NATURAL ENGLAND

Cyngor Cefn Gwlad Cymru
Countryside Council for Wales

Environment Agency

understanding water for wildlife

Water resources and conservation: Assessing the eco-hydrological requirements of habitats and species

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Environment Agency
Rio House
Waterside Drive, Aztec West
Almondsbury, Bristol BS32 4UD
Tel: 0870 8506506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

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Brief summary

The Restoring Sustainable Abstraction (RSA) Programme was set up by the Environment Agency in 1999 to identify and catalogue those sites which may be at risk from unsustainable abstraction. The RSA Programme covers work required by the Habitats Directive, Public Service Agreement PSA3, Biodiversity Action Plans and undesignated sites of local importance.

The Habitats Regulations (the UK law which enforces the Habitats Directive) require us to undertake an appropriate assessment of new or existing consents, permissions and other authorisations and evaluate effects on sites supporting habitats or species listed within the Habitats Directive. These sites are known as 'European sites' and their habitats or species are commonly referred to as 'interest features'.

As part of PSA3 we are also investigating the impacts of abstraction on designated Sites of Special Scientific Interest (SSSIs). For this we have a target to bring into 'favourable condition' 95 per cent of all SSSIs in England by 2010. The impacts of abstraction on sites supporting Biodiversity Action Plan (BAP) species or habitats and other sites of local importance will also be investigated across England and Wales.

This document is mainly intended to inform staff undertaking or reviewing appropriate assessments for abstraction licences. The assessment of abstraction licences is the responsibility of our Water Resources function who work very closely with our other functions and Natural England or the Countryside Council for Wales when undertaking appropriate assessments. The document can also be used to inform other RSA investigations which do not have a Habitats Directive driver.

The document aims to provide:

- Up-to-date information on the hydrological needs and sensitivity of ecological features considered to have fresh water resource requirements.
- A framework that can be used to structure and inform associated hydro-ecological assessments of conservation sites using a risk analysis approach based on the source-pathway-receptor concept.
- Advice on decision making within the context of multi-functional (in-combination) assessments, together with outline information on the generic issues which may arise.
- Information on common methods (or techniques) frequently used to inform hydro-ecological assessments.
- Case examples of assessments.

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1 Introduction

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1. Introduction

1.1 Background

The Restoring Sustainable Abstraction (RSA) Programme was set up by the Environment Agency in 1999 to identify and catalogue those sites which may be at risk from unsustainable abstraction. The RSA Programme is a way of prioritising and progressively examining and resolving these concerns.

There are a number of pieces of legislation and Government policy that require the environmental effects of abstraction to be examined. The bulk of work within RSA is to investigate the impacts of abstraction on sites designated under the Habitats Directive (*EC Directive on the Conservation of Natural Habitats and Wild Fauna and Flora (Council Directive 92/43/EEC)*. In England we are also investigating the possible impact of abstraction on nationally designated Sites of Special Scientific Interest (SSSI) as part of a Public Service Agreement (PSA). It may also be necessary to take action on other sites not designated under the Habitats and Birds directives or as SSSIs.

The Conservation (Natural Habitats, &c.) Regulations, 1994, (the Habitats Regulations), make provision for implementing the Habitats Directive in Great Britain. The Regulations require us as a competent authority to carry out an appropriate assessment prior to giving any consent, permission or other authorisation for a plan or project that is likely to have a significant effect on a European site. This extends to a review of existing permissions and consents, as required under Regulations 48 and 50 of the Habitats Regulations. The conclusion of an assessment should enable us to ascertain whether or not there is an adverse effect on the integrity of the site.

Public Service Agreements (PSA) are a contract between the Treasury and a Government department to deliver a number of performance targets. PSA 3 is a Defra target to bring into 'favourable condition' 95 per cent of all nationally important wildlife sites (SSSIs) in England by 2010. Whilst this PSA target applies only to England, it will involve those sites which are wholly or partly within the boundary of our Welsh region but which lie geographically within England.

This document has been commissioned by the Environment Agency in association with Natural England and the Countryside Council for Wales (CCW). It aims to provide a framework to support, both internally and externally, the appropriate assessment process and the review of existing consents, permits and other authorisations. The focus of the guidance is on Water Resource functional issues and has been designed to provide information for both the review of existing abstraction licences and the determination of new abstraction licence applications that directly or indirectly affect European sites.

Although the document has principally been developed for application to sites supporting species and habitats of European importance, the approaches proposed are applicable to other RSA sites and in the wider context of assessing hydro-ecological impact. Consequently the document could be used when assessing the effects of abstraction across a wide range of sites.

1.2 Purpose and scope

This document has been written primarily for Agency Water Resources and Conservation staff and Natural England/CCW Conservation Officers involved in the appropriate assessment process. However it is hoped that it may also prove useful to non-technical stakeholders by providing support to the process. It provides a high level summary of background and supporting information for those undertaking appropriate assessment or wishing to understand the process.

This is a 'live' document which is intended to be expanded and updated as new information becomes available.

We recommend that you do not save any part of this document but that you revisit the website to view the document as required. This ensures that you are using the most up to date version.

1.3 Document contents

Information contained is as follows:

- Section 1 – Structure and how to use the document.
- Section 2 – Summary information on the Water Resource requirements of species and habitats designated under the Habitats Directive with reference to other completed and on-going Research & Development.
- Section 3 – Provides a framework for linking species and habitats into a series of hydro-ecological 'domains' (i.e. broad habitat classes) influenced by hydrological 'regimes' e.g. surface water, groundwater.
- Section 4 – Suggested approaches (also referred to

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as techniques) giving background information on ecological and hydrological tools and methodologies together with some advice on selection.

- Section 5 – Case studies showing how some of the approaches have been applied in practice.

Information from Sections 2 and 3 can be used, as required, to help select the methods outlined in Section 4.

1.4 How to use the document

It can be used in a variety of ways depending on the experience of the user. More experienced staff familiar with the techniques and issues involved may want to use it as a useful 'toolbox' of techniques and source of references to further information. Less experienced users or non-technical readers may want to use it to gain an overview of the different types of sites, and how different features and hydro-ecological domains relate to each other.

The structure of the document is illustrated diagrammatically in Figure 1.1. Appropriate assessment is primarily concerned with risk of impact to European features, so the **source-pathway-receptor** model of risk assessment provides a useful basis for the assessment.

Of fundamental importance is the vulnerability (or sensitivity) of the European features to changes in the freshwater regime. In ***Section 2*** summary information is provided on the water resource requirements of 32 habitats and 27 species listed in Annexes I and II of the Habitats Directive, and most likely to be impacted by freshwater changes. Requirements of SPA bird species listed in Annexes of the Birds Directive are covered in a single summary.

The European features cannot be considered in isolation from the ecosystem in which they occur, so characterisation and assessment of impacts should usually be carried out on the site as a whole. ***Section 3*** defines a series of ***hydro-ecological domains and subdomains*** i.e. broad habitat classes used to describe the ecohydrological environment in which the features are most likely to be found. These domains and sub-domains are not intended to create a new classification system, but are proposed simply as a framework to set the features in context and enable an overview of the hydrological processes that may be operating at sites. Table 3.1 relates the European features to the domains and subdomains where they may occur.

When characterising a site it is essential to understand which hydrological processes are operating as **pathways** by which impacts may occur. Tables 3.2 and 3.3 relate the hydro-ecological domains to the ***hydrological regimes,*** that may be present.

There are a number of influences, or potential **sources**, which can impact a site and these may include:

- Agency consented activities, e.g. abstraction, discharges;
- Non-Agency consented activities, e.g. development planning; and
- Non-consented activities, e.g. non licensed abstractions or diffuse pollution.

The impact of water abstractions has to be assessed in terms of the 'in-combination' effect with other abstractions as well as other consented activities, such as consented effluent discharges. Due regard should also be given to other influences on the site such as site management. Table 3.4 details the main influences and through which hydrological regime they may impact upon a site.

Section 4 provides summary information on the main methods/techniques available to assist in carrying out appropriate assessment. These have been broken down into five main groups:

- Baseline data;
- Hydrological/hydrometric data;
- Ecological data;
- Tools for interpretation & site characterisation;
- Tools for impact assessment.

Choice of method depends on a number of factors and these are discussed in Section 4.3. Table 4.1 relates available methods to the hydrological regimes operating at the site. One of the factors that may influence choice of method is the sensitivity of individual species within a particular domain and this is recognised by the link from features to methods shown in Figure 1.1.

Section 5 provides examples of case studies for different domains and Table 5.2 shows which methods were used when undertaking these various case studies.

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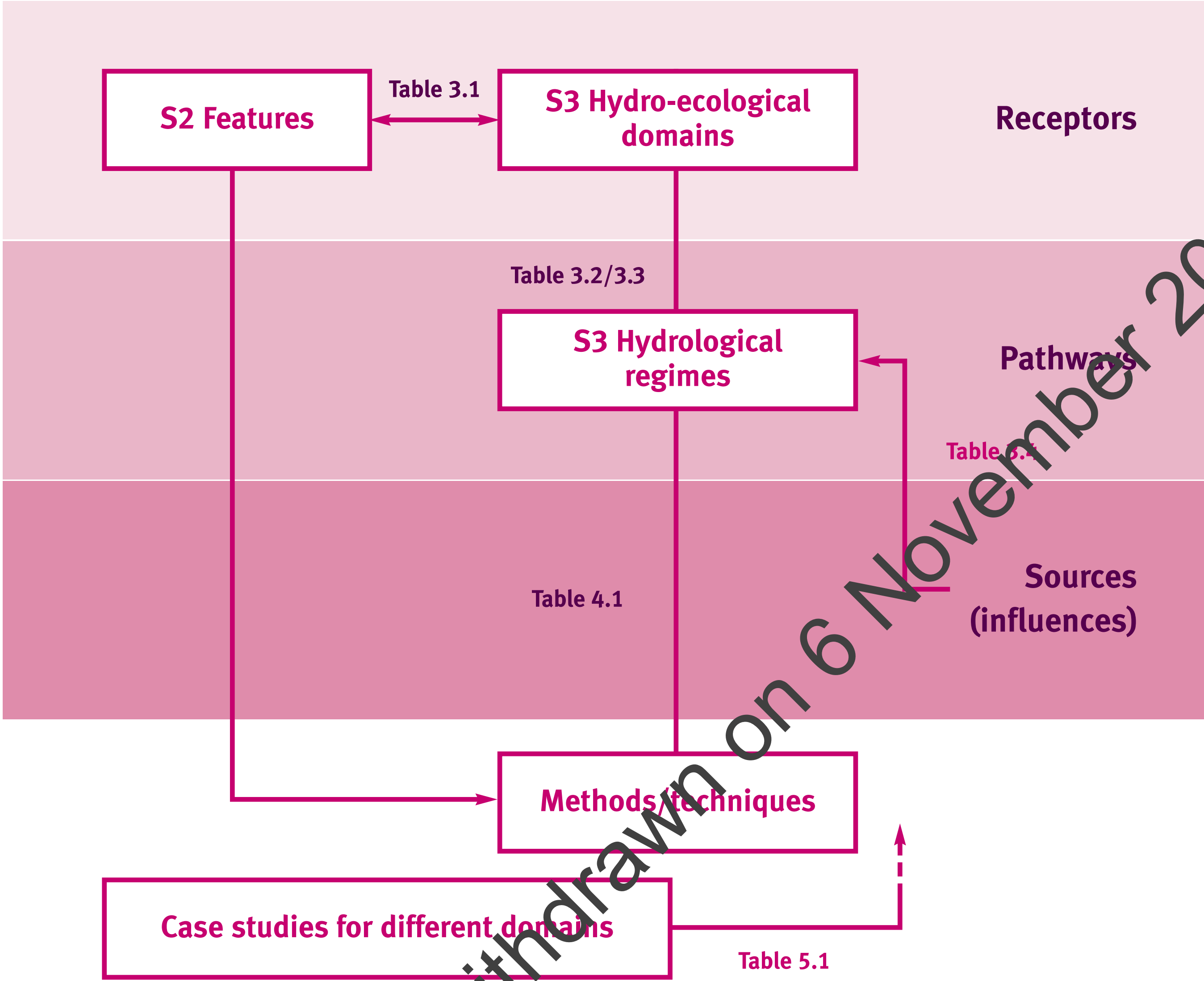
Fig 1.1 **Structure of document**



Finding your way around this PDF publication

Hyperlinks are used in this PDF publication to help you to get to the information you need more quickly. These are included in the main contents and section divider contents pages and will show the hand icon when you scroll over them with your mouse. Click to activate the links.

Hyperlinks are also positioned bottom left in the footer throughout the document. These return you to the nearest section divider. There is also a hyperlink on each section divider which can then be used to take you back to the main contents.

For example
To get to the Rutland Water case study:

In the main contents, click on '5. Case studies'.
This will take you to section 5 divider and the full section contents.
Click on 'Rutland Water'.

As section 2 is a large section you can either click on '2. Species and habitats' in the main contents to take you to the section divider listing the full contents.
Or click the sub section e.g '2.3.1 Invertebrates' to take you straight to that sub section.

To return to the main contents in all cases:

Click '‹ Section divider' in the footer to return to the nearest section divider
Click '‹ Main contents' bottom left on the divider to return to the main contents page.

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2 Species and habitats

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2 Species and habitats *continued*

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‹ Main contents

2. Species and habitats

2.1 Introduction

A review has been carried out of present knowledge on the specific hydrological (and in particular the fresh water resource) requirements for European designated habitats and species (known as interest features). The species and habitats included within the review are those that are found within cSACs and SPAs throughout England and Wales.

The results of the review, are presented as a series of hydro-ecological requirement summary sheets covering the likely water resource requirements for 31 habitats and 28 species (not including birds which are covered separately). These habitats and species do not represent the full list of habitats and species designated but only comprise those identified as having some level of dependence on freshwater.

The summary sheets thus produced are intended to provide a basic ecological description of each habitat and species identified which will be of use as a starting point but do not provide a comprehensive review of all available material. Where information is available, issues pertaining to their water resource requirements are identified in addition to other parameters considered likely to have significant implications for the health or status of the interest feature. A list of key references is identified within each note together with any known projects (either current or future) providing further research. The lists include many references to more detailed sources such as the JNCC website and various LIFE projects.

Many of these interest features have hydro-ecological requirements, which may also apply to a broad range of species and/or habitats that may occur at the same sites. Consequently the information provided in this document may be applied to a wider range of species and habitats than those listed. However, care must be taken when using the information in this way, and further advice should be sought from specialist conservation staff within the Agency, Natural England and CCW.

Sections 2.2 includes the habitats summary sheets.

Section 2.3 includes the species summary sheets.

Section 2.4 makes reference to the report Eco-hydrological Guidelines for Lowland Wetland Plant Communities which is available on the Environment Agency website.

Section 2.5 highlights other R&D projects of particular relevance to this manual.

2.2 Guidance summary notes on the water resource requirements of particular habitats

A series of hydro-ecological summary sheets has been produced for a range of habitats designated as European interest features identified as having some level of dependence on freshwater. Each habitat summary includes the following sub-sections:

- General information – provides background to the habitat and its occurrence;
- A description which provides more detailed information on the community type;
- Key influences – examines the effects of water quantity, water quality etc on the habitat;
- Current and future work – summarises key research that has recently been completed or is on-going specifically looking at the habitat being described;
- Key references – sets out a bibliography that can be used to gather further information if required.

Each summary sheet presents the most up-to-date information currently available on the requirements of each habitat, and identifies areas where further research is required or is on-going. The user will be able to interrogate these sheets to help build a conceptual understanding of the optimal hydrological conditions for the habitat and whether these allow favourable conditions to be achieved. It is envisaged that summary sheets will be periodically updated as research improves our understanding of the hydro-ecological requirements of each habitat.

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2.2.1 Coastal and halophytic habitats

The following summary has been compiled using key reference papers provided by Environment Agency, Natural England and CCW staff. It provides a summary of relevant information on the freshwater requirements of the different coastal habitat types. For further information refer to references listed in each summary.

– Atlantic salt meadow (*Glauco-Puccinellietalia maritimae*)

– Estuaries

– Humid dune slacks

– Inland salt meadow

– Large shallow inlets and bays

– Mudflats and sandflats not covered by seawater at low tide

– *Salicornia* and other annuals colonising mud and sand

– Spartina swards (*Spartinion maritimae*)

– Coastal lagoons

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Atlantic salt meadow (*Glauco-Puccinellietalia maritimae*)

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General information

Saltmarshes can be defined as intertidal areas of fine sediment transported by water and stabilised by halophytic species adapted for regular immersion (Ref. 2). Four main salt marsh zones based on tidal regime plus an upper transition zone are recognised:

Pioneer zone: open communities covered by all tides (except the lowest neap) with one or more of the following – *Spartina, Salicornia, Aster;*

Low marsh zone: generally closed communities covered by all neap tides with at least *Puccinellia* and *Atriplex portulacoides* as well as the previous species;

Middle marsh zone: generally closed communities only covered by spring tides with *Limonium* and/or *Plantago*, as well as the previous species;

High marsh zone: generally closed community only covered by the highest spring tide with one or more of the following – *Festuca, Armeria, Elymus* as well as the previous species; and

Transition zone: vegetation intermediate between the high marsh and adjoining non-halophytic areas. This zone is only covered occasionally by tidal surges during extreme storm events (Ref. 3).

It is not uncommon for one or more of these zones to be absent in an area. In areas exposed to high wave energy, middle to high marsh can occur well above the level of normal spring tides. In areas restricted by the existence of a sea wall the higher zone is virtually absent and the transition zone appears in a line along the sea wall.

Atlantic salt meadows occur on North Sea, English Channel and Atlantic shores, mostly in the large, sheltered estuaries of south-east, south-west and north-west England and in South Wales. Smaller areas of saltmarsh are found in Scotland (Ref. 4).

Description

- Atlantic salt meadows form in soft intertidal sediments (mud and sand) which are protected from strong wave action. This vegetation forms the middle and upper reaches of saltmarsh communities, where tidal inundation still occurs but with decreasing frequency and duration (Ref. 3);
- In the UK this Annex I habitat type corresponds to the NVC types:
- SM10 Transitional low-marsh vegetation
- SM11 *Aster tripolium* var. *discoideus* salt-marsh community
- SM12 Rayed *Aster tripolium* salt-marsh community
- SM13 *Puccinellia maritima* salt-marsh community
- SM14 *Halimione portulacoides* saltmarsh community
- SM15 *Juncus maritimus – Triglochin maritima* salt-marsh community
- SM16 *Festuca rubra* salt-marsh community (coastal examples only)
- SM17 *Artemisia maritima* salt-marsh community
- SM18 *Juncus maritimus* salt-marsh community
- SM19 *Blysmus rufus* salt-marsh community
- SM20 *Eleocharis uniglumis* salt-marsh community;
- Refer to Ref. 5 for further information on NVC types;
- At the lower reaches of the saltmarsh the vegetation is often naturally species-poor and may form an open sward of common saltmarsh-grass (*Puccinellia maritima*). Further up the marsh, the vegetation becomes forb-dominated and red fescue (*Festuca rubra*) becomes more important. The upper saltmarsh shows considerable variation, particularly where there are transitions to other habitats. Communities present may include tussocks of sea rush (*Juncus maritimus*) dominating a herb-rich vegetation, and saltpans supporting patches of species-poor vegetation dominated by saltmarsh flat-sedge (*Blysmus rufus*) in the north or slender spike-rush (*Eleocharis uniglumis*) (Ref. 4).

Key influences

Water resources

- Saltmarsh flora communities are dominated by halophytic species. Freshwater influences are likely to be of localised importance (Ref. 9);
- The herb component of Atlantic salt meadow may require freshwater inputs to encourage diversity. At the local scale it is possible that freshwater inputs may affect species spatial distribution and diversity, although this is likely to be restricted to the area immediately surrounding the input, due to dilution with marine water (Ref. 9); and
- Further assessment is required to ascertain the freshwater requirements and their significance for Atlantic salt meadow.

Other influences

- Coastal processes are considered the principle influence on saltmarsh. Such processes affect the height of sediments in relation to sea levels and salinity, which in turn affects species composition and distribution (Ref. 9);
- Many saltmarsh areas have been lost as a result of land reclaim for agricultural purposes. Anthropogenic influences on this habitat type include waste tipping, drowning by barrage construction, recreational pressures, oil pollution and eutrophication (caused by sewage effluent and agricultural run-off); and
- Many of the issues such as grazing, turf cutting and alteration to freshwater inputs are not considered to affect pioneer communities, but may have significant implications for mid to high salt marsh zones (Ref. 3).

Current and future work

JNCC and EHSNI have completed a saltmarsh review in 2002. Details on all aspects of saltmarsh and their management are included. Refer to Ref. 3.

Hydrological reviews for a number of SACs have been undertaken by Entec. These reports provide a discussion on considerations for particular sites, and although site specific, provide useful information for the assessment of impacts on this habitat type.

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Key references

General description

1. Allen, J. R. L. and Pye, K. (1992). *Salt Marshes: Morphodynamics, Conservation and Engineering Significance.* Cambridge University Press, Cambridge.

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Other Annex I habitats to be considered with Atlantic salt meadow are, *spartina* swards, mudflats and sandflats not covered by seawater at low tide, coastal lagoons, temperate atlantic wet heath with *Erica ciliaris* and *Erica tetralix* and also estuaries.

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Estuaries

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General information

Estuaries are generally defined as the downstream part of a river valley, subject to the tide and extending from the limit of brackish water. They comprise a range of habitat types and provide an essential migratory route for fish species making the transition between the marine and freshwater environment, and bird populations using the area for feeding, refuge, reproduction and/or nurseries (Ref. 2).

The UK has over 90 estuaries, which are widely distributed around the coast of England and Wales with few examples of this habitat type in Northern Ireland and western Scotland (Ref. 2).

Description

The structure of estuaries is largely determined by geomorphological and hydrographic factors. Four main sub-types are noted:

- **Coastal plain estuaries**: These are usually less than 30 m deep exhibiting a large width-to-depth ratio and are the main estuary type by area
- **Bar-built estuaries**: have a sediment bar across their mouths and are partially drowned river valleys that have subsequently been inundated. They are small but widespread around the UK coast
- **Complex estuaries**: formed by a variety of physical influences including glaciation, river erosion, sea-level change and geological constraints from hard rock outcrops. Few examples exist in the UK
- **Ria estuaries**: drowned river valleys, characteristically found in south-west Britain. The estuarine part of these systems is usually restricted to the upper reaches with outer parts not diluted by freshwater and typically conform to the Annex I Large shallow inlets and bays
- For further information on sub-types, refer to www.jncc.gov.uk/SACselection;
- A gradient of salinity from freshwater in the river to increasingly marine conditions towards the open sea exists in estuaries;
- Estuaries are relatively sheltered, leading to the deposition of sediment largely from marine sources. This deposition often leads to the development of extensive inter-tidal mudflats and saltmarshes. However, in the South West, the bulk of saltmarshes are on fluvial sediments arising from mining operations;
- Habitats found within the Habitats Directive estuary feature may include saltmarsh, sand dunes, intertidal sediments, water column, habitats used by seals and cetaceans and immediately adjacent habitats used by estuary birds; and
- Classification can also be based on salinity distribution, with positive (freshwater input›evaporation), negative (evaporation›freshwater input) or neutral (freshwater input=evaporation) estuaries noted (Ref. 3).

Key influences

Water resources

- Changes in salinity within the estuary can lead to changes in species distribution and may limit available habitat for particular species requiring defined salinity regimes (Ref. 5);
- Salinity along with wave exposure and sediment type are the main influences on the distribution and components making up the invertebrate community within the sediments;
- Freshwater flows into estuaries may influence sediment regime and hence estuarine morphology. The number and location of freshwater inputs should be considered, along with an understanding of estuarine morphology;
- Changes to freshwater input may alter currents within the estuary affecting sediment transport, settlement and the dispersion of organisms (Ref. 6);
- Invertebrate diversity is greatest in either marine or freshwater environments, reducing as the salinity range increases. Changes in salinity resulting from freshwater inputs will generally reduce invertebrate diversity. However, interstitial salinity tends to be much less variable than the overlying water, and as such is not considered a major limiting factor of invertebrate abundance (Ref. 5);
- Differences in salinity conditions will alter the variety of communities found in each of the sediment categories. Estuarine communities may display marked variations depending on the influence of freshwater inputs when compared to purely marine locations (Ref. 1);

- Freshwater inputs may be considered important for bird utilisation of this habitat, although it is not yet clear. It is possible that birds do rely on freshwater inputs for preening and drinking, and as such these inputs are important for the development of local niches (Ref. 9 & 10); and
- There is also evidence of a link between freshwater flows to estuaries and the ability of migratory fish to navigate their way upstream.

Other influences

- Other environmental parameters to which the biota of estuaries are sensitive include hydrographical changes and water activity (i.e. storm events) and tidal elevation change (e.g. sea level rise);
- Changes to the hydrographic regime are of considerable importance to the physical, chemical and biological integrity of estuaries. Such changes may alter the sedimentary regime, which may impact on the sediment health, the nature of infaunal communities present and consequently its use by predators (Ref. 1). Storm events can also result in the 'scouring' of benthic communities, causing reductions in biomass. Generally, the determining factors affecting such habitats are wave, current and wind action;
- Disruption of sediment supply from marine and coastal sources can adversely affect the sediment budget of muddy estuaries, or reduce the input of sand, which often predominates at the mouth of estuaries;
- For details on the sensitivity of particular species within estuarine habitats, refer to www.marlin.ac.uk; and
- Anthropogenic activities known to have an impact on the estuary feature include:
  - Land reclamation activities;
  - Coastal squeeze caused by hard defence structures preventing landward migration of intertidal sediments;
  - Barrages (amenity, storm-surge and tidal energy);
  - Organic enrichment;
  - Industrial and domestic effluent discharge;
  - Oil spills and tanker accidents;
  - Sea level rise; and
  - Recreation (including bait digging);
  - Dredging; and
  - Introduction of non-native species (Ref. 1).

Current and future work

Hydrological reviews for a number of SACs have been undertaken by Entec. These reports provide a discussion on considerations for particular sites, and although site specific, provide useful information for the assessment of impacts on this habitat type. A substantial amount of work has also been undertaken by the Severn Estuary Partnership Group.

A complete list of all projects commissioned on estuarine topics can be obtained from the Habitats Directive Estuaries Co-ordinator.

Consult the MarLIN website for work recently completed (and ongoing) on sensitivities of marine habitat: **(www.marlin.ac.uk/Bio_pages/Bio_Scripts/Habitats_info_intro.htm).**

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Consideration of birds utilising the estuary

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Annex I habitats to be considered with estuaries are mudflats and sandflats not covered by seawater at low tide, large shallow inlets and bays, *salicornia* and other annuals colonising mud and sand, *spartina* swards and Atlantic salt meadows. The Annex II species that should be considered are the allis shad (*Alosa alosa*), twaite shad (*Alosa alosa*), river lamprey (*Lampetra fluviatilis*), sea lamprey (*Petromyzon marinus*) and atlantic salmon (*Salmo salar*).

This document was withdrawn on 6 November 2017

Humid dune slacks

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General information

Dune slacks are low-lying areas within dune systems that are seasonally flooded. They occur primarily on the larger dune systems in the UK, particularly in the west and north where the wetter climate favours their development. The range of communities found in humid dune slacks is considerable and dependent on the structure of the dune system, its successional stage, the chemical composition of the dune sand, and the prevailing climatic conditions (Ref. 3).

Owing to the cool wet climate of the UK, humid dune slacks are a prominent feature of dunes in the UK. Dune slacks are widespread but local in the UK and the habitat type exhibits considerable ecological variation (Ref. 4).

Description

- Humid dune slacks occur on calcareous sand where vegetation is similar to that of small sedge mires (mires with low-growing sedges), or on acidic dunes, where the vegetation may have affinities to wet heath (Ref. 6);
- Slacks usually have a free-draining shingle base or a damp sand base (Ref. 4);
- Nutrient levels of soils are normally low and calcium content high (Ref. 8);
- Creeping willow is often found in dune slack vegetation and the boundaries between humid dune slacks and dunes with *Salix repens ssp. argentea* are often diffuse and difficult to define on the ground. Sites where creeping willow is dominant are excluded from the dune slack habitat type (Ref. 3);
- In the UK, humid dune slacks are represented by the NVC types:
  - SD13 *Sagina nodosa – Bryum pseudotriquetrum* dune-slack community
  - SD14 *Salix repens – Campylium stellatum* dune-slack community
  - SD15 *Salix repens – Calliergon cuspidatum* dune-slack community
  - SD16 *Salix repens – Holcus lanatus* dune-slack community
  - SD17 *Potentilla anserina – Carex nigra* dune-slack community
- Refer to Rodwell (1991) for further information on NVC types;
- Dune slacks are often rich in plant species. Flora is chiefly composed of marsh plants commonly found outside the dune system, with very few species confined to the dune slack habitat. Notable species found include the fen orchid (*Liparis loeselli*), petalwort (*Petalophyllum ralfsii*) and shore dock (*Rumex rupestris*) (Ref. 3);
- Species within dune slacks show extreme morphological modifications in response to excess or deficiency of water. The lower limit of many species is controlled by submergence, though precisely how, is not known (Ref. 6);
- Coastal slacks are considered transient features, liable to sea water flooding or to obliteration by the growth of embryo dunes (Ref. 6); and
- A range of other wetland types, in particular swamp, mire and tall herb fen communities occur on some dunes. These communities are not confined to dunes, although they comprise an important part of the mosaic of vegetation characteristic of dune slack (Ref. 3).

Key influences

Water resources

- True dune slacks are predominantly fed by rain water. They are characterised by a pattern of pronounced annual water table fluctuations related to the landform of the dune system, climate, and the nature of the underlying sediment (Ref. 6);
- The maintenance of suitable hydrological conditions is considered essential to the survival of this habitat type. Variations in the extent and duration of flooding of the dune surface are deemed very important in determining species composition and structure of dune slack vegetation. Such conditions can also influence the breeding of aquatic species, including the rare natterjack toad (*Bufo calamita*) (Ref. 2);
- The distribution of a number of species within dune slacks is critically related to the mean water table level (Van der Lann 1979 as cited in Jones (1993)). Some dune slack species are adapted to changes in the duration and depth of flooding, with a number noted to migrate up and down a height gradient in dune slacks in response to wet and dry period. Bog pimpernel (*Anagallis tenella*), jointed rush (*Juncus articulatus*) and lesser spear-wort (*Ranunculis flammula*) are all confined to wet sites subject to flooding while marram

(*Ammophila arenaria*) and restharrow (*Ononis repens*) are almost always found on ground above the level of the water table (Ref. 2 & 4);
- Slacks at the seaward edge and centre of a dune system aquifer typically exhibit a large annual groundwater range, whilst slacks adjacent to permanent water bodies or areas at the centre of large parabolic slacks demonstrate much reduced ranges, which may amount to 50% of the maximum (Ref. 2);
- The vegetation of wet slacks (SD14 and SD17) is considered groundwater dependent. The groundwater table rarely falls more than 1.2 m below the soil surface in well-developed slacks, with winter flooding from 0.1 to 0.5 m in depth. The rooting zone is rarely out of contact with the capillary fringe of the water table, and moderately low redox potentials may develop during the early summer months (Ref. 2, 6 & 8);
- The water table of dry slacks (SD16) may range between 0.5 and 2.0 m below the ground surface during the summer months, with soil profiles out of capillary contact with the water table throughout the growing season. Winter flooding only occurs exceptionally, and is usually short in duration (Ref. 2 & 6);
- The effects of an increase in the average water table level are difficult to predict, and it is not possible to separate the ecological effects of an increased nutrient load from an increase in mean groundwater level (Ref. 2); and
- Human interference of the natural groundwater regime of British coastal dunes is not considered large scale, with upland catchments, deep groundwater abstraction and reservoirs meeting water resource needs (Ref. 2).

Other influences
- Dune slacks are dynamic features. The continued creation of new dune slacks, often from blowouts, is considered highly desirable in order to maintain the communities characteristic of the early successional stages of dune development (Ref. 4);
- Other factors likely to affect the health and status of humid dune slacks include loss through urban and industrial development, sea defence and stabilisation, waste disposal and military defence usage (Ref. 4);
- Additions of nitrogen, phosphorus and potassium will lead to striking changes in the vegetation (Ref. 9);
- Severe grazing by rabbits will degrade humid dune slack habitats and reduce diversity (Ref. 8); and
- The effect of a global rise in sea level on natural hydrological processes in dune systems may have implications for dune stability (Ref. 4).

Current and future work

English Nature (now Natural England) published a report in 2006 on the eco-hydrological guidelines of dune habitats (Ref. 1).

This document was withdrawn on 6 November 2017

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7. Rodwell J. S. (ed) (1991). *British Plant Communities: Maritime communities and vegetation of open habitats: Volume 5.* Joint Nature Conservation Committee. Cambridge University Press, Cambridge.

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Supporting references

Other Annex I habitats to be considered with humid dune slacks are water courses of plain to montane levels with *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation, also calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*. The Annex II species that should be considered with humid dune slacks are petalwort (*Petalophyllum ralfsii*), shore dock (*Rumex rupestris*), fen orchid (*Liparis loeselli*), narrow-mouthed whorl snail (*Vertigo angustior*) and also the floating water plantain (*Luronium natans*).

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Inland salt meadow

General information

Inland saltmarsh (salt meadow) can develop where natural or artificial saline conditions prevail, and where the land is not subject to intensive management. It is now deemed a rare habitat type, having declined dramatically in the past 50 years in all areas where it occurs. The destruction of much of the natural habitat can be traced back to early salt-production activities (Ref. 1).

Pasturefields Salt Marsh in the West Midlands is one of three sites known to exist in the UK. Inland salt meadow at this site is formed by a natural salt spring, derived from solution of the subterranean salt-bearing rocks of the Keuper series (Ref. 3). The site covers approximately 0.5 hectares (Ref. 4). The remaining two inland salt meadow sites are found on the Upton Warren Pools SSSI (in Worcestershire), and Napton (Warwickshire), with the later representing a weak saline spring feature.

Description

- Inland salt meadows refer to non-coastal sites supporting the *Festuca rubra* and *Spergularia marina – Puccinellia distans* salt-marsh community types. These correspond under the National Vegetation Classification community types to SM16 and SM23 respectively (Ref. 1);
- Distinctive plant associations are observed within this habitat type and usually reflect differences in salinity, waterlogging and poaching;
- Sea plantain (*Plantago maritima*), a notable halophytic plant is found in inland salt meadows; and
- Where salinity levels are high (i.e. around salt pans) common saltmarsh-grass (*Puccinellia maritime*), lesser sea-spurrey (*Spergularia marina*), saltmarsh rush (*Juncus gerardii*) and sea arrowgrass (*Triglochin maritimum*) predominate.

Key influences

Water resources

- Little information exists on the hydrological requirements of inland salt meadows;
- A hydrogeological assessment carried out at Pasturefields Salt Marsh in 1994 identified brine springs in areas of localised permeability, with much of the area's geological deposits described as impermeable (Ref. 2);
- Major threats to the health and status of inland salt meadows pertain to changes in the hydrological regimes (Ref. 2); and
- Freshwater influences on inland salt meadow sites favour the establishment of swards of red fescue (*Festuca rubra*).

Other influences

- Drainage of agricultural land is considered to be the most significant threat to inland salt meadows (Ref 1).

Current and future work

No current or future research on the water resource requirements of inland salt meadows has been identified within the confines of this study.

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This document was withdrawn on 6 November 2017

Large shallow inlets and bays

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General information

Large shallow inlets and bays are described as large indentations of the coast which are generally more sheltered from wave action than the open coastline. Water depths are relatively shallow (usually less than 30 metres) and with a much smaller freshwater input/influence exhibited when compared to estuaries (Ref. 1).

Most coasts of the UK have some shallow inlets and bays, although the majority are considered small. By definition these habitats exhibit a soft sedimentary substratum in the body of the inlet or bay, bounded by a hard substratum. Such areas are primarily created by the underlying geological features, and then infilled with the prevailing mobile substrata, with modification by the hydrographic regime (Ref. 1).

Description

Large shallow inlets and bays vary widely in habitat and species diversity according to geographic location, size, shape, form and geology. Three main sub-types are recognised in the UK:

- **Embayment:** a marine inlet where the line of the coast typically follows a concave sweep between rocky headlands, sometimes with only a narrow entrance to the embayment
- **Fjardic sea loch:** a series of shallow basins connected to the sea via shallow, sometimes intertidal sills. Fjards are found in areas of low-lying ground which have been subject to glacial scouring and have a highly irregular outline and no main channel
- **Ria:** a drowned river valley in an area of high relief. Most have resulted from the post-glacial rise in relative sea level;
- Intertidal rock communities are often dominated by wracks (*Fucus* spp.), particularly in more sheltered locations. Extensive beds of mussels (*Mytilus edulis*) may be present on mixed substrates. Headlands are often dominated by barnacles and mussels (Ref. 1);
- Sediment shores in bays and inlets vary widely, depending on the degree of exposure to wave action. Very wave exposed conditions may result in shingle beaches, whilst less-exposed shores may consist of clean sand, with more sheltered shores consisting of fine sand and mud (Ref. 1);
- Communities of crustaceans are found on wave exposed sand shores, whilst crustaceans and polychaete worms generally develop on less-exposed shores, with polychaetes and bivalve communities tending to favour shores of fine sand and mud (Ref. 1);
- In the sublittoral zone, more exposed rocky coasts support forests of kelp (*Laminaria hyperborea*), with forests of sugar kelp (*L. saccharina*) occurring in more sheltered conditions. Communities of ephemeral algae and maerl (including *Phymatolithon calcareum* and *Lithothamnion corallioides*) may be present on wave-exposed or tide-swept coasts, whilst sheltered shallow sediments may be covered by communities of filamentous red and brown algae, by loose-lying mats of algae, or by beds of eelgrass *Zostera marina* (Ref. 1); and
- Animal-dominated rocky communities in the sublittoral zone vary according to local conditions of wave exposure and tidal streams. On more wave-exposed coasts, soft corals, anemones, sponges, sea-fans, feather stars and hydroids dominate, whilst more sheltered coasts support different species of sponges, hydroids, brachiopods and solitary ascidians.
- Animal-dominated sediment communities range from gravels and coarse sands dominated by sea cucumbers, large bivalves and heart-urchins. Finer sediments support communities of polychaetes and small bivalves, while fine muds contain beds of sea-pens, large burrowing crustaceans and bottom-dwelling fish (Ref. 1).

Key influences

Water resources

- Insufficient information exists to ascertain the importance of freshwater inputs on the feature as a whole;
- Shallow inlets and bays are largely marine features, and hence are saline features with little dilution by river runoff. Diffuse freshwater inputs may be considered of localised importance (Ref. 2);
- Localised freshwater flows onto the intertidal results in different communities of flora and fauna, according to the amount of freshwater and its distribution across the shore; and

- Freshwater inputs may be considered important for birds utilising this habitat, although it is not yet clear. It is possible that birds do rely on freshwater inputs for preening and drinking, and as such freshwater inputs are important for the development of local niches (Ref. 3 & 4).

Other influences

- The degree of wave exposure is considered a critical factor in determining habitat and species diversity of shallow inlets and bays, as it affects communities both on the shore and in the sublittoral zone (Ref. 2).

Current and future work

A hydrological review was undertaken by Entec for Hamford Water, a SSSI with large inlets and bays as an interest feature of the site. This report provides useful information for the assessment of impacts on the large shallow inlet and bay habitat type.

Key references

General description

1. McLeod, CR, Yeo, M, Brown, AE, Burn, AJ, Hopkins, JJ, & Way, SF (eds.) (2002). *The Habitats Directive: selection of Special Areas of Conservation in the UK.* 2nd edn. Joint Nature Conservation Committee, Peterborough. www.jncc.gov.uk/SACselection

Site specific studies

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Supporting references

Consideration of birds

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4. Ravenscroft, N.O.M., Beardhall, C.H., Cottle, R., Willett, P. & Wright, M.T. (1997). *The distribution of wintering waterfowl around freshwater flows over the mudflats of the Orwell Estuary', England*. Report to the Environment Agency and English Nature.

Other Annex I habitats to be considered with large shallow inlets and bays are mudflats and sandflats not covered by seawater at low tide, s*alicornia* and other annuals colonising mud and sand, s*partina* swards, estuaries and atlantic salt meadows.

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Mudflats and sandflats not covered by seawater at low tide

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General information

Mudflats are highly productive areas, which together with other intertidal habitats, support large numbers of predatory birds and fish (Ref. 5). Mudflats and sandflats can reflect low or high energy conditions depending upon their exposure to waves and/ or tidal currents.

Low energy areas are characterised by shallow slopes, high water content, low permeability and porosity, high carbon to nitrogen ratios, high organic loading, high microbial populations and high sediment stability (Ref. 1). High energy sediment shores are characterised by steeper shore profiles, which are well drained with high porosity and permeability due to large interstitial spaces, a low organic load and sparse microbial populations (Ref. 2).

Mudflats and sandflats not covered by sea water at low tide occur widely throughout the UK.

Description

The physical structure of intertidal flats ranges from mobile, coarse-sand beaches on wave-exposed coasts to stable, fine-sediment mudflats in estuaries and other marine inlets. Three broad categories have been devised:

- **Clean sands:** represent highly mobile environments, occurring on open coast beaches and in bays where wave action or strong tidal currents prevent the deposition of finer silt. Species inhabiting clean sands tend to be robust, and mobile including amphipod crustaceans, some polychaete worms and certain bivalve molluscs (Ref. 3)
- **Muddy sands:** occur on more sheltered shores of the open coast, at the mouths of estuaries or behind barrier islands. Relatively stable sediment conditions allow for a wide range of species to inhabit the substrate. Lugworm (*Arenicola marina*), other polychaete worms, and bivalve molluscs have all been noted. Eelgrass (*Zostera* spp.) beds may be present on certain shores (Ref. 3)
- **Muds:** the sediment of these areas is typically stable and dominated by polychaete worms and bivalve mollusc communities. These areas may also support very high densities of the laver spire snail (*Hydrobia ulvae*) (Ref. 3).
- The above categories display a continuous gradation between them with flora and fauna communities that also vary according to sediment type, stability and salinity (Ref. 3).

Key influences

Water resources

- Freshwater inputs do not feature as a principle environmental factor for mudflats. However, consideration should be given to those species present which may require freshwater inputs, or the presence of localised areas with reduced salinity conditions, where specific invertebrate communities are found;
- Freshwater mediated currents are only important in estuarine and coastal areas receiving runoff. In such environments, vertical stratification caused by salinity differences will influence the transport of sediment, dispersive stages of organisms and their distribution (Ref. 1);
- The large scale effect of freshwater entering an intertidal area will depend on the volume. At high tide, the influence of freshwater inputs may increase as it mixes with the saline marine water. Seasonality can also affect freshwater input with greater flows in the winter and low flows in the summer. However, the dilution effect of the freshwater will depend largely on two factors, the volume of freshwater entering the site, and the mixing rate within the site (Ref. 1);
- At a local scale, the distribution of individual species may be influenced within the vicinity of any freshwater flows. Intertidal biotopes will experience large-scale localised changes in community structure if there is a substantial change in the salinity condition experienced. The distribution of estuarine invertebrates is influenced by several factors including substrate type and salinity. In areas of lowered salinity, the macroinvertebrate fauna is predominantly of the Petersen *Macoma* community, characteristic species being: common cockle (*Cerastoderma edule*), mud shrimp (*Corophium volutator*), laver spire shell and ragworm (*Hediste diversicolor*). With a slight increase in the proportion

of sand, the polychaetes catworm (*Nephtys hombergii*) and lugworm occur. In slightly coarser areas, eelgrass beds may develop (Ref. 4);
- Invertebrate diversity is greatest in either marine or freshwater environments, reducing as the salinity range increases. Changes in salinity resulting from freshwater inputs will generally reduce invertebrate diversity. However, interstitial salinity tends to be much less variable than the overlying water, and as such is not considered a major limiting factor of invertebrate abundance (Ref. 8); and
- Differences in salinity conditions will alter the variety of communities found in each of the sediment categories. Mudflat and sandflat habitats, and the associated communities, found in estuaries may display marked variations depending on the influence of freshwater inputs when compared to purely marine locations (Ref. 1).

