n

n = Number of impeller revolutions per sec.

v = Velocity in meters per second

Diagram

Description of diagram

The graphic shows up that a band of variability is illustrated to each measuring point which is determined by the partial measuring. This band of variability represents the whole uncertainty of measuring caused by the instrument which has to be calibrated as well as by the fixation and the calibration Laboratory. The so-called "Eppereffect" may appear in the range of speed from v = 3.0 m/s up to 4.5 m/s. Measuring points which are burdened with the "Eppereffect" will be less assessed by inserting the regression equation than measuring points below and above mentioned range of speed.

Swiss Calibration Service
Accreditation no. SCS 003

Swiss National Hydrological Survey
Calibration Laboratory
Papiermühlestrasse 172
CH-3063 Ittigen
Switzerland

Revolution counters and timers

In addition to the calibration of the actual meter, it is also important to check regularly that the revolution counter, timing device, the horizontal distance and depth measuring equipment, and any other ancillary measuring devices are operating satisfactorily. The timers and counters must be checked rigorously a minimum of once every 12 months.

Counters can be checked by rotating the impeller an observed number of times and ensuring that the counter records the same number. If it does not record the correct number of revolutions, it must be taken out of operation until the problem is resolved.

Timers must be checked against a suitable timing device (e.g. digital stop watch) over, say, a 200 second period. If the difference between the two times is greater than 0.5%, the reason for the difference must be investigated and rectified before using the device further.

Electromagnetic meters (EMs)

Calibration

Just like REMs, EM meters are calibrated devices. They differ by the fact that the calibration is embedded in the electronics. This does not mean it is proof against variation with time, or that embedded calibration is necessarily adequate for all possible uses. The following must be noted:

- when purchasing an EM meter, define to the supplier the specifics of the calibration you require. Ensure that sufficient calibration points are established to be reassured that the device"s performance is to your satisfaction in any parts of the velocity range which are of special interest, e.g. very low velocities;
- ensure that the EM meter is calibrated in its entirety, as a matched set of sensing head, control electronics and signal cable. If any of these is changed, re-calibrate the new set;
- regardless of usage have your EM meter re-calibrated at least once every three years.

Hand held Acoustic Doppler Velocimeters

Calibration

- These devices are not possible to calibrate using the conventional method. They can be sent to a tow tank where the velocity measurements are checked. Particles are added to the water in the tank to ensure that enough reflectors are present, although there have been problems with maintaining an equal level of reflectors throughout the tank.
- The units have there own self test programs which should be run prior to each measurement that is taken.
- If either the tow tank test or self test program show a fault/ error the unit needs to be sent back to the manufacturer as there is not a simple calibration to apply.

Acoustic Doppler current profilers (ADCPs)

Calibration

The ADCP devices are not possible to calibrate using the conventional method. A regatta is held at a reliable gauging station where at least four ADCPS can simultaneously be effectively and safely deployed. For the regatta to collect enough data to statically prove if an ADCP has a fault at least 12 units should be tested. Each unit is required to make a number of gaugings using all appropriate modes that should work in the conditions.

Discharge measurements are then processed by an Environment Agency ADCP expert and compared against the gauging station flow and each other. Those found to be recording outside the acceptable range will be removed from service, investigated and sent back to the manufacture if required.

Each ADCP is required to be regatta tested every two years. See the work instruction „How to measure river discharge using Acoustic Doppler Current Profilers‟ for full details.

Related documents

Work instructions

- **'Monitoring & Data (hydrometry) – Field Current Meter Gauging'**
- **'Monitoring & Data (hydrometry) – Field Gauging, Volumetric'**
- **'Monitoring & Data (hydrometry) – Field Gauging, Dilution'**
- „Monitoring & Data (hydrometry) – Field Gauging by use of Acoustic Doppler Profilers (ADP)‟