Other influences
- Other environmental parameters to which the biota of mudflats and sandflats are sensitive include hydrographical changes and water activity (i.e. storm events) and tidal elevation change (e.g. sea level rise);
- Changes to the hydrographic regime are of considerable importance to the physical, chemical and biological integrity of mudflat and sandflats. Such changes may alter the sedimentary regime which may impact on the sediment health, the nature of infaunal communities present and consequently its use by predators (Ref. 1). Storm events can also result in the 'scouring' of benthic communities, causing reductions in biomass. Generally, the determining factors affecting such habitats are wave, current and wind action;
- Anthropogenic activities known to have an impact on the features of this habitat type include land reclamation activities, hard sea defences, barrages (amenity, storm-surge and tidal energy) maintenance dredging (for navigation), organic enrichment, industrial and domestic effluent discharge, oil spills and tanker accidents, sea-level rise, recreation including bait digging, introduction of non-native species and intertidal shell fisheries (Ref 1); and
- Consideration of birds utilising mudflats and sandflats is required. Refer to the estuaries summary for supporting references.

Current and future projects

Hydrological reviews for a number of SACs have been undertaken by Entec. These reports provide a discussion on considerations for particular sites, and although site specific, provide useful information for the assessment of impacts on this habitat type.

Environment Agency, Southern Region commissioned a project to determine the importance of freshwater flows to estuarine bird populations, entitled 'Freshwater Flows across Mudflats'.

Consult the MarLIN website for work recently completed (and ongoing) on sensitivities of marine habitats: **(www.marlin.ac.uk/Bio_pages/Bio_Scripts/Habitats_info_intro.htm).**

This document was withdrawn on 6 November 2017

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Supporting references

Consideration of birds utilising the estuary

9. Ravenscroft, N. O. M. (1998). *Associations of wintering waterfowl with freshwater on the mudflats of East Anglian estuaries*. Report to the Environment Agency, English Nature and Suffolk Wildlife Trust.

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Other Annex I habitats to be considered with mudflats and sandflats not covered by seawater at low tide are estuaries, large shallow inlets and bays, *salicornia* and other annuals colonising mud and sand, atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) *spartina* swards (*Spartinion maritimae*) and coastal lagoons.

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Salicornia and other annuals colonising mud and sand

General information

Saltmarshes can be defined as intertidal areas of fine sediment transported by water and stabilised by halophytic species adapted for regular immersion (Ref. 2). Four main salt marsh zones based on tidal regime plus an upper transition zone are recognised:

- Pioneer zone: open communities covered by all tides (except the lowest neap) with one or more of the following – *Spartina, Salicornia, Aster*;
- Low marsh zone: generally closed communities covered by all neap tides with at least *Puccinellia* and *Atriplex portulacoides* as well as the previous species;
- Middle marsh zone: generally closed communities only covered by spring tides with *Limonium* and/or *Plantago*, as well as the previous species;
- High marsh zone: generally closed community only covered by the highest spring tide with one or more of the following – *Festuca, Armeria, Elymus* as well as the previous species; and
- Transition zone: vegetation intermediate between the high marsh and adjoining non-halophytic areas. This zone is only covered occasionally by tidal surges during extreme storm events (Ref. 3).

It is not uncommon for one or more of these zones to be absent in an area. In areas exposed to high wave energy, middle to high marsh can occur well above the level of normal spring tides. In areas restricted by the existence of a sea wall the higher zone is virtually absent and the transition zone appears in a line along the sea wall.

Salicornia and other annuals colonising mud and sand is widespread in the saltmarshes of England and Wales but restricted in Scotland and Northern Ireland because of a lack of new sediment for saltmarsh development (Ref. 4).

Description

- The annual glassworts (*Salicornia* spp.), a pioneer saltmarsh species, is often found growing in monostands or with common cordgrass (*Spartina anglica*) in the lowest intertidal zones. This species is able to tolerate conditions of complete and long inundations with seawater, high wave energies and low nutrient conditions (Ref. 4);
- Glassworts and other annuals colonising mud and sand in the UK are represented by the NVC communities:
- SM7 *Arthrocnemum perenne* stands
- SM8 Annual *Salicornia* salt-marsh community
- SM9 *Suaeda maritima* salt-marsh community
- SM27 Ephemeral salt-marsh vegetation with *Sagina maritima*
- SM7, SM8 and SM9 contain open stands of perennial glasswort (*Sarcocornia perennis*), glasswort (*Salicornia* spp.), and/or annual seablite (*Suaeda maritima*). The density of these plants can vary and may be lower on sites with sandier substrate (Ref. 4);
- Other species that are found in association include common saltmarsh-grass (*Puccinellia maritima*), common cord-grass (*Spartina anglica*) and sea aster (*Aster tripolium*) (Ref. 4);
- The glassworts are highly adaptable, growing in all sediment textures (shingle, sand, silt and clay), and are believed to be tolerant of turbid and moderately contaminated conditions such as those found in marinas and ports (Ref. 3);
- Annual glassworts generally colonise slopes, flats and shelves around -1.0 m below mean sea level (Ref. 10);
- It colonises intertidal mud and sandflats in areas protected from strong wave action and is an important precursor to the development of more stable saltmarsh vegetation; and
- It also develops at the lower reaches of saltmarshes where the vegetation is frequently flooded by the tide, and can also colonise open creek sides, depressions or pans within saltmarshes, as well as disturbed areas of upper saltmarsh (Ref. 10).

This document was withdrawn on 6 November 2017

Key influences

Water resources

- Due to their halophytic nature, freshwater input is not considered a principle environmental parameter for pioneer species such as *Salicornia*. Mid to high saltmarsh zones are more likely to be influenced by freshwater inputs if herb and grass species are present (Ref. 7, 8 & 9);
- Freshwater and its influence on salinity was also not considered to be a significant factor on the health or status of this habitat type (Ref. 1); and
- Freshwater inputs may be considered important for bird utilisation of this habitat, although it is not yet clear. It is possible that birds do rely on freshwater inputs for preening and drinking, and as such are important for the development of local niches (Refs. 11 & 12).

Other influences

- Allen and Pye (1992) evaluated factors responsible for the occurrence and distribution of saltmarsh. It was concluded that coastal physical processes (wind, tide and wave energy, sediment supply, climate change and geological setting), ecological processes and anthropogenic activity are principle factors governing distribution.

Current and future projects

JNCC and EHSNI have recently completed a saltmarsh review (2002). Details on all aspects of saltmarsh and their management are included (Ref. 3).

Hydrological reviews for a number of SACs have been undertaken by Entec. These reports provide a discussion on considerations for particular sites, and although site specific, provides useful information for the assessment of impacts on this habitat type.

This document was withdrawn on 6 November 2017

Key references

General description

1. Allen, J. R. L. and Pye, K. (1992). *Salt Marshes: Morphodynamics, Conservation and Engineering Significance.* Cambridge University Press, Cambridge.

2. Boorman, L.A. (1995). *'Sea level rise and the future of the British coast'. Coastal Zone Topics: Process*, Ecology and Management; 1: 10-13.

3. JNCC & EHSNI (2002). *Saltmarsh Review: An overview of coastal salt marshes, their dynamic and sensitivity characteristics for conservation and management.* L.A. Boorman, JNCC and EHSNI, Peterborough.

4. McLeod, CR, Yeo, M, Brown, AE, Burn, AJ, Hopkins, JJ, & Way, SF (eds.) (2002). *The Habitats Directive: selection of Special Areas of Conservation in the UK.* 2nd edn. Joint Nature Conservation Committee, Peterborough. www.jncc.gov.uk/SACselection

5. Stump, R.J. (1983). *'The process of sedimentation on the surface of a salt marsh'. Estuarine, Coastal and Shelf Science*; 17:495-508.

6. UK Biodiversity Group. (1999). *Tranche 2 Action Plans: Volume V Maritime Species and Habitats.* English Nature, Peterborough.

Site specific studies

7. Betts, S. & Lawson, R. (2002). *Hydro-ecological Review of Selected European Sites within the Agency's Anglian Region: Blackwater Estuary SPA/cSAC/ SSSI.* Entec Ltd, Newcastle.

8. Green, C. & Robson, G. (2001). *Hydro-ecological Review of Selected European Sites within the Agency's Anglian Region: Dengie SSSI.* Entec Ltd, Newcastle.

9. Green, C. & Robson, G. (2002). *Hydro-ecological Review of Selected European Sites within the Agency's Anglian Region:* Foulness SSSI. Entec Ltd, Newcastle.

Supporting references

10. Brooke, J., Landin, M., Meakins, N. & Adnitt, C. (1999). *The Restoration of Vegetation on Saltmarshes.* Research and Development Technical Report W208. Environment Agency, Bristol.

Consideration of birds

11. Ravenscroft, N. O. M. (1998). *Associations of wintering waterfowl with freshwater on the mudflats of East Anglian estuaries.* Report to the Environment Agency, English Nature and Suffolk Wildlife Trust.

12. Ravenscroft, N.O.M., Beardhall, C.H., Cottle, R., Willett, P. & Wright, M.T. (1997). *The distribution of wintering waterfowl around freshwater flows over the mudflats of the Orwell Estuary, England*. Report to the Environment Agency and English Nature.

Other Annex I habitats to be considered with *Salicornia* and other annuals colonising mud and sand are s*partina* swards, mudflats and sandflats not covered by seawater at low tide, large shallow inlets and bays, coastal lagoons and estuaries. The Annex II species that also need to be considered is the narrow mouthed whorl snail (*Vertigo angustior*).

This document was withdrawn on 6 November 2017

Spartina swards (*Spartinion maritimae*)

This document was withdrawn on 6 November 2017

General information

Saltmarshes can be defined as intertidal areas of fine sediment transported by water and stabilised by halophytic species adapted for regular immersion (Ref. 2). Four main saltmarsh zones based on tidal regime plus an upper transition zone are recognised:

- Pioneer zone: open communities covered by all tides (except the lowest neap) with one or more of the following – *Spartina, Salicornia, Aster*;
- Low marsh zone: generally closed communities covered by all neap tides with at least *Puccinellia* and *Atriplex portulacoides* as well as the previous species;
- Middle marsh zone: generally closed communities only covered by spring tides with *Limonium* and/or *Plantago*, as well as the previous species;
- High marsh zone: generally closed community only covered by the highest spring tide with one or more of the following – *Festuca, Armeria, Elymus* as well as the previous species; and
- Transition zone: vegetation intermediate between the high marsh and adjoining non-halophytic areas. This zone is only covered occasionally by tidal surges during extreme storm events (Ref. 4).

It is not uncommon for one or more of these zones to be absent in an area. In areas exposed to high wave energy, middle to high marsh can occur well above the level of normal spring tides. In areas restricted by the existence of a sea wall the higher zone is virtually absent and the transition zone appears in a line along the sea wall.

Four species occur in the UK, the native small cord-grass (*Spartina maritima*); the naturalised non-native smooth cord-grass (*S. alterniflora*), the sterile hybrid Townsend's cord-grass (*S. x townsendii* (crossing of *S. alterniflora* and *S. maritima*)) and invasive fertile common cord-grass (*S. anglica* (crossing of *S. alterniflora* and *S. maritima*)).

Small cord-grass, smooth cord-grass and Townsend's cord-grass are limited by climatic factors. Small cord-grass has experienced a decline in distribution throughout the UK, but substantial populations still exist on the Essex coast (Ref. 4).

Description

- Cord-grass (*Spartina* spp.) colonises a wide range of substrates, from very soft muds to shingle in areas sheltered from strong wave action. It occurs on the seaward fringes of saltmarshes and creek-sides and may also colonise old pans in the upper saltmarsh (Ref. 4);
- Communities containing cord-grass species corresponds to the NVC types:
- SM4 *Spartina maritima* salt-marsh community
- SM5 *Spartina alterniflora* saltmarsh community
- SM6 *Spartina anglica* salt-marsh community
- Only saltmarshes with native small cord-grass, smooth cord-grass and Townsend's cord-grass are proposed for conservation (Ref. 3).

Key influences

Water resources

- Due to their halophytic nature, freshwater input is not considered a principle environmental parameter for pioneer species such as *Spartina*. Other species present in the mid to high saltmarsh zones are more likely to be influenced by freshwater inputs into the habitat. Insufficient information exists to make a true assessment as to the importance of freshwater (Ref. 7 & 8);
- Freshwater and its influence on salinity was not considered to be a significant factor on the health or status of this habitat type (Ref. 1); and
- Freshwater inputs may be considered important for bird utilisation in this habitat, although it is not yet clear. It is possible that birds do rely on freshwater inputs for preening and drinking, and as such are important for the development of local niches (Refs. 10 & 11).

Other influences

- Allen and Pye (1992) evaluated factors responsible for the occurrence and distribution of salt marsh. It was concluded that coastal physical processes (wind, tide and wave energy, sediment supply, climate change and geological setting), ecological processes and anthropogenic activity are principle factors governing distribution; and

- Many saltmarsh areas have been lost as a result of land reclaim for agricultural purposes. Anthropogenic influences on this habitat type include waste tipping, drowning by barrage construction, recreational pressures, oil pollution and eutrophication (caused by sewage effluent and agricultural run-off).

Current and future projects

JNCC and EHSNI have completed a saltmarsh review in 2002. Details on all aspects of saltmarsh and their management are included (refer to Ref.3).

Hydrological reviews for a number of SACs have been undertaken by Entec. These reports provide a discussion on considerations for particular sites, and although site specific, provide useful information for the assessment of impacts on this habitat type.

Key references

General description

1. Allen, J. R. L. and Pye, K. (1992). *Salt Marshes: Morphodynamics, Conservation and Engineering Significance.* Cambridge University Press, Cambridge.

2. Boorman, L.A. (1995). 'Sea level rise and the future of the British coast'. *Coastal Zone Topics: Process, Ecology and Management*; 1: 10-13.

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4. McLeod, CR, Yeo, M, Brown, AE, Burn, AJ, Hopkins, JJ, & Way, SF (eds.) (2002). *The Habitats Directive: selection of Special Areas of Conservation in the UK.* 2nd edn. Joint Nature Conservation Committee, Peterborough. www.jncc.gov.uk/SACselection

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6. UK Biodiversity Group. (1999), *UK Biodiversity Group Tranche 2 Action Plans – Volume V:Maritime species and habitats*, HMSO, London.

Site specific studies

7. Betts, S. & Lawson, R. (2002). *Hydro-ecological Review of Selected European Sites within the Agency's Anglian Region: Blackwater Estuary SPA/cSAC/SSSI.* Entec Ltd, Newcastle.

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Supporting references

9. Brooke, J., Landin, M., Meakins, N. & Adnitt, C. (1999). *The Restoration of Vegetation on Saltmarshes*. Research and Development Technical Report W208. Environment Agency, Bristol.

Consideration of birds

10. Ravenscroft, N. O. M. (1998). *Associations of wintering waterfowl with freshwater on the mudflats of East Anglian estuaries.* Report to the Environment Agency, English Nature and Suffolk Wildlife Trust.

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Other Annex I habitats to be considered with *Spartina* swards are s*alicornia* and other annuals colonising mud and sand, atlantic salt meadow mudflats and sandflats not covered by seawater at low tide, large shallow inlets and bays, coastal lagoons and also estuaries.

This document was withdrawn on 6 November 2017

Coastal lagoons

This document was withdrawn on 6 November 2017

General information

Coastal lagoons are described as areas of shallow, coastal salt water which are wholly or partially separated from the sea by sandbanks, shingle or, less frequently, rocks or other hard substrata. They retain a proportion of their water at low tide and may develop as brackish, fully saline or hyper-saline water bodies (Ref. 4).

Ecological and geographical variations between lagoon habitats exist and consequently a number of classification schemes have evolved. Sheader and Sheader (1989) classified UK coastal lagoons into five main sub-types based on their physiography. The five sub-types are isolated lagoons, percolation lagoons, silled lagoons, sluiced lagoons and lagoonal inlets.

Coastal lagoons are relatively uncommon in the UK, with sub-types exhibiting very restricted distribution patterns (Ref. 6).

Description

Coastal lagoons are divided into five main sub-types:

- **Isolated lagoons:** separated completely from the sea or estuary by a barrier of rock or sediment. Seawater enters by limited groundwater seepage or by over-topping of the sea barrier. Salinity is variable but may remain high due to water loss by evaporation. They are often transient features with a limited life-span
- **Percolation lagoons**: separated from the sea by shingle banks. Seawater enters by percolating through the shingle or occasionally by over-topping the bank (e.g. in storms). Tidal range is normally significantly reduced and salinity may vary. They are normally formed by natural processes of sediment transport and as such may be transient features which are eroded and swept away over a period of years or decades, or infilled by shingle bank movement
- **Silled lagoons:** retain water at all states of the tide by a barrier of rock, termed the 'sill'. There is usually little tidal rise-and-fall. This may be out of phase with the adjacent sea. Seawater input is regular (i.e. on most tides) and salinity may be seasonally variable. These lagoons are potentially long-lived with extinction occurring over extended periods of time
- **Sluiced lagoons:** are formed where the natural movement of water between the lagoon and the sea is modified by artificial structures such as a culvert under a road or valved sluices. Tidal range is dependent upon the sluice efficiency and may be very low. Longevity is comparable with silled lagoons. Communities present in sluiced lagoons vary according to the type of substrate and salinity
- **Lagoonal inlets**: are formed when seawater enters the lagoonal inlet on each tide, usually through an open but narrow connection to the sea. Salinity is usually high, particularly at the seaward part of the inlet. The tidal range is usually marked and in phase with the adjacent sea. This salinity gradient significantly increases the habitat and species diversity of the sites in which it occurs. Longevity is comparable with silled lagoons;
- Salinity conditions in coastal lagoons can vary from brackish to hypersaline (0.5-30 ppt to excess of 35 ppt). Flora and fauna communities vary according to the physical characteristics and salinity regime of the particular lagoon (Ref. 6);
- Flora and fauna found to exist within coastal lagoons are usually divided into those which are essentially freshwater origin, marine/brackish species and those only associated with coastal lagoons (Ref. 7). Bamber *et al* (1992) identified six suites of species:
- Freshwater/low salinity species
- Lagoonal species
- Euryhaline (able to live in a wide range of salinities) specialist species tolerant of estuarine conditions
- Stenohaline (adapted to a narrow range of salinities) marine specialist lagoonal species
- Estuarine species pre-adapted to lagoonal conditions
- Estuarine species incidental in lagoons; and
- All lagoonal specialist species require specific environmental conditions. A large number of lagoonal specialist species are closely related to fully marine rather than estuarine or freshwater species (Ref. 3). Species requiring specific environmental conditions provided within saline lagoons include the starlet sea anemone (*Nematostella vectensis*), lagoon sandworm (*Armandia cirrhosa*), lagoon sand-shrimp (*Gammarus insensibilis*) and foxtail stonewort (*Lamprothamnium papulosum*) (Ref. 6).

Key influences

Water resources

- Despite the marine nature of communities found in coastal lagoon habitats, freshwater inputs into the system, where they exist are likely to be important to maintain the salinity regime. Water abstraction or changes to freshwater inputs may affect water levels and the salinity regime of some lagoons;
- It is important to note that salinity in coastal lagoons may vary in the short term (over tidal cycles), medium term (in response to rainfall) and longer term (in response to seasonality and drought);
- The freshwater input for coastal lagoons is usually supplied through rainwater, and surface drainage. The importance of freshwater input is site specific, but a freshwater supply is not always considered necessary to a saline lagoon (Ref. 4 & 5). The number of freshwater species present within the habitat can be used as an indicator of the freshwater influence;
- Many coastal lagoons existing in England and Wales are transient features. Changes in salinity regimes that shift sites to a more freshwater environment may lead to the establishment of terrestrial communities such as fen carr (Ref. 8). High freshwater inputs can result in the establishment of marsh vegetation and the loss of specialist species associated with coastal lagoons (Ref. 1);
- Where there are hypersalinity problems, freshwater inputs can be used to address issues raised; and
- In some lagoons where the seawater exchange exceeds freshwater supply, and where the lagoon outlet can readily dispense peaks of freshwater input, salinity gradients produced are thought to assist in increasing the diversity of species found in the site (Ref. 4).

Other influences

- As a distinct habitat, the essence of saline lagoons is their tidal restriction, or low hydrodynamic state (Ref. 1). The exchange of saline (sea-) water into the lagoon system is considered one of the most important criteria for successful maintenance of habitat (Ref. 5 & 7);
- When considering the sensitivity of a lagoon to impacts, it is necessary to consider the type of lagoon and its exchange with the sea; its size and the communities and species present. Threats to the integrity of the lagoon habitat in the UK include *Phragmites* spp. encroachment, interference with margins from grazing animals, infilling from shingle bank encroachment, land reclaim or other developments, degradation by excavation for shingle-bank redevelopment, sea-level rise and coastal erosion, changes in saline water ingress into lagoon systems, input of pollution from surrounding land (e.g. nutrient enrichment), and toxic contamination from surrounding land and tidal inputs;
- Due to the limited exchange with the sea (and associated reduced flushing time of dissolved or suspended materials), coastal lagoons are particularly sensitive to changes in nutrient loading associated with anthropogenic activities; and
- Optimal criteria for specialist, marine, lagoonal species using a hypothetical saline lagoon (according to Ref. 4) require at least 60% of the water to persist in the lagoon at all times of the year at all states of the tide; salinity to vary over the range of 15–40Ŵ, the sea-water input to exceed freshwater input, a muddy-sand substratum to sandy-mud substratum, rocky substratum for specialist hard substratum biotopes, shelter from wind effects, aspect ratio issues depths of up to one metre, and shallow margins.

Current and future projects

In 2001 The Countryside Council for Wales reviewed saline lagoons in Wales (Ref. 2).

English Nature(now Natural England) commissioned the development of a saline lagoon habitat inventory for England. The project has developed a GIS inventory for the saline lagoon Biodiversity Action Plan (BAP) Priority Habitats for England, based on existing accurate information.

This document was withdrawn on 6 November 2017

Key references

General description

1. Bamber, R. N. (1997). *Assessment of saline lagoons within Special Areas of Conservation.* English Nature Report 235. English Nature, Peterborough.

2. Bamber, R.N., Evans, N.J., Sanderson, W.G. & Whittall, A. (2001). *Coastal saline lagoons and pools in Wales: review and proposals*. Countryside Council for Wales, Science Report 464.

3. Bamber, R. N. & Barnes, R. S. K. (1996). *Coastal and Seas of the United Kingdom, Region 10 South-west England: Seaton to Roseland Peninsula*. Joint Nature Conservation Committee, Peterborough, Chapter 3-4.

4. Bamber, R. N., Gilliland, P. M. & Shardlow, E. A. (2001). *Saline Lagoons: A guide to their management and creation*. English Nature, Peterborough.

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9. Covey, R. (1999). 'The saline lagoon survey of Scotland'. In *Scotlands Living Coast.* Ed. Baxter, J. M., Duncan, K., Atkins, S. & Lees, G. HMSO, London, pp150-165.

10. Johnson, C. & Gilliland. P. M. (2000). *Investigation and management of water quality (nutrients) in saline lagoons based on a case study from the Chesil and the Fleet European marine site.* UK Marine SACs Project. English Nature, Peterborough.

Supporting references

Other Annex I habitats to be considered with coastal lagoons are mudflats and sandflats not covered by seawater at low tide, s*alicornia* and other annuals colonising mud and sand, s*partina swards* (*Spartinion maritimae*) and atlantic salt meadows.

This document was withdrawn on 6 November 2017

2.2.2 Freshwater habitats

The following summaries have been compiled using key reference papers provided by Environment Agency and Natural England staff. They provide a summary of relevant information on the freshwater requirements of freshwater habitats. For further information, refer to references listed below each habitat account.

– Natural dystrophic lakes and ponds

– Hard oligo-mesotrophic waters with benthic vegetation of chara spp

– Natural eutrophic lakes with *Magnopotamion or Hydrocharition* – type vegetation

– Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or *Isoëto-nanojuncetea*

– Watercourses of plain to montane levels with *Ranunculion fluitantis* and *Callitricho-batrachion* vegetation

– Oligotrophic waters containing very few minerals of sandy plains (*Littorelletalia uniflorae*)

– Mediterranean temporary ponds

This document was withdrawn on 6 November 2017

Natural dystrophic lakes and ponds

This document was withdrawn on 6 November 2017

General information

Dystrophic pools are peaty, often very acidic water bodies which are poor in plant nutrients. Due to the exposure to peat their waters are usually stained dark brown (Ref. 1). Most examples of this habitat are small (<5 hectares in extent), shallow and contain a limited range of flora and fauna. Fringing vegetation is a characteristic of the habitat and several notable scarce dragonfly species are associated with these waterbodies (Ref. 1).

Dystrophic water bodies are closely linked to the distribution of peat, and are particularly frequent on large areas of blanket peat in northern Britain such as the Scottish Flow Country. In England and Wales they are less numerous, but have a widespread distribution. Lowland sites have particular value for nature conservation because of the rarity of the habitat type in England and Wales (Ref. 3).

Description

- Dystrophic pools most often occur on blanket bogs and are characterised by peaty water, dominated by bog-mosses (*Sphagnum* spp.) and lesser bladderwort (*Utricularia minor*) in northern regions (Ref. 3);
- Some dystrophic lakes have developed a 'schwingmoor' where bog-mosses are found in association with cottongrass (*Eriophorum angustifolium*) and white water-lily (*Nymphaea alba*) (Ref. 1);
- Many of these habitat types occur on blanket bogs, plains or valley bottoms and may include isolated seasonal pools, collections of irregularly-shaped semi-permanent waters and ordered linear or concentric arrays of pools and small lochs (Ref. 1).

Key influences

Water resources

- The small size and volume of these water bodies makes them particularly susceptible to drainage and changes in nearby hydrology (Ref. 2);
- Abstraction is unlikely to be a significant issue for most of these sites due to their predominantly remote upland location. However, the possibility of impact from abstraction should be considered in lowland catchments affected by human influences.

Other influences

- Peat extraction and forestry pose the biggest threats to this habitat type;
- Changes to land management, such as over grazing and/or drainage, is also a significant threat (Ref. 2); and
- Eutrophication may be a threat in lowland catchments where the incidence of diffuse pollution and run-off is likely to be higher.

Key references

1. Joint Nature Conservation Committee, *freshwater habitats 3160 natural dystrophic lakes and ponds*. Retrieved March 13, 2006, from http://www.jncc.gov.uk/ProtectedSites/SACselection/habitat.asp?FeatureIntCode=H3160

2. Joint Nature Conservation Committee (JNCC). 2005. *Common Standards Monitoring Guidance for Standing Waters*. Joint Nature Conservation Committee, Peterborough.

3. McLeod CR, Yeo M, Brown AE, Burn AJ, Hopkins JJ and Way SF, 2002 *The Habitats Directive: selection of Special Areas of Conservation in the UK, second edition.* Joint Nature Conservation Committee: Peterborough.

Further reading

4. Carvalho L and Monteith D, 1999 *Conservation objectives of Oligotrophic and Dystrophic lake types.* Environmental Change Research Centre, University College London. Research report number 71, Report to English Nature EIT 20/23/01.

5. Duigan C, Kovach W, Palmer M. 2006. *Vegetation Communities of British Lakes: a revised classification*. Joint Nature Conservation Committee (JNCC), Peterborough.

6. European Commission. 2003. *Interpretation of European Union Habitats.* EUR25. European Commission, DG Environment, Nature and Biodiversity.
http://ec.europa.eu/environment/nature/nature_conservation/eu_enlargement/2004/pdf/habitats_im_en.pdf

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This document was withdrawn on 6 November 2017

Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.

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General information

This habitat type is characterised by water with a high base content, most often calcium but also magnesium. It is confined to areas of limestone and other base-rich substrates, from which the dissolved minerals are derived (Ref. 1). This habitat is quite rare as calcareous rocks often have high porosity so water bodies rarely occur on their surface. However, this habitat type is present in 15 EU member states but is scarce in the UK with the best examples restricted to the north and west (Ref. 1).

Description

This type of habitat may occur in four situations:

- Lakes on a predominantly limestone substrate (most common in the UK);
- Coastal sites based on calcium-rich shell-sands (including machair lochs);
- Lakes with inputs from other base-rich influences, such as boulder clays;
- Artificial situations, such as dammed river valleys and abandoned mineral works;
- Waterbodies are characterised by abundant charophytes (stoneworts) which can occur as dense beds that cover a significant part of the lake bottom over muddy marl deposits (Ref. 1). Many stonewort species are themselves threatened, and some are BAP species;
- Water in these lakes tends to be very clear with a low nutrient status rich in dissolved bases;
- As a guide, pH at these sites is frequently above neutral and ranges from 7 to 8.5 and can be over 9 in some cases (Ref. 2);
- Total Phosphorous (TP) values are often below $40ugl^{-1}$, above this stoneworts tend to decline as other macrophytes and/or phytoplankton become dominant. In more oligotrophic situations an excess of $20ugl^{-1}$ may prove detrimental (Ref. 1);
- Marl lakes have a high capacity for P immobilisation, due to coprecipitation of P with calcium and magnesium, making it unavailable for phytoplankton in the water column. Therefore, P concentrations are typically low in these lakes even under relatively high external P loads (Ref. 2);
- This habitat type is restricted to situations where the catchment or aquifer from which the water is supplied remains relatively unaffected by intensive land-use or other sources of nutrients. (Ref. 3); and
- The best examples of this habitat type tend to be predominantly groundwater fed.

Key influences

Water resources

- Both surface water and groundwater abstractions within the supplying catchment may depress water levels, increase water retention time and reduce flushing rates;
- All of the above could result in nutrient enrichment and a concomitant reduction of *Chara* and other associate species and an increase in phytoplankton and nutrient tolerant macrophytes;
- The diversity and composition of the marginal vegetation could be degraded through excessive and/or long-term lake drawdown; and
- In coastal areas, a reduction in freshwater flow due to abstraction may increase salinity.

Other influences

- Activities such as land drainage, intensive agriculture/forestry, flood defence works etc, could significantly affect the catchment hydrology resulting in nutrient enrichment and excessive sedimentation, the principle threats to the health and status of these waters; and
- Changes in fish populations may increase turbidity, limiting light penetration and inhibiting macrophyte growth.

Key references

1. Joint Nature Conservation Committee, F*reshwater Habitat 3140 Hard oligo-mesotrophic waters with benthic vegetation of Chara spp*. Retrieved March 10, 2006, from http://www.jncc.gov.uk/ProtectedSites/SACselection/habitat.asp?FeatureIntCode=H3140

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This document was withdrawn on 6 November 2017

Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation

General information

Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation have levels of nutrients greater than those of dystrophic, oligotrophic, or mesotrophic waters, this typically results in higher natural productivity and species richness (Ref. 4).

Magnopotamion vegetation are dominated by submerged rooted perennials such as *Potamogeton perfoliatus, P. lucens, P. praelongus, P. coloratus* and various submerged associates such as *Myriophyllum spicatum* and *Ceratophyllum demersum*.

Hydrocharition-type vegetation are largely free-floating surface communities with species such as *Lemna* spp., *Hydrocharis morsusranae* and *Stratiodes aloides*.

Unfortunately, many eutrophic lakes have recently been damaged by excessive nutrient enrichment, which results in hypertrophic conditions and a reduction in species- richness (Ref. 3). Undamaged examples of these lakes are now uncommon in European countries and the exact status of this habitat type is unknown (Ref. 3) as naturally occurring eutrophic lakes cannot easily be distinguished from non-natural eutrophic lakes or enriched examples of other lake types (e.g. *Chara* lakes) (Ref. 4 & 3). No comprehensive data exists on the extent of this habitat type in the UK.

Description

Three sub-types of this habitat may be identified (Ref. 3):

– (a) southern eutrophic lakes
– (b) northern or western eutrophic lakes and
– (c) coastal eutrophic lakes;

- *Magnopotamion* vegetation is generally sensitive to adverse impacts such as eutrophication or physical disturbance;
- *Hydrocharition*-type vegetation is rare in lakes and in the UK seems to be confined to Northern Ireland. In the rest of the UK the most complete expression of this community type is found in the ditch systems of the Norfolk Broads;
- As a guide, pH is generally › 7 and ›9 (Ref. 2);
- Both N and P are important chemical controls, with most systems tending to be P limited, although this should be established on an individual system basis (Ref. 2);
- Water hardness and pH play a role in determining the amount of TP available for uptake in the water column (Ref. 2); and
- Where aquatic macrophyte communities are healthy phytoplankton is controlled within the water column by a combination of shading and nutrient uptake by macrophytes.

Key influences

Water resources

- The most significant threat to eutrophic waters is nutrient enrichment;
- Abstraction within a lake or its contributory catchment can reduce water levels, reduce flushing rates and increase residence time, thereby exacerbating nutrient enrichment. Deterioration in marginal vegetation can also occur if drawdown is excessive and desiccation prolonged; and
- A reduction in freshwater flow to coastal sites may increase salinity.

Other influences

- Organic and inorganic fertiliser inputs as well as land use changes can cause eutrophication or siltation and may damage biological communities in these habitats. This can be from point source or diffuse pollution;
- The introduction of non-native plants and animals can destabilise the ecosystem. For example, Zebra mussel colonies are able to smother plants stems and lake substrates and densities greater than 120,000 individuals m^2 are not unusual (Ref. 1); Ecological impacts include exclusion of native swan mussels, reduced food availability for organisms dependent upon phytoplankton and increased nutrient and sediment loading from waste material;

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- Introduction of fish, the removal of predators or manipulation of fish stocks may alter the natural fish community and detrimentally impact the invertebrate and plant communities. This can result in a 'forward switch' to turbid, phytoplankton dominated conditions; and
- Recreational activities such as boating and other physical disturbance may reduce the cover of aquatic plants and disturb sediment. The former will allow light penetration into the water whilst the latter can release nutrients, mainly P, into the water column. These can then favour a switch to a phytoplankton dominated system.

Ongoing work

The UK Lakes Habitat Action Plan group is currently (2006/2007) carrying out an exercise to identify the extent of this resource in the UK.

This document was withdrawn on 6 November 2017

Key references

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Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or *Isoëto-nanojuncetea*

This document was withdrawn on 6 November 2017

General information

The clear soft water which characterises oligotrophic to mesotrophic standing waters contains low to moderate levels of plant nutrients and supports a characteristic assemblage of plant species. The vegetation community is characterised by aquatic short perennial vegetation, with shore-weed (*Littorella uniflora*) often a dominant component (Ref. 3) although in some situations it may be absent as other characteristic species of the *Littorelletea* flora become more abundant. For example *L. uniflora* tends to be a constant in younger stands, as it is a good coloniser, and wave action probably favours its abundance while in more sheltered, deeper waters the abundance of *Lobelia dortmanna* can exceed that of *L. uniflora* (Ref. 1).

Water bodies of this type are widespread throughout Europe, particularly in mountainous areas where oligotrophic waters are more common than mesotrophic examples. They are also widespread throughout upland parts of the UK, particularly in Wales and Scotland although many sites are small and larger lakes have often been modified by human activity (Ref. 2). Examples of this habitat may be found in Loch nan Cat on Ben Lawers in the central highlands, Llyn Cau within the Cadair Idris range in Gwynedd, tarns in the Lake District, high fells in Cumbria, Ullswater in Cumbria and temporary ponds in the New Forest, Hampshire. The latter is also representative of oligotrophic waters containing few minerals of sandy plains (*Littorelletalia uniflorae*) (Ref. 3).

Mesotrophic standing waters potentially have the highest biodiversity of any standing water habitat (Ref. 2) and also contain some species that only occur within this habitat. However, they tend to occur in less upland locations and are more vulnerable to human influences.

Description

- Plant and animal biomass is often low in oligotrophic standing waters, which are usually clear with sparse phytoplankton populations. These lakes also tend to be larger, deeper and due to being located predominantly in the uplands of the north and west tend to have a more rocky littoral zone than their lowland counterparts (Ref. 3 & 4);
- Marginal components of the plant community can be exposed on the lake shores during summer or times of drought (Ref. 3);
- The *Littorelletea* flora contains a good number of characteristic species such as *Littorella uniflora, Isoetes lacustris, Isoetes echinospora* and *Lobelia dortmanna*. These waters also support other characteristic and associate species which should be considered (Ref. 2);
- Characteristic species of oligotrophic waters containing few minerals of sandy plains (*Littorelletalia uniflorae*) also include *Littorella uniflora, Isoetes lacustris, Isoetes echinospora* and *Lobelia dortmanna*. Other characteristic and associate species also occur and need to be considered (Ref. 2); and
- Mesotrophic standing waters have the potential to support a more diverse flora with charcteriastic species including *Potamogeton spp*, *Nitella spp, Sparganium natans, Najas flexilis and Persicaria amphibia* (Ref. 2).

Key influences

Water resources

- Water resources requirements of oligotrophic to mesotrophic standing waters are likely to be site specific; and
- Changes in the availability of water through abstraction, drainage or drought may be detrimental to this habitat through changes in both hydrology and water quality. Abstraction may depress water levels, increase water retention time and reduce flushing rates, which may exacerbate nutrient enrichment, cause deterioration of marginal vegetation through drawdown and cause shallow lakes to dry out.

Other influences

- Eutrophication, acidification and sedimentation are the greatest threats to this habitat type;
- *L. uniflora, L. dortmanna* and *Isoetes* prefer oligotrophic waters and eutrophication has contributed to their decline (Ref. 4). Eutrophication stimulates phytoplankton blooms which shade out aquatic macrophytes and can cause deoxygenation of the water column resulting in fish kills;
- Acidification may occur in areas with sensitive geology and soils as a result of atmospheric deposition. Intensive forestry practices associated with coniferous plantations have also been linked to acidification of upland waters. This can lead to damage or loss of certain plant species (e.g. *Myriophyllum alterniflorum*), the invertebrate fauna and fish populations;
- Organic pollution, siltation, heavy metals and thermal pollution may also influence the condition of these habitats, and sedimentation can release nutrients and increase turbidity, inhibiting light penetration and macrophyte growth (Ref. 4);
- Fish stocking can be a problem if inappropriate species are stocked, high stocking densities occur or supplementary feeding takes place and may lead to the loss of natural fish population and affect plant and invertebrate communities (Ref. 2); and
- Recreational activities such as boating may directly damage aquatic plants, increase turbidity and cause bank side erosion. The suppression of macrophyte communities by these mechanisms may promote algal growth. (Ref. 2 & 4).

Associated habitats/species

Annex II species – floating water plantain (*Luronium natans*)

SAC habitats – oligotrophic waters containing few minerals of sandy plains (*Littorelletalia uniflorae*)

Current and future work

All of the Acid Water Monitoring Network (AWMN) sites are relevant to this habitat **www.ukawmn.ucl.ac.uk/site15/index.htm** Additionally, data from some Environmental Change Network sites is relevant **www.ecn.ac.uk/sites.htm**

This document was withdrawn on 6 November 2017

Key references

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This document was withdrawn on 6 November 2017

Watercourses of plain to montane levels with *Ranunculion fluitantis* and *Callitricho-batrachion* vegetation

This document was withdrawn on 6 November 2017

General information

Watercourses of plain to montane levels with *Ranunculion fluitantis* and *Callitricho-Batrachion* (CB) vegetation are freshwater habitats characterised by the abundance of certain aquatic vegetation. This vegetation generally consists of a mixture of species such as water-crowfoots *Ranunculus* spp., subgenus *Batrachium*; water-starworts *Callitriche*; aquatic mosses, especially *Fontinalis* spp; pondweeds *Potamogeton* spp. and various other aquatic, marginal and floating-leaved plants. The presence of this plant assemblage provides shelter and food for a wide variety of fish and invertebrates, and may modify water flow and encourage localised flow and substrate diversity, especially over the summer months when the plants are in growth.

Such rivers (or rivers supporting these plant communities) are widespread in the UK and occur in a wide range of rivers from sluggish, eutrophic rivers in the Norfolk Broads to fast-flowing oligo-mesotrophic rivers in upland areas. These support a variety of distinct plant communities. Plant communities are strongly influenced by geology and river flow regime, and those provisionally described in the UK may differ from communities found in other European countries.

Description

- CB community variance is linked to geology and river type. In each habitat type, a different assemblage of aquatic plants occurs;
- CB communities are characteristic of flowing water conditions and commonly associated with riffles and stable gravel-pebble substrate. Silt is generally restricted to macrophyte beds and river margins;
- Semi-natural water courses characterised by *Callitricho-Batrachion* communities will contain a diverse range of flow types and physical habitats including riffle-pool sequences, marginal deadwater and exposed riverine sediments; and
- Scientific information relevant to the ecological requirements of rivers with *CB* plant communities in the British Isles and in Europe is limited.

Key influences

Water resources

- The effects of flow are of great importance for lotic macrophytes, and will determine which plants occupy specific locations in the channel;
- Stream size and flow will determine community type, as individual species are adapted to specific flow types in several ways, such as anchoring strength (Ref. 3);
- Alteration of flow regime will affect channel flora and may cause a change in the composition of the substrate. The growth pattern of *Ranunculus penicillatus* subsp. *pseudofluitans* has been demonstrated to coincide with maximum flow in chalk streams. (Ref. 7);
- The season and extent of inundation is critical to the development and stability of winterbourne plant communities (ephemeral spring-fed headwater streams) (Ref. 5);
- Spates in rivers with predominantly upland catchments often lead to a reduction or the loss of channel macrophytes through washout (Ref. 7);
- Winterbournes and headwaters subject to abstraction and drought will exhibit a decline in the extent and condition of *CB* plant communities and an increase in species characteristic of slower flows such as *Callitriche stagnalis* and *Rorippa nasturtium-aquaticum*. Marginal plant species may increase in cover and long periods of drying will lead to a transition with terrestrial grasses (Ref. 7);
- Haslam (1987) observed Canadian pondweed (*Elodea canadensis*) and *Ranunculus* cover to increase in hill stream communities in years of low rainfall, whilst *Ranunculus fluitans* (which requires swift water for good growth) declined (Ref. 7); and
- The impact of abstraction and low flow is greatest in modified catchments where retention time for water entering the catchment is reduced.

Other influences

- Geology and soil type are important in determining the character of plant communities in rivers;
- Plant community diversity will be greater in river systems with mixed geology;

- Water quality parameters (alkalinity, pH, nitrate, phosphate, potassium and suspended solids) will influence species composition. For suggested phosphorus levels for main river types refer to (Ref. 6);
- Siltation, induced by low flows and channel modification, will impact upon macrophyte communities. The accumulation of silt deposits and increased turbidity will decrease light and smother macrophytes, causing a shift in species composition (Ref. 1) and preventing regeneration;
- Overgrazing of banks leads to reduction in community diversity, siltation (see above), increased scour and proliferation of ruderal species including Himalayan Balsam;
- Increased nutrient supply may lead to an overall reduction in species diversity, and increase the presence of pollution tolerant species. More extreme nutrient increases lead to an overall impoverishment of the community, with algae dominating (Ref. 1). It is also thought that high nutrient levels may make the component species more susceptible to wash out under high flows; Increased pesticide and herbicide loading may be detrimental (Ref. 4);
- The introduction of non-native species such as Japanese Knotweed (*F.japonica*), Himalayan Balsam (*I.glandulifera*), and Giant Hogweed (*H. mantegazzianum*) may be detrimental to this habitat type (Ref. 4); and
- A healthy community of marginal vegetation is also important.

Current and future work

The LIFE in UK Rivers Project is developing conservation strategies and monitoring protocols for use on rivers designated as Special Areas of Conservation under the European Union Habitats Directive. Refer to the LIFE in UK Rivers website for further information.

This document was withdrawn on 6 November 2017

Key references

General description & habitat details

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Supporting references

Annex I habitats associated with water courses of plain to montane levels with *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation to be considered are; Humid dune slacks, Atlantic salmon, Sea lamprey, River lamprey, Allis shad, Brook lamprey, Bullhead and Floating water-plantain.

For further information refer to guidance notes produced.

Oligotrophic waters containing very few minerals of sandy plains (*Littorelletalia uniflorae*)

This document was withdrawn on 6 November 2017

General information

Oligotrophic waters containing very few minerals of sandy plains are restricted to sandy plains that are acidic and low in nutrients, and therefore very scarce. The water is typically very clear and moderately acidic. The habitat type is characterised by the presence of the *Littorelletalia* type vegetation (Ref. 2);

Only four sites have been identified in the UK that are considered to represent high-quality examples. These occur in Dorset (Little Sea); on fluvio-glacial deposits in the New Forest (Hatchet Pond); the Cheshire Plain (Oak Mere); and on more recent sand deposits of marine origin in the Outer Hebrides (South Uist Machair). Little Sea in Dorset is a land locked lake on sand dunes with a heathland catchment. The catchment area of the New Forest (Hatchet Pond) and of the Cheshire Plain (Oak Mere) site is acid lowland heath, with the Machair lochs in the Outer Hebrides being acid moorland (Ref. 2).

Description

- *Littorelletalia* type vegetation is characterised by the presence of water lobelia (*Lobelia dortmanna*), shoreweed (*Littorella uniflora*), or quillwort (*Isoetes lacustris*). Only one of these species needs to be present to conform with the definition of this Annex I habitat type; and
- Typically the vegetation consists of zones in which the individual species form submerged, monospecific lawns (Ref. 2).

Key influences

Water resources

- There appears to be little information available on the hydrological requirements of this habitat type; and
- Of what is known of the hydrological regime at Oak Mere in the Cheshire Plains, water level fluctuations have been implicated in the decline of the macroinvertebrate community between 1980 and 1996. The study concluded that an initial recovery of the macroinvertebrate community had occurred since 1996, but that further recovery would depend upon the maintenance of water levels. (Ref. 3);
- Water abstraction may depress water levels, increase water retention time and reduce flushing rates. This may exacerbate nutrient enrichment, cause deterioration of marginal vegetation through drawdown and cause shallow lakes to dry out. For coastal sites, a reduction in the throughput of freshwater may increase salinity; and
- As the plant species tend to grow in distinct zones this habitat type may be particularly susceptible to drawdown, *Littorella* may grow in the drawdown zone but changes to hydrological regime may affect this species.

Other influences

- Destruction of lowland heaths, land drainage and nutrient enrichment has contributed to the scarcity of this habitat type (Ref. 3); and
- Oligotrophic waters, by definition, have low levels of dissolved nutrients and as such, water quality requirements may focus on associated variables, such as pH and dissolved oxygen. Detailed data on the water quality of lowland sites only exists for Oak Mere, but limited data is available for the South Uist SAC sites (Ref. 1).

Current and future work

The Environment Agency and landowners currently carry out monitoring of pH and water level informally at Oak Mere (Ref. 1) but no other projects have been identified within the confines of this study.

An Environment Agency R&D project 'Development of GIS Based Inventory of Standing Waters for England and Wales' is ongoing. This is a GIS–linked database of all standing waters and includes information on designations, modelled nutrient loads amongst others.

Key references

General description & habitat details

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Site specific hydrological consideration studies

3. Labadz, J.C., Harding, R.J., Potter, A. & Butcher, D.P. (2000). *Oak Mere SSSI cSAC: NGR SJ575676. Progress report (working draft) to English Nature/ECUS.* Dept of Land-Based Studies, Nottingham Trent University.

Supporting references

The Annex I habitat Oligotrophic to mesotrophic standing waters and Annex II species floating water plantain (*Luronium natans*) should be considered with this habitat.

This document was withdrawn on 6 November 2017

Mediterranean temporary ponds

This document was withdrawn on 6 November 2017

General information

Mediterranean temporary ponds are winter-flooded areas, which periodically dry out to give a vegetation composition rich in annuals; many of which are nationally rare species, and principally confined to this habitat type. Species confined to Mediterranean temporary ponds include pygmy rush (*Juncus pygmaeus*), pennyroyal (*Mentha pulegium*) and yellow centaury (*Cicendia filiformis*).

The habitat has been divided into two main pool types, a more acid pool community of trampled and grazed areas, often found on flooded trackways, and a basic pool type on serpentine rock. The Lizard heath in Cornwall represents the only UK site where significant areas of the basic pool type have been recorded (Ref. 4).

Description

- The DETR Lowland Pond Survey (1996) found temporary ponds (which include the Mediterranean habitat type) to be more shaded, have organic rich sediments, but to be less silty than their permanent equivalents. Exceptions to this are noted, and include the Lizard where Mediterranean ponds are largely unshaded;
- The acid pool type contains an important assemblage of rare species, including pigmy rush, the three-lobed crowfoot (*Ranunculus tripartitus*) and yellow centaury. A number of pools also support important invertebrate populations, including the water beetles *Graptodytes flavipes* and *Dryops striatellus*;
- Ponds are usually fish free and support fewer invertebrate predators than permanent ponds due to their periodic drying-out (Ref. 2); and
- The invertebrate fauna of temporary ponds in the UK is characterised by taxa that are mobile or tolerant to fluctuating water levels and periodic desiccation. They are commonly used by amphibians, including (although rarely) the great crested newt (*Triturus cristatus*) (Ref. 5).

Key influences

Water resources

- Little data exists on the relationship between hydrological regime and the status of the Mediterranean temporary pond habitat; and
- Mediterranean temporary ponds are more likely to be fed by near surface runoff than more permanent ponds, and less likely to be spring fed (Ref. 3);

Other influences

- The disuse of trackways that once ensured the creation of the acid type pond habitat may have reduced its distribution (Ref. 4). However it is the upgrading of such tracks to road status that is considered the major threat to Mediterranean temperate ponds;
- Given the shallow nature of Mediterranean temporary ponds soil drainage for agriculture or urban development will destroy this habitat;
- The small water volumes of temporary ponds imply they are likely to be highly susceptible to pollution; and
- A lack of awareness and recognition of this habitat type has resulted in their destruction through infilling, or by deepening for the creation of permanent ponds (Ref. 6). However, on the Lizard, the loss of Mediterranean temporary ponds are more likely to be through reduced disturbance along trackways or infilling to improve trackways.

Current and future work

The University of Plymouth is currently undertaking research on the ecology, status and management of Mediterranean temporary ponds in the UK (Ref. 1).

An Environment Agency R&D project 'Development of GIS Based Inventory of Standing Waters for England and Wales' is ongoing. This is a GIS–linked database of all standing waters and includes information on designations, modelled nutrient loads amongst others.

Key references

General description & habitat details

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Supporting references

The Annex II Great Crested Newt (*Triturus cristatus*) species should be considered with Mediterranean temporary ponds habitat.

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2.2.3 Temperate heath, scrub and grasslands

The following summaries have been compiled using key reference papers provided by Environment Agency and Natural England staff. They provide a summary of relevant information on the freshwater requirements of the temperate habitats. For further information, refer to references listed below each habitat account.

- *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caerulea*)
- Northern atlantic wet heaths with *Erica tetralix*
- Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*)
- Temperate atlantic wet heaths with *Erica ciliaris* and *Erica tetralix*

This document was withdrawn on 6 November 2017

Molinia meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caerulea*)

This document was withdrawn on 6 November 2017

General information

Molinia meadows are primarily found on moist, moderately base-rich peats and peaty gley soils, often with fluctuating water tables. They usually occur as components of wet pastures or fens, and often form mosaics with dry grassland, heath, mire and scrub communities. *Molinia* meadows are widely but discontinuously distributed throughout the UK, with concentrations in south-west England, western and central Wales, East Anglia, northern England and the south-west of Northern Ireland (Ref. 4).

A number of *Molinia* meadows hold populations of notable species, including the Cambridge milk parsley (*Selinum carvifolia*), vipers grass (*Scorzonera humilis*), soft-leaved sedge (*Carex montana*), and the marsh fritillary butterfly (*Euphydryas aurinia*).

Description

- *Molinia* meadows are distinctive in character, containing various species-rich types of fen meadow and rush pasture (Ref. 8);
- *Molinia* grasslands in the UK are represented by two NVC types:
  – M24 *Molinia caerulea* – *Cirsium dissectum* fen-meadow
  – M26 *Molinia caerulea* – *Crepis paludosa* mire
- The M25 NVC type is a *Molinia* based community, which is not part of the SAC type. Some stands are species-rich and of high conservation value, particularly in the lowlands;
- A full description of these NVC types can be found in Ref. 7;
- This habitat type includes the most species-rich of the *Molinia* grasslands in the UK, in which purple moor-grass (*Molinia caerulea*) is accompanied by a wide range of associated species which include rushes, sedges and herbs (Ref. 4);
- The sharp-flowered rush (*Juncus acutiflorus*) is generally abundant (Ref. 8);
- The vegetation often occurs in a mosaic with patches of wet heath, dry grassland, swamp and scrub (Ref. 8), and can also represent transitions to these other communities; and
- The more impoverished forms of *Molinia* pasture on acidic substrates are excluded from the Annex I definition (Ref. 4).

Key influences

Water resources

- The ecological requirements for *Molinia* meadows is not fully understood, however, the integrity of the meadow may be affected by changes to the hydrological regime, and is likely to be a key factor preventing vegetation change. Abstraction may therefore affect this habitat type;
- Critical influences on *Molinia* grasslands are the hydrology and water quality status including base-status (Ref. 8);
- The hydrological regimes necessary for this habitat are narrowly defined. More data is required before conclusions can be drawn (Ref. 6);
- *Molinia* meadows occur in a number of situations. In lowland landscapes, M24 and M26 both occur where the water table is near the ground surface (Ref. 6). These conditions are typically found on undulating plateaux and hillsides as well as in stream and river valleys;
- M26 occurs in upland situations associated with flushed slopes in enclosed sub-montane meadows and pastures or as part of the toposequence around open waters and mires (Ref. 7);
- When hydrological requirements are not met, species that are not present in high frequencies in *Molinia* grasslands can increase and invade, changing the composition of the grassland (Ref. 6); and
- Catchment hydrology can also have an impact where it may alter run-off or reduce local water tables (Ref. 6).

Other influences

- It has been suggested that soils for *Molinia* meadows are generally poor in nutrients. Alterations of the catchments nutrient budget can affect this habitat (Ref. 6);
- Atmospheric deposition may also contribute to the nutrient budgets of this habitat (Ref. 6);
- Regular grazing and hay cutting of *Molinia* meadows is required (Ref. 6); and
- Long term climate change may affect *Molinia* meadows, particularly through decreasing groundwater recharge (Ref. 6).

Current and future work

Dr. David Gowing of the Open University and Cranfield University has conducted extensive research into the ecohydrological requirements of plants, particularly grasslands and meadows (Ref. 2).

Key references

General description & habitat details

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Supporting references

Annex I habitat types to be considered with the *Molinia* meadow habitat are calcareous fens with *Cladium mariscus* and species of the *Caricion davalliana* alkaline fens calcium-rich springwater-fed fens. The Annex II species that should be considered are the marsh fritillary (*Euphydryas aurinia*) and narrow-mouthed whorl snail. Birds of lowland wet and dry grasslands should also be looked at.

This document was withdrawn on 6 November 2017

Northern atlantic wet heaths with *Erica tetralix*

This document was withdrawn on 6 November 2017

General information

Wet heaths usually occur on acidic, nutrient-poor substrates, such as shallow peats or sandy soils with impeded drainage. Mixtures of cross-leafed heath (*Erica tetralix*), heather (*Calluna vulgaris*), grasses, sedges and bog-mosses (*Sphagnum* spp) typically dominate them (Ref. 8).

Northern Atlantic wet heaths with *Erica tetralix* occur throughout the UK but populations present in southern and central England are highly localised. Wet heaths become more extensive in coverage in the cool and wet north and west of the UK, particularly in the Scottish Highlands. The area covered by wet heath is significantly smaller than that covered by blanket bogs or dry heath (Ref. 8).

Description

Wet heaths occur in several types of ecological gradient:

- In the drier areas of the south and east, wet heaths are local and often restricted to the transition zone between European dry heaths and constantly wet valley mires;
- In the uplands they occur most frequently in gradients between dry heath or other dry, acid habitats and blanket bogs;
- At high altitude in the Scottish Highlands wet heaths occur in mosaics with Alpine and Boreal heaths (lichens and northern or montane species may be well-represented in these situations); and
- Flushed wet heaths are especially frequent in areas of high rainfall, and occur as topogenous fens, usually in channels within heath or grassland vegetation (Ref. 8).

In the UK, wet heath corresponds to the NVC communities:

- H5 *Erica vagans – Schoenus nigricans* heath
- M14 *Schoenus nigricans – Narthecium ossifragum* mire
- M15 *Scirpus cespitosus – Erica tetralix* wet heath
- M16 *Erica tetralix – Sphagnum compactum* wet heath

- Refer to Ref. 10 for further details on NVC type compositions;
- On the Lizard in Cornwall, Cornish heath (*Erica vagans*) growing with *S. nigricans*, cross-leaved heath and purple moor grass (*Molinia caerulea*) forms a distinctive and unique form of wet heath (H5 *Erica – Schoenus* heath), found nowhere else in Europe (Ref. 8);
- A further very local wet heath type is *Schoenus – Narthecium* mire (M14), which is mainly associated with transitions from heath to valley bog at a small number of lowland sites in southern Britain (Ref. 8);
- *Scirpus – Erica* wet heath (M15) is found in areas of moderate to high rainfall, and is typical of wet heath vegetation in the north and west of the UK. Cross-leaved heath and heather are typically accompanied by abundant deergrass (*Trichophorum cespitosum*) and purple moor-grass (Ref. 8); and
- *Erica – Sphagnum* wet heath (M16) is characteristic of drier climates in the south and east, and is usually dominated by mixtures of cross-leafed heath, heather and purple moor grass (Ref. 8).

Key influences

Water resources

- Cross-leafed heath is most prevalent on areas of shallow slope, particularly when this leads to an accumulation of water. The substratum is typically waterlogged and poorly aerated with a high organic content (Ref. 2);
- Wet heath may be completely inundated for periods during the winter months but summer soil surface conditions can be very dry on bare or exposed areas (Ref.12);
- The distribution and abundance of purple moor grass, cross-leafed heath and heather are largely determined by the depth to the water table and the degree and duration of water-logging. Co-existence by all three species requires a balance between waterlogging, fluctuating water levels and sub-surface flow (Ref. 13);
- The change from a fluctuating to a constantly high water table is correlated with a decrease in the importance of heather and an increased proportion of cross-leafed heath (Ref. 13);

- Experiments conducted to determine the effect of water level and soil moisture on growth, drought resistance and leaf transpiration in four heathland species, which included cross-leafed heath indicated that (refer to Ref. 5):
- All species grow best at a water level of -8 cm
- Cross-leafed heath is the most tolerant of permanently saturated soils (water level of 0 cm) and of high substrate drought conditions. It also tolerates conditions almost as dry as bell heather, a species typical of dry heath
- Dorset heath is less resistant to high substrate drought conditions;
- With the exception of Michael (1996) there is little published quantitative information on the soil water regimes of wet heaths (Ref. 7); and
- Refer to Refs. 12 and 15 for further information on the water level requirements of a number of species.

Other influences

- Heathland habitats are dependent upon base-deficient (acidic) soils with low nutrient status (Refs. 12 & 14);
- When phosphorus or nitrogen availability is increased, cross-leafed heath is out competed by purple moor grass, which responds quicker to increased nutrient availability (Refs. 1 & 3);
- The percentage cover of cross-leafed heath is enhanced with rising carbon dioxide and hydrogen sulphide concentrations in the ground water (Ref.15);
- A high level of soil organic matter may be important for *Erica* species but further research is required to determine the relationship between soil organic matter and cross-leafed heath. Organic substrates have a better moisture retention capacity than mineral substrates (Ref. 4); and
- In addition to changes in water resources, lowland heathlands are subject to a range of pressures, including inappropriate grazing management, scrub encroachment, pollution and fire which lead to habitat loss and fragmentation.

Current and future work

Recent work includes guidelines on the eco-hydrological requirements of wet heaths compiled by English Nature (now Natural England) and the Centre for Ecology and Hydrology (Ref. 9). In 2004 The Environment Agency published Eco-hydrological guidelines for lowland wetland communities (Ref. 16). Both documents provide details that may be of use in assessing the requirements of North Atlantic Wet Heaths.

This document was withdrawn on 6 November 2017

Key references

General description & habitat details

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13. Rutter, A.J. (1955). 'The composition of wet-heath vegetation in relation to the water-table'. *Journal of Ecology.* 43: 407-443 (as cited in Bannister, 1966).

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16. Wheeler *et al* 2004 *Ecohydrological Guidelines for Lowland Wetland Plant Communities* Available: http://publications.environment-agency.gov.uk/pdf/GEAN0305BIPZ-e-e.pdf Accessed 23rd Feb 2007.

Supporting references

The following Annex I habitat types and Annex II species which should be considered with Northern Atlantic wet heaths with *Erica tetralix*; blanket bogs, calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*. The great crested newt and southern damselfly should also be refered to.

This document was withdrawn on 6 November 2017

Lowland hay meadows

(*Alopecurus pratensis, Sanguisorba officinalis*)

General information

This Annex I type comprises species-rich hay meadows on moderately fertile soils of river and tributary floodplains. Most examples are cut annually for hay, with light aftermath grazing. Seasonal flooding maintains an input of nutrients (Ref 6). Lowland Hay Meadows are species rich areas, which occur on fertile soils of river and tributary floodplains. Most examples are cut or grazed and seasonal flooding maintains nutrient input (Ref. 6). It is estimated that this habitat type covers less than 1500 hectares in total and survives at small scattered sites (Ref. 8). This habitat occurs throughout Europe but is rare in the UK, inhabiting central and southern England as well as the Welsh borders. There are particularly important concentrations in the flood plains of the River Thames and its tributaries, and those associated with the Vale of York rivers, especially the Derwent (Ref. 8).

Agricultural intensification has contributed to the decline of this habitat type which is estimated to have receeded by 97 per cent over the past 50 years and are continuing to decline at 2-10 per cent annually (Ref. 8).

Description

This habitat type is characterised by species-rich swards containing frequent red fescue (*Festuca rubra*), crested dog's-tail (*Cynosurus cristatus*), meadow foxtail (*Alopercurus pratensis*), great burnet (*Sanguisorba officinalis*), meadow sweet (*Filipendula ulmaria*) and meadow buttercup (*Ranunculus acris*) and provides the primary habitat of the *Fritillaria meleagris* in the UK (Ref. 6). This habitat type corresponds to the National Vegetation Classification type MG4 *Alopecurus pratensis-Sanguisorba officinalis* grassland (Ref. 6).

Key influences

Water resources

- A reduction in inundation frequency and duration in lowland hay meadows as a result of irrigation, land drainage, flood defences, surface and ground water abstraction, floodplain gravel abstraction or changes in the climate has contributed to the decline of this habitat type (Ref. 8).

Other influences

- Lowland hay meadows have been declining due to a reduction in the quality and quantity of their habitat and its fragmentation resulting from:
- Agricultural improvement through drainage, ploughing, re-seeding, fertiliser treatment, slurry application, conversion to arable land and a shift from hay-making to silage production (Ref. 8)
- Abandonment and the invasion of bracken (*Pteridium aquilinum*) and scrub (Ref. 8)
- A reduction in water quality due to eutrophication, application of herbicides and pesticides, atmospheric deposition and acidification
- Floristic impoverishment due to grazing pressures (Ref. 8).

Current and future work

Several studies currently in progress are investigating possibilities for establishing species-rich grasslands by cessation of nutrient inputs, seeding and turfing with wild species and arable reversion (Ref. 8).

This document was withdrawn on 6 November 2017

Key references

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7. Rodwell JS, 1992 *British Plant Communities Volume 3, Grasslands and Montane Communities*. University Press: Cambridge.

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Supporting references

Lowland hay meadows are an important habitat for the corncrake (*Crex crex*) and a number of farmland birds including the skylark (*Alauda arvensis*) and the *Fritillaria meleagris* in the UK (Ref. 8 & 6).

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Temperate atlantic wet heaths with *Erica ciliaris* and *Erica tetralix*

This document was withdrawn on 6 November 2017

General information

Heaths containing the cross-leaved heath (*Erica tetralix*) or the nationally rare Dorset heath (*E. ciliaris*) are generally found on acid soils with slightly impeded drainage, although in Cornwall they extend onto dry soils. The abundance of Dorset heath differentiates this habitat from other Annex I heath types (Ref. 8).

Dorset heath is at the northern limit of its present distribution in the UK. It has been suggested that the northern range may be limited by lower summer temperatures acting on the maturation of seed (Ref. 13). This form of heathland is confined to warm, oceanic locations in the UK. It is a rare habitat, occurring naturally only in Dorset and Cornwall (Ref. 8).

Description

- Temperate Atlantic wet heaths with Dorset heath and crossed-leaved heath often contain heather (*Calluna vulgaris*) and varying proportions of bell heather (*Erica cinerea*). Other associated species include purple moor-grass (*Molinia caerulea*), bristle bent (*Agrostis curtisii*) and dwarf gorse (*Ulex minor*), with the latter being replaced by western gorse (*U. gallii*) in south-west England (Ref. 8).

This habitat type is not recognised as a distinct community in the NVC but includes forms of the following communities in which Dorset heath is abundant:

- H3 *Ulex minor – Agrostis curtisii* heath
- H4 *Ulex gallii – Agrostis curtisii* heath
- M16 *Erica tetralix – Sphagnum compactum* wet heath
- M21 *Narthecium ossifragum – Sphagnum papillosum* valley mire;
- Refer to Ref. 11 for further details on NVC type compositions; and
- These heaths may grade into wetter heath and bog communities, notably valley mires with bog-moss (*Sphagnum* spp.) and bog asphodel (*Narthecium ossifragum*) (Ref. 8).

Key influences

Water resources

- In the UK, cross-leaved heath and Dorset heath generally grow on soils that are permanently or frequently waterlogged (Ref. 7);
- Wet heath may be completely inundated for periods during the winter months but summer soil surface conditions can be very dry on bare or exposed areas (Ref. 14);
- In Cornwall, Dorset heath occurs at a number of localities where soil conditions are drier and in one case it has been recorded growing on turf-clad stone walls (Ref. 13);
- The distribution and abundance of purple moor grass, cross-leaved heath and heather are largely determined by the depth to the water table and the degree and duration of water-logging. Co-existence by all three species requires a balance between waterlogging, fluctuating water levels and sub-surface flow (Ref. 15);
- The change from a fluctuating to a constantly high water table is correlated with a decrease in the importance of heather and an increased proportion of cross-leaved heath (Ref. 15);
- Experiments conducted to determine the effect of water level and soil moisture on growth, drought resistance and leaf transpiration in four heathland species, which included cross-leaved heath indicated that (Ref. 5):
- All species grow best at a water level of -8 cm
- Cross-leaved heath is the most tolerant of permanently saturated soils (water level of 0 cm) and of high substrate drought conditions. It also tolerates conditions almost as dry as bell heather, a species typical of dry heath
- Dorset heath is less resistant to high substrate drought conditions
- With the exception of Michael (1996) there is little published quantitative information on the soil water regimes of wet heaths (Ref. 7); and
- Refer to Rose & Webb (2000) and Newbold & Mountford (1997) for further information on the water level requirements of a number of species.

Other influences

- Within Dorset populations of Dorset heath, growth is most prolific in the wet heath zone where there is shallow peat. In this situation the plants root into both the peat layer and the underlying mineral soil and may, in such circumstances, dominate the vegetation (Ref. 13);
- Poorly aerated soils with a high organic content are preferred (Ref. 2). Organic substrates have a better moisture retention capacity than mineral substrates (Ref. 4);
- Heath habitats are dependent upon base-deficient (acidic) soils with low nutrient status (Ref. 14 & 15);
- When phosphorus or nitrogen availability is increased, cross-leaved heath is out competed by purple moor grass, which responds quicker to increased nutrient availability (Ref. 1 & 3);
- The percentage cover of cross-leaved heath is enhanced with rising carbon dioxide and hydrogen sulphide concentrations in the ground water (Ref. 16); and
- Lowland heaths are subject to a range of pressures including habitat loss and fragmentation, pollution and fire (Ref. 6).

Current and future work

Recent work includes guidelines on the eco-hydrological requirements of wet heaths compiled by English Nature (now Natural England) and the Centre for Ecology and Hydrology (Ref.10). In 2004 The Environment Agency published Eco-hydrological guidelines for lowland wetland communities (Ref. 17). Both documents provide details that may be of use in assessing the requirements of Temperate Atlantic Wet Heaths.

This document was withdrawn on 6 November 2017

Key references

General description & habitat details

1. Aerts, R. and Berendse, F. (1988). 'The effects of increased nutrient availability on vegetation dynamics in wet heathlands'. *Vegetatio.* 76: 63-69.

2. Bannister, P. (1966). 'Biological Flora of the British Isles: *Erica tetralix*'. *Journal of Ecology.* 52: 795-813.

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17. Wheeler *et al* 2004 *Ecohydrological Guidelines for Lowland Wetland Plant Communities* Available: http://publications.environment-agency.gov.uk/pdf/GEAN0305BIPZ-e-e.pdf Accessed 23rd Feb 2007.

Supporting references

The following Annex I habitats and Annex II species types should be considered with temperate Atlantic wet heaths with *Erica ciliaris* and *Erica tetralix*: european dry heaths, blanket bogs, alpine and boreal heaths, calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae* and southern damselfly (*Coenagrion mercuriale*).

This document was withdrawn on 6 November 2017

2.2.4 Raised bogs, fens, mires, alluvial forests and bog woodland

The following accounts are intended to provide a summary of relevant information on the freshwater requirements of raised bogs, fens, mires, alluvial forests and bog woodlands. For many of the habitat types there is very little published material directly associated with them and as such these summaries should be treated with the necessary precautions. For further information, refer to references listed in each habitat summary.

- *Tilio-Acerion* forests
- Alkaline fens and calcium rich springwater fed fens
- Alluvial forest with Alnus glutinosa and Fraxinus excelsior (*Alno-Padion, Alnion incanae, Salicion albae*)
- Alpine pioneer formations of the *Caricion bicoloris-atrofuscae*
- Blanket bogs
- Bog woodlands
- Calcareous fens with Cladium mariscus and species of the *Caricion davallianae*
- Depressions on peat substrates of the *Rhynchosporion*
- Petrifying springs with tufa formation (*Cratoneurion*)
- Raised bog (*Ombrotrophic bog*)
- Transition mires and quaking bogs

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Tilio-Acerion forests

This document was withdrawn on 6 November 2017

General information

Tilio-Acerion ravine forests are woods of ash (*Fraxinus excelsior*), wych elm (*Ulmus glabra*) and lime (*Tilia cordata* and *T. platyphyllos*; 1). This habitat type has its centre of distribution in continental Europe, but is widespread from Scandinavia through to the Pyrenees and into Italy.

Typically it occurs in association with base-rich rocks in the steep-sided immature river valleys of the colline, sub-montane and high mountain belts across Europe. Introduced sycamore *Acer pseudoplatanus* is often present and is a common part of the community in mainland Europe, where it is native.

This habitat type is widespread in the upland-lowland boundary in England and on the Welsh border and occurs through Scotland. Fragmented stands also occur on the chalk combes in south-east England (Ref. 1).

Description

- The habitat type typically occurs on nutrient-rich soils that often accumulate in the shady micro-climates towards the bases of slopes and ravines;
- It is found on calcareous substrates associated with coarse scree, cliffs, steep rocky slopes and ravines, where inaccessibility has reduced human impact;
- It often occurs as a series of scattered patches grading into other types of woodland on level valley floors and on slopes above, or as narrow strips along stream-sides. More extensive stands occur on limestone and other base-rich rocks;
- This habitat type is ecologically variable, particularly with respect to the dominant tree species. To the north and west, ash and wych elm assume increasing importance in the canopy, and lime may be completely absent; and
- Floristic differences due to variations in slope, aspect and nature of the substrate add to the diversity of the habitat.

The ground flora can be very varied, but the following elements are usually present:

- – fern banks (particularly hart's-tongue *Phyllitis scolopendrium*, soft shield-fern *Polystichum setiferum* and buckler-ferns *Dryopteris* spp.);
- – stands of ramsons *Allium ursinum* in the moister zones; dog's mercury *Mercurialis perennis* and enchanter's-nightshade *Circaea* spp. on drier but still base-rich soils;
- – wood avens *Geum urbanum*, and natural 'disturbance communities' comprising common nettle *Urtica dioica*, herb-Robert *Geranium robertianum* and cleavers *Galium aparine* associated with scree and cliff-bases;
- – A wide range of other basiphilous herbs and grasses may occur within these stands;

- The main NVC types conforming to ***Tilio-Acerion* forests** are the 'western' forms:
  - – W8 *Fraxinus excelsior – Acer campestre-Mercurialis perennis* woodland
  - – W9 *Fraxinus excelsior – Sorbus aucuparia – Mercurialis perennis* woodland; and
- ***Tilio-Acerion* forests** provide a habitat for a number of uncommon vascular plants, including, dark-red helleborine *Epipactis atrorubens*, violet helleborine *Epipactis purpurata*, wood fescue *Festuca altissima*, purple gromwell *Lithospermum purpureocaeruleum* and herb-Paris *Paris quadrifolia*. Many sites support notable bryophytes, in particular calcicoles associated with base-rich rock outcrops and (in western stands) Atlantic species. Some localities have important assemblages of epiphytic lichens.

Key influences

Water resources

- Little information is available on the influence of water resources on *Tilio-Acerion* forests; however, changes to the hydrological regime may have a detrimental impact on this habitat type.

Other influences

- This habitat type has declined in recent years as a result of habitat loss and fragmentation; as well as
- overgrazing by sheep, deer and rabbits;
- Dutch elm disease;
- eutrophication; and
- the introduction of non-native species such as conifers (Ref. 4).

Current and future work

A study by Slack (2004) on the response of seedlings of this habitat to combined shade and drought found the species to have a greater tolerance of shade than drought (Ref. 3).

Key references

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2. European Nature Information System, *Factsheet for Tilio-Acerion forests*. Retrieved March 30, 2006 from eunis.eea.int/habitats-factsheet.jsp

3. Slack L, 2004 *Responses of temperate woody seedlings to shade and drought: do trade-offs limit potential niche differentiation*? Oikos 107, 1.

4. UK Biodiversity Action Plan, *Upland mixed ashwoods*. Retrieved March 30, 2006 from www.ukbap.org.uk/UKPlans.aspx?ID=3

Supporting references

Tilio-Acerion forests should be considered with the netted carpet moth (*Eustromia reticulatum*), pearl bordered fritillary (*Boloria euphrosyne*), high brown fritillary (*Argynnis adippe*) and dormouse (*Muscardinus avellanarius*; Ref. 4).

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Alkaline fens and calcium rich springwater fed fens

General information

Fens are divided into two major groups based upon their topography and hydrology, topogenous fens and soligenous fens (Ref. 6). Topogenous fens are formed where the topography creates a basin-type water collection system with little water movement out of the system. Three sub-types are recognised, open-water transition fens, flood plain fens and basin fens. Soligenous fens are formed where sloping terrain provides a continuous supply of flowing water. Three sub-types are recognised, valley fens, flush fens and calcareous spring fens. Both fen types are groundwater-fed systems.

Calcareous spring fens develop around freshwater springs rich in calcium. The water feeding these fens wells up from the ground and often deposits a white crust known as 'tufa' on the ground vegetation. Sites are usually very small and often occur within larger wetland systems (Ref. 6).

Alkaline fens occur over a wide geographical range throughout the UK, but are uneven and localised in distribution. Important concentrations of this habitat are found in East Anglia, Cumbria, and north-west Wales. Alkaline fen vegetation has declined dramatically in the past century throughout the UK, and in many parts of the country only small, fragmented stands survive (Ref. 6).

Description

- Few studies have been undertaken on spring-fed fen sites and the factors determining vegetation composition and productivity (Ref. 4); and
- Alkaline fens contain a complex assemblage of vegetation types characteristic of sites with tufa and/or peat formation, a high water table and a calcareous base-rich water supply (Ref. 4).

Core vegetation is short sedge mire (mire with low-growing sedge vegetation). Alkaline fens are transposed into the NVC types:

  – M9 *Carex rostrata – Calliergon cuspidatum/giganteum* mire
  – M10 *Carex dioica – Pinguicula vulgaris* mire
  – M13 *Schoenus nigricans – Juncus subnodulosus* mire;

- A full description of these NVC classifications can be found in *Rodwell* 1991 (Ref. 7); and
- At most sites, transition to a range of other fen vegetation types is well marked. Alkaline fens may occur with various other vegetation types including swamps (in particular species-poor stands of great fen-sedge *Cladium mariscus*), wet grasslands (particularly various types of purple moor-grass *Molinia caerulea* grassland) and areas rich in rush species (*Juncus* spp.). This habitat has also found to occur with fen carr, wet heath and acid bogs (Ref. 4).

Key influences

Water resources

- Species which constitute the fen habitat type are considered to be either critically dependent or supported by groundwater (Ref. 10). The response of fen vegetation to groundwater abstraction is difficult to generalise as sensitivity to hydrological change will vary between communities (Ref. 6);
- The seepage of groundwater is essential for the conservation of the typically mesotrophic character of the fens (Ref. 9);
- Abstraction of water from boreholes will produce localised depressions in groundwater-water levels, termed a cone of depression. A reduction in pressures may lead to a decline or cessation in spring flow, to the detriment of the alkaline fen habitat (Ref. 6);
- The hydrological response of fen communities to change is not simply limited to a seasonal decline in water level tables but also to increases in the magnitude and frequency of water table fluctuations, and increases in the duration of water table level changes. Such alterations may lead to an increase in the depth of aeration of the peat profile. Decomposing and dewatered peat may undergo irreversible physical changes and even if the system is re-watered the response of the fen water table may not be re-established in the same way (Ref. 3);

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- Alkaline fens experience lateral water movement derived from the mineral ground. The water table (and usually the site) is strongly sloping and with water movement maintained primarily by groundwater discharge (Ref. 2);
- Fairly high and constant summer water tables are required with the absence of protracted or deep winter flooding (Ref. 2); and
- Absence of strongly reducing conditions in the rooting zone (caused by water flow and often by subsurface water tables) (Ref. 2).

Other influences

- Specific hydrochemical processes (especially calcite precipitation) associated with degassing of discharging groundwater and concomitant Phosphorus adsorption (Ref. 2);
- Spring-fed, rich-fen sites are irrigated by base-rich groundwater discharge of high pH (>6.0), calcium, iron and hydrogen carbonate (HCO_3) concentrations (Ref. 1);
- Oligotrophic to mesotrophic soil water conditions are required (Ref. 1); and
- The maintenance of the nutrient status and moving water conditions are regarded as important factors, if not more, than water levels in alkaline fen habitats (Ref. 1).

Current and future work

Drs. B. Wheeler and S. Shaw of the Department of Animal and Plant Sciences, University of Sheffield have provided an international lead on wetland research for many years. They have related the hydrogeology to plant communities and Natura 2000 interest features in many East Anglian fens in producing the first edition of the Wetland Framework. It arose from a collaborative project between Sheffield University, the Environment Agency and English Nature. It is continuing over the next two years to encompass fen types not adequately represented in East Anglia, bringing in the Countryside Council for Wales as an additional partner. The work has also proposed an updated approach to the classification of wetlands, based on their defining landscape features and recurring water supply mechanisms (WETMECS).

English Nature (now Natural England) have published a report on the eco-hydrological guidelines for wet heaths which may be of use when assessing the requirements of alkaline fens (Ref.5) The Environment Agency has published guidelines for lowland wetland communities (Ref.12).

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Supporting references

Annex I habitats and Annex II species to be considered with alkaline fens include calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae,* petrifying springs with tufa formation (*Cratoneurion*) and marsh saxifrage (*Saxifraga hirculus*). Also geyer's whorl snail (*Vertigo geyeri*), marsh fritillary *Euphydryas aurinia*), slender feather-moss (*Drepanocladus vernicosus*), fen orchid (*Liparis loeselii*)*,* alpine pioneer formations of the *Caricion bicoloris-atrofuscae,* Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*), molinia meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caerulea*) and the round-mouthed whorl snail (*Vertigo genesii*) should be considered.

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Alluvial forest with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*)

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General information

Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)* habitat covers a range of riparian woodland types. These habitats have been much reduced in coverage throughout Europe by drainage, clearance for agriculture and river management schemes to prevent flooding.

Grey alder is not native in the UK (and not relevant to UK in this habitat type) and the black poplar is poorly developed as an extensive high-forest type, though it may occur locally as linear stands along the edges of watercourses. Clearance of riverine woodland has eliminated most true alluvial forests in the UK. Many surviving fragments, as elsewhere in Europe, are fragmentary and often of recent origin. However, residual alder woods do frequently occur in association with other woodland types or with other wetland habitats such as fens (Ref. 9).

Description

The NVC System recognises three main communities of the Alno-Padion alluvial forest. In order of "wetness", these are:

- *Alnus glutinosa-Carex paniculata* swamps (W5);
- *A. glutinosa-Urtica dioica* (W6);
- *A glutinosa-Fraxinus excelsior-Lysmachia nemorum* woods (W7);
- These communities are divided into a number of sub-communities;
- Key species apart from the plants in alder woodlands include a number of dependent invertebrates such as the moths, dingy shell, alder kitten and pale tussock, a number of crane fly species, sawflies, and gall mites. Alder seed cones provide a winter food source for a number of finches such as siskin and redpoll, older trees may provide habitat for bats such as Daubenton's, and the woods provide cover for otter;
- W5 woodlands are widespread but local in the English lowlands with the reed sub-community more common, refer to Ref. 8 for JNCC distribution maps;
- Yellow loosestrife alder woods are more typical of East Anglia while the rarer golden saxifrage woods occur mainly in the Weald. W2a willow fen has a similar distribution, predominating in East Anglia with further examples in Cheshire;
- W6 woodlands are widespread, but confined to un-drained floodplains, eutrophic mires or other sites where continued periodic flooding with active alluvial deposition occurs; and
- W7 woodlands are more characteristic of wooded valleys of slightly sharper relief and are consequently more common on the fringes of the uplands in the north and west of the UK and areas such as the Weald in south-east England.

Key influences

Water resources

- Alder (*A. glutinosa*) achieves dominance in woodlands where light levels are high and the substrate is very wet or permanently inundated. It is therefore a typical species of the waters edge where both requirements are met. Alder is weakly competitive and declines in conditions of decreasing water levels that allow other tree species to colonise, with light competition the likely principle factor (Ref. 4);
- The W5 and W6 communities are essentially those of lowland habitats where the ground is level and water is derived from surface flow or groundwater inputs. The W5 swamp community is characteristic of the edges of standing or very slow moving waters. They are also found on flood-plain mires but are not normally in close proximity to the river channel, or valley mires. They are permanently wet and waterlogged but do not generally receive direct and regular alluvial inputs from surface flows, though some flood-plain mires on the more extensive flood-plains may experience occasional inundation. These systems normally rely on ground-water inputs of base-rich waters from chalks, limestones or calcareous sandstones. W5a, reed and W5b, yellow loosestrife sub-communities represent a seral transition from open waters to drier woodland. The W5c golden saxifrage sub-community is commonly associated with seepage zones in other woodland types. Fen carr of the W2a sub community has similar characteristics to W5a and b;

- W6 alder-nettle woods are generally typical of conditions of alluvial deposition and nutrient enrichment derived from periodic flooding from river channels. A similar woodland type may develop from inputs of particularly nutrient-rich groundwaters. As described above, the degree of soil wetness and frequency of flooding with its associated inputs of silt and organic matter, determine the nature of the sub-community with willow species forming a common riverside fringe. The importance of water level fluctuations in determining the sub-community zonation is shown by Van Splunder *et al.* (1995). They noted how the distribution of the larger willow species in alluvial woodlands is related to the water levels at seeding time while black poplar, with a longer seed viability, germinates at lower soil moisture levels. As water levels in the flood plain soils decreases with an increase in height away from the river channel, the cover of alder decreases and other tree species occur with ash being one of the first to achieve dominance. The community then typically grades into an oak/ash or an oak/elm association, the community depending on soil type and geography;
- Valley side woodlands W7 are less susceptible to water management issues within the main river channel, but may be vulnerable to operations that affect the ground water inputs either from abstractions or other developments that may interrupt the supply;
- The W7 alder-ash-yellow pimpernel woods described in the NVC rely mainly on ground water supplied either laterally as springline flow from the rock strata or from subsurface flows down the valley slopes; and
- Continuing demands on water resources renders fen habitats in general vulnerable to vegetation change arising from fluctuating water levels, eutrophication, or from succession to drier woodland types following decreases in water level.

Other influences

- Variation in the UK alderwood community arises from differences in the soil nutrient status or the nutrients supplied by water inputs, geography and topography;
- With a pH tolerance of around 4.5 – 8, alder avoids more acid substrates typical of sphagnum mires and bogs;
- W5 and W6 commonly stand on organic-rich soils or deposits of fen peat;
- Historically the drainage of marshes and fens with agricultural intensification has reduced the cover of the W5 woodland. W6 have also suffered losses from similar activities. Where woodlands remain, the riparian zones are typically contracted to regulate river flows and reduce the area and frequency of flooding (Ref. 18 & 19). More complete levels of flood protection, e.g. embankments, which prevent flooding altogether and the concomitant processes of alluvium and nutrient deposition, may eliminate some riparian woodland types (Ref. 18) and result in changes to the species composition, wood and structure and aspects of soil chemistry;
- In some of the smaller basin or valley mire systems where peat levels are building, there may be a natural succession to more open sphagnum dominated mires with loss of alder as substrate acidity increases (reviewed in Ref. 15);
- Nutrient pollution may result in changes to the ground flora from a more species-rich low-herb community to a tall herb type dominated by nettle in W7. Changes in the ground flora can also arise from colonisation by invasive alien plant species of which Himalayan balsam (*Impatiens glandulifera*) is the most significant for riverside alder woods; and
- The implications of the disease in alder caused by the fungus *Phytophthora* for native alder woods in the UK and Europe have yet to be established (Ref. 3).