General

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- Gregory K. J. and Walling D. E. 1973, “Drainage Basin Form and Process,” Publishers - Edward Arnold.
- ISO 748, 2007: “Measurement of liquid flow in open channels using current-meters or floats”.
- Environment Agency, Health and Safety, “Safety Instructions for Hydrometric Field Activities”.
- BS EN ISO 4375:2004, “Cableway System for Stream gauging”.
- Environment Agency. 1996, R&D Project record W6/I/529/I, “Current Meter Gauging Methods Small Streams and Rapidly Changing Stage”.
- ISO 9555: Parts 1-4 1992/1994, “Dilution methods”.
- ISO 1070: 1992, “Slope Area Method of Estimation”.
- Herschy R. W. 2008, “Streamflow Measurement”.
- National Rivers Authority. 1992, R&D Note 59: “Review of Hydrometric Field Techniques Used in the National Rivers Authority”.
- BS 3680: Part 3Q: 2002, “Guide for safe practice in river flow measurement”.

Appendix 14
Data Sources

Table A14.1 Flow and Groundwater levels

Data	Source	Database	Contact/web link
Flow (discharge) and level	EA	WISKI	Contact national customer contact or Area office – External Relationship team enquiries@environment-agency.gov.uk
Flow (Discharge)	CEH	National River Flow Archive	http://www.ceh.ac.uk/data/nrfa/index.html
Hydrometric data	CEH	National Water Archive	http://www.ceh.ac.uk/data/nrfa/publications.html
Information on Gauging stations	CEH	UK Hydrometric Register	http://www.ceh.ac.uk/data/nrfa/publications.html
Network of UK Gauging stations	CEH	UK Gauging Station Network	http://www.ceh.ac.uk/data/nrfa/uk_gauging_station_network.html
Flood flows	EA	Hi Flows	http://www.environment-agency.gov.uk/hiflows/search.aspx
Groundwater data	EA	WISKI	Contact national customer contact or Area office – External Relationship team enquiries@environment-agency.gov.uk
Groundwater data	CEH	National Groundwater Archive	http://www.ceh.ac.uk/data/nrfa/groundwater.html
Information on UK Groundwater Network	CEH	UK Groundwater Network	http://www.nwl.ac.uk/ih/nrfa/groundwater/register_of_boreholes1999.htm
Flows in un-gauged Catchments	CEH	IAHS Predicted Un-gauged Basins	
Flow and level data	Rivers Agency		
Spot flow gauging and ADCP	EA	BIBER	Contact national customer contact or Area office – External Relationship team enquiries@environment-agency.gov.uk

Water quality	EA	WIMS	Contact national customer contact or Area office – External Relationship team enquiries@environment-agency.gov.uk
Flood mapping	EA	NFCD	Contact national customer contact or Area office – External Relationship team enquiries@environment-agency.gov.uk

Table 14.2 Ecology, Fish and Habitat

Data	Source	Database	Contact/web link
Invertebrates	EA	BIOSYS	Contact national customer contact or Area office – External Relationship team enquiries@environment-agency.gov.uk
Macrophytes	EA	BIOSYS	Contact national customer contact or Area office – External Relationship team enquiries@environment-agency.gov.uk
Habitat	EA	ECOSYS	Contact national customer contact or Area office – External Relationship team enquiries@environment-agency.gov.uk
Fish	EA	NFPD	Contact national customer contact or Area office – External Relationship team enquiries@environment-agency.gov.uk
Habitat	EA	RHS	Contact national customer contact or Area office – External Relationship team enquiries@environment-agency.gov.uk
Multi-species and habitat	Mixed - >100	NBN	National Biodiversity Network: http://data.nbn.org.uk/index_homepage/index.jsp
Multi-species and habitat	SNH	SNHi	(Data for Scotland) http://www.snh.org.uk/snhi

Table 14.3 Models

Model Type	Source	Model Name	Contact/web link
Invertebrates	SNIFFER	RICT	www.rict.org.uk
Rainfall-runoff Flow	EA	CATCHMOD	enquiries@environment-agency.gov.uk or area hydrologist

Flow at ungauged sites	CEH/EA	LF2000	enquiries@environment-agency.gov.uk or area hydrologist
Fish	USGS	PHABSIM	http://www.fort.usgs.gov/Products/Software/PHABSIM/
Fish	EA	HABSCORE	