Current and future work

English Nature (now Natural England) have published a research report on the eco-hydrological guidelines for wet woodlands which includes a section on alluvial forests. English Nature Research Report number 619 should be consulted (Ref. 2).

This document was withdrawn on 6 November 2017

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Supporting references

Other Annex I habitats to be considered with alluvial forests are calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae,* alkaline fens calcium-rich springwater-fed fens. The Annex II species that should be considered are the barbastelle bat (*Barbastella barbastellus*) and the otter (*Lutra lutra)*.

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Alpine pioneer formations of the *Caricion bicoloris-atrofuscae*

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General information

Alpine pioneer formation of the *Caricion bicoloris-atrofuscae* is a type of flush mire that occurs only at high altitude. The characteristic plant communities colonise open substrates, which are constantly subjected to flushes by surface seepage of cold, base-rich water. Alpine pioneer formations are amongst the few remaining natural plant communities in the UK and are maintained by harsh climatic and soil conditions (Ref. 2).

This habitat type is rare in the UK and largely restricted to the Scottish Highlands, where it is considered relatively widespread. Outliers exist in northern England and North Wales (Durham in Cumbria and Conwy, Gwynedd). Alpine pioneer formations are rarely extensive, but contain some of the rarest plant species in the UK (Ref. 2).

Description

Alpine pioneer formation vegetation consists of mixtures of small sedges, rushes, small herbs and bryophytes, including many arctic-alpine species. Four NVC types are recognised for high-altitude stands:

- M10 *Carex dioica – Pinguicula vulgaris* mire
- M11 *Carex demissa – Saxifraga aizoides* mire
- M12 *Carex saxatilis* mire
- M34 *Carex demissa – Koenigia islandica* flush (Ref. 2);

- Differences in altitude, geographic location, length of snow-lie, the nature of the substrate, and the amount of water flushing the communities result in variations in this habitat type (Ref. 2);
- Generally the habitat is characterised by the presence of a number of rare species and include the scorched alpine-sedge (*Carex atrofusca*), bristle sedge (*C. microglochin*), alpine rush (*Juncus alpinoarticulatus*), chestnut rush (*J. castaneus*), two-flowered rush (*J. biglumis*), three-flowered rush (*J. triglumis*), false sedge (*Kobresia simpliciuscula*) and Scottish asphodel (*Tofieldia pusilla*). There is also a range of calcicolous mosses, (mosses which grow in habitats rich in calcium) some of which are rare (Ref. 2);
- Other uncommon species may occur, and include the hair sedge (*C. capillaris*), sheathed sedge (*C. vaginata*) and variegated horsetail (*Equisetum variegatum*) (Ref. 2);
- Commoner species characteristic of this habitat include yellow sedge (*C. viridula*), carnation grass (*C. panicea*), flea sedge (*C. pulicaris*), russet sedge (*C. saxatilis*), jointed rush (*J. articulatus*), common butterwort (*Pinguicula vulgaris*), yellow saxifrage (*Saxifraga aizoides*), alpine bistort (*Persicaria vivipara*), alpine meadow-rue (*Thalictrum alpinum*) and the moss *Blindia acuta* (Ref. 2); and
- This habitat usually forms mosaics and shows complex transitions to other upland Annex I habitat types (Ref. 2).

Key influences

Water resources

- No published information on the specific hydrological requirements of alpine pioneer formations of the *Caricion bicoloris-atrofuscae* was obtained within the confines of this project. However, it is likely that any activity which reduces the constant flushing of alpine pioneer formations of the *Caricion bicoloris-atrofuscae,* will have a negative impact on the status of this habitat;
- *Carex dioica – Pinguicula vulgaris* (M10) mires require consistent maintenance of a high water-table, although considerable seasonal fluctuations do occur at some sites. However, fluctuations experienced probably do not leave the fen mat desiccated for long periods of time. *Carex demissa – Saxifraga aizoides* (M11) mires require vigorous flushing (Ref. 3);
- Direct snow-melt, rather than lateral flushing, may provide *Carex saxatilis* (M12) mires with much of the soil moisture required for their continuous irrigation. Snow-melt may have an effect by diluting base-enrichment or induce sufficient surface-leaching to allow the good representation of non-calcicolous species (Ref. 3); and

- The arctic-subantarctic climate where the *Carex demissa – Koenigia islandica* (M34) community is found and vigorous flushing by circumneutral (more or less neutral) and oligotrophic waters (poor in nutrients), are probably of most important parameters for this species composition, helping to maintain its open nature (Ref.3).

Other influences

- No information was obtained on additional pressures and influences on alpine pioneer formations of the *Caricion bicoloris-atrofuscae* within the confines of this project.

Current and future work

No current or future projects pertaining to the hydrological regime of alpine pioneer formations of the *Caricion bicoloris-atrofuscae* in the UK were identified within the confines of this study.

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Supporting references

At some sites in the Scottish Highlands, alpine pioneer formations occur in association with petrifying springs with tufa formation (*Cratoneurion*), temperate Atlantic wet heaths with *Erica ciliaris* and *Erica tetralix* and alkaline fens and calcium-rich springwater-fed fens.

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Blanket bogs

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General information

Blanket bogs are extensive peatlands, which have formed in areas of high rainfall and low evapotranspiration. These conditions have allowed peat to develop not only in wet hollows but over large expanses of undulating ground (Ref. 3). Blanket bogs are essentially shallow bogs that form a 'blanket' like layer over poor soils leached by constant flushing with rainwater (Ref. 8). Their average depth is 2.6 metres (Ref. 4).

Blanket bogs are found in the north and west of the UK, extending from Devon in the south to Shetland in the north. *Scirpus – Eriophorum* mire predominates in the west, while *Calluna – Eriophorum* mire are abundant in the east and at higher altitudes. *Erica – Sphagnum* mire is widely but patchily distributed (Ref. 3).

Description

The most abundant blanket bog habitat types in the UK are represented by the NVC types:

- M17 *Scirpus cespitosus – Eriophorum vaginatum* blanket mire;
- M18 *Erica tetralix – Sphagnum papillosum* raised and blanket mire;
- M19 *Calluna vulgaris – Eriophorum vaginatum* blanket mire;
- M20 *Eriophorum vaginatum* blanket and raised mire
- M25 *Molinia caerulea – Potentilla erecta* mire;
- A full description of these NVC classifications can be found in Ref. 7;
- Although they are mostly ombrotrophic (rain fed), lateral flow and contact with rock outcrops mean they contain species associated with fen and bog habitat;
- Blanket bogs show variations related to climatic factors. These are particularly illustrated by the variety of patterning within the bog surfaces in different parts of the UK. An important element in defining variation is the relative proportion of pools on the bog surface. In general, the proportion of surface patterning occupied by permanent pools increases to the north and west of the habitat's distribution (Ref. 3);
- Climatic factors also influence the floristic composition of bog vegetation. Many of the bogs in the Hebrides and Northern Ireland have affinities to types in western Ireland. These sites all exhibit more oceanic influences in their composition. Blanket bogs found towards the eastern limit of distribution show more continental affinities (Ref. 3); and
- Variety within the bog vegetation mirrors the above affinities, and altitude. The number of associated habitats and communities (springs, flushes, fens and heath), is greater in the milder, wetter, geologically and topographically more complex north and west sites (Ref. 3).

Key influences

Water resources

- The hydrological mechanisms of blanket bogs are not readily quantified (Ref. 1). Sites designated for their blanket bog habitat differ in hydrological regime and complexity, making it impossible to quantify water requirements in set measurements for the habitat as a whole. As such only broad based water resource requirements taken from literature reviewed can be outlined. It is thus imperative to assess hydrological requirements on a site by site basis;
- Blanket bogs develop under conditions of water logging, but are not confined to landscapes with poor drainage, and can cloak whole landscapes, (Ref. 9);
- Vertical water exchanges between upper and lower peat horizons are important for bog geochemistry (Ref. 6);
- The structure of blanket bogs dictates a hydrological response which favours surface water runoff over evapotranspiration (Ref. 6);
- The comparatively high topographic gradients of blanket bogs result in much higher groundwater flows than in other types of peatlands (Ref. 6) which can give rise to erosion;
- The topographic structure of the substrate can be indicative of groundwater flow patterns and can be used to predict distribution; and
- The water table needs to be at a level to sustain permanent pooling. The extent of this pooling cannot be quantified due to topographical differences between sites.

Other influences

- The greatest single cause of raised bog habitat loss is through afforestation (Ref. 8);
- Drainage, heavy grazing, peat cutting and atmospheric pollution have also caused habitat loss (Ref. 8);
- Water inputs primarily originate from precipitation and therefore are low in solutes. Significant increases in the base or nutrient status of the system will alter the vegetation composition to favour non-bog species (Ref. 1);
- Water chemistry has a strong influence on mire formation. Groundwater affecting topogeneous and sologeneous mires can supply them with nutrients from a local or regional catchment outside the system (Ref. 1);
- Climate change may have a significant impact on the status of the raised bog habitat (Ref. 3); and
- Extensive erosion, particularly at its climatic limits, can cause total loss of this resource.

Current and future work

The LIFE peatlands project has produced a series of reports on the restoration of blanket bogs in the north of Scotland. For more information please see: **www.lifepeatlandsproject.com/intro.asp**

Dr. B. Wheeler, Dr. S. Shaw and Dr. R. Lindsay of the University of Sheffield run the Sheffield Wetlands Research Centre, a key bog research centre.

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Supporting references

Annex I habitats to be considered with blanket bogs include temperate Atlantic wet heath with *Erica ciliaris* and *Erica tetralix*, northern atlantic wet heaths, bog woodlands, depressions in peat substrates and natural dystrophic lakes and ponds.

This document was withdrawn on 6 November 2017

Bog woodlands

This document was withdrawn on 6 November 2017

General information

The true bog woodland habitat type has recently been recognised in the UK as a rare habitat type of stable open woodland on peat, rather than a successional stage of tree colonisation arising from, for example, changes in land-use, management and the water regime. Current knowledge on the distribution and extent of the bog woodland habitat type is limited.

Bog woodland is not described as a separate community in the NVC system (Ref. 10). Scottish examples are essentially a combination of open Scots pine woodland growing on deep peat supporting mire communities such as M18 (*Erica tetralix-Sphagnum papillosum*) or M19 (*Calluna vulgaris-Eriophorum vaginatum*). Those in England and Wales are more likely to be composed of birch and sallow (NVC W4). The JNCC has issued a description for such habitat types in the UK **(www.jncc.gov.uk)**.

Description

- Trees on bogs/mires are slow growing due to the less than optimum conditions and a sparse scattering is maintained by many areas of the bog surface being too wet to support tree growth;
- Trees are stunted but may achieve considerable age with a Scottish example citing trees to be over 350 years old. Growth is self-limiting with enlarging trees gradually sinking into the bog, dying off as the roots become waterlogged; and
- Dead timber is a feature of bog woodlands.

Key influences

Water resources

- The precise ecological requirements for the bog woodland habitat type are not fully understood, though integrity of the bog, particularly in relation to water supply, is likely to be a key issue in limiting the cover of trees.

Other influences

- Limiting factors in addition to surface wetness is likely to be the species composition of the bog flora. Highly acidic substrates provided by the Sphagnum mosses results in relatively adverse pH conditions for tree colonisation. Kelly (1993) showed the distribution of trees on Irish bogs to be associated with localised flushing. This allowed for conditions where pH, oxygen levels and nutrients were slightly elevated; and
- The primary impacts of soligenous bogs and ombrogenous bogs arise from direct changes in land-use, such as bog drainage and peat extraction in raised mire systems. This has often led to the colonisation of secondary woodland from the peripheral lagg stream courses, onto the peat body, or directly from forestry introductions.

Current and future work

English Nature (now Natural England) has published a report on the eco-hydrolgical guidelines for wet woodlands which includes a section on alluvial forests. English Nature Research Report number 619 should be consulted (Ref. 1).

Mire restoration is attracting considerable attention in both academic research (for recent reviews see Wheeler 1995, Wheeler *et al*. 1998, Lindsay 1999) and in practical conservation initiatives (e.g. RSPB 2001). Mire restoration is also undertaken with funding under the European LIFE initiative. One such project is being co-ordinated by the Forestry Commission in the New Forest (life@forestry.gov.uk).

A sub-group of The British Ecological Society, the Mires Research Group, share information and facilitate contacts between researchers in this area. The current secretary of the group is Dr. D. Pearce of the School of Biological and Molecular Sciences, Oxford Brookes University.

The University of Sheffield is regarded as one of the key centres for research on peatlands. Dr. B. Wheeler in the Department of Animal and Plant Sciences at the University, and Dr. S. Shaw in the Sheffield Wetlands Research Centre (SWeRC), which forms part of the Geography Department, are the key contacts. The School of Biosciences at the University of East London also conducts research on mires and peatlands. The key contact for this institution is Dr. R. Lindsay.

Key references

General description & habitat details

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12. UK Biodiversity Action Plan, *Wet woodlands*. Retrieved March 30, 2006 from www.ukbap.org.uk/UKPlans.aspx?ID=4

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Supporting references

Other Annex I habitats to be considered with bog woodlands are:

- Active raised bogs;
- Degraded raised bogs still capable of natural regeneration;
- Blanket bogs;
- Transition mires and quaking bogs; and
- Depressions on peat substrates of the *Rhynchosporion*.

For further information refer to relevant guidance notes.

This document was withdrawn on 6 November 2017

Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*

This document was withdrawn on 6 November 2017

General information

Fens are groundwater-fed wetlands on peat or normally-wet mineral deposits. They are divided into two major groups based upon their topography and hydrology, topogenous fens and soligenous fens (Ref. 2). Topogenous fens are formed where the topography creates a basin-type water collection system with little water movement out of the system. A water level is maintained by impeded drainage, as caused by the topography. Three sub-types are recognised, open-water transition fens, flood plain fens and basin fens. Soligenous fens are formed where sloping terrain provides a continuous supply of flowing water, by groundwater-runoff and or seepage. Three sub-types are recognised, valley fens, flush fens and calcareous spring fens. Any particular wetland site may be fed by more than one water supply mechanism. Both fen types are groundwater-fed systems.

Calcareous spring fens develop around freshwater springs rich in calcium. The water feeding these fens wells up from the ground and often deposits a white crust known as 'tufa' on the ground vegetation. Sites are usually very small and often occur within larger wetland systems (Ref. 2).

Calcareous fens are rare in the UK, having a restricted and discontinuous geographical range. Two main centres of distribution are noted, the Broadlands of East Anglia and, to a lesser extent, the fen systems of Anglesey. Elsewhere in the UK this habitat type is very scattered and localised (Ref. 3).

Description

The calcareous fen habitat type comprises of the more species-rich examples of great fen-sedge (*Cladium mariscus*) fen, particularly those stands enriched with elements of the *Caricion davallianae* (i.e. small-sedge fen with open low-growing sedge vegetation) community. Davall's sedge *Carex davalliana* itself is extinct in the UK (Ref. 3). Such stands occur in:

- Sites with a mixture of closed, species-poor *Cladium* beds, which at their margins have transitions to species-rich small-sedge mire vegetation;
- Sites where *Cladium* beds retain their species-richness owing to management;
- Situations where *Cladium* fen is inherently species-rich, possibly owing to conditions not allowing the *Cladium* to grow vigorously and dominate the vegetation (Ref.3);

Calcareous fen vegetation transposes into the NVC communities:

- S2 *Cladium mariscus* swamp and sedge beds
- S24 *Phragmites australis – Peucedanum palustris* tall-herb fen
- S25 *Phragmites australis – Eupatorium cannabinum* tall-herb fen
- M9 *Carex rostrata – Calliergon cuspidatum/giganteum* mire
- M13 *Schoenus nigricans – Juncus subnodulosus* mire
- M14 *Schoenus nigricans – Narthecium ossifragum* mire
- M24 *Molinia caerulea – Cirsium dissectum* fen-meadow
- SD14 *Salix repens – Campylium stellatum* dune slack community
- SD15 *Salix repens – Calliergon cuspidatum* dune slack community; and
- A full description of these NVC classifications can be found in Ref. 5.

Key influences

Water resources

- Species which constitute the fen habitat type are considered to be either critically dependent or supported by groundwater (Ref. 9). The response of fen vegetation to groundwater abstraction is difficult to generalise as sensitivity to hydrological change will vary between communities (Ref. 2);
- The seepage of groundwater is essential for the conservation of the typically mesotrophic character of the fens (Ref. 8);
- Abstraction of water from boreholes will produce localised depressions in groundwater-water levels, termed a cone of depression. A reduction in pressures may lead to a decline or cessation in spring flow, which will have implications for the alkaline fen habitat (Ref. 6);

- The hydrological response of fen communities to change is not simply limited to a seasonal decline in water level tables. Increases in the magnitude and frequency of water table fluctuations and the duration of water table level changes will also affect community composition. Such alterations may lead to an increase in the depth of aeration of the peat profile. Decomposing and dewatered peat may also undergo irreversible physical changes and even if the system is re-watered the response of the fen water table may not be re-established in the same way (Ref. 2);
- Calcareous fens are usually found in areas with a high piezometric head and permanently high water table. Natural seasonal fluctuations do still occur in these areas (Ref. 9);
- Rarer fen species tend to be confined to wetter sites (Ref. 6); and
- The great fen sedge can persist for long periods in dry conditions in the East Anglian region.

Other influences

- Calcareous fens can be found in a large range of calcium conditions, but generally favour low fertility conditions (mean fertility 7.0)(Ref. 6);
- Water pH usually ranges from 4.8-7.1; and
- In rich fens there is no apparent relationship between conductivity and species density; however rarer fen species have an aversion for conditions of very high ionic strength (Ref. 6)

Current and future work

The Countryside Council for Wales has an active programme of positive management of calcerous fens that is focused on National Nature Reserves and aims to restore favourable conditions at key sites. In addition, The Broads Authority also conducts a fen management programme in association with Natural England. Dr. B. Wheeler, Dr. S. Shaw and Dr. R. Lindsay run the Sheffield Wetlands Research Centre based at Sheffield University, which carries out key bog research.

English Nature (now Natural England) have published a report on the eco-hydrological guidelines for wet heaths which may be of use when assessing the requirements of calcerous fens (Ref. 4) The Environment Agency has published guidelines for lowland wetland communities (Ref. 10).

This document was withdrawn on 6 November 2017

Key references

General description & habitat details

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Supporting references

Annex I habitats and Annex II species that should be considered with calcareous fens are alkaline fens Calcium-rich springwater-fed fens, petrifying springs with tufa formation (*Cratoneurion*), marsh saxifrage (*Saxifraga hirculus*) whorl snail (*Vertigo geyeri*), marsh fritillary (*Euphydryas aurinia*); humid dune slacks, fen orchid *Liparis loeselii*), slender feather moss (*Drepanocladus vernicosus*), alluvial forests with *Alnus glutinosa* and (*Fraxinus excelsior* (*Alno-Padion, Alnion incanae*, *Salicion albae*), mo*linia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*), northern Atlantic wet heaths with *Erica tetralix* and temperate atlantic wet heaths.

This document was withdrawn on 6 November 2017

Depressions on peat substrates of the *Rhynchosporion*

Depressions on peat substrates occur as a sub-habitat on raised bogs and valley mires. Refer to the raised bog habitat summary for an overview of the likely parameters, which may influence the integrity of this habitat type.

This document was withdrawn on 6 November 2017

General information

Depressions on peat substrates of the *Rhynchosporion* represent a rare habitat type in the UK with a narrow variation in ecological range and restricted (discontinuous) geographical distribution. The largest coverage of this habitat type is found on heaths in southern England and on blanket and raised bogs in western Britain. One example of this habitat is found outside this range in East Anglia (Ref.4).

Description

- Depressions on peat substrates of the *Rhynchosporion* occur in complex mosaics with lowland wet heath, valley mires, transition mires, on the margins of bog pools, and in hollows in both raised and blanket bogs;
- The vegetation is typically very open, and usually characterised by an abundance of white beak-sedge (*Rhynchospora alba*), the bog moss (*Sphagnum denticulatum*), round-leaved sundew (*Drosera rotundifolia*) and, in relatively base-rich sites, brown mosses such as *Drepanocladus revolvens* and *Scorpidium scorpioides*. The nationally scarce brown beak-sedge (*R. fusca*) and marsh clubmoss (*Lycopodiella inundata*) also occur in this habitat (Ref. 4);
- Algal mats are often well-developed;
- On lowland heaths in southern and eastern England, this habitat occurs on humid, bare or recently exposed peat in three distinct situations:
- In and around the edges of seasonal bog pools, particularly on patterned areas of valley mire
- In flushes on the edges of valley mires in heaths
- In artificially disturbed areas, such as along footpaths, trackways, abandoned ditches and in old peat-cuttings (Ref. 4); and
- In southern localities, depressions on peat substrates of the *Rhynchosporion* are often associated with NVC community M21 *Narthecium ossifragum – Sphagnum papillosum* mire (in southern localities), while in the north and west (within active raised bogs and blanket bogs) depressions usually form part of the transition between bog pools (M1 *Sphagnum auriculatum* and M2 *Sphagnum cuspidatum/recurvum* bog pool communities) and the surrounding bog vegetation (mainly M17 *Scirpus cespitosus – Eriophorum vaginatum* blanket mire and M18 *Erica tetralix – Sphagnum* papillosum raised and blanket mire) (Ref. 4).

Key influences

Water resources

- No specific data on the water resource requirements of depressions on peat substrates of the *Rynchosporion* was found. Refer to the raised bog guidance note for considerations; and
- Information of the hydro-ecological requirements of valleys mires would also be of assistance, but was not covered in this project.

Other influences

- No specific data on factors affecting depressions on peat substrates of the *Rynchosporion* were found. Refer to the raised bog guidance note for considerations.

Current and future work

The LIFE peatlands project has produced a series of reports on the restoration of mires in the UK. For more information please see:
www.lifepeatlandsproject.com/intro.asp

Dr. B. Wheeler, Dr. S. Shaw and Dr. R. Lindsay of the University of Sheffield run the Sheffield Wetlands Research Centre, a key bog research centre.

A sub-group of the British Ecological Society, the Mires Research Group shares information and facilitate contacts between researchers in this field. The contact for this group is Dr. D. Pearce of the School of Biological and Molecular Sciences at Oxford Brookes University. Additionally, the University of Sheffield undertakes a great deal of research at the Sheffield Wetlands Research Centre (SWeRC).

Key references

General description & habitat details:

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2. Gerdol R and Bragazza L, 2001 *Syntaxonomy and community ecology of mires in the Rhaetian Alps (Italy),* Phytocoenologia, 31 (2), 271-299.

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Supporting references

Other Annex I habitats to be considered with depressions in peat substrates are active raised bogs, blanket bogs, transition mires and bog woodlands.

This document was withdrawn on 6 November 2017

Petrifying springs with tufa formation (*Cratoneurion*)

This document was withdrawn on 6 November 2017

General information

Petrifying springs with tufa formation *(Cratoneurion)* are found within the classifications of fenland habitat. Refer to the guidance note on alkaline fens for more detailed information on fenlands.

Tufa formations are associated with hard-water springs, where groundwater rich in calcium bicarbonate reaches the surface. On contact with the air, carbon dioxide is lost from the water and a hard deposit of calcium carbonate (tufa) is formed. These conditions are most prevalent in areas underlain by limestone or other calcareous rocks such as the uplands of northern England and the Scottish Highlands (Ref. 5).

Petrifying springs with tufa formation is a relatively rare phenomenon in the UK occurring as small, scattered flushes, with a small total area (Ref. 5).

Description

- Tufa-forming spring-heads are characterised by the swelling yellow-orange mats of the mosses *Cratoneuron commutatum* and *C. filicinum*. Many rare, lime-loving (*calcicole*) species live in the moss carpet, particularly arctic-alpine species, such as bird's-eye primrose (*Primula farinosa*), Scottish asphodel (*Tofieldia pusilla*), alpine bartsia (*Bartsia alpina*) and false sedge (*Kobresia simpliciuscul*) (Ref. 5);
- Two main NVC types are associated with tufa formations:
- M37 *Cratoneuron commutatum – Festuca rubra* spring (widely distributed)
- M38 *Cratoneuron commutatum – Carex nigra* spring (found only at moderate to high altitudes and contains rare arctic-alpine species);
- A full description of these NVC classifications can be found in Rodwell (1991); and
- This habitat type often associated with alkaline fens, where they may form prominent upwelling masses of short open vegetation around the spring-heads that feed the fen system. There may also be transitions to a wide range of other habitats, particularly calcareous grassland, acid grassland, heath, limestone pavements, and calcareous cliff and scree (Ref. 5).

Key influences

Water resources

- The precise ecological requirements for this habitat type are not fully understood, though it is known that this community is especially vulnerable to changes in the hydrological regime. This will be especially problematic to those species found within hollows, but also to the calcite precipitation process (Ref. 3);
- The seepage of groundwater is essential for the conservation of the typically mesotrophic character of the fens (Ref. 7);
- The M37 NVC vegetation type is a community of ground vegetation kept permanently moist by irrigation with base rich calcareous and generally oligotrophic waters. It is dependent on the kind of sustained irrigation common in areas of higher rainfall (Ref. 6); and
- M38 is confined to montane springs and flushes strongly irrigated by base-rich, calcareous and oligotrophic waters (Ref. 6).

Other influences

- Specific hydrochemical processes (especially calcite precipitation) associated with degassing of discharging groundwater and concomitant Phosphorus adsorption (Ref. 2);
- Spring fed, rich-fen sites are irrigated by base-rich groundwater discharge of high pH (>6.0), Calcium, Iron and hydrogen carbonate (HCO_3) concentrations (Ref. 1); and
- Oligotrophic to mesotrophic soil water.

Current and future work

The LIFE peatlands project has produced a series of reports on the restoration of the mires in the UK. Available: www.lifepeatlandsproject.com/ intro.asp

Dr. B. Wheeler, Dr. S. Shaw and Dr. R. Lindsay of the University of Sheffield run the Sheffield Wetlands Research Centre.

Key references

General description & habitat details

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5. McLeod, C.R., Yeo, M., Brown, A.E., Burn, A.J., Hopkins, J.J., & Way, S.F. (eds.) (2002). *The Habitats Directive: selection of Special Areas of Conservation in the UK.* 2nd edn. Joint Nature Conservation Committee, Peterborough. www.jncc.gov.uk/SACselection

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Supporting references

Annex I habitats to be considered with petrifying springs with tufa formation include alkaline fens, calcium rich springwater-fed fens, alpine pioneer formations of the *Caricion bicoloris-atrofuscae,* calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae.* The Annex II species that should be considered are the marsh saxifrage (*Saxifraga hirculus*), geyer's whorl snail (*Vertigo geyeri*), slender feather moss (*Drepanocladus vernicosus*).

This document was withdrawn on 6 November 2017

Raised bog (*Ombrotrophic bog*)

This summary encompasses both the Annex I active raised bogs and degraded raised bogs still capable of natural regeneration habitats. Refer to the general information section for reasons why these two habitat types have been combined. For further information on raised bogs, refer to key references listed below.

This document was withdrawn on 6 November 2017

General information

Annex I of the EC Habitats Directive includes two raised bog habitats, active raised bog, which includes areas that still support a significant amount of peat forming vegetation and bogs where active formation is at a temporary standstill (induced from fire or climatic cycles); and degraded raised bogs, which are areas that have experienced wide spread disruption to the hydrological regime of the peat body, leading to pronounced surface desiccation or peat wastage and the loss of species or changes to the composition of species assemblages (Ref. 9). The degraded raised bog habitat includes only those sites which are 'capable of natural regeneration', that is, where the hydrology can be repaired and where, with appropriate rehabilitation management, there is a reasonable expectation of re-establishing vegetation with peat-forming capability within 30 years (Ref. 7).

Raised bogs are peatland ecosystems, which develop, primarily, but not exclusively, in lowland areas including the head of estuaries, along river floodplains and in topographic depressions. At these localities drainage may be impeded by a high groundwater table, or by low permeability substrata such as estuarine, glacial or lacustrine clays. The resultant waterlogged conditions provide an anaerobic environment, which slows down the decomposition of plant material, leading to peat accumulation. The continual accrual of peat elevates the bog surface above regional groundwater levels to form a gently-curving dome from which the term 'raised bog' is derived. The thickness of the peat mantle varies considerably but can exceed 12 metres (Ref. 9).

Raised bogs are widespread but unevenly distributed throughout the UK. Notable concentrations are in the central belt of Scotland, the Solway region on the England/Scotland border, north-west England, Northern Ireland and mid Wales. Degraded raised bogs occur throughout the range of raised bogs in the UK and are believed to be more extensive than active raised bogs (Ref. 7).

Description

- The surface of raised bog habitats typically displays a distinctive microtopography, with patterns of hummocks and hollows rich in *Sphagnum* and other peat-forming species;
- The principal NVC types found on active raised bogs are:
  - M1 *Sphagnum auriculatum* bog pool community
  - M2 *Sphagnum cuspidatum/recurvum* bog pool community
  - M3 *Eriophorum angustifolium* bog pool community
  - M18 *Erica tetralix – Sphagnum papillosum* raised and blanket mire
  - M19 *Calluna vulgaris – Eriophorum vaginatum* blanket mire
  - M20 *Eriophorum vaginatum* blanket and raised mire;
- A full description of these NVC classifications can be found in Ref. 8;
- Patches of the Annex I *Depressions on peat substrates of the Rhynchosporion* may be found around bog pools (Ref. 7);
- Classical descriptions of the habitat report raised bogs to have discrete lens-shaped peat domes with flat or imperceptibly sloping topography and a halo of fen vegetation in the zone where water draining from the bog meets that from adjoining mineral soils. This is known as the 'lagg'. The lagg zone normally has greater plant nutrient availability, is more alkaline and shows greater species diversity, with a predominance of sedge (*Carex* spp.); and
- Peat digging and other practices have resulted in there being no example of a raised bog habitat that conforms exactly to classic descriptions. The selection of sites for designation has been undertaken to ensure remnant lagg vegetation has been included.

Key influences

Water resources

- The hydrological mechanisms for which raised bog habitats depend on are not readily quantified (Ref. 9 & 10). Designated sites differ in both their hydrological regime and complexity, making it impossible to quantify water requirements in set measurements for the habitat as a whole. As such only broad based water resource requirements can be discussed and sites will need to be assessed individually;
- Water inputs for raised bogs are believed to be derived solely from precipitation (thus termed ombrotrophic bogs), although groundwater recharge may yet prove to be a factor at a few sites (Ref. 5) ;
- Raised bogs rely on waterlogged conditions to retain their characteristic features. The water supply of wetlands may be regarded as one of their fundamental defining features. Alterations to the rate of water loss will also destabilise these habitats (Ref. 10);
- Raised bogs develop from other bog types, commonly the basin or floodplain mire (Ref. 1). This mire is exclusively dependent upon precipitation for its water supply, with the water table characteristically mounded above the regional groundwater table by impeded precipitation drainage (Ref. 10); and
- Water flow may be of importance to plant growth and distribution, affecting oxidation-reduction potentials and nutrient availability. Detailed studies of water flow in this habitat are limited, in part because of difficulties in obtaining meaningful estimates of flow rates (Ref. 8).

Other influences

- Raised bog vegetation can occur in regions with periodic protracted summer droughts. The possession of a surface layer, which has important hydro-regulation functions, appears to be an important mechanism by which it is able to withstand such conditions (Ref. 10). The destruction or alteration of this vegetation layer will have significant implications on the long-term stability of the raised bog habitat as a whole (Ref. 9);
- Given water inputs are from precipitation alone, these habitats are likely to be low in solutes. Significant increases in the base or nutrient status of the system will alter the vegetation in favour of non-bog species (Ref. 9). Groundwater affecting topogeneous and sologeneous mires may supply them with nutrients from a local or regional catchment outside the system (Ref.1);
- Soil pH is important. This parameter summarises other hydrochemical attributes, including concentration of phytotoxic metals with pH related solubilities (Ref. 9). Bogs are generally acidic (pH<5.5) predominantly occurring on peat, but have been recorded on mineral soils (Ref. 10);
- Peat extraction, landfill development, built development, forestry, pollution (including atmospheric nitrogen deposition), livestock and game management, and climate change all have the potential to disrupt the balance of conditions within bog habitats and lead to their partial or total destruction (Ref. 9); and
- Raised bogs are particularly susceptible to atmospheric contaminants, given they are more or less exclusively rainwater fed, and particular plant species making up the community may 'scavenge' solutes. Sulphur dioxide and its derivatives (bisulphite), nitrogen oxides and its derivatives (in particular nitrate and ammonia), the main constitutes of acid rain are most likely to affect plants growing on raised bogs (Ref. 10).

Current and future work

Mire restoration is attracting considerable attention in both academic research (for recent reviews see Wheeler (1995), Wheeler *et al.* (1998) & Lindsay (1999)) and in practical conservation initiatives (e.g. RSPB 2001), UK Biodiversity Group (1999).Mire restoration has been undertaken with funding under the European LIFE initiative.

A sub-group of The British Ecological Society, the Mires Research Group, share information and facilitate contacts between researchers in this area. The current secretary of the group is Dr. D. Pearce of the School of Biological and Molecular Sciences, Oxford Brookes University.

The University of Sheffield is regarded as one of the key centres for research on peatlands. Dr. B. Wheeler in the Department of Animal and Plant Sciences at the University, and Dr. S. Shaw in the Sheffield Wetlands Research Centre (SWeRC), which forms part of the Geography Department, are the key contacts. The School of Biosciences at the University of East London also conducts research on mires and peatlands. The key contact for this institution is Dr. R. Lindsay.

This document was withdrawn on 6 November 2017

Restoration

The restoration of raised bog requires an adequate supply of precipitation (of appropriate quality) with sufficient retention time at the bog's surface to provide effective rewetting; and the availability of suitable recolonising plant species for re-establishment (Ref. 10). These conditions cannot always be met (even in some former raised bog sites) due to changes in drainage dynamics, the surrounding vegetation, soil characteristics and/or the addition of atmospheric pollutants (Ref. 10).

Between 1996 and 1999, 1.8 million Euros was spent by Dúchas and the European Union on the Raised Bog Restoration Programme in Ireland. This programme produced management plans for candidate raised bog SACs to restore them to favourable condition status (Raeymakers (2000) as cited in Ref. 9). One of the positive outcomes of this investment and previous research initiated under the Irish/Dutch Raised Bog Study Project has been the development of a management tool kit to restore raised bog hydrology (Ref. 9).

Defra has also stopped commercial peat extraction at three sites in Cumbria and south Yorkshire in order to assist the restoration of degraded peat bogs at these sites. Natural England will be monitoring these sites, where it is hoped that peat will begin to reform over the next 30 years.

This document was withdrawn on 6 November 2017

Key references

General description & habitat details

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2. Cruickshank, M. M. & Tomlinson, R. W. (1998). *Northern Ireland Peatland Survey. Report to Countryside and Wildlife Branch*, Department of the Environment (NI), Belfast.

3. European Commission (1999). *NATURA 2000 Interpretation manual of European habitats*, *Eur 15/2*., European Commission DG Environment, http://europa.eu.int/comm/environment/nature/habit-en.pdf

4. Irish Peatland Conservation Council (2001). *Action 17 Peatland Management and Restoration*, http://www.ipcc.ie/currentaction2005-17.html

5. Jones, Peter. County Countryside for Wales, Pers comm. 2003.

6. Lindsay, R. A. & Immirizi, C.P. (1996). *An inventory of lowland raised bogs in Great Britain* Scottish Natural Heritage, Battleby.

7. McLeod, CR, Yeo, M, Brown, AE, Burn, AJ, Hopkins, JJ, & Way, SF (eds.) (2002). *The Habitats Directive: selection of Special Areas of Conservation in the UK*. 2nd edn. Joint Nature Conservation Committee, Peterborough. www.jncc.gov.uk/SACselection

8. Rodwell J. S. (ed) (1991). *British Plant Communities: Mires & Heaths Volume 2.* Joint Nature Conservation Committee. Cambridge University Press, Cambridge.

9. UK Biodiversity Group. (1999), *UK Biodiversity Group Tranche 2 Action Plans – Volume VI: Terrestrial and freshwater species and habitats*. Tranche: 2 Volume: VI. HMSO, London.

10. Wheeler, B.D. & Shaw, S.C. (2000). *A Wetland Framework for Impact Assessment at Statutory Sites in Eastern England*. R&D Technical Report W6-068/TR1, University of Sheffield, Sheffield.

11. Wheeler, B. D. & Shaw, S. C. (1995). *Restoration of Damaged Peatlands with particular references to lowland raised bogs affected by peat abstraction*, Department of the Environment London.

Supporting references

The Annex I habitat depressions on peat substrates of the *Rhynchosporion* should be considered with the raised bog habitat. For further information refer to relevant guidance notes.

Transition mires and quaking bogs

This document was withdrawn on 6 November 2017

General information

The term 'transition mire' (also known as a 'quaking bog') refers to vegetation with a floristic composition and general ecological characteristics that are transitional between acid bog and alkaline fens. Surface conditions range from markedly acidic to slightly base-rich and the vegetation is a mixture of acidophile species (species that thrive in acidic conditions), as well as calciphile (plants thriving in lime or calcium rich soils) or basophile species (species that thrive in alkaline conditions) (Ref. 3). Transition mires provide important refuge sites to a number of specialized and threatened flora and fauna. The richness and diversity of invertebrate communities is considered to be greater than that of most other mire ecosystems (Ref. 1).

Transition mires are widespread throughout the UK. Local habitats are ecologically variable, occurring in a wide range of geomorphological contexts (Ref. 3).

Description

- Transition mires can occupy a physical transitional location between bog and fen vegetation. In other cases the creation of the transition mire habitat reflects the process of succession. As peat accumulates in groundwater-fed fens or open water, rainwater-fed bogs are created. These features are isolated from groundwater influences. Many of these systems are unstable underfoot and often described as 'quaking bogs' rather than transitional mires (Ref. 3);
- Transition mires can occur in a variety of situations, primarily related to different geomorphological processes. Transition mires can occur in flood plain mires, valley bogs, basin mires, the lagg zone of raised bogs, and as regeneration surfaces within mires that have been cut-over for peat or areas of mineral soil influence within blanket bogs (Ref. 3). Refer to Ref. 8 for further information on these habitat types.

NVC types which form the core vegetation of transition mires in the UK are:

- M4 *Carex rostrata – Sphagnum recurvum* mire;
- M5 *Carex rostrata – Sphagnum squarrosum* mire;
- M8 *Carex rostrata – Sphagnum warnstorfii* mire;
- M9 *Carex rostrata – Calliergon cuspidatum/ giganteum* mire;
- S27 *Carex rostrata – Potentilla palustris* tall-herb fen;
- This list is not exhaustive, transition mires are defined by physical structure and water chemistry rather than by existence of particular NVC plant communities; and
- A full description of these NVC classifications can be found in Ref. 5.

Key influences

Water resources

- Given that transition mires occur over a wide range of varying topographic features, and the precise ecological requirements are not fully understood, difficulties arise in deriving any generic hydrological requirements for this habitat type. However, water supply is considered a key parameter in sustaining the integrity of bog habitats;
- The hydrological mechanisms of transition mires are not readily quantified (Ref. 1). Sites designated for their transition mire habitat differ in hydrological regime and complexity, making it impossible to quantify water requirements in set measurements for the habitat as a whole. The assessment of hydrological requirements should be carried out on a site by site basis;
- Transition mires are an intermediate habitat between soligenous (groundwater fed) and topogenous (areas with a permanently high water table) mires and those which are strictly ombrogeneous (precipitation fed) bogs (Ref. 1);
- Transition mires with more soligenous or topogenous affinities are more likely to be susceptible to interruptions in the water supply from abstraction or watercourse management. NVC vegetation types present within the transition mire may be utilised to predict connection with a water source; and
- The M4 NVC type characteristics are pools and seepage areas on the raw peat souls of topogenous and soligenous moors where waters are fairly acidic and only slightly enriched. M5 communities are also more typical of topogenous and soligenous sites. M9 is commonest in the wetter parts of topogenous moors, but can also occur in areas with a strong soligenous influence (Ref. 5).

Other influences

Transition mires are largely occupied by peat-forming plant communities which develop at the surface of oligotrophic or meso-oligotrophic water, sometimes well above the substratum. There is generally little mineral or nutrient supply to such communities and as such changes to the nutrient status via inputs (e.g. agricultural runoff) may alter the status and health of this habitat (Ref. 1).

Current and future work

The LIFE peatlands project has produced a series of reports on the restoration of the mires in the UK. Available: www.lifepeatlandsproject.com/ intro.asp

English Nature (now Natural England) have published a report on the eco-hydrological guidelines for wet heaths which may be of use when assessing the requirements of transition mires and quaking bogs (Ref. 4) The Environment Agency has published guidelines for lowland wetland communities (Ref. 9)

Key references

General description & habitat details:

1. Devillers, P., Rédei T., Zimányi Zs., Barabás S. & Horváth F (2002). *Transition mires*. Web Access: http://www.botanika.hu/project/habhun/habitats/545.html

2. Joint Nature Conservation Committee, 7140 Transition mires and quaking bogs. Retrieved 15 Feb 2007. http://jncc.gov.uk/ProtectedSites/SACSelection/habitat.asp?FeatureIntCode=H7140

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4. Mountford J.O, Rose R.J, and Bromley J. 2005. Development of eco-hydrological guidelines for wet heaths-phase 1. English Nature Report Number 620. Available: http://www.english-nature.org.uk/pubs/publication/PDF/620.pdf

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Supporting references

Annex I habitats and Annex II species to be considered with transition mires include fen orchid *Liparis loeselii,* Bog woodland and depressions on peat substrates of the *Rhynchosporion*.

This document was withdrawn on 6 November 2017

2.3 Guidance summary notes on the water resource requirements of particular species

A series of hydro-ecological summary sheets has been produced for a range of species designated as European interest features identified as having some level of dependence on freshwater. Each species summary includes the following sections:

- General information – provides background to the species and their occurrence;
- Habitat preferences- describes the range and character of the habitats where specific species (or particular communities) typically occur;
- Key influences – examines the effects of water quantity, water quality etc on the species and its habitat;
- Current and future work – summarises key research that has recently been completed or is on-going specifically looking at the species being described;
- Key references – sets out a bibliography that can be used to gather further information if required.

Each summary sheet generally presents the most up-to-date information available on the requirements of each species, and identifies areas where further research is required or is on-going. The user will be able to interrogate these sheets to help build a conceptual understanding of the optimal hydrological conditions for the species and whether these allow favourable condition to be achieved. It is envisaged that summary sheets will be periodically updated as research improves our understanding of the hydro-ecological requirements of each species.

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2.3.1 Invertebrates

The following summaries are not based on an exhaustive literature review but compiled using key reference papers provided by Agency, Natural England and CCW staff. These notes are intended to provide a summary of relevant information on the hydrological requirements of the listed invertebrates. For further information, refer to key references listed in the summaries.

- Desmoulin's whorl snail (*Vertigo moulinsiana*)
- Geyer's whorl snail (*Vertigo geyeri*)
- Narrow mouthed whorl snail (*Vertigo angustior*)
- Ramshorn snail (*Anisus vorticulus*)
- Round mouthed whorl snail (*Vertigo genesii*)
- Freshwater pearl mussel (*Margaritifera margaritifera*)
- Southern damselfly (*Coenagrion mercuriale*)
- White-clawed crayfish (*Austropotamobius pallipes*)
- Fisher's estuarine moth (*Gortyna borelii lunata*)
- Marsh fritillary butterfly (*Euphydryas aurinia*)

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Desmoulin's whorl snail (*Vertigo moulinsiana*)

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General information

The Desmoulin's whorl snail (*Vertigo moulinsiana*) is the largest of the eleven species of whorl snail living in the UK. It is a climbing species, living over a high vertical range at different times of the year. The body of the animal is a light grey or white colour with a darker grey to black head and tentacles and a brown shell. It occurs principally in a band from east Dorset to north-west Norfolk, although it has been found in other areas outside this key area. The Desmoulin's whorl snail was once more widely distributed in the UK, but its retreat is believed to be partly due to a gradual cooling since the climatic optimum c. 5000 years ago (Ref. 1).

Habitat preferences

- Desmoulin's whorl snail lives in permanently wet, usually calcareous, swamps, fens and marshes, bordering rivers or in river floodplains, lakes and ponds. It is most often found in open situations (Ref. 1);
- Humidity is important;
- The snail has been recorded on a wide range of plants, usually on tall monocotyledons including sedges (*Carex riparis, C. acutiformis, C. paniculata, C. elata*), saw sedge (*Cladium mariscus*), reedmace (*Typha latifolia* and *T. angustifolia*), branched bur-reed (*Sparaganium erectum*), iris (*Iris pseudacorus*) and reed canary grass (*Phalaris arundinacea*). In many English sites the most typical habitats are open areas of sweet reed grass (*Glyceria maxima*). Refer to the LIFE report for details on each particular habitat type (Ref. 1); and
- Originally only considered to occupy old, long-established calcareous wetlands, recent studies have found the snail to successfully occupy habitats that have arisen from relatively recent watercourse manipulation (i.e. habitat creation schemes such as new wetlands adjacent to rivers which have been engineered for other purposes) and which are subject to other management practices such as grazing, burning and mowing (Ref. 1).

Key influences

Water resources

- High ground water levels throughout the year are considered to be one of the most important factors influencing the distribution of Desmoulin's whorl snail (Ref. 2);
- A detailed study of the Kennet and Lambourn Floodplain and the Norfolk Valley fens found maximum *V.moulinsiana* densities at locations where water levels were above the ground surface throughout the year and where the mean annual water levels were more than 0.25 metres above the surface (Ref. 6);
- Water levels must remain close to the surface so that the ground remains at least moist for most of the summer, although some seasonal drying may be acceptable;
- The relatively high ground-water level is also likely to contribute to maintaining high humidity in the vegetation;
- Conditions must not become wet enough to allow aquatic plants such as water-cress (*Rorripa nasturtium-aquatilis*) to become dominant;
- Drainage of wetlands is considered a principal cause of the species' decline throughout its European range (Ref. 1); and
- Encroachment by scrub and/or alien plants may be induced under dry conditions. Alien plant species may also increase shade, reducing the suitability of the habitat to the snail.

Other influences

- There is currently no quantitative information on the relationship between Desmoulin's whorl snail and water quality (Ref. 1);
- Pollution, which has the potential to alter the plant community composition or structure, may impact on the status of the snail. Key water quality concerns may include elevated phosphate and nitrate levels, and organic pollution;
- The use of pesticides and herbicides may impact on the snail population. No information into its effects was reviewed or found to be available on this topic;
- The canalisation of rivers, deepening of drainage channels, and creation of vertical profiles to river banks provide unsuitable habitat for the snail;

- The regular cutting of riparian margins of rivers and tidying of riverside paths constitutes unfavourable management for the species. In particular the introduction of cutting or burning programmes at sites where there is no history of these activities are likely to have greater impact on snail populations than areas with historic management; and
- Changes in land use (e.g. from rough pasture or meadow to improved grassland) and increased levels of grazing may reduce snail populations.

Current and future work

The LIFE in UK Rivers Project is developing conservation strategies and monitoring protocols for use on rivers designated as Special Areas of Conservation under the European Union Habitats Directive. Refer to the LIFE in UK Rivers website for further information.

A workshop on the four target Vertigo species was held in 2002, its proceedings were collated into the article Speight MCD, Moorkens E and Falker G 2003 *Proceedings of the workshop on conservation biology of European Vertigo species* (Dublin, April 2002) Heldia, 5, 7, 1-183.

Key references

General description/biology & habitat details

1. Killeen, I. (2002). *The ecological requirements of Desmoulin's whorl snail Vertigo moulinsiana*. LIFE in UK Rivers Project. http://www.english-nature.org.uk/lifeinukrivers/ecological.html

2. Killeen, I.J. & Stebbings, R.E. (1997). *A34 Newbury bypass. Results of monitoring the translocated habitat for Vertigo moulinsiana*. First annual report. Unpublished report. Mott MacDonald, Winchester.

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4. Pokryszko, B.M. (1990). The Vertiginidae of Poland (Gastropoda: Pulmonata: Pupilloidea) – a systematic monograph. *Annales Zoologici,* Warsaw 43: 133-257.

5. Tattersfield, P & McInnes R, 2003 *The hydrological requirements of Vertigo moulinsiana on three candidate Special Areas of Conservation in England* (Gastropdoa, Pulmonata: Vertiginidae). Heldia **5**:7, 135-147.

Site specific studies

6. Killeen, I.J. (2001a). *A survey to assess the status & distribution of Desmoulin's whorl snail, Vertigo moulinsiana at Sweat Mere SSSI, Shropshire*. English Nature, (Unpublished report).

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8. Killeen, I.J. (2001c). Surveys of EU Habitats Directive *Vertigo* species in England: 3. *Vertigo moulinsiana*. Part 2: The River Avon SAC. *English Nature Research Report*, Peterborough.

9. Killeen, I.J. (2001e). Surveys of EU Habitats Directive *Vertigo* species in England: 3. *Vertigo moulinsiana*. Part 4: The Waveney and Little Ouse Valley Fens SAC. *English Nature Research Report*, Peterborough.

Supporting references

Calcareous wetland and fen habitats should be considered (but not limited to) with the Desmoulin's whorl snail.

This document was withdrawn on 6 November 2017

Geyer's whorl snail (*Vertigo geyeri*)

General information

The tiny Geyer's whorl snail (*Vertigo geyeri*) is currently found in North Wales, northern England, the Scottish Highlands, the Inner Hebrides, and Northern Ireland. In total it has been recorded in approximately 30 localities (Ref. 5). This mollusc feeds on algae/bacteria on vegetation and decaying humic or plant material (Ref. 2).

Habitat preferences

- Throughout its range, the Geyer's whorl snail is found in relatively exposed, constantly humid calcareous flush-fens that are fed by tufa-depositing springs (Ref. 5);
- It requires dense cover of low-growing grasses and sedges relatively free from *Sphagnum* and other mosses (Ref. 5); and
- Black bog-rush (*Schoenus nigricans*) and yellow sedge (*Carex viridula*) have been found at all recorded Geyer's whorl snail habitat sites (Ref. 5).

Key influences

Water resources

- Little data exists on the relationship between the hydrological regime and the status of the Geyer's whorl snail; and
- The habitat of the Geyer's whorl snail is believed to be vulnerable to destruction from drainage and changes in the hydrological regime (Refs. 4 & 5).

Other influences

- Fossil records indicate that the Geyer's whorl snail was once common in lowland England. Climatic change and drainage by man is believed to have led to a dramatic contraction of its range (Refs. 5 & 4); and
- The snail's habitat is vulnerable to changes in grazing levels and trampling by humans and animals (Ref. 6).

Current and future work

A conference on the four target vertigo species was held in 2002. The proceedings can be found in: Speight MCD, Moorkens E and Falkner G, 2003 *Proceedings of the workshop on conservation biology of European Vertigo species* (Dublin, April 2002) Heldia, 5/7, 1-183.

Horsak and Hajek (2005) have published a study on the habitat preferences of V.*geyeri* in Europe. Their results suggest that it may be found in a range of different habitats, including sites relatively poor in carbonates. Their findings indicate that the distribution of *V.geyeri* follows that of the fen vegetative species *Primula farinosa, Carex dioica, C.hostiana, C.lepidocarpa* and *Pingulicula vulgaris*. It avoids areas with *Sphagnum* species (Ref. 3).

This document was withdrawn on 6 November 2017

Key references

General description/biology & habitat details

1.Cameron R, 2003 *Life-cycles, molluscan and botanical associations of Vertigo angustior and Vertigo geyeri (Gastropoda, Pulmonata: Vertiginidae)*. Heldia, **5**, 95-110.

2. Cameron R, 2003 *Species accounts for snails of the genus Vertigo listed in Annex II of the Habitats Directive V.angustior, V.genesii, V.geyeri and V.moulinsiana (Gastropoda, Pulmonata:Vertiginidae)*. Heldia, **5**, 151-170.

3. Horsak M and Hajek M, 2005 *Habitat requirements and distribution of Vertigo Geyeri (Gastropods:Pulmonata) in western carpathian rich fens*. Journal of Conchology, 38, 6, 683-69.

4. JNCC (1991). Invertebrates and other insects. *In: British Red Data Book.* Ed. J.H. Bratton. JNCC, Peterborough.

5. McLeod, C.R., Yeo, M., Brown, A.E., Burn, A.J., Hopkins, J.J., & Way, S.F. (eds.) (2002). *The Habitats Directive: selection of Special Areas of Conservation in the UK.* 2nd edn. Joint Nature Conservation Committee, Peterborough. www.jncc.gov.uk/SACselection

6. UK Biodiversity Group. (1995). UK UKBAP Action Plan Species Action Plan: Whorl snail (*Vertigo geyeri*). *In: Biodiversity: The UK Steering Group Report – Volume II: Action Plans.* HMSO, London.

Supporting references

Annex I habitats to be considered with the Geyer's whorl snail are alkaline fens and petrifying springs with tufa formation (*Cratoneurion*).

This document was withdrawn on 6 November 2017

Narrow mouthed whorl snail (Vertigo angustior)

This document was withdrawn on 6 November 2017

General information

The tiny narrow-mouthed whorl snail (*Vertigo angustior*) is found in only eight widely scattered localities in England, Wales and Scotland (Ref. 2).

Habitat preferences

- The narrow-mouthed whorl snail is primarily found in marshy ground of high, even humidity and flowing groundwater. Areas must not be subjected to deep or prolonged flooding or periodic desiccation (Ref. 1 & 2);
- Unshaded conditions are required by the snail which inhabits short vegetation (grasses, mosses or low herbs) which are quickly warmed by the sun. The vegetation may be grazed by cattle (Ref. 1 & 2);
- The narrow-mouthed snail has been found in wet base-rich meadows, in coastal marshes, dune slacks and maritime turf, and in depressions within limestone pavement; several of these habitats are listed in Annex I of the Habitats Directive (Ref. 1 & 2); and
- In the UK the largest known population is found where freshwater seeps onto the upper edges of a saltmarsh in South Wales. However, elsewhere in Europe calcareous fen is the species' most typical habitat (Ref. 1 & 2).

Key influences

Water resources

- Little data exists on the relationship between hydrological regime and the status of the narrow-mouthed whorl snail; and
- The disturbance of hydrological conditions essential to the habitat of this species is regarded as the primary threat to its status (Ref. 1).

Other influences

- All habitats of the narrow-mouthed snail are fragile and may be easily destroyed by drainage, afforestation or other changes in land-use (Ref. 1);
- At Oxwich, natural erosion of the dunes has altered tidal patterns, leading to increased deposition of sediment. Deposition of material is gradually raising the land surface of the dune-saltmarsh transition zone, leading to drier conditions and scrub encroachment. Seepage from the dunes is thought to keep the transition zone damp, but can fail in drought years (Ref. 1).

Current and future work

A workshop on the conservation of the four target *Vertigo* species was held in 2002 and its proceedings were collated in the article: Speight MCD, Moorkens E and Falkner G, 2003 Proceedings of the workshop on conservation biology of the European Vertigo species (Dublin, April 2002) Heldia, **5**, 7, 1-183.

Population monitoring is being carried out by CCW on two sites in Wales.

Key references

General description/biology & habitat details

1. JNCC (1991). Invertebrates and other insects. *In: British Red Data Book.* Ed. J.H. Bratton. JNCC, Peterborough.

2. McLeod, C.R., Yeo, M., Brown, A.E., Burn, A.J., Hopkins, J.J., & Way, S.F. (eds.) (2002). *The Habitats Directive: selection of Special Areas of Conservation in the UK.* 2nd edn. Joint Nature Conservation Committee, Peterborough. www.jncc.gov.uk/SACselection

Further reading

Cameron R, 2003 *Species accounts for snails of the genus Vertigo listed in Annex II of the habitat directive: V.angustior, V. genesii, V.geyeri and V.moulinsiana (Gastropoda, Pulmonata: Vertiginidae)*. Heldia, 5, 151-170.

Cameron R, 2003 *Life-cycles, molluscan and botanical associations of Vertigo angustior and Vertigo geyeri (Gastropoda, Pulmonata: Vertiginidae)*. Heldia, **5**, 95-110.

Supporting references

Annex I habitats to be considered with the narrow-mouthed whorl snail are humid dune slacks, *salicornia* and other colonising mud and sand and *Molinia* meadows on calcareous, peaty or clayey silt-laden soils (*Molinion caeruleae*).

This document was withdrawn on 6 November 2017

Ramshorn snail *(Anisus vorticulus)*

General information

The Lesser whirlpool Ram's-horn Snail (*Anisus vorticulus*) is a small aquatic snail with a flattened spiral shell of approximately 5mm in diameter (Ref. 2). It has been declining from the UK since the 1960s, although the reason for decline is not clear. Populations may be found at sites in Norfolk, Suffolk and Sussex and a recent survey has found a re-colonised ditch system in Suffolk, which may be a result of improving water quality (Ref. 1 & 2).

Habitat preferences

- *A.vorticulus* occurs in unpolluted, calcareous waters in well-vegetated marsh drains and is often found with a number of other rare and vulnerable molluscs including *Segmentina nitida* and may be found floating on the surface amongst duckweed (*Lemna* spp.) (Ref. 1);
- It prefers ditches or channels of >3m in width and >1m in depth with a diverse flora but little emergent vegetative cover and often occurs in ditches in wet fields that flood in winter as this may be important in enabling young snails to colonise new ditches; and
- *A. vorticulus* distribution is largely dependent on aspect and water temperature and can often be restricted to one side of a ditch.

Key influences

Water resources

- Conversion of grazing marshes to arable farming with associated water table lowering may be affecting populations of the Ramshorn snail.

Other influences

- *A. vorticulus* populations are sensitive to nutrient enrichment and water pollution; although, specific parameters have not been available; and
- Ditch clearance, conversion of grazing levels and other land use changes may restrict or fragment its habitat (Ref. 2).

Current and future work

Surveys are currently being undertaken on the populations in East Anglia and ditches where populations have previously been found will be resurveyed and adjacent ditches will be checked for signs of colonisation.

A study by Watson and Ormerod (Ref. 3) suggests that the distribution of *A. vorticulus* is not related to vegetation structure but vegetation diversity. This study also indicates that the snail has declined in areas where ditches became wider and deeper with more open water. The authors correlated the distribution of *A. vorticulus* with calcium, pH, BOD, water depth and the percentage of ditches colonised by amphibious vegetation.

Key references

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Supporting references

Unpolluted, calcareous waters and well vegetated marsh drains and ditches should be considered with *A. vorticulus*.

This document was withdrawn on 6 November 2017

Round mouthed whorl snail (Vertigo genesii)

This document was withdrawn on 6 November 2017

General information

The round-mouthed whorl snail (*Vertigo genesii*) is a tiny boreal and alpine species, considered a relict of the fauna and flora of the late glacial period. Seven populations are known in the UK, with most occupying two upland regions; Upper Teesdale, in Durham, and the Blair Atholl area in Perthshire. The species has also been recorded further north in Scotland on the Black Isle (Ref. 2).

Habitat preferences

- In the UK, the round-mouthed whorl snail is found in calcareous flushes, often with an arctic-alpine element (Ref. 2).

Key influences

Water resources

- Little data exists on the relationship between hydrological regime and the status of the round-mouthed whorl snail but it is likely that the species is susceptible to hydrological changes.

Other influences

- Once abundant in lowland England (Ref. 1), post-glacial climatic change and forest growth is believed to have led to a dramatic contraction of its range (Ref. 2); and
- The small, isolated nature of the sites where it survives makes the populations vulnerable to accidental damage (Ref. 2).

Current and future work

A workshop on the conservation biology of *Vertigo* species was held in April 2002. The primary objective of the workshop was to collate as much data as possible (in an easily accessible format) on the conservation of the *Vertigo angustior, V. genesii, V. geyeri* and *V. moulinsiana*. Researchers involved have reported on recent work undertaken in Europe, including:

- Ecology and conservation issues of the *Vertigo* spp. in Central Europe;
- Distribution, status and conservation of *Vertigo* spp. in Scandinavia, Bavaria and Hungary;
- Autecological and monitoring studies carried out on *Vertigo* spp. in Wales;
- Review of *Vertigo* spp. habitats in Britain;
- Survey and monitoring work on a *Vertigo angustior* site in Ireland;
- Hydrological studies on *Vertigo moulinsiana* at some sites in England;
- Surveys of *Vertigo geyeri* in Ireland; and
- Survey methods for *Vertigo genesii*.

A workshop on the conservation of the four target *Vertigo* species was held in 2002 and its proceedings were collated in the article: Speight MCD, Moorkens E and Falkner G, 2003 Proceedings of the workshop on conservation biology of the European Vertigo species (Dublin, April 2002) Heldia, **5**, *7*, 1-183.

Key references

General description/biology & habitat details

1. JNCC (1991). Invertebrates and other insects. *In: British Red Data Book.* Ed. J.H. Bratton, JNCC, Peterborough.

2. McLeod, C.R., Yeo, M., Brown, A.E., Burn, A.J., Hopkins, J.J., & Way, S.F. (eds.) (2002). *The Habitats Directive: selection of Special Areas of Conservation in the UK.* 2nd edn. Joint Nature Conservation Committee, Peterborough. www.jncc.gov.uk/SACselection

Supporting references

The Annex I alkaline fen habitat should be considered with the round mouthed whorl snail. For further information refer to guidance notes produced.

Freshwater pearl mussel *(Margaritifera margaritifera)*

This document was withdrawn on 6 November 2017

General information

The freshwater pearl mussel (*Margaritifera margaritifera*) is a bivalve mollusc, which can grow to 140mm in length. Formerly widespread in England, the freshwater pearl mussel has declined rapidly, with very little active recruitment observed and is now considered highly endangered. Its life span is highly variable between populations, but generally the mussel develops slowly and can live for over 100 years, but may not reach sexual maturity until they are 10-15 years of age (Ref. 7).

Fertilised eggs develop in a pouch on the gills of the freshwater pearl mussel, with larvae (termed glochidia) released from females from July to September. These eggs remain in the water, but a small number attach themselves to the gill filaments of host fish (salmon and brown trout and sea trout), where they remain until the following spring. This mechanism allows the mussel to colonise suitable habitat further upstream. Consideration of host fish is therefore essential.

Habitat preferences

- The typical substrate preference of freshwater pearl mussels are small sand patches stabilised amongst large stones or boulders in fast-flowing rivers and streams;
- Cool, well-oxygenated soft water, free of pollution or turbidity is required;
- Riffle areas with mixtures of rocks, cobbles, sand, with low organic content are important habitats, particularly for juveniles (Ref. 7);
- Adult mussels live in dense beds in substrates of mixed cobble, stone and sand at the tail end of pools or in the moderate flow channels of river bends; and
- Stable channels with little bed transport (except in floods) are important features.

Key influences

Water resources

- The influence of stream hydrological processes on microhabitat (in particular how it effects juvenile recruitment) is poorly understood;
- Slight hydrological changes may result in freshwater pearl mussel habitat degradation. Studies to date report minimum/maximum depths and velocities for *M. margaritifera, M. laevis* and *M. falcate* within the ranges of 0.1-2 m and 0.1-2 m/s (Ref. 6); No absolute values are available for a minimum suitable flow velocity (Ref. 7);
- Low summer flows may reduce oxygen levels, increase temperatures and allow the formation of algal mats. The uncovering of shallow riffle areas and aggregation of detrital silt may be detrimental to juvenile populations;
- Moderate flooding may have a positive effect in cleaning silts from gravel beds and riffles. Autumn flows can wash out algal mats and sediments accumulated over the summer; and
- High flows (e.g. severe floods) can remove mussels from their beds. This is of particular concern for future populations where recruitment is currently not taking place (Ref. 7).

Other influences

- Freshwater pearl mussels prefer oligotrophic conditions. Critical parameters affecting recruitment are BOD, calcium and phosphate levels. Phosphate levels should not exceed 0.03 mg/l and conductivity should be less than 100 uS/cm (Ref. 2);
- Increased nitrate concentrations were observed by Bauer (1998) to increase adult mortality (Ref 1). Research has indicated that nitrate levels should not exceed 1.0 mg/l although higher values may be encountered in the UK (Ref. 2);
- Pearl mussels are sensitive to pollution during all life stages, with juveniles considered far less tolerant than adults are. Particular vulnerabilities are from those pollutants likely to affect the host fish, and metal and pesticide accumulation in adults;
- Freshwater pearl mussels prefer waters with a slightly less than neutral pH (7.5 or less) (Ref. 1);
- Gradient may affect mussel distribution indirectly by determining the stability of the substrata (Ref. 7);
- Siltation induced by increased sediment loads and detrital production (from eutrophication) can alter the interstitial environment of the substrate and suffocate young mussels;
- Channel modification can impede flow, increase flooding and alter substrate distribution. Dredging, canalisation, scouring and weir construction works have the potential to cause local population extinctions;

- The long-term survival of the freshwater mussel depends upon host availability. Introduced non-native salmonids species such as rainbow trout may out-compete native fish species and have indirect implications for mussel populations (Ref. 7); and
- Illegal pearl mussel fishing.

Current and future work

The LIFE in UK Rivers Project is developing conservation strategies and monitoring protocols for use on rivers designated as Special Areas of Conservation under the European Union Habitats Directive. Refer to the LIFE in UK Rivers website for further information.

Research into population genetics using DNA analyses is also underway and an initial study using RAPD techniques has suggested that physical factors act on genetic variation and that there are differences in variability within populations (Ref. 4).

The Environment Agency is currently investigating the feasibility of breeding *M. margaritifera* in captivity. Specifically examining whether it is possible using young capture salmon as hosts and releasing them in the wild.

Key references

General description/biology & habitat details

1. Bauer, G. (1988). Threats to the freshwater pearl mussel in Central Europe. *Biol. Cons.*, 45: 239-253.

2. Oliver, (2000). *Conservation Objectives for the freshwater pearl mussel Margaritifera margaritifera L.* Report for English Nature, Peterborough.

3. Reis J, 2003 The freshwater pearl mussel *(Margaritifera margaritifera L.) rediscovered in Portugal and threats to its survival.* Biological Conservation, 114, 447-452

4. Skinner A, Young M and Hastie L, 2003 Ecology of the Freshwater Pearl Mussel, Conserving Natura 2000 Rivers Ecology Series Number 2. Life in UK Rivers, Scottish Natural Hertiage: Edinburgh.

5. UK Biodiversity Action Plan, Species Action Plan. Retrieved 20 Feb 2006 from http://www.ukbap.org.ukUKPlans.aspx?ID=437

6. Vannote, R.L. & Minshall, G.W. (1982). *Fluvial processes and local lithology controlling abundance, structure and composition of mussel beds*. Proceedings of the National Academy of Science, USA *79*, 4103-4107.

7. Young, M. (2001). *The ecological requirements for freshwater pearl mussel (Draft)*. LIFE in UK Rivers Project. http://www.english-nature.org.uk/lifeinukrivers/ecological.html

8. Young, M. R., Hastie, L. C. & Cooksley, S. L (2002). *A monitoring protocol for the freshwater pearl mussel Margaritifera, margaritifera (Draft)*, Ocean Laboratory & Centre for Ecology, Newburgh.

Supporting references

All Annex I freshwater habitats should be considered in the context of this species. The Atlantic salmon (*Salmo salar*) should also be considered.

This document was withdrawn on 6 November 2017

Southern damselfly *(Coenagrion mercuriale)*

This document was withdrawn on 6 November 2017

General information

The southern damselfly (*Coenagrion mercuriale*) is one of the five members of the genus *Coenagrion* currently found in the UK. Distribution of this species is mainly in south west England and in South Wales, generally at low altitudes (usually less than 90 m above sea level). It has declined in many places and appears to be present only in low numbers at most of its localities. Its presence in the UK represents the northern boundary of its range. The southern damselfly is blue and black in colouration and is a member of the 'blue damselflies' grouping (Ref. 10).

Habitat preferences

- The southern damselfly is found in heathland stream/valley mires, calcareous fenland and water meadow ditch systems surrounding chalk streams;
- There is no consistent trend in plant species used by the southern damselfly. Ideal emergence sites contain plants with rigid stems which are less prone to being blown in the wind *Hypericum elodes* and *Potamogeton polygonifolius* were used in the majority of heathland sites where populations are found. *Glyceria maxima*, *Apium nodiflorum*, and *Nasturtium officinale* were used in chalk stream water meadow sites, on average a low to medium cover of submerged and emergent vegetation (0.2 – 0.6m) Ref. 5;
- A range of NVC community types are associated with the southern damselfly (refer to Ref. 10); and
- The majority of watercourses where the southern damselfly is found fall within a pH range of 7.0 – 7.5 although pH is not thought to determine distribution (Ref. 4).

Key influences

Water resources

- Southern damselfly populations require watercourses with slow to moderate flow. Strange (1999) found adult populations in chalk stream water meadow systems to be concentrated on channel flows where water velocities ranged from 7.5 to 20 cm/s (Ref. 9). In areas with fast flowing main channels, the shallow stream margins or areas of dense vegetation can be utilised;
- Water flow rates in the larval habitats studied by Purse & Thompson (2002a) in the Glan-yr-afon Uchaf, Pembrokeshire were found to range from 2 to 15 cm/s;
- Water abstraction may alter the movement of water through meadow systems and reduce groundwater spring flow, affecting habitat suitability;
- Water currents of around 10 cms^{-1} (maximum of 35cm s^{-1}) allow for a minimum oxygen concentration of 2.5 – 3.0 mg/l^{-1}. Oxygen levels have been cited as an important factor in the distribution of the southern damselfly (Ref. 8);
- Permanent conduction of water and proximity to springs or groundwater are cited as important factors in determining habitat suitability (Ref. 3); and
- Springs maintain a higher than average temperature in winter and are more constant in temperature throughout the year, preventing freezing over or drying up (Ref. 8).

Other influences

- The southern damselfly tends to favour habitats where the water is unpolluted, has high oxygen concentrations and the conductivity is generally low (less than 150 uS/cm), but levels up to 500 uS/cm have been recorded (Ref. 10);
- Studies have found phosphate levels to be less than 0.025 mg/l in most watercourses and sites occupied by the southern damselfly. There are however exceptions to this (Ref. 10);
- Nitrates levels are generally low (less than 0.2 mg/l) in southern damselfly habitats (Ref. 10);
- Habitat fragmentation has affected populations. Overzealous clearance of channel vegetation can pose a serious threat to populations if undertaken at certain stages of the life cycle; and
- Alteration of grazing regimes may affect the status of southern damselfly populations. Moderate grazing regimes are needed to reduce the establishment of scrub and invading emergents.

Current and future work

The LIFE in UK Rivers Project is developing conservation strategies and monitoring protocols for use on rivers designated as Special Areas of Conservation under the European Union Habitats Directive. Refer to the LIFE in UK Rivers website for further information.

Key references

General description/biology & habitat details

1. Berrie, A.D. (1992). The chalkstream environment. *Hydrobiologia*, 248, 3-9.

2. Buchwald, R. (1989). Die Bedeutung der Vegetation fur die Habitatbindung einiger Libellenarten der Quellmoore und Fliessgewasser. *Phytocoenologia*, 17, 307-448.

3. Burchwald, R. (1994). Zur Bedeutung der Vegetation fur die Habitatbindung einiger Libellenarten der Quellmoore und Fliessgewasser. Phyocoenologia, 17, 307-448.

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9. Strange, A. (1999). Distribution of Southern Damselfly on the River Itchen, Ecological Planning and Research for English Nature and the Environment Agency.

10. Thompson, D., Purse, B. & Rouquette, J. (2002). *Ecological requirements of the southern damselfly (Coenagrion mercuriale Charpentier (Draft)*. Document provided in confidence. LIFE in UK Rivers Project. http://www.english-nature.org.uk/lifeinukrivers/ecological.html)

Further reading

11. B.Purse (2002) R & D Technical Report W1-021/TR: The Ecology and Conservation of the Southern Damselfly (*Coenagrion mercuriale* – Charpentier) in Britain.

12. Rouquette JR and Thompson DJ, 2005 *Habitat associations of the endangered damselfly, Coenagrion mercuriale, in a water meadow ditch system in southern* England. Biological Conservation, **123**, 225-235.

Supporting references

Annex I habitats to be considered with the southern damselfly are; North Atlantic wet heaths with *Erica tetralix,* Temperate Atlantic wet heaths with *Erica ciliaris* and *Erica tetralix;* and Ranunculus habitats.

This document was withdrawn on 6 November 2017

White-clawed crayfish *(Austropotamobius pallipes)*

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General information

The distribution of the white-clawed crayfish (*Austropotamobius pallipes*) is governed by geology and water quality. The species can be found in a variety of locations including canals, streams, rivers, lakes, reservoirs and water-filled quarries, where it occupies cryptic habitats. Populations are concentrated in northern and central England. They are largely nocturnal, with breeding taking place from September to November when water temperatures drop below 10˚C for an extended period (Ref. 1).

Habitat preferences

- White-clawed crayfish occur in relatively hard, mineral-rich waters on calcareous and rapidly weathering rocks;
- Populations in the UK are associated with chalk, limestone or sandstone deposits in water bodies where calcium content is a minimum of 5 mg/l and pH ranges between 6.5-9.0 (Ref. 1); and
- Flowing water habitats in which the white-clawed crayfish is found often have undermined, overhanging banks; sections which exhibit heterogeneous flow patterns; cobbles and rock riffles; roots and woody vegetation; and under water-saturated logs.

Key influences

Water resources

- The white-clawed crayfish typically inhabits watercourses with depth ranging between 0.75-1.25 m. The species may also occur in very shallow streams (0.05 m depth) and in deeper, slow-flowing rivers (2.5 m depth);
- Populations occur in both still and running water. White-clawed crayfish can survive in rivers with a strong flow, providing suitable refuges such as weirs and boulders are present;
- They can occur in shallow riffles and in streams less than 0.5m wide with water depths of just a few centimetres;
- Low water levels can increase the white-clawed crayfish's vulnerability to predation;
- Flow conditions which affect bankside vegetation and submerged plant communities may have indirect consequences to white-clawed crayfish; and
- Increased silt loads (and turbidity) caused by land practices or flow changes (natural and induced) can clog the gills of crayfish. No quantitative data is available.

Other influences

- White clawed crayfish are susceptible to acute pollution incidents caused by spills of organic material with a high BOD (e.g. cattle slurry). In a simulated experiment, Foster & Turner (Ref. 3) found that increased ammonia concentrations and reduced oxygen conditions caused significant mortalities. The majority of records show the white-clawed crayfish to occupy waters with GQA classifications of A or B, and high BMWP scores;
- Oxygen levels below 5 mg/l for more than a few days in summer months may cause stress (Ref. 7);
- Porcelain disease (*Thelohania contejeani*) and crayfish plague (*Aphanomyces astaci*) affect the white-clawed crayfish. Porcelain disease is rarely fatal, but crayfish plague can cause mass mortalities;
- Submerged plant communities and banks are required for refuge;
- The presence of overhanging bankside vegetation (for shelter, food and cover) may determine crayfish abundance (Ref. 1);
- Direct predation and competition by the introduced signal crayfish (*Pacifastacus leniusculus*) has the potential to eliminate white-clawed crayfish populations. Signal crayfish may also act as vectors of the crayfish plague;
- Other non-native crayfish also have the potential to outcompete the white-clawed crayfish for resources; and
- Susceptibility to biocides is noted. One study demonstrated crayfish sensitivity at concentrations of 0.0042 mg/l, with levels above 0.208 mg/l toxic. An EQS for the protection of freshwater life has been proposed at 0.1 mg/l (AA) and 1 mg/l.

Current and future work

The LIFE in UK Rivers Project has developed conservation strategies and monitoring protocols for use on rivers designated as Special Areas of Conservation under the European Union Habitats Directive. Refer to the LIFE in UK Rivers website for further information.

Key references

General description/biology & habitat details

1. Holdich, D. (2001). *Ecological requirements of the white clawed crayfish Austropotamobius pallipes (Lereboullet).* LIFE in UK Rivers Project. http://www.english-nature.org.uk/lifeinukrivers/ecological.html

2. Holdich D, 2003 *Ecology of the White-clawed crayfish, conserving Natura 2000 Rivers, Ecology Series No.1* English Nature: Peterborough.

3. Foster, J. & Turner, C. (1993). Toxicity of field simulated farm waste episodes to the crayfish *Austropotamobius pallipes* (Lereboullet): elevated ammonia and reduced dissolved oxygen concentrations. *Freshwater Crayfish*, 9, 249-258.

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6. UK Biodiversity Action Plan, *Species Action Plan* Retrieved Feb 21, 2006, from http://www.ukbap.org.uk/UKPlans.aspx?ID=124

This document was withdrawn on 6 November 2017

Fisher's estuarine moth (*Gortyna borelii lunata*)

General information

Fisher's estuarine moth, *G. borelii lunata* is an insect restricted to a small area of sea-walls and coastal grassland in north Essex (although a small colony in Kent may also exist; Ref. 1). The moth has a widespread but localised European distribution and is limited by the availability of food sources as it feeds exclusively on *Peucedanum, P. officinale,* or Sea Hog's Fennel in England (Ref. 4). *G. borelii lunata* lays its eggs on the Fennel and the larvae hatch in late spring, feeding on its stems and then later boring into the roots of the plant (Ref. 4). After pupation, the adult moths emerge in autumn with a wingspan of 42-60mm (Ref. 4). The species is nocturnal and sedentary with only a few moths ever found more than 10 metres away from a food plant. The total UK population has been estimated to be 1000-5000 adults (Ref. 3). Recent genetic studies have indicated that the British form of the moth may be an endemic subspecies, distinct from the population in mainland Europe (Ref. 2). The decline of this species in Britain may be due to sea-level rise and the loss or fragmentation of its habitat.

Habitat preferences

- The Fisher's moth inhabits marshy fields, raised banks, offshore islands and wasteland where the Sea Hog's Fennel is present.

Key influences

Water resources

- *G. borelii lunata* may be directly affected by sea level rise; or
- Indirectly impacted if hydrological changes alter the availability of Sea Hog's Fennel (Ref. 1).

Other influences

- Changes in land use, such as agricultural intensification can reduce the habitat of *G. borelii lunata*; additionally, any changes that affect the habitat of Sea Hog's Fennel may also impact the moth.

Current and future work

Studies on the population and distribution of the Sea Hog's Fennel are on-going, please see Supporting references.

Key references

1. ARKive, *Fisher's estuarine moth (Gortyna borelii lunata)*. Retrieved February 23, 2006, from: http://www.arkive.org/species/ARK/invertebrates_terrestrial_and_freshwater/Gortyna_borelii_lunata/more_info.html

2. Essex Biodiversity Project, *Essex Biodiversity Action Plan*. Retrieved February 21, 2006, from: http://www.essexbiodiversity.org.uk/species.htm#moth2

3. Gibson C, 2000 *The conservation of Gortyna borelii lunata (freyer; Lep: Noctuidae)*. Entomologist's Record and Journal of Variation, 112, **1**, 1-5.

4. Joint Nature Conservation Committee, *Invertebrate species: arthropods Gortyna borelii*. Retrieved February 21, 2006, from: http://www.jncc.gov.uk/ProtectedSites/SACselection/species.asp?FeatureIntCode=S4035

5. Ringwood Z, Hill J and Gibson C, 2004 *Conservation management of Gortyna borelii lunata (Lepidoptera: Noctuidae) in the United Kingdom*. Journal of Insect Conservation, **8**, 173-183.

Supporting references

Several studies involving Sea Hog's Fennel have been undertaken, please see:

6. Iley M and Ringwood Z, 2004, *Progress report on research trials to establish Sea Hog's Fennel Peucedanum officinale L. at Abbots Hall Farm, Gt. Wigborough*. Retrieved February 21, 2006, from: http://www.essexbiodiversity.org.uk/projects/progress_report_on_trials_establish_seahogs.pdf (PDF, 213966 bytes)

Estuaries should be considered with the Fisher's moth.

This document was withdrawn on 6 November 2017

Marsh fritillary butterfly (*Euphydryas aurinia*)

This document was withdrawn on 6 November 2017

General information

The marsh fritillary (*Euphydryas aurinia*) is found in a range of habitats in the UK, but is essentially a grassland butterfly. Populations are known to occasionally occur on wet heath, bog margins and woodland clearings. The appearance of the marsh fritillary butterfly is highly variable, with marked differences within and across populations noted. The upper sides of the wings are dark brown, strongly marked with cream and orange square spots, most of which are arranged in bands. The under sides are brighter, orange with cream spots (Ref. 6).

Populations vary greatly in size from year to year and are, at least in part, related to cycles of attack from parasitic wasps. Another key factor is weather conditions in late May/early June. During this time populations are heavily dependent on favourable conditions. Adults tend to be sedentary and remain in a series of linked metapopulations, forming numerous temporary sub-populations (Ref. 6 & 4).

Numbers have declined dramatically across Europe since records started, with the UK and Spain now constituting the greatest proportion of remaining populations. Although formerly widespread in central and eastern England, important centres of distribution are now in South-west England (particularly Devon, Dorset and Wiltshire), South and west Wales, Cumbria and western Scotland (Ref. 8 & 1).

Habitat preferences

Colonies of the marsh fritillary primarily occur in two contrasting biotypes:

- 1. Damp unimproved acidic grassland;
- 2. Dry, calcareous grassland;
- Requirements for the marsh fritillary are considered different between the two habitats, and require further investigation;
- In damp unimproved acidic grassland habitats, the sites are generally flat with vegetation dominated by tussocky, coarse grasses (*Molinia caerulea* on acidic soils and *Deschampsia caespitosa* on more neutral soils). Historical grazing (nearly always by cattle or ponies) is also characteristic of the sites management (Ref. 10). Breeding areas are generally open and unshaded, though many are sheltered either by scattered scrub or by adjacent woodland (Ref. 2); The 2001 Foot and Mouth Disease outbreak affected sites where historic seasonal grazing patterns had been established;
- The occurrence of the butterfly on calcareous grassland in the UK is a recent observation. It appears that colonisation of calcareous grassland has occurred after the switch from sheep to cattle on some lowland hills around 100 years ago. (Ref. 11);
- The larval food plant required by the marsh fritillary is the devil's-bit scabious (*Succisa pratensis*). Large leaves are generally required for egg-laying, although small leaves are utilised in chalk downland habitats;
- Colonies can survive in fairly short-grazed turf on chalk grassland (e.g. 2-5 cm) if the food plant (devil's-bit scabious) is sufficiently abundant (Ref. 7);
- The adult marsh fritillary feeds on nectar and may have a preference for thistles (*Carduus* spp. and *Cirsium* spp.);
- South and west-facing slopes are favoured with north-facing slopes not used (Ref. 5); and
- As a weak flyer, topographic shelter or the presence of scrub is required.

Key influences

Water resources

- No information on the water resource requirements of the marsh fritillary were identified;
- Water resources are not believed to be a major parameter involved in the decline of the marsh fritillary butterfly. However, high water tables on many of this species damp acidic grassland habitat sites have rendered the ground too heavy for cultivation, re-seeding or other development. This has been a major contributory factor to the survival of the marsh fritillary butterfly at these locations. Field drainage is thus a serious threat; and
- Consideration of the water requirements of the larval food plant is required.

Other influences

- The marsh fritillary is a basking insect, and utilises solar radiation to raise its body temperature above the ambient. Basking sites are chosen on the basis of their solar radiation absorbance-reflection characteristics (Ref. 7);
- Loss of habitat through agricultural improvement of marshy and chalk/limestone grasslands and changes in management practices (i.e. large burns or burning

without grazing) will affect marsh fritillary populations;
- Changes in grazing stock practices may reduce habitat availability and food plant source abundance (e.g. sheep generally consume devil's-bit scabious and create a tight sward); and
- Fragmentation and isolation of habitats will impact on populations.

Current and future work

Current and future work being undertaken to conserve the marsh fritillary in the UK are outlined in Ref. 10. Extensive surveys are to be carried out on Dartmoor by the National Park Authority, and collection of data from Islay in the Inner Hebrides and Salisbury Plain are also proposed.

A European LIFE project on Salisbury Plain is proposed in an attempt to improve the quantity and quality of available breeding habitat.

A PhD undertaken by K. Porter (1981) on 'The population dynamics of small colonies of the butterfly Euphydras aurinia' may provide additional information on this species. Access to this document was not possible through the British Library. Work from a PhD undertaken by Francien van Soest and sponsored by English Nature (Devon) should soon be available on the habitat preference of the marsh fritillary in relation to culm grassland.

Work continues on influencing Countryside Stewardship and other Defra agrienvironment initiatives (Ref. 3)

Key references

General description/biology & habitat details

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Supporting references

The Annex I habitats to be considered with the marsh fritillary butterfly are: *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*); Alkaline fens Calcium-rich springwater fed fens; Temperate Atlantic wet heaths with *Erica ciliaris* and *Erica tetralix*; and Calcareous fens with *Cladium marisus* and species of the *Caricion davallianae*.

This document was withdrawn on 6 November 2017

2.3.2 Fish and amphibians

The following summaries have been compiled using key reference papers provided by Environment Agency and Natural England staff. They provide a summary of relevant information on the freshwater requirements of fish and amphibians. For further information, refer to references listed below each habitat account.

– Sea lamprey (*Petromyzon marinus*)

– Brook lamprey (*Lampetra planeri*)

– River lamprey (*Lampetra fluviatilis*)

– Allis shad (*Alosa alosa*)

– Twaite shad (*Alosa fallax*)

– Atlantic salmon (*Salmo salar*)

– Spined loach (*Cobitis taenia*)

– Bullhead (*Cottus gobio*)

– Great crested newt (*Triturus cristatus*)

This document was withdrawn on 6 November 2017

Sea lamprey (*Petromyzon marinus*)

This document was withdrawn on 6 November 2017

General information

The sea lamprey, *Petromyzon marinus,* belongs to a group known as Agnatha, or jawless fish, which is the most primitive of all living vertebrates. Not true fish, their bodies are made of cartilage and their mouth is surrounded by a round, sucker-like disc within which are strong, horny rasping teeth. Spawning occurs in late May to July when water temperatures reach at least 15 degrees centigrade. Adult lampreys often die following spawning (Ref. 7). After hatching, juvenile lampreys leave the nest and drift downstream, burrowing into suitable silt beds (Ref. 7). Following metamorphosis between July and September, the lamprey migrate downstream and out to sea (Ref. 7). Juvenile lamprey filter feed on various unicellular organisms including ciliates, eugledoids and rhizopods, while adult lamprey are parasitic and feed on salmon, basking shark, cod and sturgeon and may travel to considerable depths to find prey (Ref. 7). Although *P. marinus* is fairly widespread in UK rivers, its populations have recently declined, current strongholds are the rivers Wye and Severn Rivers (Ref. 3). Outside of the UK *P. marinus* may be found along Atlantic coastal areas of western and northern Europe between Norway and the Mediterranean as well as in the eastern parts of North America (Ref. 3).

Habitat preferences

- *P. marinus* favour larger streams and rivers but may be found in a range of habitat types (Ref. 5);
- Lamprey normally breed in high quality, deep, fast flowing rivers with clean gravels (Ref. 3). Nests are often constructed from gravel pebble substrate (9.5-50.8 mm in diameter); and
- Sand must be available for eggs to adhere. Larval nursery beds are found at the edges of streams and rivers, away from the main current.

Key influences

Water resources

- Water abstraction and land drainage may create unstable habitats through varying water levels and these activities may also dewater the marginal habitats used by larvae;
- High flows may reduce access to spawning sites and sweep eggs and larvae downstream into the sea. Low flows may prevent migration through shallow waters and physical barriers. However, adults prefer flows of approximately 0.4 m^3s^{-1} and an adequate flow of at least 8-10 cms^{-1} is necessary over the nest for successful spawning (Ref. 7);
- Water depth at spawning sites varies from 0.05-1.52 m, with an extreme of 3.7 metres. Depth in nursery areas ranges from 0.01-1 metre but is most often between 0.4-0.5 metres;
- Migration is influenced by tides and river flows and may be inhibited by shallow water or artificial barriers such as weirs and sluices; and
- Sea lamprey may also be at risk from entrainment.

Other influences

- The removal or siltation of gravel used in spawning areas may damage the habitat and inhibit spawning. The optimum particle size for larval silt beds in 0.18-0.38 mm with a gradient ranging from 1.9-5.7 m/km;
- Sea lamprey are sensitive to pollution and rivers should be of GQA chemical Class B for adult lamprey and Class A for spawning. Sufficient oxygen concentrations are also important (Ref. 7 & 3);
- Water temperature is an important factor during the life cycle of and successful hatching and metamorphosis, and critical spawning temperatures range from 8.5-12 degrees centigrade (Ref. 5 & 6); and
- Larvae may be predated by eels, sticklebacks and other fish, as well as birds such as heron, and adult sea lamprey may be attacked during spawning (Ref. 7).

Current and future work

The LIFE in UK Rivers Project has developed conservation strategies and monitoring protocols for *P. marinus* and are available from: **www.english-nature.org.uk/lifeinukrivers/species/lamprey.html**

Key references

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Supporting references

Habitats that should be considered with *P. marinus* are water courses of plain to montane levels with *Ranunculion fluitantis* and *Callitrichol-Batachion* vegetation and estuaries.

This document was withdrawn on 6 November 2017

Brook lamprey (*Lampetra planeri*)

This document was withdrawn on 6 November 2017

General information

The brook lamprey, *Lampetra planeri,* is a primitive, jawless fish resembling an eel. It is a non-migratory freshwater species, occurring in streams and occasionally in lakes in north-west Europe (Ref. 9). Not true fish, the bodies of *L. planeri* are made of cartilage and their mouth is surrounded by a round, sucker-like disc within which are strong, horny rasping teeth. Unlike sea and river lampreys which are anadromous, *L. planeri* live entirely in freshwater and are non-parasitic. The brook lamprey has declined in some areas of the UK but is still widespread and common in parts of England. In Europe it extends from Sweden to France (Ref. 3). Unlike its close relatives, the sea and river lamprey, the brook lamprey is not parasitic and feeds by filtering fine organic particles such as diatoms and protozoans as well as detritus from the substrate surface (Ref. 10).

Habitat preferences

- *L. planeri* lives in small streams, rivers and lakes with clean gravel beds to spawn in and silt or sandy areas for the larvae (Ref. 3). *L. planeri* tend to spawn in sections of the river where the current is not too strong (Ref. 9). Spawning occurs in British rivers when the water temperatures reach 10-11 degrees centigrade (Ref. 10).

Key influences

Water resources

- Water abstraction and land drainage can create unstable habitats through the variance of water levels and change flow, reducing the suitable habitat particularly for the larvae;
- Recent studies have indicated that larvae inhabit areas with flows of 0.4 to 0.5ms^{-1} and depths of 0.25 metres;
- Surveys have indicated that *L. planeri* prefer areas with rooted macrophytes' and changes in flow or depth which may reduce this vegetative presence could have a negative impact on the lamprey (Ref. 10); and
- Water depth in nursery areas should range from 0.1-1 metres and the installation of gauging weirs may have a detrimental impact on the brook lamprey and their spawning (Ref. 3).

Other influences

- A decline in water quality, particularly resulting from pollution and eutrophication has contributed to the decline in *L. planeri*. In the absence of specific tolerance data for this species it must be assumed that conditions in all parts of any river where brook lampreys occur, or pass through on migration, are at least UK Water Quality Class B (Ref. 10);
- Oxygen tension is a major factor in the maintenance of the burrowing habit of larvae (Ref. 10);
- Water temperature is also important for successful hatching and for metamorphosis, which may only occur at 12 degrees centigrade;
- Stream bed stability is also important and larvae may be absent from beds characterised by frequent sand drift. Siltation of the substrate may also smother spawning gravels and nursery silts as it creates anoxic conditions; and
- *L. planeri* can be affected by the placement of obstacles and the inadequacy of fish screens on intakes which can entrain lamprey.

Current and future work

The LIFE in UK Rivers Project has developed conservation strategies and monitoring protocols for the *L. planeri* and are available from: www.english-nature.org.uk/lifeinukrivers/species/lamprey.html

Key references

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Further information

Water courses of plain to montane levels with *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation should also be considered with the brook lamprey.

This document was withdrawn on 6 November 2017

River lamprey *(Lampetra fluviatilis)*

General information

The river lamprey, *Lampetra fluviatilis*, belongs to a group known as Agnatha, or jawless fish, which is the most primitive of all living vertebrates. Not true fish, their bodies are made of cartilage and their mouth is surrounded by a round, sucker-like disc within which are strong, horny rasping teeth. Adults migrate upstream into rivers to reach spawning areas and lay eggs in crude nests, shallow depressions created by lifting away stones, and die shortly after spawning (Ref. 8). After hatching the larvae burrow into sandy or silty areas until they metamorphose after a few years of development (Ref. 8). Unlike its close relative, the brook lamprey, *L. fluviatilis* is a parasitic organism which feeds on the flesh of a variety of estuarine fish.

L. fluviatilis is only found in western Europe where it has a wide distribution from southern Norway to the western Mediterranean. In the UK, *L. fluviatilis* has a wide distribution with young lampreys (ammocoetes) occurring in many rivers from the Great Glen in Scotland southwards. Declines have been recorded over the last century as a result of pollution, river engineering and barriers, particularly those that inhibit spawning as *L. fluviatilis* are an anadromous species (Ref. 8 & 7). Because of known declines throughout the species' European range, UK populations of river lamprey are now internationally important (Ref. 2).

Habitat preferences

- River lampreys are often found in association with the sea and brook lamprey but may also occur on their own;
- They prefer rivers of high water quality and water temperatures of 10-11 degrees centigrade (Ref. 2);
- Nursery areas for lamprey larvae occur in beds of sand where deposition features occur in the river so that the larvae may burrow into the substrate and filter feed before metamorphosing;
- A diversity of habitat is also important and *L. fluviatilis* prefer areas with riffles, pools, gravel beds and bars; and
- As river lamprey feed on estuarine fish as adults, it is important that estuarine conditions are suitable with low levels of pollution and suitable prey (Ref. 8).

Key influences

Water resources

- Water abstraction and land drainage can create unstable habitats for lamprey through varying water levels and may be detrimental to larvae if marginal habitat is reduced or unsuitable flow regimes produced;
- Water depth in nursery areas may range from 0.01-1 metre and water depth for spawning often ranges from 0.2-1.5 metres;
- Larval nursery beds are often found at the edges of streams and rivers, distanced from the main current. Flows of 8-10 cms^{-1} have been recorded over larvae burrows;
- Adult lamprey prefer flows of 1-2ms^{-1} and larvae prefer flows of 1 – 50 cms^{-1} (1). High flows during spates are detrimental to river lamprey as they may prohibit access to spawning sites or sweep eggs and larvae downstream. Low flows may also inhibit migration through shallow waters and passage over physical barriers or exacerbate the impacts of poor water quality; and
- Lamprey are also at risk from entrainment by water intakes.

Other influences

- River lamprey are sensitive to pollution, particularly heavy metals and pesticides, eutrophication and are intolerant of low oxygen concentrations, particularly as larvae and require 4 mgl^{-1} to migrate (Ref. 8) . Rivers should be of GQA chemical Class B where migration occurs, and Class A in spawning areas (Ref. 2);
- Studies have indicated that water temperature is also an important parameter during the lamprey life cycle, critical spawning water temperatures normally range from 8.5-12 degrees centigrade;
- Adult lamprey feed predominantly in estuaries, which must support healthy populations of prey such as flounder, sprat, sea trout and herring;
- Barriers may inhibit upstream migration of lamprey from their nursery areas to spawning grounds and the removal of vegetation or its alterations may be detrimental; and
- The removal or siltation of gravel in spawning areas will inhibit spawning.

This document was withdrawn on 6 November 2017

Current and future work

The LIFE in UK Rivers Project has developed conservation strategies and monitoring protocols for the *L. fluviatilis* and are available from: **www.english-nature.org.uk/lifeinukrivers/ species/lamprey.html**

Key references

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Supporting references

Habitats which should be considered with *L. fluviatilis* are water courses of plain to montane levels with *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation and estuaries.

This document was withdrawn on 6 November 2017

Allis shad (*Alosa alosa*)

This document was withdrawn on 6 November 2017

General information

The allis shad is a member of the herring family (Clupeidae) and may be found in shallow coastal waters and estuaries as well as large rivers during the breeding season where it spawns. Spawning occurs from May to July when non-adhesive eggs are laid in gravel beds in shallow waters and hatch 4-8 days later (Ref. 6 & 10). The shad population has declined significantly throughout Europe in recent years and only in small numbers around the coast of Britain. Although the allis shad may spawn in the Solway Firth, there is not definite evidence of spawning stocks in the UK (Ref. 6).

Habitat preferences

- In a marine environment, *A. alosa* have been recorded from depths of 10-150 metres and are exclusively planktivorous. A suitable estuarine habitat is important for allis shad both for passage of adults and as a nursery ground for juveniles (Ref. 6).
- In freshwater, *A. alosa* require a clear migration route to spawning grounds, suitable resting pools and clean gravels at the spawning area. Juveniles require a slow-flowing nursery above the estuary after hatching (Ref. 6). The narrowest river in Britain supporting *A. alosa* spawning is the River Teme, which is approximately 20 metres wide. It has been suggested that the upstream migration from the estuary is catalysed by water temperature increases to 10-14^{o} Celsius (Ref. 6).

Key influences

Water resources

- *A. alosa* require suitable river flows to allow them passage to a spawning ground and adequate water depths. Abstraction may also be detrimental to shad as low flows may prevent access to upstream spawning grounds as well as exacerbate the impact of poor water quality (Ref. 3 & 6);
- Studies have suggested that any significant management of channels which removes resting pools or creates stretches of fast flow (>2m s^{-1}) or very shallow water (<10 cm) must be avoided along the shads migration route (Ref. 6);
- Crecco *et al*. (1986) suggested that climatic factors such as river flow, rainfall and temperature during May and June are major regulatory factors for shad populations. Their study produced a model, which found that flow and rainfall accounted for 80-90 per cent of stock recruitment variability (Ref. 4 & 5);
- High flows, particularly from June to September, may be detrimental to *A. alosa* as eggs and fry may be swept downstream to the sea; additionally, shad have difficulty swimming upstream if the flow exceeds 2m s^{-1}; and
- Shad can be entrained by various water intakes if their design and/or intake velocity allows(Ref. 9).

Other influences

- *A. alosa* need a migration route that is free of obstacles, such as navigation weirs, hydropower barrages and other in-stream barriers which have contributed to the population decline of the shad which may also be lost to water intakes (Ref. 6);
- Shad have also declined from areas with historically poor water quality such as the Thames and have not yet returned. *A. alosa* require a UK water quality class of B or greater;
- The eggs are quite sensitive to temperatures below 16 degrees Celsius (Ref. 3) so there may be impacts from regulation and compensation releases from reservoirs; and
- Habitat fragmentation or destruction, particularly the loss of suitable substrate for spawning (which often occurs in faster currents at the end of pools where gravely shallows begin and where there is a maximum penetration of gravels by currents) and excess of siltation which can inhibit oxygen uptake by gills or egg membrane.

Current and future work

The LIFE in UK Rivers Project is developing conservation strategies and monitoring protocols for use on rivers designated as Special Areas of Conservation under the European Union Habitats Directive. Refer to the LIFE in UK Rivers website for further information.

A workshop on the four target Vertigo species was held in 2002, its proceedings were collated into the article: Speight MCD, Moorkens E and Falker G 2003 *Proceedings of the workshop on conservation biology of European Vertigo species* (Dublin, April 2002) Heldia, 5, 7, 1-183.

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Supporting references

The Allis shad should be considered with; Water courses of plain to montane levels with *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation and Estuaries

This document was withdrawn on 6 November 2017

Twaite shad (Alosa fallax)

This document was withdrawn on 6 November 2017

General information

The twaite shad (*Alosa fallax*) is a member of the herring family Clupeidae. *A. fallax* occurs along the west coast of Europe, from southern Norway to the eastern Mediterranean Sea and in the lower reaches of accessible rivers along these coasts; in Britain they may be found in the Severn, Wye, Usk and Twyi Rivers (Ref. 12). At maturity, adult twaite shad stop feeding and gather in the estuaries of suitable rivers in early summer to move upstream and spawn. Spawning occurs in flowing water over stones and gravel and the eggs hatch in 4-6 days (Ref. 12). The juvenile fish feed on invertebrates but move onto larger crustaceans as they mature (Ref. 12). Several studies have suggested that river flow, rainfall and temperature are major regulatory factors for shad populations (Refs. 2 & 4 & 5).

Habitat preferences

- Twaite shad have been found in marine habitats of 10-110 metres with a preference for water 10-20 meters deep. A suitable estuarine habitat is required for shad, both for the passage of adults and as a nursery ground for juveniles (Ref. 12); and
- In freshwater, *A. fallax* require a clear migration route to spawning grounds, suitable resting pools and clean gravels at the spawning area. Juveniles require a slow-flowing nursery area in freshwater above the estuary after hatching (Ref. 12). It has been suggested that the upstream migration from estuary is triggered when the water temperature rises to 10-14º Celsius (Ref. 12). The twaite shad spawning runs are also influenced by estuarine tides and river flows, although migration has been recorded at relatively high discharge levels, if flows are too high then the number may drop (Ref. 12).

Key influences

Water resources

- *A. fallax* require suitable river flows to allow them passage to a suitable spawning ground and adequate water depths of 45 centimetres to 3 metres. Research indicates that egg density declines with depth (Ref. 12);
- Studies have suggested that any significant management of channels which removes resting pools or creates stretches of fast flow (>2m s^{-1}) or very shallow water (<10 cm) must be avoided along the shads migration route (Ref. 12); and
- Abstraction may also be detrimental to shad as low flows may inhibit access to spawning grounds and exacerbate the impact of poor water quality.

Other influences

- *A. fallax* need a migration route free of obstacles such as navigation weirs and hydropower barrages which have contributed to the reduction in population; the shad may also be consumed by industrial water intakes (Ref. 8 & 12);
- Shad have also declined from areas with historically poor water quality such as the Thames and have not yet returned and it has been suggested that *A. fallax* require a UK water quality class of B or greater (Ref. 12);
- Water temperatures are important and spawning often occurs at temperatures between 18-22º Celsius while larvae prefer waters between 17-24º Celsius (Ref. 12);
- Overfishing has also contributed to the decline of *A. fallax*;
- Habitat fragmentation or destruction, particularly the loss of suitable substrate for spawning (which often occurs in faster currents at the end of pools where gravelly shallows begin and where there is a maximum penetration of gravels by currents); and
- Siltation of rivers can inhibit oxygen uptake by gills or egg membranes and has also contributed to shad decline on some rivers. Shad are often found in waters with 4-5 mg$O_2$$l^{-1}$ (Ref. 10).

Current and future work

The Life in UK Rivers project has developed a guide to the ecology, conservation and monitoring of the allis shad and is available at: **www.english-nature.org.uk/lifeinukrivers/species/shad.html**

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Supporting references

Estuaries and watercourses of plain to montane levels with *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation should be considered with the twaite shad.

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Atlantic salmon (*Salmo salar*)

General information

The Atlantic salmon (*Salmo salar*) is an anadromous species (adults migrate from the sea to freshwater for breeding) which can reach up to 1.5 metres in length and can live for up to 10 years. Historically, this species was distributed in all countries whose rivers enter the North Atlantic, but its current distribution has been restricted by anthropogenic factors, particularly man-made barriers which impede its movement and poor water quality. Atlantic salmon may be found in suitable river systems unaffected by poor water quality and migration barriers throughout Britain (Ref. 3). Although improvements in water quality have allowed *S. salar* to return to rivers such as the Taff, there has been a steady decline in British waters in recent years.

Habitat preferences

- The suitability of a habitat for juvenile salmon depends upon water depth (17-76 centimetres), water velocity (25-90cm s^{-1}), streambed substratum composition and refuge availability (Ref. 3). Typically, *S. salar* spawn in transitional areas between pools and riffles where the flow is accelerating and depth decreasing as well as gravel of suitable coarseness (Ref. 3);
- Salmon fry and parr may be found in shallow, fast-flowing water with a moderately coarse substrate and cover, suitable cover for juveniles includes areas of deep water, surface turbulence, loose substrate, large rocks, overhanging vegetation, woody debris and/or aquatic vegetation (Ref. 3); and
- Salmon <7cm in length require habitat in pebbly riffles without boulders; as they mature they move to a cobble/boulder habitat with greater depth, >300millimetres.

Key influences

Water resources

- Upstream river migration for *S. salar* occurs at higher flows and may be catalyzed by an increase in flow. Solomon *et al.* (1999) suggests that the threshold flow required to induce salmon to enter a river from the sea varied from 101 per cent to 284 per cent of the Q95 (or the flow exceeded 95 per cent of the time; Ref. 3). Spawning and nursery areas must be accessible to adult salmon and should provide adequate depth and velocity for juveniles (Ref. 3);
- Successful incubation of ova and emergence of fry is dependent on the adequate flow of water through gravel and previous studies have found that a level of <10 percent fines below 83 mm of water allow 50 per cent fry emergence (1);
- Yearling and older parr need a depth of 20-40 centimetres and velocity of 60 to 75 cm s^{-1};
- A previous study has also indicated that the ability of salmon to negotiate barriers to upstream migration is heightened when the depth of the pool below is 1:1.25 (Ref. 3);
- Similar studies on juveniles have concluded that a flow of 0.03 $m^3 s^{-1}$ per metre of channel width are adequate (Ref. 3);
- A possible consequence of river regulation may be that freshets may not be sufficient in magnitude or frequency to provide adequate migration opportunities for adult salmon (Ref. 3). Previous studies have suggested that salmon commenced upstream migration when the flow reached a level of 0.084 $m^3 s^{-1}$ per metre of channel width and that peak migration occurred at a flow of 0.2 $m^3 s^{-1}$ per metre width (Ref. 3);
- Salmon may be at risk of entrainment, and
- Temperature changes as a result of regulation and compensation releases may impact on salmon.

Other influences

- *S. salar* require very good water quality, typically that found in upland streams and spring-fed chalk streams, they are particularly sensitive to heavy metals, sheep dip, organic chemicals and increased acidity;
- General Quality Assessment (GQA) defines salmonid waters as being of grade A or B;
- Salmon waters are typified by the presence of high-scoring (Biological Monitoring Working Party, BMWP) pollution-intolerant invertebrate taxa such as mayfly and stonefly nymphs;
- Changes in sea surface temperature, fish farming and industrial fishing can exacerbate the loss or fragmentation of habitat suitable for *S. salar* (Ref. 3). Sea lice resulting from fish farming and parasites can also detrimentally impact the salmon;
- Increased predation by birds/seals or exploitation by humans;

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- The management of rivers can increase reduce flow and increase siltation, decreasing the area available for spawning and suspended solids may choke fish or disrupt feeding behaviour; and
- Artificial barriers preventing upstream migration restrict the distribution and abundance of salmon populations.

Current and future work

The LIFE in UK Rivers project has developed an ecological guide, conservation strategies and monitoring protocols for *S. salar* available at: **www.english-nature.org.uk/lifeinukrivers/species/salmon.html**

Key references

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Further information

Habitats associated with the Atlantic salmon are: Watercourses of plain to montane levels with *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation; estuaries; and the freshwater pearl mussel.

This document was withdrawn on 6 November 2017

Spined loach *(Cobitis taenia)*

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General information

The spined loach (*Cobitis taenia)* a small bottom-dwelling fish, usually less than 12 cm in length. It has a strongly patterned laterally compressed body and its mouth is surrounded by six barely visible barbells (Ref. 9). In the UK the spined loach appears to be restricted to five east-flowing river systems in eastern England – the Rivers Trent, Welland, Witham, Nene and Great Ouse, with their associated waterways (Ref. 2). It is thought to be widely distributed within these systems, but detailed information is lacking since it is often over looked in fish surveys (Ref. 3).

Habitat preferences

- Spined loach has a restricted microhabitat associated with its specialised feeding mechanism. Using its complex branchial apparatus to filter-feed, it requires fine but well-oxygenated sediments; and;
- Optimal habitat consists of patchy submerged macrophyte cover (and possibly emergents) which is important for spawning and a sandy, silty substrate into which juvenile fish tend to bury themselves (Ref. 9).

Key influences

Water resources

- There is little available information on specific water quantity or quality requirements of the spined loach. Data available are concentrated on flow velocities;
- An indirect relationship between flow regimes and distribution may exist in response to the relationship between macrophyte density and water flow (Ref. 4);
- The spined loach may favour low water velocity (Ref. 4). A study on the Great Ouse found this species to select low flows (mean 15 cm/s) and avoid higher flows (mean 29cm/s) (Ref. 2); and
- In high winter flows individuals become concentrated in deeper, slacker areas (Ref. 8).

Other influences

- The spined loach tolerates a pH range of 5-10, with preferred conditions at 7 (taken from Habitat Geschiktheid Index model: Kliene modderkruiper & Habitat suitability index model for spined loach – Witteveen & Bos *unpubl. Data,* as cited in Ref. 3);
- Predation from a range of omnivorous and carnivorous species may be a major factor influencing the distribution pattern of the spined loach. Benthivorous species, in particular carp and bream are likely to constitute the largest threat. These two species can alter the sediment characteristics, which has implications for the entire ecology of the habitat (Ref. 3); and
- The abundance of refuges such as macrophytes may be critical in determining the strength of recruitment and any long term population viability (Ref. 4).

Current and future work

Copp and Vilizzi (2004) examined the microhabitat use of *C. taenia* in the Great River Ouse basin. Their findings indicate that water velocity and filamentous algae were the most influential variables in determining microhabitat suitability and that the preferred water velocities decreased with age for *C. taenia* (Ref. 1).

Recent research by Natural England and Entec has outlined the occurrence of spined loach throughout England and some of its sensitivity to diffuse pollution (Ref. 10).

Natural England and the Environment Agency have recently produced the following: Genetics and ecology of spined loach in England: implications for conversation management. Science report SC000026/SR

Key references

General description/biology & habitat details

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Bullhead (*Cottus gobio*)

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General information

The bullhead (*Cottus gobio*) is the only freshwater species of cottidae found in the UK. This small species is easily identified from its large head (eyes on top) and dorso-ventrally flattened tapering body modified for life on the bottom of flowing waters. Bullheads also lack a swim bladder, a further adaptation to its benthic habitat. The species is widely distributed in Europe, and common in England and Wales. It is absent from Ireland and only present in a small number catchments in Scotland. The bullhead is only considered indigenous to east and some southern English rivers.

Bullheads appear to be territorial and are considered sedentary. Feeding primarily occurs at dusk (and presumably dawn), with benthic invertebrates making up the bulk of their diet (Ref. 4).

Habitat preferences

- Bullheads predominantly occur in stony streams and rivers where flows are moderate and waters are oxygen rich. These range from high altitude beds to the chalk streams of southern England. Bullheads are also commonly found in streams without a stony substrate (e.g. clay dominated catchments) and populations are equally sustainable in habitats where cover is afforded by substrate other than gravel i.e. tree roots and other in-stream material;
- Differences in population densities, sexual maturity and longevity are apparent between bullhead populations (Refer to Ref. 4 for further information);
- Spawning takes place from February to June. Various habitats are required by bullheads according to their different life stages;
- Coarse, hard substrates of clean, gravel and stones are required for breeding. Males are territorial and encourage females to lay their sticky eggs under large, flat stones. Males then defend the nest and care for the eggs until hatching;
- Shallow stony riffles are important habitat for young fish (‹1 year); and
- Sheltered areas created by natural wooded riparian margins (woody debris, tree roots, leaf litter, macrophytes and large stones) are preferred (especially during daylight hours) by adult bullhead.

Key influences

Water resources

- Water depth is not considered critical to the bullhead, provided it is ›5 cm. Bullheads present in lakes have been found in depths of up to 20 m (Ref. 1);
- Moderate water velocity is required with studies to date suggesting 10-40 cm/sec. These conditions are often associated with riffles. Slack water refuges are also necessary for all life stages during high flows (Ref. 4);
- It has been suggested that bullheads are likely to suffer under low flow conditions. Studies have shown that where low flows have been reversed, bullhead populations have recovered (Ref. 4);
- Low flows can increase temperatures and reduce oxygen levels. This can directly affect egg survival and indirectly affect adult males who then 'fan' eggs when oxygen levels become reduced;
- Low flows may lead to the siltation of preferred stony substrates; and
- Bullheads are generally found in water of moderate velocity, but may tolerate considerable flow velocity through utilising microhabitat refuges such as large stones and debris. Differences in velocities have been observed between studies (Ref. 4).

Other influences

- Shade and cover are important habitat requirements for the bullhead through the provision of protection from predation;
- Vertical structures and barriers greater than 18-20 cm will impede movement, causing population fragmentation (Ref 4);
- Bullheads are vulnerable to a wide range of predators. Known predators include brown trout and signal crayfish (*Pacifastacus leniusculus*);
- Signal crayfish may also compete for shelter and food and reduce recruitment through predation of bullhead eggs;
- Channelisation which changes natural flow regimes and sediment dynamics may remove suitable substrate and reduce available habitat for the bullhead. Excessive management of riparian trees and the clearance of woody debris / leaf litter during routine operations to maintain flood defence capacity are also likely to affect bullhead abundance;
- Bullheads appear to be particularly sensitive to temperature. The critical thermal limits are -4.2 and 27.7°C (Ref. 2);

- Little work has been undertaken on water quality requirements. There is no published information on the tolerance of bullheads to typical freshwater pollutants which include nutrients and heavy metals (Ref. 4);
- Given the territorial nature and poor dispersal ability of bullheads, they are likely to be less able to recolonise areas after a pollution incident;
- Utzinger *et al* (1998) found bullheads directly downstream of sewage treatment works, although in lower densities than observed upstream. Provided oxygen saturation is high, bullhead may tolerate the presence of nitrogen compounds (Ref. 5); and
- Activities likely to increase siltation rates may affect bullhead populations through the reduction in available habitat.

Current and future work

The LIFE in UK Rivers Project is developing conservation strategies and monitoring protocols for use on rivers designated as Special Areas of Conservation under the European Union Habitats Directive. Refer to the LIFE in UK Rivers website for further information.

Key references

General description/biology & habitat details
1. Crisp, D. T. & Mann, R. H. K. (1991). Effects of impoundment on populations of bullhead, *Cottus gobio* L. and minnow, *Phoxinus phoxinus* (L.), in the basin of Cow Green Reservoir. *Journal of Fish Biology,* 38, 731-740.

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Supporting references

Watercourses of plain to montane levels with *Ranunculion fluitantis* and *Callitricho-Batachion* vegetation should also be considered with the bullhead.

This document was withdrawn on 6 November 2017

Great crested newt *(Triturus cristatus)*

This document was withdrawn on 6 November 2017

General information

The great crested newt (*Triturus cristatus*) is the largest of all the newt species occurring in the UK. As an adult it can reach up to 17 cm in length, although size variation is apparent between populations. The great crested newt is dark, often black in colour, with fine white spots on its lower flanks (Ref. 13). Its skin is granular and the belly is predominately an orange or yellow colouring, with black blotches (Ref. 12). In the spring to early summer period, the adult males have two jagged crests along the back and tail.

Distribution of this species is widespread throughout much of England and Wales, although its abundance in the south-west England, mid Wales and Scotland is described as sparse. The total UK population is relatively large and is distributed over sites that vary greatly in their ecological character (Ref. 7).

Habitat preferences

- Great crested newts are mainly found in lowland habitats;
- They occupy both natural and semi-natural aquatic habitats including marshes, reed beds, spring-fed ponds, pingos, bog pools, sand dune pools and ox-bow lakes (Ref. 3);
- The newt is commonly recorded in artificially created ponds and terrestrial habitats, many of which have been greatly modified by human activity (Ref. 12);
- Deep open water is required for breeding with abundant macrophytes (Ref. 7);
- Scrub or woodland (deciduous and coniferous) is required by adults for foraging;
- The species appears to prefer medium sized breeding ponds, around 50-200m^2 (Ref. 13); and
- Recent research has indicated that presence of *T. cristatus* increases significantly with the density of ponds in an area (Ref. 10).

Key influences

Water resources

- Water must be present in the great crested newts breeding water body until September to allow larvae to emerge successfully (Ref. 1);
- Ponds that dry for short periods in late summer, or in occasional years may provide favourable conditions by ensuring fish do not dominant the system (Ref. 3); and
- The great crested newt tends to favour water that is relatively deep, allowing for its size and breeding habits (Ref. 8).

Other influences

- Great crested newt larva appear to require fish free ponds for development, as they tend to prefer open water rather than hiding in weeds with the larva from other newt species (Ref. 1);
- Terrestrial scrub/woodland habitat within 200 m of the breeding pond is required by the adult population, a minimum area of 0.4 ha has been estimated (Ref. 9). Forestry activities can therefore influence the health and status of populations (Ref .5);
- The great crested newt prefers hard waters with a pH between 5-6.5 and calcium concentrations between 5-10 mg/l (Ref. 3);
- Fragmentation of the landscape can cause local extinction of great crested newt populations (Ref. 7); and
- Populations distributed across a dense network of farm ponds are considered more robust (Ref. 13).

Current and future work

Dr. Richard Griffiths of the University of Kent has been researching the success of *T.cristatus* translocation, which has increased dramatically since 1990. His results have suggested that although the number of new ponds created compensated for the number lost, there was an overall net loss of aquatic habitat. Despite this loss of habitat the findings indicate that breeding at most sites one-year post-development was successful. Long-term results from such sites are not yet available.

The Great Crested Newt Conservation Handbook which was produced in 2001 will be updated shortly. Additionally, the Environment Agency will be implementing a new national amphibian recording scheme including *T. cristatus* among other species.

Key references

General description/biology & habitat details

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Supporting references

Annex I habitats to be considered with the great crested newt are; Natural eutrophic lakes with *Magnopotamion* or *Hyrdocharition*-type vegetation; Mediterranean temperate ponds; North Atlantic wet heathlands with *Erica tetralix*; and refer to guidance notes produced for these habitats.

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2.3.3 Mammals

The following summaries are not based on an exhaustive literature review but compiled using key reference papers and websites provided by Environment Agency, Natural England and CCW staff. These notes are intended to provide a summary of relevant information on the hydrological requirements of the listed mammals. For further information, refer to key references listed in the summaries.

- Barbastelle bat (*Barbastella barbastellus*)
- Otter (*Lutra lutra*)

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Barbastelle bat (*Barbastella barbastellus*)

This document was withdrawn on 6 November 2017

General information

The barbastelle (*Barbastella barbastellus*) is a medium-sized bat that is easily identified by its distinctive features, which make it unlike any other bat in Europe. The fur is almost black, usually with very pale or golden brown tips. The ears are very broad with the inner edges joined together across the forehead (Ref. 2).

The barbastelle is one of the UK's rarest mammals with few maternity roost sites known. It is widely distributed across southern England and Wales but may be significantly under-recorded within its range (Ref. 2).

Habitat preferences

- The ecology of the barbastelle is poorly-known. In Europe, it is believed to be an upland and forest species while in the UK it seems to prefer wooded river valleys (Ref. 2);
- Most UK records come from caves or abandoned mines, which are important hibernation sites;
- Barbastelles forage in mixed habitats, usually over water (Ref. 2). They feed mainly on Lepidoptera taken in flight, but may also glean insects and spiders from vegetation (Ref. 4);
- Barbastelles appear to select cracks and crevices in wood for breeding, mostly in old or damaged trees. Cracks and crevices in the timbers of old buildings may also be used (Ref. 2);
- Maternity colonies may move between suitable crevices within a small area, such as a piece of woodland or a complex of buildings (Ref. 2); and
- In spring and autumn, barbastelles are frequently found behind the loose bark of trees (Ref. 1).

Key influences

Water resources

- There is little published material directly associated with water resource requirements of the barbastelle, however flightlines of foraging bats frequently follow small rivers or streams, particularly in spring (Ref. 1); and
- Maintenance of open water within woodlands has been suggested to help preserve barbastelle habitat (Ref. 1).

Other influences

- Threats to the barbastelle are poorly understood, but its low population density and slow population growth make it particularly vulnerable to habitat loss. Fragmentation of ancient deciduous woodland habitat, and the loss, destruction and disturbance of roosts or potential roosts in buildings, trees and underground sites may pose significant threats to the status of this species;
- Reduction in the bats food source (Lepidoptera and other insects) due to habitat simplification, instigated by fertiliser use and intensive grazing will impact on populations (Ref. 4);
- The microclimate of the area surrounding roost sites and within these sites is important to ensure warmth for rapid development of juveniles and reduce the risk of mortality (Ref. 1); and
- The species is very sensitive to disturbance.

Current and future work

The barbastelle is the subject of a Species Recovery Programme (Phase 1 project funded by English Nature) and is included in the DETR (now Defra) sponsored National Bat Monitoring Programme which aims to establish baseline data and propose long-term monitoring protocol (Ref. 4).

Research is currently being carried out in Norfolk, Surrey, Devon, Hampshire and the Isle of Wight to locate roosts and identify habitat requirements of the barbastelle bat (Ref. 3).

A study by Wickramasinghe *et al.* (2003 Ref. 5) found that bat activity and foraging was significantly higher on organic than conventional farms, potentially as a result of unfragmented habitat and higher densities of insects.

Parsons *et al.* (2003) have recently completed a survey of swarming sites for *B. barbastellus* and their importance (Ref. 3).

Key references

General description/biology & habitat details

1. Greenaway, F. (2001). The Barbastelle in Britain. *British Wildlife*, 12: 327-34.

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Supporting references

The Annex I habitat alluvial forests should be considered with the barbastelle.

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Otter (*Lutra lutra*)

This document was withdrawn on 6 November 2017

General information

The Eurasian otter (*Lutra lutra*) is a brown furred semi-aquatic mammal with a long and sleek body with partially webbed paws and a strong tapering rudder-like tail for swimming. An adult male may be up to 4 feet long including the tail, with females typically being smaller.

The otter population of the British Isles declined rapidly from the mid 1950s until at least the mid 1970s. A slow but gradual recovery of the species is now being observed.

Habitat preferences

- Otter populations occur in a wide range of ecological conditions, including inland freshwater and coastal areas. In Scotland, otters are widespread in coastal habitats as well as on inland lakes and rivers, whereas in England and Wales the tendency to utilise coasts is less marked but may be increasing as recovery continues;
- Inland otter populations utilise a range of running and standing freshwaters. Vegetated river banks, islands, reedbeds and wetlands, adjacent ponds and woodland provide suitable habitat for foraging, breeding and resting (Ref. 3); however, otters may make use of almost all types of watercourse and wetland habitat for foraging or moving between foraging areas;
- Populations in coastal areas utilise shallow, inshore areas for feeding but require freshwater for bathing. Terrestrial areas are also required for resting and breeding holts. Coastal otter habitat ranges from sheltered wooded inlets to more open, low-lying coasts; and
- Holts are commonly located in places where the risk of direct physical disturbance is low (e.g. reeds, dense scrub, culverts, piles of rocks). However, the availability of these sites does not limit the otter population, although few breeding holt sites are known in the UK and it is possible that these may be limiting in certain areas.

Key influences

Water resources

- No specific water requirements are noted for otter populations, but indirect impacts on habitat and food supply alteration (linked to water quantity changes) should be considered; and
- The primary impact of flow changes to otters will be the loss of freshwater sites and the reduction in available fish, crayfish and amphibian food source populations. These impacts may occur due to poor survival or reduced total biomass of prey as a result of the impacts of reduced flows or levels on habitat availability, or poor recruitment due to the flow and level impacts on egg/fry/larval stages. Impacts may need to be on a medium to large scale to significantly affect otters, although the loss of an important local food source such as e.g. an amphibian population through pond/wetland drying could be significant for individual otter territories. It should be borne in mind that otters live at very low densities compared to most UK carnivores.

Other influences

- Obstructions and barriers and culverts which concentrate flows and increase velocities in watercourses may force otters to leave the waterside, particularly in flood events increasing the risk of road deaths;
- Otter use of freshwater habitats is associated with the abundance of prey (Ref. 6). Fish dominate otter diet in freshwater environments, but crayfish and amphibia (mostly frogs) may also contribute a substantial proportion; therefore quality and extent of habitat will ultimately affect food supply and therefore the carrying capacity for otters;
- Loss of trees and shrubs along river margins may reduce invertebrate prey and shading, having implications for fish populations and subsequently otters utilising the area, and may also reduce available cover for otters, both of which may reduce the suitability of habitat at a local scale for otters;
- Organic pollution may indirectly affect and limit otter populations through reductions in food supply (Ref. 4);
- Direct spillage of oil and other contaminants in coastal areas may result in direct otter deaths. Bioaccumulation of heavy metals, pesticides and PCBs (Ref. 4) may also have detrimental effects to

otter populations over time, although otters are now recovering as a result of the removal from general use of certain organochlorine pesticides which were the main cause of their original rapid decline in the UK; and

- Mason and Macdonald (1989) found that otters were not resident in Welsh streams where the pH fell below 5.5 although this may have been due to the lack of suitable food sources rather than a sensitivity to acidified waters (Ref. 2 & 5).

Current and future work

The LIFE in UK Rivers Project developed conservation strategies and monitoring protocols for use on rivers designated as Special Areas of Conservation under the European Union Habitats Directive. Refer to the LIFE in UK Rivers website for further information (Ref. 2).

Other research underway includes investigations into DNA fingerprinting of otter spraints (faeces), national distribution surveys and research into road-death mitigation techniques.

Key references

General description/biology & habitat details

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Supporting references

The Annex I habitat alluvial forests should be considered with otters.

This document was withdrawn on 6 November 2017

2.3.4 Plants

The following accounts are intended to provide a summary of relevant information on the freshwater requirements of the plants. With many of the species there is little published material directly associated with water resource requirements, and as such these notes should be treated with the necessary precautions. For further information, refer to key references listed in each species account.

- Slender green-feather moss (*Drepanocladus vernicosus*)
- Petalwort (*Petalophyllum ralfsii*)
- Marsh saxifrage (*Saxifraga hirculus*)
- Creeping marshwort (*Apium repens*)
- Floating water plantain (*Luronium natans*)
- Fen orchid (*Liparis loeselii*)
- Shore dock (*Rumex rupestris*)

This document was withdrawn on 6 November 2017

Slender green-feather moss

(*Drepanocladus vernicosus*)

This document was withdrawn on 6 November 2017

General information

Slender green-feathe rmoss (*Drepanocladus vernicosus*) is a medium-sized moss of mildly base-rich flushes and springs in the uplands and more rarely, lowland sedge fens. Slender green-feather moss and related genera are taxonomically difficult, with the group being recently revised. The slender green-feather moss is referred to in most current literature as *Hamatocaulis vernicosus (Mitt.) Hedenäs*. It has been confused with the related *Scorpidium cossonii (Drepanocladus cossonii)*, but its distribution has been clarified by examination of herbarium specimens and recent survey work (Ref. 3).

Factors pertaining to the decline of this species include the destruction of habitat, the lowering of the local water table at lowland sites, and heavy grazing of flushes by sheep and deer in upland sites (Ref. 3).

Habitat preferences

- The slender green-feather moss has been identified in very wet, unshaded, mesotrophic mires, with moderate (but not high) concentrations of calcium in both water inputs and soil (Ref. 2);
- It occurs predominately in base-rich flushes and springs (Ref. 3);
- The species may grow with small sedges (*Carex* spp.), black bog-rush (*Schoenus nigricans*) and other characteristic mosses of base-rich flushes and fens, such as *Campylium stellatum* and rarely if ever grows with *Scorpidium scorpioides* (a strong basophile) or *Leiocolea bantriensis*. It is often in neutral associations with bryophytes that include *Calliergonella cuspidatum, Philonotis fontana, Campylium stellatum* and *Dicranella palustris* ; and
- It is more frequently found in uplands but does not reach very high altitudes, with the highest record at 450 m on Snowdon (Ref. 3).

Key influences

Water resources

- Limited information is available on the specific water quantity and flow regime requirements for the slender green-feather moss;
- The slender green-feather moss are generally only found in localities which are wet all year and include spring heads and large flushes (Ref. 2);. However several of the Pembrokeshire sites are only wet in winter and could only really be described as damp in the summer (Ref. 8);
- The species is commonly in rushy but open flushes where water movement is minimal. Water movement is required nearby to provide calcium input; and
- A strong relationship between water quantity/flow regimes and the distribution of the moss is likely (Ref. 2) but more research is required before any conclusions can be drawn on the relationship between flow regime, water quantity requirements and the ecological status of this moss.

Other influences

- The eutrophication of spring waters feeding the slender green-feather moss habitat will have an adverse effect on the plant and may result in local extinction in some instances (Ref. 3);
- The moss is likely to have a low pH variation tolerance with the species favouring the more calcareous environments (Ref. 2);
- Unshaded areas that are grazed to prevent vegetation encroachment are preferred but over-grazing can destroy populations (Ref. 2); and
- Atmospheric pollution as well as forest creation is also thought to have contributed to its decline (Ref. 4).

Current and future work

As part of Scottish Natural Heritage's (SNH) lower plant conservation project, The Edinburgh Royal Botanical Gardens is assessing the taxonomic status of the slender green-feather moss using available herbarium samples (Ref. 1).

Key references

General description/biology & habitat details

1.HMSO (1999). *UK Biodiversity Group Tranche 2 Action Plans – Volume VI: Terrestrial and freshwater species and habitats*. HMSO, Tranche: 2 Volume: VI.

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Supporting references

Annex I habitats to be considered with the slender green-feather moss are: calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*, petrifying springs with tufa formation (*Cratoneurion*) and alkaline fens.

This document was withdrawn on 6 November 2017

Petalwort (Petalophyllum ralfsii)

This document was withdrawn on 6 November 2017

General information

Petalwort (*Petalophyllum ralfsii*) is a pale green thalloid liverwort with erect lamellae on its upper surface. The species is dioecious but commonly produces capsules, which mature from March to May (Ref. 5). It is commonly associated with the Annex I humid dune slacks habitat, but has occasionally been recorded in other coastal grasslands with similar conditions (Ref. 4).

The petalwort appears to be increasing at a number of sites as a result of trampling and soil compaction. At English and Welsh sites the thalli appear above ground from autumn to spring, and perennate through the summer as underground tubers packed with lipid. Some thalli may be visible on the surface during wet weather in summer (Ref. 2). At the one Scottish site, where there is a continual flow of fresh water through the population, the petalwort remain throughout the summer, as well as winter, months.

Habitat preferences

- The liverwort grows in open, damp, calcareous dune slacks, often on low hummocks rather than on the very wet ground, and on compacted sandy/muddy bryophyte-rich turf;
- The species typically occurs in very short (<0.5cm) vegetation, typically with 10-50% bare substrate exposed (Ref. 5);
- The petalwort requires low nutrient status waters; and
- An association with sand dunes, in particular dune slacks has been noted, but the species has also been recorded near pond edges, along damp pathways among dunes, in small hollows among dunes, and on former industrial sites adjoining dunes (Ref. 5).

Key influences

Water resources

- The petalwort is strongly characterised by hydrological regimes, however little research data exist on this relationship;
- A fluctuating water table, with periodic flooding is considered optimal for petalwort habitats. Fertilisation requires transport of spermatozoids in water. Sites that are periodically flooded may assist in this transport (Ref. 5);
- A seasonally high water table is considered important (Ref. 5), however the petalwort can tolerate seasonal drought;
- The nutrient concentration of the water supply could be affected by the amount of water entering the site (dilution effect); and
- Drainage of sites will remove this species from the habitat composition.

Other influences

- Eutrophication of water supplies may result in this species being out-competed;
- The petalwort will only tolerate minimal shading in the UK;
- Maintenance of low vegetation by low nutrient loading, and intense grazing by rabbits is considered important;
- Light trampling on pathways may play a part in maintaining suitable conditions at some sites (Ref. 5); and
- The species is not found in permanently water-filled slacks or in slacks where willow (*Salix* spp.) scrub predominates (Ref. 6).

Current and future work

Scottish Natural Heritage (SNH) as part of their lower plant conservation project has recently surveyed the only Scottish site where the petalwort is found. The Countryside Council for Wales (CCW) have surveyed all the Welsh populations in recent years, and monitoring is taking place at some sites (Ref. 8).

In the absence of relevant information on the hydrological regime requirements of the petalwort, there is a strong need to pursue research in this area.

Key references

General description/biology & habitat details

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Supporting references

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The Annex I humid dune slack habitat should be considered with the petalwort.

This document was withdrawn on 6 November 2017

Marsh saxifrage (*Saxifraga hirculus*)

General information

The rare marsh saxifrage (*Saxifraga hirculus*) is an attractive, yellow-flowered perennial requiring base-rich soils and wet conditions. It occurs in base-rich flushes and mires in the northern Pennines, the Grampians, Pentlands and the Antrim Mountains of Northern Ireland (Ref. 4).

The marsh saxifrage has suffered from overgrazing and drainage, with distribution on the decline in both the UK and Europe (Ref. 3).

Habitat preferences

- The marsh saxifrage occurs in base-rich flushes;
- The species is now considered an upland species with all favoured lowland habitats lost;
- Large numbers of the species and a high proportion of the larger plants can be associated with the mesotrophic zones of sites which it inhabits (Ref. 3); and
- Wet conditions are required.

Key influences

Water resources

- Little is known about the hydrology and chemistry of flushes where the marsh saxifrage is found. The hydrology of most flushes is complex and further research is required to assist in determining the hydrologic requirements of the marsh saxifrage (Ref. 4).

Other influences

- Although moderate levels of grazing may be considered beneficial to the marsh saxifrage, heavy grazing and climatic change are considered threats to the distribution and abundance of the plant; and
- Water quality may impact on the health and status of the marsh saxifrage. Kelly & Hallman (2002) collected water samples (from flowing waters) from flushes with the marsh saxifrage present and found them to be alkaline, have a pH of 7.0 to 8.6, and contain no significant nitrate or phosphorous concentrations. The calcium content of all water samples was in excess of 20mg/l, but generally between 20 and 40mg/l. Values varied from flush to flush, with some samples recording concentrations over 110mg/l. These high values may be associated with tufa formation. It is important to note that intermediate springs and seepages some distance down a flush can differ in chemical composition from the principle source (or sources) at the head of the flush (Ref. 3).

Current and future work

A three year study was completed by Kelly and Hallam (2002) on behalf of Natural England looking at the impacts of grazing on the marsh saxifrage.

As a precautionary measure seeds have been collected and stored in the Millennium Seed Bank by the Royal Botanical Gardens, Kew and may be propagated and re-introduced in the wild (Ref. 1).

This document was withdrawn on 6 November 2017

Key references

General description/biology & habitat details

1. ARKive, Yellow Marsh Saxifrage (Saxifraga hirculus), Retrieved March 9, 2006, Available: http://www.arkive.org/species/ARK/plants_and_algae/Saxifraga_hirculus/more_info.html

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3. Kelly, P and Hallam, C (2002). *Marsh Saxifrage monitoring project – Final Report*, English Nature, unpublished report.

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Other Annex I habitats to be considered with the marsh saxifrage are alkaline fens, calcium-rich springwater-fed fens, calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae* and also petrifying springs with tufa formation *(Cratoneurion.)*

This document was withdrawn on 6 November 2017

Creeping marshwort *(Apium repens)*

General information

The creeping marshwort (*Apium repens*) is a creeping perennial, forming rosettes of once-pinnate leaves. It closely resembles certain varieties of the related fool's water-cress (*Apium nodiflorum*), which has led to some confusion over its true status (Ref. 1 & 6).

Distribution of the creeping marshwort in Great Britain is limited and until recently was believed to be restricted to one meadow in Oxfordshire (Port Meadow), where a population of 100 plants has been estimated. The species has now reappeared at a nearby site, Binsey Green, following the reintroduction of grazing (Ref. 9). The species also appeared on the Walthamstow Marshes SSSI in 2001 and is likely to have originated from buried seed following ditch clearance.

Habitat preferences

- The creeping marshwort grows in wet grassland subject to winter flooding, typically by rivers;
- The species grows in open, wet, usually base-rich (lime-river alluvium) permanent pasture (Ref. 2); and
- In the UK, the creeping marshwort is confined to the MG13 NVC community type (Ref. 5).

Key influences

Water resources

- The specific hydrological requirements of the creeping marshwort is considered to be a principle parameter responsible for the decline in the UK (Ref. 7);
- The creeping marshwort is dependent on a shallow flood during winter and spring (found on river flood plains), followed by retreat of the surface water (Ref. 7);
- The species is also found adjacent to still water (as well as flowing waters) with a fluctuating watertable, which is believed to protect the covered plants from severe frost (Ref. 3);
- Groundwater levels must remain close to the surface during summer months, but the soil conditions are still described as dry (Ref. 5 & 7); and
- Summer flooding has a negative influence on the creeping marshwort, reducing growth rates and detaching the plant from the soil (Ref. 3). Summer floodwaters if accompanied by pollution may also reduce dissolved oxygen levels leading to bacterial conversion of sulphate to poisonous hydrogen sulphide (Ref. 2).

Other influences

- The creeping marshwort can flourish on highly organic, silty or sandy soils (Ref. 5);
- The species is known to favour habitats with some bare mud and where water has lain during winter, allowing colonisation by seedlings and runners. Poaching of the ground by cattle is therefore desirable (Ref. 2);
- The creeping marshwort is usually found in short (0-10cm) cattle grazed swards (Ref. 2); and
- Agricultural intensification, herbicides, the control of winter flooding, and overgrazing, ploughing are considered the principle activities causing the decline and/or loss of the creeping marshwort (Ref. 9 &7).

Current and future work

English Nature, in conjunction with the Rare Plants Group of the Ashmolean Natural History Society of Oxfordshire commenced a recovery programme for the creeping marshwort in 1995. This programme has involved experimental introductions of the creeping marshwort at various sites, monitoring, and research into gene flow, reproductive biology and seed viability and longevity (Ref. 8).

This document was withdrawn on 6 November 2017

Key references

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This document was withdrawn on 6 November 2017

Floating water-plantain (*Luronium natans*)

This document was withdrawn on 6 November 2017

General information

Floating water-plantain (*Luronium natans* Rafinesque) is an aquatic monocotyledon of the family Alismataceae. It is endemic to Europe and has a fairly complex life history and ecology, and is difficult to identify. Native populations in the UK have been recorded in Glamorgan, Worcestershire and Northamptonshire north to Anglesey, Argyll and County Durham. Introduced populations are also noted.

It has two characteristic forms of leaf – a submerged grass-like form and a floating spoon-shape form – determined by light availability and water-depth. Detailed published information on the life history of floating water-plantain is limited.

Habitat preferences

- Floating water-plantain occur in a range of different environments including natural standing waters, natural flowing waters and artificial waterbodies such as canals, ditches, reservoirs and balancing ponds;
- A wide range of chemical and substrate tolerances are noted. Floating water-plantain has been associated with sand, sand with gravel, boulder clay and or silt. It is mainly restricted to substrates of a high mineral composition and disappears under an accumulation of organic detritus i.e. under hydroseral transition to swamp;
- Floating water-plantain occurs in waters with a pH ranging from 3.6-7.4. The solid geology may vary from mildly acid to base-rich (Ref. 3);
- Records have observed floating water-plantain to inhabit oligotrophic, mesotrophic and meso-oligotrophic waters; and
- Accounts of habitat requirements for this species are occasionally conflicting but are well described in Ref. 8.

Key influences

Water resources

- Ref. 4 recorded floating water-plantain within a preferred water depth of 0.1 to 1.0 m, but it occurs at depths of up to 4 m in clear water and can be found, ephemerally, as a terrestrial form on damp mud ;
- Populations in natural habitats appear to be greatest when water levels are low and much bare mud is exposed. When water levels are high, many plants may be present as rosettes (Ref. 6);
- Water quantity requirements should be assessed on how they may suppress the colonisation of floating water-plantain habitat by more aggressive plant species;
- Floating water-plantain grows in depths of 2 m or greater where there is no seasonal depth variation;
- Floating water-plantain populations can occupy temporary water bodies. The drying out of the substrate may suppress colonisation by other aggressive species; and
- Flow changes, drainage of water bodies for development and conversion to agricultural land may result in direct habitat loss.

Other influences

- pH tolerance ranges from 3.6 to 8.0, levels; outside this range may impact on populations;
- Floating water-plantain is believed to be largely intolerant of competition, and fast-growing macrophytes such as duckweed (*Lemna spp.*), common reed (Phragmites) and invasive aliens like New Zealand pygmy weed *Crassula helmsii*, are likely to limit distribution and abundance;
- A lack of light at depth and poor nutrient status are limiting factors for populations in deeper waters; and
- Eutrophication will reduce floating water-plantain populations through increased competition by more aggressive species.

Current and future work

The LIFE in UK Rivers Project is developing conservation strategies and monitoring protocols for use on rivers designated as Special Areas of Conservation under the European Union Habitats Directive. Refer to the LIFE in UK Rivers website for further information.

Natural England and The Countryside Council Wales are currently producing management guidelines for canals containing this plant (Ref. 7).

Key references

General description/biology & habitat details

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Supporting references

Annex I habitats associated with the floating water-plantain are oligotrophic waters containing very few minerals of sandy plains (*Littorelletalia uniflorae*), oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletalia uniflorae* and/or the *Isoeto-Nanojuncetea*, water courses of plain to montane levels with *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation.

This document was withdrawn on 6 November 2017

Fen orchid *(Liparis loeselii)*

This document was withdrawn on 6 November 2017

General information

The fen orchid (*Liparis loeselii*) is a small green-flowered orchid of fen and dune systems. Two distinct morphological forms are noted *Liparis loeselli* (fenland) and *Liparis loeselli* var *ovata*. The new Flora of GB & Ireland by Sell & Murrell (2006) affords the fenland form varietal rank as var. *loeselii*. It might clear up confusion if the authors of this account follow this.

*Liparis loeselli (*fenland*)* is found in the East Anglian fens and has acute oblong-elliptical leaves. It inhabits wet calcareous or neutral fens, and is now only known from three sites in Norfolk. This form is confined to species-rich fens that have experienced historic disturbance through peat-cutting. *Liparis loeselli var ovata* occurs in dune slacks with moist calcareous conditions and is generally shorter with fewer-flowers and blunt, broadly elliptical leaves. This form is now only found in four sites in south Wales (and one in north Devon) and is confined to successionally young dune slack communities where some open soil remains (Ref. 4). In the UK these forms are mutually exclusive with respect to their distribution, but in mainland Europe the fenland form also occurs in dune slacks (Ref. 7).

Habitat preferences

- The fen orchid requires fairly open conditions to flourish;
- It is often found on the edges of pools, pingos and floating fen (Ref. 6);
- *Liparis loeselii var.ovata* favours newly created dune slacks (Ref. 6);
- This species is characteristic of basin mires, and is never associated with *soligenous* species or percolating fen (Ref. 6);
- It is characteristic of lower slump succession (Ref. 6); and
- The fen orchid is associated with certain bryophytes such as the brown mosses: *Calliergon cuspidatum, Drepanocladus revolvens, Calliergon cuspidatum* and *Scorpidium scorpiodes* in the lower layer (Ref. 6).

Key influences

Water resources

- There seems to be some disagreement about the relationship between the fen orchid and the nature of water inputs (Ref. 6). The current research into the water supply mechanisms of wetlands being undertaken by Sheffield University may help to clarify this issue;
- The proximity of the fen orchid to open water as opposed to seasonal flooding may be an important factor in its distribution for the Broadland populations;
- Both forms favour stagnant water conditions and may require exposure to air at certain times of the year (Ref. 6);
- The species can tolerate variable water levels and seasonal inundation may be an important consideration (Ref. 3);
- The fenland fen orchid form requires high water tables throughout the year and possibly winter flooding (Ref. 7);
- *Liparis loeselii var.ovata* tolerates winter flooding, with inundation often occurring for up to five months in a year. It requires relatively high and stable water conditions, but is considered more tolerant of a wider range of hydrological conditions than the fenland variety (Ref. 6);
- Drainage and other factors affecting groundwater play an important role in the status of the fen orchid (Ref. 6); and
- A high summer water table is essential for survival of the *Liparis loeselii var.ovata* form (Ref. 6).

Other influences

- Open conditions are required by the fen orchid to flourish (Ref. 5);
- A base rich water supply is required with the fenland form being associated with pH values of between 6.5-8.2 (Ref. 3&6);
- The cessation of peat-cutting in the fens is probably the most important contributory factor leading to the decline of the fenland type (Ref. 7); and
- *Liparis loeselii var.ovata* requires regular disturbance over medium time-scales to ensure a steady supply of newly formed dune slack substrates for colonisation (Ref. 5).

Current and future work

The Countryside Council for Wales (CCW) and the Norfolk Wildlife Trust have recently produced a management plan for the conservation of the fen orchid and have plans to re-introduce the species to suitable sites within its known former range (Ref. 1). CCW have also funded experimental management programmes at Kenfig NNR, which supports the largest UK population.

Key references

General description/biology & habitat details

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Supporting references

Annex I habitats associated with the fen orchid are, humid dune slacks, Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae,* Alkaline fens Calcium-rich springwater-fed fens, transition mires and quaking bogs, hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp and natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation.

This document was withdrawn on 6 November 2017

Shore dock *(Rumex rupestris)*

This document was withdrawn on 6 November 2017

General information

The shore dock, *Rumex rupestris,* is a long-lived woody perennial maritime plant with greyish leaves and green or reddish-brown flowers in whorls spread out up the stem (Ref. 7 & 6). It is a poor competitor and often behaves like a pioneer species (Ref. 6). It occurs on upper shores or in wet hollows in sand dunes at approximately 40 locations in Anglesey, South Devon, Cornwall and the Isles of Scilly although the number of mainland UK sites has declined by over 80 per cent over the past century (Ref. 8 & 6). Although the largest British population has no more than 50 individuals, the UK is the world stronghold for this species (Ref. 3). Recently, several new colonies have been found along the coastline in south-west England and Wales (Ref. 3).

Habitat preferences

- *R. rupestris* grows on rocky, sandy and raised beaches, shore platforms and the lower slopes of cliffs, and rarely in dune slacks (Ref. 3);
- Most commonly, it may be found growing by the side of streams entering beaches, on soft-rock cliffs and in rock clefts where flushing occurs and it only occurs where there is a constant source of freshwater, running or static (Ref. 3); and
- *R. rupestris* often occurs in National Vegetation Classifications MC8, MG12b, MG11, MG11b, MC8, SD2, S25 and SD14 (Ref. 6).

Key influences

Water resources

- *R. rupestris* is dependent upon a constant source of freshwater and is often found near seepage zones or groundwater springs at the junction of superficial depositions such as quaternary head and impervious underlying rock strata and even surrounding septic tank leaks (Ref. 2 & 6).

Other influences

- The loss or fragmentation of its habitat through the culverting of streams, coastal defence, tourism along beaches, and sea level rise have contributed to the decline of *shore dock* (Ref. 3);
- It has also declined as a result of competition from the Hottentot fig (*Carpobrotus edulis*), an established non-native species as well as from bramble and other invasive species;
- *R. rupestris* is sensitive to pollution, particularly oil spills and eutrophication (Ref. 6);
- Shore dock is sensitive to the weather and severe winter storms can cause fluctuations in populations, rising sea levels can also reduce the availability of suitable habitat (Ref. 3 & 6);
- Surveys have suggested that the shore dock is somewhat mobile and consideration should be given to suitable habitat even if it is not yet occupied; and
- Surveys have suggested that moderate grazing is beneficial for colonization of *R. rupestris* as it helps to create suitable bare ground for seedling establishment (Ref. 6).

Current and future work

A species recovery programme, undertaken by Plantlife, began in 1994 and its results and the results of other research are available at:
www.plantlife.org.uk/uk/assets/saving-species/saving-species-dossier/Rumex_rupestris_dossier.pdf

Key references

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Supporting references

Humid dune slack habitats should be considered with the shore dock.

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2.3.5 Birds

The following summaries have been compiled using key reference papers provided by Environment Agency and Natural England staff. They provide a summary of relevant information on the freshwater requirements of birds. For further information, refer to references listed below each habitat account.

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SPA bird species

Introduction

The Birds Directive (Council Directive 79/409/EEC) compliments the Habitats Directive by requiring member states to protect rare or vulnerable bird species through designating Special Protection Areas (SPAs). Bird species for which an SPA is designated can be grouped by the type of habitat that supports them. These groups are:

3.1 Birds of uplands;
3.2 Birds of woodland and scrub;
3.3 Birds of lowland heaths and brecks;
3.4 Birds of lowland wet grassland;
3.5 Birds of lowland dry grassland;
3.6 Birds of lowland freshwaters and their margins;
3.7 Birds of farmland;
3.8 Birds of coastal habitats;
3.9 Birds of estuarine habitats; and
3.10 Birds of open sea and rocks.

Bird species can be associated with particular habitat types, but links to more than one habitat type are common due to the mobility, spatial range, life cycle and migration patterns of populations. For SPA designation, only one habitat group is generally identified as the primary habitat, unless there is more than one primary habitat type present. (e.g. groups 3.6 and 3.9 as an estuarine SPA).

This section focuses on the habitat groupings 3.4, 3.6 and 3.9, lowland wet grasslands, lowland freshwaters and their margins (for which water resource issues are considered to have significant implications) and estuarine habitats (for which water resources issues may prove to be important). Table 1 provides a listing of bird species considered and which habitat type they are generally associated with. The selection is based on the rarity or degree of vulnerability, and the legislative requirements, for the species concerned as indicated by its inclusion in Annex 1 of the EC Birds Directive (79/409/EEC), Schedule 1 of the1981 Wildlife & Countryside Act, or the Red Data Birds in Britain listing (NCC/RSPB 1990). Predominantly marine birds and common bird species were not included, although listed in groupings 3.4, 3.6. & 3.9.

While a number of species have highly specific habitat requirements of either habitat type, there are many species dependent on more than one. Lowland grasslands and lowland freshwaters are commonly co-joined habitats, exhibiting a strong functional interdependence between them. There are many situations where freshwater habitats are in close proximity to estuarine habitats and can overlap. An indication of UK wintering/passage habitats and breeding habitats is also provided in the table.

Water resource management needs to take account of the vulnerable seasons (weather conditions and supply) in relation to the seasonal requirements of the avian population. Water needs for the key habitat types are relatively well understood; but the challenges remain to understand the freshwater needs of birds using estuarine habitats and to apportion a resource with multiple demands.

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Table 1. Species of lowland wet grassland (3.4) and lowland freshwaters (3.6)

Key habitat type	Species	Breeding requirements	Passage/wintering requirements	Additional information
3.4	Bewicks swan***		Shallow-water lakes, ponds, river flood plains	
	Barnacle goose		Pastures	Mainly coastal
	Golden plover**	Upland moors and pastures	Unimproved wet grassland, arable	Higher prey density in old grasslands
	Black-tailed godwit*	Wet grasslands, fens (peat substrates)	Flooded grassland, mainly coastal	
	Curlew	Wet heath, bogs, unimproved wet grassland	Coastal	Mainly upland breeding
	Dunlin	Upland bogs and peatlands	Coastal	Rarely in lowland, inland habitats
	Redshank	Wet grasslands, saltmarshes	Mainly coastal	Requires moderate grazing on breeding grasslands
3.6	Bittern***	Dense reedbeds	Reedbeds, open waters, rivers	Open waters/rivers in hard winters
	Marsh harrier***	Reedbeds	Reedbeds, saltmarshes	Also nests in arable crops
	Mediterranean gull***	Lakes, marshes, gravel pits	Lakes, marshes, gravel pits, arable land	Rare
	Gadwall	Marshes, shallow eutrophic, open waters	Shallow, eutrophic open waters	
	Pintail	Shallow waters in grasslands, washes	Mainly coastal, certain washlands and nearby arable	Rare breeder, susceptible to water level management
	Ringed plover	Gravels on river bars, lake/reservoir shores	Mainly coastal, some at breeding sites inland	
	Shelduck	Hole nester (burrows, tree hollows)	Some on open waters, mainly coastal	
	Shoveler	Shallow freshwaters with marshland edges	Similar to breeding sites, ditches in washlands	
	Wigeon	Mainly in upland neutral waters	Flooded pastures, washlands, mainly coastal	
3.4/3.6	Ruff***	Wet grassland, floodplains	Lake/pool margins, flooded grassland	Requires summer grazing, winter flooding
	Whooper swan***	Reed fringes, forest ponds	Shallow lakes, ponds, floodplains, arable	
	Hen harrier***	Upland moor	Reedbeds, river valleys, marshes, heathland	
	Pink foot goose**		Pastures, arable, lakes	High proportion coastal
	Teal	Well vegetated wetlands, peatland pools	Well vegetated wetlands in lowlands	High proportion of breeding in uplands
3.9	Avocet***	Coastal lagoons nest within reserves	Coastal lagoons, estuaries	Most of the British birds
	Bar-tailed godwit**	Sheltered shorelines, bays and estuaries with mud and sand	Almost certainly restricted to estuaries	
	Brent Goose		Mudflats where they graze for eel grass *Zostera*.	

*** Annex 1, Schedule 1, RDB ** Annex 1, RDB * Schedule 1, RDB

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Table 1. Species of lowland wet grassland (3.4) and lowland freshwaters (3.6) *cont.*

Key habitat type	Species	Breeding requirements	Passage/wintering requirements	Additional information
	Common tern	Shingle beaches, rocky islands and saltmarshes along coasts, also islands in gravel pits and rivers	Prey abundance likely to be key controlling factor	
	Cormorant	Cliffs or rocky islands & trees by freshwater lakes, gravel pits and reservoirs	Anywhere there is sufficient fish prey	Adaptable and opportunistic species
	Great crested grebe	Shallow, reed-fringed freshwater lakes, gravel pits and slow rivers	As per breeding but then extends to estuaries and coasts	
	Grey Plover		Very few are found away from estuaries where over 90% of UK wintering population are found	
	Knot		Estuary sites are important fuelling stops as part of their migration	
	Lapwing	Pasture, wet grassland and marshes, especially if it contains flood pools and damp patches	Flooded grassland, estuaries, coastal wetlands, short grassy fields and ploughed fields.	Food supply at breeding sites v. important
	Little egret	Reedbeds, wetland scrub and in trees near water	As per breeding but also along estuaries	Former visitor now breeding
	Purple sandpiper	Restricted to one or very few sites in Scotland	Rocky shores and islands and around jetties, piers and breakwaters	Not uncommon on estuaries in winter
	Sanderling		Winter visitors and passage migrants entirely restricted to sandy coasts and estuaries	
	Slavonian grebe***	Hill lochs, gravel pits and lowland lochs in Scotland	Sheltered estuaries and coastal bays	
	Turnstone		All types of coastline are used from rocky coasts to sandy shores and tidal mud	

*** Annex 1, Schedule 1, RDB ** Annex 1, RDB * Schedule 1, RDB

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Habitat descriptions

The water level regime in marshes or wet grasslands is particularly important during the breeding phase of many bird species. Appropriate grazing regimes and varying water table levels are required. Water level management has received considerable attention (Ref. 21) in relation to providing the correct mosaic of open water, soft ground for feeding and, more recently, in relation to the distribution of soil-invertebrate prey.

In flood-plains that regularly flood in winter, soil invertebrates, which are dominated by earthworms, are flood adapted. Long periods of flooding can lead to a reduction in invertebrate biodiversity, particularly of the arthropod fauna. New flooding, particularly if prolonged, in grasslands formerly not subject to annual inundation can lead to a loss of invertebrate diversity and biomass. Ausden *et al.*, working on those areas of new flooding in ESA schemes, concluded that the optimum practice may be to ensure a mosaic of flooded conditions during the winter and spring months, rather than subject pastures in new flooding schemes, to prolonged and deep floodwater.

Lowland wet grasslands

Water resource related influences

- Winter flooding of river flood-plains has been regarded as beneficial in sustaining wet grassland habitat. It assists in maintaining a shorter sward, keeps the ground soft for probing birds such as redshank and snipe ,and it provides winter feeding and roosting areas for a number of wetland bird species;
- Water levels in the flood-plain grasslands during the breeding season generally need to be sufficiently high to maintain soft enough ground for feeding, keeping soil invertebrates in the upper 20-30 cm of soil and in the maintenance of high water levels in ditches and pools. A mosaic of drier grassland and damp hollows, together with the variation in sward structure that arises from topographical variation and grazing management, provides optimum conditions for most species and in particular the more demanding species, ruff, black-tailed godwit and redshank. In providing such mosaics, other typical species of wet grasslands are catered for, e.g. snipe and lapwing where the former requires soft ground with tall tussocky vegetation for concealment, while lapwing prefers short vegetation with good all round visibility;
- In marshlands where there is traditionally some constancy in water levels, e.g. spring-fed systems or other forms of ground water supply from the underlying aquifer, abstraction leading to frequent fluctuations in water level can induce changes in the vegetation e.g. increasing dominance by certain grasses, tall herbs or willow scrub with consequent implications for the bird communities;
- Ground-water abstraction may lead to the lowering of water levels in marshes and reedbeds, while river abstraction may lead to lowering water levels in the flood-plain; and
- Abstractions resulting in regularly varying water levels leading to vegetation changes.

Other influences

- Use of washlands for flood storage during summer rainfall and the loss of nesting populations;
- Drainage of marshes and wet grasslands for agricultural intensification or other developments;
- Improvements in the drainage regime for agricultural intensification;
- Water pollution and excess eutrophication; and
- Disturbance from recreational uses of water bodies.

Lowland freshwaters and their margins

Water resource related influences

- In lowland freshwaters, (particularly shallow marshes and reedbeds), small decreases in water level make habitat unsuitable. In general, relatively constant levels are required, particularly during summer months when natural drawdown can occur. Constant levels ensure the growth of submerged and emergent water plants and maintain invertebrate and fish populations for duck species and for bittern in reedbeds; and
- Drawdown in the summer months and lower water volumes is often coupled to increasing concentrations of nutrients from agricultural applications or domestic water disposal.

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Other influences

- Water quality remains an important issue for while most species of lowland freshwaters and lowland wet grasslands benefit from eutrophic and species-rich habitats, excess nutrients (particularly nitrates and phosphates) can lead to a loss of diversity where algal blooms predominate, or single species, adapted to rapid nutrient uptake, are favoured;
- Nutrient enrichment in wet grassland can lead to dominance by a few grass species and a loss of diversity in the flowering herb community. Reeds loose their structural qualities under conditions of excess nutrients leading to lowering reed density and weak stems;
- Construction of embankments or bunds for flood protection;
- Deepening and canalisation of rivers for flood control, ditch deepening in flood-plains; and
- Water pollution and excess eutrophication.

Estuarine habitats

Water resource related influences

- Estuaries comprise a range of habitat types and provide a gradient between the marine and freshwater environment and are important wildlife resources, especially as they support large numbers of waterbirds;
- Freshwater flows into estuaries may influence sediment regime and hence estuarine morphology. The number and location of freshwater inputs should be considered, along with an understanding of estuarine morphology;
- Changes to freshwater input may alter currents within the estuary affecting sediment transport, settlement and the dispersion of organisms;
- Invertebrate diversity is greatest in either marine or freshwater environments, reducing as the salinity range increases. Changes in salinity resulting from freshwater inputs will generally reduce invertebrate diversity. However, interstitial salinity tends to be much less variable than the overlying water, and as such is not considered a major limiting factor of invertebrate abundance;
- Freshwater inputs may be considered important for bird utilisation of this habitat, although it is not yet clear. It is possible that birds do rely on freshwater inputs for preening and drinking, and as such these inputs are important for the development of local niches (Ref. 19);
- The zonation of non-breeding waterbirds has been shown along the salinity gradient for the Schelde estuary on the Dutch-Belgian border (Ref. 28); Oystercatcher and dunlin were dominant in polyhaline areas (salinity 18 – 30ppt), wigeon and greylag goose dominated the mesohaline areas (5 – 18ppt) while teal and mallard were dominant in the oligohaline areas (0.5 – 5ppt); and
- Salinity gradient and freshwater inputs can influence habitat diversity and suitability for use by waterbirds, mainly through food availability (Ref. 28).

Other influences

- Tidal barrages and other development which affect flows through the estuary can affect sediment transport processes and habitat diversity for birds;
- Recreational activities can create significant disturbance to feeding or roosting estuarine birds; and
- Human activities which affect bird food distribution and/or abundance can have an effect on bird condition and this may be detrimental to some important overwintering or migratory populations.

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Species descriptions

Avocet *Recurvirostra avosetta*

Avocet use coastal lagoons on the east coast in summer, and south and east-coast estuaries in winter. They now also breed in north-east England, north-west England, South Wales and the Fens. Most of the British birds nest within reserves, where the management of brackish lagoons is tailored to the birds' requirements, and where they are safe from human disturbance. Protection of wintering birds on estuaries such as the Exe requires the involvement of other organisations and private individuals, and forms a part of broader scale estuary conservation and management plans.

It became extinct as a breeding bird in 1842 as a result of extensive land claim and the building of sea walls, which dried out its habitat. The breeding population stood at 1,020 pairs in 2000. The primary food is invertebrates, especially crustaceans and worms. In fresh water they also take insects found on the surface or within the top layers of the bottom sediments.

Key influences

- Chick survival can be poor, and is determined largely by weather and food supply;
- They can breed at higher densities and more successfully when the density of invertebrates (the biomass) is high;
- Correct management of breeding habitat is vital (Ref. 20);
- Relationship between salinity, invertebrate food supply and breeding success still imprecisely known (Ref. 20); and
- Availability of saline lagoon complexes and areas of brackish water likely to influence expansion of this species.

Bar-tailed godwit *Limosa lapponica*

On their northern breeding grounds in the Arctic of Scandinavia and Siberia they use peatbogs and swamp with areas of raised ground and occasional trees. In winter they are found almost exclusively along coasts, liking sheltered shorelines, bays and estuaries with mud and sand. The large numbers of birds which pass through the UK on their way to and from southern wintering grounds will stop off to refuel at suitable estuaries and bays. They will take a range of larger molluscs and polycheate worms, but their main food consists of lugworm *Arenicola marina*.

Key influences

- Almost certainly restricted to estuaries;
- Major threat from estuary land claim for development; and
- Bait digging is a particularly important threat but other factors which could reduce prey density need to be considered.

Bewick's swan *Cygnus columbianus bewickii* and Whooper swan *Cygnus cygnus*

The Bewick's swan is an overwintering/passage species utilising shallow-water lakes, reservoirs, and ponds, rivers and their flood-plains to feed on low emergent and submerged aquatic plants. Increasing, use is being made of arable fields (Ref. 21), with up to 60% of the population recorded to use this resource. The transfer to this feeding pattern may have arisen as a result of the eutrophication of aquatic habitats (Ref. 3). The swan is primarily a southerly species in the UK (Ref. 21), partly a function of the migration routes from the Russian breeding grounds to the wintering quarters in NW Europe. Major concentrations in the Ouse washes (Cambridgeshire/Norfolk), Slimbridge in Gloucester and Martin Mere in Lancashire.

Whooper swans have a more northerly breeding distribution than Bewick's and small numbers breed annually in marshes and lochs in northern Scotland and wintering mainly in northern England and Scotland on and in the proximity of shallow permanent open waters, inland and coastal, where the birds feed on submerged plants and adjacent wet grassland. Foraging in arable land is also frequent.

Key influences

- Wetlands are important refuge areas for this bird species with standing water on grazing marshes, levels and flood-plains providing valuable wintering feeding and roosting sites;
- Threats to this species pertain to water management that reduces or prevents winter flooding;
- Eutrophication and drainage of farmland are considered to be the principle threats to the health and status of this species; and
- Other threats to both swan species also includes disturbance in the wintering grounds and breeding areas.

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Bittern *Botaurus stellaris*

Bittern is one of the key indicator species for high-quality extensive reed-swamp dominated by *Phragmites australis*. In the UK the species requires such areas of dense reedbed for breeding. Small areas of Salix scrub appear to improve the UK habitat for this species (Ref. 9). During the winter it may emerge to feed along well vegetated margins of river margins and other open waters. Food items include fish, amphibia, aquatic insects and occasionally birds and small mammals.

Key influences

- The breeding habitat of this species requires water levels to be deep enough to support fish and amphibian prey, a mosaic of open water and reed-swamp giving a long length of reed-edge habitat, good water quality and a significant area of total reed cover, the optimal size being around 20 ha (Ref. 9 & 26). Drier reedbeds are avoided;
- The lowering of water tables is considered a real threat to the status of this species;
- The historical loss of reedbed habitat to land drainage and intensive farming has reduced populations of this bird, making its status rare; and
- Threats other than direct habitat loss and fragmentation, include eutrophication under which reed quality and prey items decline.

Brent Goose *Branta bernicla*

Brent geese overwinter in internationally important numbers on estuaries and shallow coasts with mudflats where they graze for eel grass *Zostera*. They also graze on fields near the coast and as numbers have increased can prove problematic for arable farmers who have winter sown crops near to overwintering sites. Main concentrations are found in the Wash, the North Norfolk coastal marshes, Essex estuaries, the Thames Estuary and Chichester and Langstone Harbours.

Key influences

- Major threats include shooting in wintering areas, habitat loss or change and other human disturbance.

Common tern *Sterna hirundo*

Common terns are summer visitors breeding on shingle beaches, rocky islands and saltmarshes along coasts, and also on islands in gravel pits and rivers. They will also use artificial rafts if provided on reservoirs/lakes. Breeding success is determined by the abundance of fish, mainly small clupeids for coastal birds but inland birds will take small freshwater fish. Prey abundance also affects pre-migration condition and subsequently determines migration success.

Key influences

- Habitat loss at breeding sites either through natural causes (storm events, flooding, sea level rise) or human induced (engineering works, flooding or draining at inland freshwater sites);
- Inland breeding sites tend to be close to a suitable supply of prey items (small fish) normally caught in gravel pits, reservoirs, lakes and river backwaters; and
- Changes in hydrology which result in prey reduction at these sites could affect breeding success if alternative feeding areas are not available.

Cormorant *Phalacrocorax carbo*

As coastal seabirds Cormorants are found wherever there are cliffs or rocky islands. New colonies inland are mainly in trees by freshwater lakes, gravel pits and reservoirs. The species is adaptive, will hunt for fish in urban ponds or lakes. They are also opportunistic and will target fish farms and lakes or ponds with sufficient fish stocks.

Key influences

- Loss of suitable breeding sites on rock shores due to coastal development;
- Loss of woodland at suitable inland breeding sites;
- Disturbance at breeding sites;
- Reduction in fish stocks is likely to affect breeding success; and
- Conflicts with fishery managers who see cormorant as a threat.

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Great crested grebe *Podiceps cristatus*

Breeding sites can be found in shallow, reed-fringed freshwater lakes, gravel pits and slow rivers. Emergent vegetation in standing water provides cover and protection from nest predation. Overwintering habitats are the same as breeding habitats but birds are also found along sheltered coastal areas, including estuaries. In severe winters, coastal numbers increase as inland freshwater habitats freeze up and prohibit access to prey items, which is mainly fish but some amphibians and invertebrates are taken.

Key influences

- Loss of suitable breeding habitat through drainage, flood defence works, dredging etc;
- Reductions in fish stocks caused by changes in hydrology, hydro-morphology and water quality can prove detrimental to breeding success; and
- Significant hydrological changes are likely to result in complete habitat loss.

Grey Plover *Pluvialis squatarola*

This species is a localised winter visitor and passage migrant to Britain in internationally important numbers. Very few are found away from estuaries where over 90% of UK wintering population are found (Ref. 20). Large muddy and sandy estuaries and bays are preferred, sometimes they are found on saltmarsh. They may even move into coastal fields at high tide. Largest numbers are found on the Wash, Ribble, Thames, Blackwater, Medway, Dee and Humber estuaries, and Chichester and Langstone Harbours. Shellfish but mainly polycheate worms make up their diet.

Key influences

- As with most waders, estuarine land claim for development or the creation of tidal barrages poses the biggest threat (Ref. 20); and
- Bait digging is a key threat, especially at the few sites where birds occur in large numbers.

Hen Harrier *Circus cyaneus* and Marsh Harrier *C. aeruginosus*

Hen harrier is a breeding species mainly of upland moors but, as with marsh harrier, obtains winter hunting over extensive open lowland wet grasslands, reedbeds and marshes. Arable land may also be used. Marsh harrier requires extensive areas of reedbed in which to nest and food items comprise birds, small mammals and frogs. Smaller reedbeds in arable land and even cereal crops have recently been used for nesting. During spring and autumn passage, the species commonly uses river valleys as migration routes and for foraging.

Of the two species, marsh harrier is the rarer and somewhat more dependent on water resource management in its breeding habitat. At one time the species was extinct in the UK but since 1900, a relatively small breeding population has established throughout the country.

Key influences

- While habitat loss in the past must have reduced the population, and pesticide residues in eggs notably reduced raptor populations from around 1950 to 1970, persecution, disturbance where extensive areas of nesting habitat are unavailable, and predation of nest sites (e.g. by foxes) are current threats; and
- The eutrophication of reedbeds will reduce the density vigour of the reed stand, thus reducing the capacity of the reed to support the nest platform.

Knot *Calidris canuta*

Knot are localised winter visitors and passage migrants to the UK and are almost entirely restricted to estuaries (Ref. 20). They can be seen around UK coasts between August and May but largest numbers can be seen at high tide roosts between December and March. Greatest numbers are found on The Wash, Morecambe Bay, Thames, Humber and Dee estuaries, the Solway Firth and Strangford Lough. Knot are specialist feeders on marine bivalve molluscs, particularly *macoma balthica, Mytilus edulis* and *Cerastoderma* spp.

Key influences

- Of particular importance is the very large concentration of this species in a very few estuaries at any one time. These sites are important fuelling stops as part of their migration;
- Any reduction in food availability in UK sites is likely to prove a serious threat to the birds' ability to accumulate sufficient reserves; and
- Equally, disturbance at key feeding sites is likely to result in reduced food intake.

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Lapwing *Vanellus vanellus*

This species mainly breeds on farmland, especially among crops sown in spring which are adjacent to grass and bare land. Also on pasture, wet grassland and marshes, especially if it contains flood pools and damp patches. Wintering habitats include flooded grassland, estuaries, coastal wetlands, short grassy fields and ploughed fields. The highest known winter concentrations of lapwings are found at the Somerset Levels, Humber and Ribble estuaries, Breydon Water/Berney Marshes, the Wash, and Morecambe Bay. Coastal grazing marshes can provide important breeding sites, especially where wet areas occur as these are important foraging areas for chicks (Ref. 13). Adults and chicks feed on a wide range of soil, surface-active and aquatic invertebrates with Tipulid and Chironomid larvae making the largest proportion of their diet (Ref. 2).

Key influences

- Reductions in soil moisture in breeding areas can affect the density of invertebrate prey (Ref. 2);
- Flooding from high river levels and/or high groundwater levels are important for creating the wet mosaic necessary for breeding;
- Management should focus on creating this mosaic with the appropriate hydrological regime; and
- Human disturbance at breeding sites can lead to reduced breeding success.

Little egret *Egretta garzetta*

Little egrets are wetland birds with a preference for lowland shallow waters, especially along coasts and estuaries. They nest communally, often alongside the nests of other herons and associated wetland species. Colonies are located in reedbeds, wetland scrub and in trees near water, up to a height of 20m. They overwinter on coastal estuaries, saltmarshes and tidal inlets. A recent colonist, it is most commonly found along the south coast, and on parts of the east coast. The estuaries of south Devon and Cornwall; Poole Harbour and Chichester Harbour hold some of the largest concentrations and birds can be seen right round to North Norfolk.

It is predominantly a fish eating species but invertebrates, amphibians and small mammals will also be taken.

Key influences

- Changes in hydrology (flow and level) which affect fish stocks can have a knock-on effect, especially within or close to breeding sites; and
- Wetland sites should be managed to ensure optimum conditions are maintained for associated invertebrates, amphibians and fish to provide sufficient food supply for egrets.

Mediterranean gull *Larus melanocephalus*

The global distribution of the Mediterranean gull is highly restricted with a few pairs (77 at the most recent count in 2001) now regularly breeding in the UK (using coastal marshes in south and eastern England, the Swale and Dungeness/Pett levels in Kent, Poole Harbour, Dorset, the Solent and the north Norfolk coast). Nesting typically occurs with black-headed gull colonies or with sandwich terns. The species winters in the Mediterranean and in the UK.

Key influences

- The main threats to this species are considered to be disturbance and predation;
- In its coastal breeding sites, the species is relatively independent of issues relating to the management of freshwater resources; and
- Implications may arise from sea-level rise, a factor that pertains to a number of coastal species (Ref. 18 & 22).

Ruff *Philomachus pugnax*

The Ruff is a rare breeding wader in the UK, considered to have highly specific requirements of the lowland wet grassland and floodplain habitat in which it nests (Ref. 23). Coastal grazing marsh and the higher levels of saltmarshes are also used.

The species is semi-colonial and males congregate in leks in suitable areas where raised areas of shorter turf provide display sites. Females nest solitarily but nearby where taller vegetation can conceal the nest (Ref. 10). The species is migratory with the main population in sub-Saharan Africa. However, some numbers winter in north-west Europe and the UK, along estuaries and also inland wetlands. The wintering population is thought to be distinct from the summer breeding population which arrives relatively late on the breeding grounds. Nesting commences in late May to early June.

The species is dependent on the water management regime, the micro-topography and the appropriate grazing patterns, to maintain the complex structural mosaic in the wet grasslands.

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Key influences

- Adult birds and particularly chicks require wetter depressions and areas of open water for feeding. This combination of requirements calls for a complex mosaic of unimproved grassland with a good population of invertebrate prey, produced by appropriate levels of summer grazing and winter flooding;
- Summer water table levels need to remain high to retain invertebrate prey items in the top layers of the soil and provide areas of open water in lower-lying depressions;
- The continued loss, and improved drainage, of wet grasslands has maintained the rare status of this species despite greater levels of species protection. The species is particularly sensitive to the drainage regime and its late nesting cycle means that even slight improvements in drainage may render the pastures too dry during the summer months; and
- At sites managed as flood storage areas, e.g. the Ouse Washes, recent high rainfall events during the summer months have resulted in the loss of nests through flooding.

Purple sandpiper *Calidris maritima*

This is a rare breeding species that has successfully bred at one site in Scotland since 1978. Other than that it is restricted to arctic tundra and moors outside the UK. It is an important wintering and passage migrant utilising rocky shores and islands and around jetties, piers and breakwaters particularly on the east coast north of the Humber. Winkles, insects, spiders, crustaceans, and some plants are key dietary components.

Key influences

- Human disturbance and habitat loss due to development are key threats.

Sanderling *Calidris alba*

Breeding sites are found in High Arctic tundra near freshwater lakes. In the UK sanderlings are localised winter visitors and passage migrants entirely restricted to sandy coasts and estuaries (Ref. 20) but may occasionally turn up on the edges of large inland lakes and reservoirs. Birds feed almost exclusively in areas with sandy substrates where small marine worms, crustaceans and molluscs are taken.

Key influences

- Estuarine barrage development and land claim for development are the main threats; and
- The protection of critical migration stop-over sites should be emphasised.

Slavonian grebe *Podiceps auritus*

Slavonian grebes breed on hill lochs, gravel pits and lowland lochs in Scotland and on shallow lakes and pools with thick surrounding vegetation in Scandinavia. In the UK breeding birds are confined to Scotland (Ref. 20). In winter they favour sheltered estuaries and coastal bays with concentrations in some Scottish firths and along the south coast of England. Their diet consists of fish and insect larvae.

Key influences

- Human disturbance, a decrease in invertebrate populations due to overstocking of fish, and a change in nutrient status of lochs etc as a result of human activities are the main threats to this species (Ref. 20); and
- Fluctuating water levels can cause problems at nesting sites.

Turnstone *Arenaria interpres*

This species breeds on bare ground along coasts and on islands in Canada, Greenland, Scandinavia and N Siberia. Breeding has never been recorded in this country, although it was suspected in 1976 (Ref. 20). The wintering population of turnstones in Britain is of international importance. Turnstones particularly like feeding on rocks covered with seaweed, and will feed along seawalls and jetties. It forages for insects, crustaceans and molluscs amongst seaweed and small rocks, literally turning stones, rocks and other material to expose its prey hence the common name turnstone.

Key influences

- Habitat loss and other factors leading to prey reduction are threats to certain parts of the wintering population utilising estuaries; and
- Such threats are less important to this species compared with other waders as this bird occurs mainly on rocky shores and will adapt to some artificial structures (Ref. 20).

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Barnacle goose *Branta leucopsis* and Pink-footed goose *Anser brachyrhynchus*

The Barnacle and Pink-footed goose winter in the UK, concentrating mainly on a few open coastal sites where a gradation from saltmarsh to grazing pasture, with arable land, provides good feeding and roosting habitat. The species are highly gregarious and can congregate in large numbers, locally leading to conflicts with farming interests. Pink-foot geese may forage in arable land up to 30 kms away from the coastal roosting sites and this species is principally dependent on farmland for winter foraging. Geese may be attracted away from arable crops by managing the pastures so as to provide good grazing, this mainly being a function of sward height (relatively short) and fertilisation. These geese, as do other members of this group, gain more benefit from agriculturally improved grasslands (Ref. 19 & 27).

Conservation of this species at its coastal wintering grounds has few implications for water resource management issues.

Golden plover *Pluvialis apricaria*

The Golden plover is a characteristic breeding species of the high, flat, open moors of the Pennines and Scotland but on passage and during the winter the species may be found in the more southerly estuaries and lowlands inland, feeding on extensive unimproved wet grasslands and permanent pastures rich in invertebrate prey. Large arable fields also provide mainly roosting areas.

Key influences

- Threats to the species are mainly on alterations to the breeding grounds through loss of habitat to upland afforestation or overgrazing. The loss of lowland unimproved wet grassland may affect winter survival in some areas.

Black-tailed godwit *Limosa limosa*

As with the ruff, the Black-tailed godwit is entirely dependent on extensive, open, wet grasslands for breeding. It is a rare breeding species in the UK, currently only present at five locations. The species is semi-colonial, requiring extensive areas of open habitat where grazing maintains a relatively short turf.

Wintering takes place on a few key estuarine sites where populations are vulnerable to disturbance, either on the feeding grounds or on high-tide roosts. It is during the breeding season, however, where water resource issues pertain directly to the survival of this species.

Key influences

- Softer peat soils are preferred to allow probing. Ideally the summer water table is no more than 20-30 cms below the surface (Ref. 7 & 23). Grassland structure needs to be varied with short turf for feeding and for predator visibility, tussocks for nest concealment and areas of taller grass favoured by feeding chicks (Ref. 4). Additional feeding areas are available if shallow temporary or permanent pools are present and the species generally breeds within 300 metres of open water;
- Threats to the species are also similar as for the ruff and include land-use changes resulting in the loss of wet grasslands by conversion to arable or improvements in land drainage;
- High summer rainfall events can lead to flooding in the favoured washland nesting areas resulting in their loss. Summer flooding can also temporarily suspend the correct grazing regime required to maintain a shorter turf structure for the breeding season; and
- This species is vulnerable to disturbance of its feeding grounds or roost sites.

Curlew *Numenius arquata*

In the UK Curlew typically breeds on the moors and rough grasslands of the uplands though there are a few sites in the lowlands where the species breeds on extensive areas of bog and wet-heath, and extensive wet rushy pastures and rough grasslands.

Key influences

- Curlew are particularly sensitive to disturbance during the breeding season;
- In the grassland sites, traditional management such as grazing is required to maintain an open sward with good invertebrate population in the upper soil horizons and vegetative layers; and
- Threats to the species include grassland improvement, cessation of pasture farming, improvements to the drainage regime and replacement of late cuts for hay by more intensive silage production.

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Dunlin *Calidris alpina*

Dunlin is primarily a coastal species during wintering and passage movements. It is a breeding species of the peatlands of the northern uplands and the coastal machair grasslands of the Scottish Western Isles. Lowland wet grasslands are of lesser importance to this species though it does occupy this habitat type at a few coastal locations.

Key influences

- The species is vulnerable to habitat change in its breeding grounds via afforestation, drainage of coastal marshes and developments at its key estuarine wintering grounds; and
- The spread of the cord grass (*Spartina anglica*) has deprived dunlin of its favoured foraging habitat (open mudflats and low saltmarsh of the middle and upper shore).

Gadwall *Anas strepera* and Pintail *A. acuta*

These ducks winter in the UK in internationally important numbers but as a breeding species they are rather local and scarce, pintail in particular.

Adult gadwall are herbivorous, taking Glyceria, Juncus, Scirpus, Carex and submerged and floating pondweeds, *Potamogeton, Myriophyllum, Elodea, Callitriche* and *Ranunculus*. Chicks are carnivorous in the first few weeks taking mainly insects from the water surface. Shallow lakes, ponds with adjacent marsh or rough grassland and slow rivers may be used.

During the winter, gadwall occupy more extensive open waters of lakes, reservoirs and gravel pits. Unlike some other ducks and geese, this species rarely emerges from the cover of its marshland habitat to feed in open grasslands.

Pintail nests in a variety of locations close to water in marshes, lake shores, islets and periodically inundated grassland adjacent to large lakes and moorland pools. It is omnivorous, feeding preferentially on freshwater invertebrates in shallow waters during the summer, shifting towards a herbivorous diet in winter. Estuaries provide the main wintering habitat for pintail though the species also occurs in extensive wet grasslands and washlands.

Key influences

- Breeding gadwall require marshes with clear eutrophic standing waters which provide a variety of plants for food as low emergent and submerged species with taller reeds for cover;
- Threats to gadwall populations include disturbance and water pollution; and
- The potential for developments at key estuarine sites and loss of extensive inland wetland habitats are threats to the status of the pintail.

Redshank *Tringa totanus*

While the majority of nesting birds in the UK are found in coastal grazing marshes and saltmarshes, there are a number of key sites where the species continues to breed in suitable extensive wet grasslands of river flood plains.

Key influences

- Habitat requirements for redshank in wet grasslands require a high water table with open pools and ditches with a high water level (Ref. 13), grasslands grazed to produce a shorter (15 cm and lower) sward with tussocks for nest concealment (Ref. 23);
- Inland sites have been lost to flood defence works, land drainage and agricultural intensification. These activities have reduced soil wetness, leading to losses in open water habitat and incorrect sward characteristics;
- Threats in the coastal locations to the redshank include drainage of grazing marshes, grassland improvement and conversion to arable (Ref. 12), developments on estuaries (Ref. 22);
- The spread of the cord grass *Spartina anglica*, which is reducing foraging areas on the saltmarshes and adjacent mudflats in many southern estuaries, is also a threat to the status of the redshank;
- Grazing regimes on saltmarshes affect nesting density. Light to moderately grazed marshes produce optimum conditions (Ref. 15 & 16); and
- Severe weather leads to heavy mortality in redshanks (Ref. 14), a factor that can be exacerbated by disturbance at the feeding grounds.

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Ringed Plover *Charadrius hiaticula*

Both the wintering and breeding distribution of the ringed plover is coastal with shingle beaches providing the ideal nesting grounds. The machair grasslands in the Scottish Western Isles also attract high numbers and similar short-cropped coastal grasslands and arable land close to the sea may also attract nesting birds in England.

There are a few inland breeding locations for this species, on gravel bars along the larger unmanaged river reaches or on shingle "beaches" at reservoirs and gravel pits though these habitats are mainly the preserve of the related and less common little-ringed plover. Threats principally concern disturbance from recreation and development at shingle beaches where the birds nest.

Shelduck *Tadorna tadorna*

Shelduck is primarily a coastal species of muddy shores and estuaries, breeding on adjacent marshes and farmland. There are a few inland breeding sites, particularly in Norfolk, and this trend may be continuing. Nest sites include holes in old rabbit burrows, crevices in rocks or between boulders and dense bramble or gorse scrub. Feeding sites providing surface invertebrates on wet sands and muds, insects, seaweeds, and grassland herbage are utilised. Wintering takes place on estuaries and shallow freshwaters near the shore. Estuarine developments are considered to constitute the main potential threats to the UK population.

Shoveler *A. clypeata*

Shoveler is well distributed mainly in the central and eastern counties of England, inhabiting marshes and shallow open eutrophic waters. The species is notable for its specialised feeding technique, skimming small invertebrates, including zooplankton, and plant seeds from the water surface or shallow sediments (Ref. 8). Deeper, nutrient-rich waters may be used where the surface layers have a high plankton population. Plant material forms a greater part of the diet in winter and flooded river valleys can prove attractive at this time. Nesting takes place, often in the open by the water's edge, or in taller clumps of sedge or similar vegetation.

Land drainage is thought to have considerably reduced populations in the past and may continue to pose a potential threat.

Teal *A. crecca* and Wigeon *A. penelope*

Teal and wigeon winter in the UK in internationally important numbers. Wigeon tends to have a coastal distribution whereas teal also occurs in well vegetated inland marshes. Relatively few wigeon breed in the UK, the population being mainly restricted uplands of the northern Pennines and the north of Scotland, mainly in upland neutral waters. Teal breed in greater numbers throughout the UK, usually in secluded well-vegetated and enclosed marshes, often with a partial cover of scrub and trees.

Wigeon is almost entirely herbivorous and utilises extensive coastal grazing marshes and washlands during the winter. They will also feed on arable stubble. Inland reservoirs and gravel pits may also be used. Teal also frequent shallow estuaries in winter but will also continue to winter in inland marshes.

Threats to the teal population include land drainage and loss of the shallow marshland habitat and developments and disturbance at its shallow-water coastal locations. Wintering populations of wigeon, with its lesser reliance on inland marshes, are considered to be less vulnerable to water-resource management issues.

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Key references

Reference material has been derived from a variety of key publications such as Red Data Birds in Britain (NCC/RSPB 1990), the UK atlases for breeding and wintering birds (BTO 1986, 1993) and The Wet Grassland Guide (RSPB, ITE, EN, 1997). A literature search for more recent work within the last 10 years used the British Library facility to scan key data bases such as Biological Abstracts, Life Sciences Collection, Environment Abstracts, and Zoological Record. Additional information is available on certain web sites, in particular that of the RSPB and British Trust for Ornithology (BTO).

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Supporting references

Refer to the EN research Report No 359 for further information on habitat requirements for particular bird species.

Consideration of the Annex I habitat estuaries is required. Refer to this guidance note for further information.

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2.4 Eco-hydrological guidelines for lowland wetland plant communities

The Agency document *Eco-hydrological Guidelines for Lowland Wetland Plant Communities* contains a series of community-based descriptions of the hydrological regimes required by selected communities.

The descriptions put each community in context by providing data on floristic composition, distribution, landscape situation and substratum. The main water supply mechanisms and preferred hydrological, nutrient and management regimes are then covered. The descriptions conclude by providing guidance, under the heading 'Implications for Decision Making', on the vulnerability to change and restorability of each community and on knowledge gaps.

2.5 Other sources of information

Other on-going R&D of potential relevance to these Guidelines includes:

- A joint funded project by the Agency and CEH; *The impact assessment of wetlands -Focus on hydrological and hydrogeological issues. – A Scoping Study*. This project is ongoing but output will not be available for some time. The project aims to identify assessment techniques for inland, largely groundwater fed, wetland systems. When this output becomes available it is likely to provide additional tools for reference in the Assessment Methods described in Section 4.

Other useful information can also be downloaded from the internet, with the following web sites providing useful sources of data:

- The Environment Agency's Science R&D reports can be obtained from http://intranet.ea.gov/organisation/df/environment_protection/science/contents.htm)
- English Nature's publications and Science Series can be found at http://www.english-nature.org.uk/pubs/publication/pub_search.asp
- CCW's Publications and Research section can be found at http://www.ccw.gov.uk/reports/index.cfm?Action=ViewRecent&lang=en

Useful information may also be obtained from relevant experts and it is recommended that discussions are held with local conservation officers from Natural England or CCW and the Agency to ensure the correct application of relevant information.

This document was withdrawn on 6 November 2017

3 Hydro-ecological domains and hydrological regimes

This document was withdrawn on 6 November 2017

Environment Agency

NATURAL ENGLAND

Cyngor Cefn Gwlad Cymru
Countryside Council for Wales

3. Hydro-ecological domains and hydrological regimes

This document was withdrawn on 6 November 2017

3.1 Introduction

This section sets out a framework to aid in the hydrological characterisation and conceptualisation for sites specifically supporting European interest features (species and/or habitats) by developing the concept of the source – pathway – receptor links to support the evaluation of impacts and their ecological effects.

The framework identifies a series of hydro-ecological domains (and sub-domains) enabling sites to be categorised in accordance with their ascribed interest features and with due regard to the hydrological systems/processes (particularly those providing freshwater supplies) believed to support them. Within this framework the main hydrological regimes (ground water, riverine etc) can be readily identified which provide the pathway along which activities that give rise to potential impacts can be conveyed to the site of interest (receptor). Finally, a whole range of possible activities (sources of potential impact) are briefly considered.

3.2 Hydro-ecological domains

For the purpose of these guidelines sites should, where possible, be characterised (or grouped) into a series of hydro-ecological domains and sub-domains. The domains suggested are not intended to form a new (or varied) hydrologically based classification system for sites with existing classifications such as those proposed by D J Gilvear and R J McInnes (1994) and B D Wheeler and S C Shaw (1995). The purpose of the domains proposed in these guidelines is intended to help characterise sites in terms of the key freshwater regimes, which may potentially be impacted by consented activities which come under the control of the Agency's Water Resource function, thus modifying any or all of the:

- Supply of freshwater to the site (required at a particular quantity and/or quality) or otherwise needed to abate the intrusion of alternative water supplies with unsuitable quality characteristics;
- Water level (surface or ground water) regime at the site. Here it should be noted that although at some sites the dominant freshwater supply may come directly from rainfall, the key pathway by which consented activities can affect the site is through regional (or local) ground water (or surface water) regimes;
- Substrate characteristics (material, size, depth, sorting and interstitial water quality) for the site.

All wetland sites receive direct rainfall and this supply of water is of importance to a greater or lesser extent depending on the site. For some sites, direct rainfall may provide the predominant supply and such sites are referred to as having an ombrotrophic regime. In this guidance, sites which are essentially Ombrotrophic, but which do not rely upon a ground water (or surface water) regime which extends beyond the site, are not considered further. The reason for this is that water abstraction licences cannot fundamentally impact rainfall regimes. Rain water quality can be influenced by consented emissions to atmosphere which in turn can impact the hydrochemistry and the condition of certain sites such as raised bogs, blanket bogs and sites with *Sphagnum recurvum* (such as the Cheshire Meres and Mosses). Additionally, and on a global scale, certain emissions to atmosphere may also be giving rise to effects on climate too. However, for the purpose of these guidelines consideration will be limited to impacts/effects on sites resulting from sources (consented activities) which depend upon a hydrological (ground water or surface water) pathway rather than an atmospheric pathway.

When characterising and assessing impacts/effects on sites it is important to consider both the natural and anthropogenic (man-made) factors which govern them. In the broadest sense the fundamental natural influences on a site stem from climate and geology (both past and present) which govern their form (size, shape and topography), hydrology, marine influence (if relevant) and ecology. Anthropogenic influences on sites can be wide ranging such as:

- Artificial creation of habitats such as reservoirs, canals, quarry lakes, controlled washlands, tidal barrages and reclaimed salt marshes.
- Management of habitats through localised schemes to control (or optimise):
  – water quantity and/or quality;
  – influences on site flora/fauna from predation, invasion, grazing and harvesting (or cutting);

– interference from man's working or leisure activities through trampling, noise or similar.

- Direct impacts and effects to a habitat from a range of activities (including consented activities) through; physical loss or disruption; modifications to the hydrological regime (quantity or quality); and enhanced threats from pollution, disease, genetic disruption and predation (or invasion) by foreign species.
- Indirect effects on a habitat which may be influenced by climate change affecting site hydrology (through increased flood/drought severity) and (if relevant) interaction with the marine environment (through sea level rise and/or enhanced storm-surge generation).

In Section 2.2 details were given of the species and habitats, constituting European interest features, of specific relevance to these guidelines. In general, it is the habitats which determine the hydro-ecological domain (and sub-domain) into which a site is categorised. However, for many sites the habitat is not formally designated in its own right and the only qualifying interest feature/s are individual species. In order to help categorise hydro-ecological domains (and sub-domains) a matrix is provided in Table 3.1 to help relate domains primarily to habitats and, secondarily, to species.

When using Table 3.1 it is important to bear in mind that:

- Large sites may well contain more than one hydro-ecological domain.
- Some species may occur across many habitat types and therefore selection of the relevant hydro-ecological domain should be more strongly influenced by the site hydrology rather than by consideration of the qualifying species.

A few points to note when referring to Table 3.1 are as follows:

- Not every hydro-ecological sub-domain is identified in this table (i.e. Controlled washland which is really a special class of flood plain).
- The sub-division into domains and links to habitats/species are never perfectly clear-cut, and therefore the table should only be used as a guide; individual site circumstances/characteristics should be used to guide detailed investigations and assessments.
- The header row titled 'Annex 1 habitats' broadly corresponds to the habitats listed in Section 2.2 as European features. A separate row has been included to allow for wet grasslands which provide an important habitat (not classed Annex 1 or covered specifically in Section 2.2) supporting certain European designated species (notably SPA features).
- In addition, the listing of species covered in Table 3.1 (or Section 2.3) should not be regarded as definitive. It is advisable to check with Natural England or the Countryside Council for Wales (CCW) to check there are no 'special' features for sites considered to have European designation in their own right. For example, the local Norwich office of Natural England regard tidal reed, a very notable species within the Atlantic Salt Meadow habitat, as being an interest feature in it's own right.

The hydro-ecological domains are outlined below.

3.2.1 Fresh surface waters domains

The fresh surface waters domains includes rivers and lakes/ponds, and is further broken down into sub-domains as set out below.

The Riverine domain is broken down into the following sub-domains:

- **'Natural' river systems;**
- **Canals** man-made linear ponded systems.

The Lakes/ponds domain is broken down into the following sub-domains:

- **broads and meres**
- **open-water features** associated with springs
- **artificial features** (such as reservoirs, other impounded water bodies and water filled extraction pits).

Rivers and, to a certain degree lakes/ponds, can be further subdivided depending on the following factors:

- size (ranging from a small ditch to a large river);
- geomorphological regime (including gradient, substrate, channel configurations);
- flow regime (including relative ground water flow contribution);
- water quality regime;
- the degree of artificial engineering (particularly canalisation and level/flow control structures).

In deep lakes (and reservoirs) and deep sluggish (ponded) rivers, the potential development of thermal layering (thermoclines) and related dynamics may also be an important consideration.

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3.2.2 Freshwater wetlands domain

The freshwater wetlands domain includes bogs, mires, swamps, marshes, fens and wet meadows. Vegetation can vary from reed and sedge to carr (woodland), and in 'land managed' areas may also include wet grazing meadows. This domain can be further broken down into sub-domains including:

- **Upland valley mires/flushes** typically upland valley sites are ground water influenced and fed by either ground water or rainwater.
- **Lowland valley fens** typically lowland valley fens are dominantly ground water fed and influenced.
- **Lowland fens and marshes** many lowland fens and marshes are ground water (but some are surface water) fed and/or influenced.
- **Natural riparian floodplains** natural riparian floodplains are typically surface water fed (under flood conditions) and influenced but some are also ground water influenced.
- **Controlled washlands** controlled washlands (not individually identified in Table 3.1) are typically surface water fed (under flood conditions) and influenced but some are also ground water influenced.
- **Transitional wetlands** transitional wetlands can exist in a wide range of hydro-ecological sub-domains and habitats. Note; this is not regarded as a separate hydro-ecological sub-domain.

For reasons given previously, sites which essentially rely upon direct rainfall input (i.e. which have an ombotrophic regime) are not detailed in these guidelines.

Within freshwater wetland domains and in particular those sub-domains fed by ground water, the hydrochemistry of the ground water, can be an important factor which further influences sub-domain characteristics and resulting habitats and species at sites. The mineral content is important in governing whether ground waters are base rich, neutral or acidic. Further, the redox potential for ground waters flowing through the site may be influenced by the 'flushing' regime at a particular site. Additionally, if ground waters are enriched with nutrients this can impact the site hydrochemistry and effect ecology.

3.2.3 Marine/coastal domain

The marine/coastal domain can include an array of transition elements. Typically, from sea to shoreline, this domain can be broken down into the following sub-domains:

- **Sub-tidal/marine** sites that are permanently inundated.
- **Inter-tidal** including mud/sand banks, through to salt marsh and possibly coastal lagoons.
- **Extreme tidal** including salt meadow and some coastal lagoons.
- **Humid dune slacks** typically seasonal ponds supplied by rainfall and sometimes also influenced by a shallow ground water table regime.
- **Marine/coastal transition** this is not classed as a hydro-ecological sub-domain in it's own right but the term is often used to describe a range of habitats which can include an array of coastal/marine sub-domains referred to above. This may also incorporate habitats associated with reclaimed coastal marshes in which an 'artificial' fresh or brackish water regimes are maintained.
- **Estuarine/shallow embayment** riverine/marine interfaces give rise to estuarine, and occasionally large shallow embayment, regimes.

Along some inter-tidal zones the discharge (as springs or seeps) of fresh ground water may give rise to locally special regimes. Within salt marsh zones these can support tidal reed beds, and in mud/sand bank may support specialist invertebrate communities.

At the coast there may be a sharp transition between the saline and freshwater regimes introduced through artificial drainage and coastal sea defence schemes/management. This can allow artificial maintenance of landward freshwater wetlands and lakes immediately adjacent to the coastal sea defence. Similarly distinct saline/freshwater regimes frequently occur on the boundaries between rivers and estuaries where tidal control structures are incorporated.

3.3 Linking hydro-ecological domains with hydrological regimes

In characterising the hydro-ecological domain or sub-domain at a site (or part of a site) Table 3.2 can be used to help identify the likely broad hydrological regimes which could govern supply of and/or influence the regime of the fresh (or brackish) systems at the domain. This table is merely intended as a guide and should be used with some degree of caution, with certain points to note including:

- It is expected that riverine or lake/pond sub-domains will **probably** be influenced by a surface water regime and more often than not this will provide the key pathway. However, in certain instances these sub-domains can also be equally (or more) influenced by a ground water regime and hence this regime is identified as a **possible** pathway for an impact/effect.

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- Where it is indicated that a link is 'unlikely' this should not be interpreted as impossible. For example it is occasionally possible for certain fresh surface water or freshwater wetland domains, located near to the coast, to receive some tidal influences, although Table 3.2 indicates this as unlikely.
- The table is no substitute for site-specific hydrological conceptualisation (see Section 4 Method Summaries). The hydrological regimes are too broad to identify key influences and the actual nature of the potential mechanisms operating at a particular site. Therefore, as part of the overall hydrological conceptualisation for a site the range of possible hydrological regimes need to be examined in more detail.

Figure 3.1 provides a diagram with a hierarchy of hydrological regimes (from broad to detailed) which could be used to help determine the level of detail that may be required for adequate hydrological conceptualisation of a site. The general emphasis in Figure 3.1 is given to quantity related components of the main hydrological regimes (such as flow and level). In general, little detail is provided on the range of water quality considerations that may be required for site characterisation and assessment as this is generally considered outside the scope of these guidelines although further information can be obtained from Work Instruction (95_01) – Habitats Directive Technical Guidance for Water Quality: Review of Permissions to Discharge and New Applications. In addition, further guidance will become available when output from ongoing R&D projects become available such as:

- Environment Agency R&D; Establishing Practical Measures for Assessment of eutrophication risks and Impacts in Estuaries. (At the time of going to press full details on this R&D project were not available).
- Environment Agency R&D (P4-083(10)); Atmospheric Deposition Threat to Freshwater Habitats Sites; Risk Screening and Assessment based on Freshwater Critical Loads. Project being undertaken by ENSIS (at University College of London) and CEH and is due for completion in 2004.

Identification of geomorphological components for the main hydrological regimes is limited – this may need to be considered on a site-specific basis.

Table 3.3 sets out the likely links between more detailed (or intermediate) hydrological regimes and domains. For example, Table 3.2 shows a probable link between the broad surface water hydrological regime and the estuaries and embayments hydro-ecological sub-domain. However, when the more 'detailed' subdivision of hydrological regimes is considered in Table 3.3, only flow and quality are shown as probable links whilst the level and geomorphology regimes are indicated as possible links.

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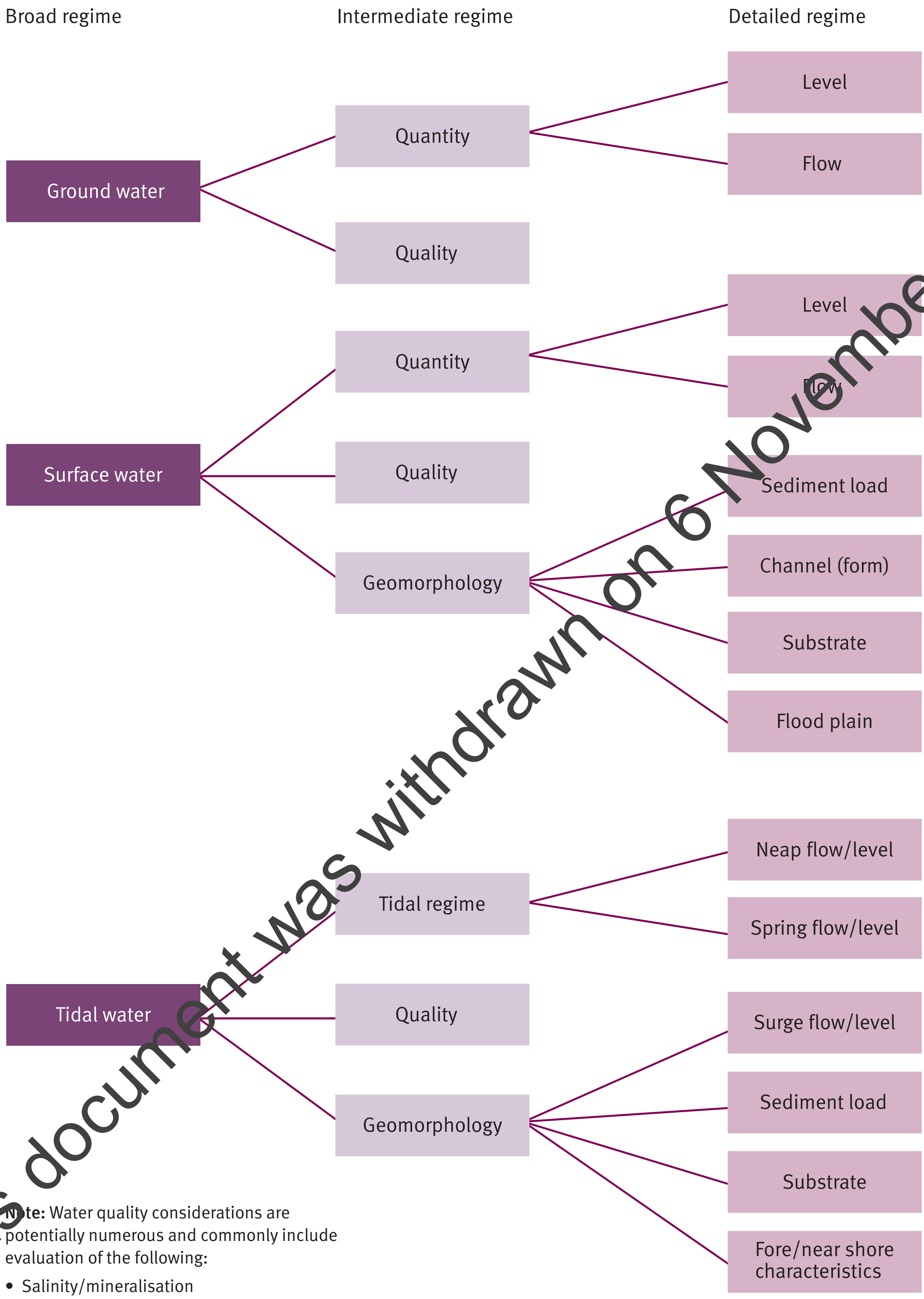
Figure 3.1 **Hydrological regimes diagram**



Note: Water quality considerations are potentially numerous and commonly include evaluation of the following:

- Salinity/mineralisation
- Sanitary/pH
- Nutrients
- Specific pollutants/contaminants
- REDOX
- Biologically based classifications

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3.4 Linking hydrological regimes to the potential source of impacts/effects

In this sub-section further details are provided on the **source – pathway – receptor** links. The **source – pathway – receptor mechanism** involves:

- **Source**; an activity (often consented such as an abstraction) which gives rise to a possible impact, in this case hydrological, and related effect/s.
- **Pathway**; a hydrological regime in which an impact can be transmitted (such as in an aquifer system as relevant to a ground water regime).
- **Receptor**; the hydro-ecological domain (or sub-domain) where a hydrological impact, under consideration, may be received. Translation of this impact into ecological effect, and significance, at the feature will depend upon the magnitude of the impact and the sensitivity of the key interest features to these impacts.

Table 3.4 highlights the general likelihood that various consented activities (**sources**) may act with different hydrological regimes providing a **pathway** by which impacts/effects may occur. The consented activity of primary concern in these guidelines involves licensed water abstractions. However, there is a requirement (set out within the habitats regulations) to assess the impact of abstraction 'in-combination' with activities regulated by other Environment Agency functions and non Agency activities. These activities may also give rise to potential hydrological impacts/effects, but may also have other effects not related to hydrology. These also need to be borne in mind and considered when 'in-combination' assessments are undertaken.

Within the Agency's water resources function other activities that will probably be managed by this function but may be consented, wholly or partly, by a separate Agency function, include:

- artificial recharge and Aquifer Storage & Recovery (ASR) schemes;
- raw water transfers; and
- major impoundments (construction/installation only).

Other Agency functions that have a consenting, or some other regulatory, role which may give rise to potential hydrological impacts/effects, via the hydrological **pathway**, include:

- Water quality discharge consents usually prescribed for treated effluent discharge activities. The main impact consideration from such activities is normally on water quality in the receiving water.
- Integrated Pollution Control (IPC) and RadioActive Substances (RAS) consents involving discharge to water. The main impact consideration from such activities is normally on water quality in the receiving water. Here it should be noted that those IPC consents involving emissions to atmosphere and in particular those which may pollute rainfall (i.e. cause rain acidification) and impact European sites are considered to have an atmospheric rather than hydrological **pathway**.
- Flood defence and land drainage activities. Major inland schemes can typically give rise to significant impacts on the flow, level and geomorphological regimes of affected rivers whilst sea defence schemes can give comparable impacts to the tidal water regime. It should be noted that other Authorities, in addition to the Environment Agency, also have responsibility for flood defence and drainage matters and most notably these include Internal Drainage Boards and Local Authorities.
- Major navigation schemes can give rise to significant impacts on the flow, level and geomorphological regimes of affected rivers and tidal waters. Whilst the Environment Agency are the Navigation Authority for certain inland waterways (mainly selected navigable rivers), the major Authority is British Waterways. Other small-scale regulators of inland water include localised bodies such as the Middle Level Commissioners. British Waterways responsibility also extends to some navigable tidal waters, but many of these are regulated by separate Harbour Authorities while others are the responsibility of the Local Authority.
- Waste management, and in particular landfill licensing, is regulated by the Environment Agency. Poorly designed or operated landfill sites can impact on the ground water (or surface water) quality regimes. Another form of waste management, which may be hydrologically significant, is the dumping of dredged sediments to tidal waters. Such activities are predominantly undertaken to maintain navigation channels (these are generally regulated by DEFRA). Where dredging is undertaken in river (or drainage) channels to maintain flood conveyance capacities (the Environment Agency (or appropriate Drainage Authority) will have management responsibility for such works. Where these works involve deposition adjacent to channel dredging no other authorities are normally involved but if such sediment is disposed of in tidal waters regulation by DEFRA may apply.

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- Water Level Management Plans are regulated by DEFRA but many plans, particularly those involving a strategic approach to water resource management, have been formulated and may also be operated, monitored or co-ordinated by the Environment Agency. Plans compiled by the Environment Agency include those for the River Avon cSAC/SPA in Hampshire.

The most notable non Agency consented activities (or allied management) which may give rise to potential hydrological impacts/effects include:

- Site management activities regulated by Natural England and the Countryside Council for Wales.
- Nearby inland mining and quarrying activities, regulated by County Councils or Metropolitan/Unitary Authorities concerning mineral extraction (or the Coal Authority concerning coal mining), may involve de-watering activities which can potentially impact both ground water and surface water regimes. Marine aggregate extractions, (undertaken both for conventional aggregate use and beach nourishment schemes), may potentially impact tidal water regimes and these activities are regulated by the Crown Estates.
- Major planning development including; residential; commercial; industrial; transport infrastructure; and major pipelines can all lead to potential hydrological impacts. Such developments involve a range of regulating authorities such as Local, Metropolitan, County, Highways and Rail Authorities.
- Good Agricultural Practice and comparable requirements for aquaculture activities are the responsibility (in terms of formulation and implementation) of DEFRA. Inappropriate practices can impact both ground water and/or surface water quality regimes.

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Table 3.1 **Species: habitats; hydrological domains matrix**

Hydro-ecological sub-domain 'boundary' - - -   Hydro-ecological domain 'boundary' ——   Annex 1 habitat can straddle hydro-ecological sub-domains ·······

Hydro-ecological domains	**Marine/Coastal Sites (MCS)**								
Hydro-ecological sub domains	**Estuaries & embayments**		**Intertidal**			**Extreme tidal**			**Dunes**
Sub habitats	**Subtidal/marine & intertidal transition**		**Intertidal**					**Dunes/inland halophytic**	
Broad habitats	**Coastal & halophytic**								**Dunes**
Annex 1 habitats	Estuaries	Large shallow embaymants	Mud/sand-flats	Colonising mud/sand	*Spartina* sward	Coastal lagoons	Atlantic salt meadow	Inland salt meadow	Humid dune slacks
Sub category (non annex 1 habitats)									
Invertebrate									
Geyer's whorl snail									
Narrow mouthed whorl snail								✔	✔
Round mouthed whorl snail									
Desmoulin's whorl snail									
Freshwater pearl mussel									
Southern damselfly									
Marsh fritillary butterfly									
White-clawed crayfish									
Ramshorn snail									
Fisher's estuarine moth								✔	
Fish									
Sea lamprey	✔	✔							
Brook lamprey									
River lamprey	✔								
Allis shad	✔								
Twaite shad	✔								
Atlantic salmon	✔								
Bullhead									
Spined loach									
Amphibian									
Great crested newt									
Mammal									
Barbastelle bat									
Otter	✔								
Plant									
Slender green-feather moss									
Petalwort									✔
Marsh saxifrage									
Floating water plantain									
Shore dock									✔
Fen orchid									✔
Creeping marshwort									
Bird	✔	✔	✔	✔	✔	✔	✔	✔	✔

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Table 3.1 **Species: habitats; hydrological domains matrix** continued

Hydro-ecological sub-domain 'boundary'   Hydro-ecological domain 'boundary' ——   Annex 1 habitat can straddle hydro-ecological sub-domains ·······

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Hydro-ecological domains	**Freshwater Surface Waters (FSW)**						
Hydro-ecological sub domains	**Riverine (& lakes/ponds)**			**Lakes/ponds**			
Sub habitats	**Riverine**	**Riverine and lakes/ponds**		**Lakes/ponds**			
Broad habitats	**Freshwaters**						
Annex 1 habitats	Plain to montane watercourses (lowland mesotrophic)	Hard oligo-mesotrophic waters (standing/ flowing)	Oligotrophic waters (mainly acidic flowing waters)	Oligo-mesotrophic standing waters	Natural eutrophic lakes	Natural dystrophic lakes	Mediterranean Temp. ponds
Sub category (non annex 1 habitats)							
Invertebrate							
Geyer's whorl snail							
Narrow mouthed whorl snail							
Round mouthed whorl snail							
Desmoulin's whorl snail	✔			✔			
Freshwater pearl mussel	✔		✔				
Southern damselfly			✔				
Marsh fritillary butterfly							
White-clawed crayfish	✔	✔					
Ramshorn snail		✔		✔	✔		
Fisher's estuarine moth							
Fish							
Sea lamprey	✔						
Brook lamprey	✔			✔			
River lamprey	✔						
Allis shad	✔						
Twaite shad	✔					✔	
Atlantic salmon	✔						
Bullhead	✔	✔	✔	✔			
Spined loach	✔						
Amphibian							
Great crested newt				✔	✔		
Mammal							
Barbastelle bat							
Otter	✔	✔	✔	✔	✔	✔	✔
Plant							
Slender green-feather moss							
Petalwort							
Marsh saxifrage							
Floating water plantain		✔	✔	✔			
Shore dock							
Fen orchid							
Creeping marshwort							
Bird	✔	✔	✔	✔	✔	✔	✔

Table 3.1 **Species: habitats; hydrological domains matrix** continued

Hydro-ecological sub-domain 'boundary' Hydro-ecological domain 'boundary' — Annex 1 habitat can straddle hydro-ecological sub-domains ·······

Hydro-ecological domains	Freshwater Wetlands (FW)							
Hydro-ecological sub domains	Upland valley – GW fed/influenced				Transitional			LVF
Sub habitats	Rainwater fed & GW influenced		GW fed & influenced		Rainwater fed & GW influenced		GW fed & influenced	
Broad habitats	Heath	Bogs, mires & fens					Forest	Heath
Annex 1 habitats	Northern wet heath	Blanket bog	Alpine formations	Petrifying springs	Depression on peat	Transition mire & quaking bog	Bog woodland	Temperate wet heath
Sub category (non annex 1 habitats)								
Invertebrate								
Geyer's whorl snail			✔	✔				
Narrow mouthed whorl snail								
Round mouthed whorl snail			✔					
Desmoulin's whorl snail								
Freshwater pearl mussel								
Southern damselfly	✔							✔
Marsh fritillary butterfly	✔	✔				✔		✔
White-clawed crayfish								
Ramshorn snail								
Fisher's estuarine moth								
Fish								
Sea lamprey								
Brook lamprey								
River lamprey								
Allis shad								
Twaite shad								
Atlantic salmon								
Bullhead								
Spined loach								
Amphibian								
Great crested newt								
Mammal								
Barbastelle bat							✔	
Otter								
Plant								
Slender green-feather moss			✔			✔		
Petalwort								
Marsh saxifrage		✔						✔
Floating water plantain								
Shore dock								
Fen orchid								
Creeping marshwort								
Bird		✔						

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Table 3.1 **Species: habitats; hydrological domains matrix** continued

Hydro-ecological sub-domain 'boundary' Hydro-ecological domain 'boundary' —— Annex 1 habitat can straddle hydro-ecological sub-domains ·······

Hydro-ecological domains	Freshwater Wetlands (FW)						
Hydro-ecological sub domains	Lowland valley fen or fen/marsh			Lowland fen/marsh & floodplain			Floodplain
Sub habitats	GW fed & influenced			GW or SW infl.	Rainwater fed & GW influenced or SW infl.		Surface water
Broad habitats	Bogs, mires & fens			Grassland	Bogs, mires & fens		Forest
Annex 1 habitats	*Molinia* meadows	Calcareous fen	Alkaline fens		Active raised bog	Degraded raised bog	Alluvial forest
Sub category (non annex 1 habitats)				Wet grassland			
Invertebrate							
Geyer's whorl snail		✓	✓				
Narrow mouthed whorl snail		✓	✓				
Round mouthed whorl snail			✓				
Desmoulin's whorl snail		✓	✓				
Freshwater pearl mussel							
Southern damselfly		✓					
Marsh fritillary butterfly	✓	✓	✓	✓	✓	✓	
White-clawed crayfish							
Ramshorn snail							
Fisher's estuarine moth							
Fish							
Sea lamprey							
Brook lamprey							
River lamprey							
Allis shad							
Twaite shad							
Atlantic salmon							
Bullhead							
Spined loach							
Amphibian							
Great crested newt							
Mammal							
Barbastelle bat							✓
Otter							
Plant							
Slender green-feather moss		✓	✓				
Petalwort							
Marsh saxifrage		✓	✓				
Floating water plantain							
Shore dock							
Fen orchid		✓	✓				
Creeping marshwort				✓			
Bird	✓	✓	✓	✓			

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Table 3.2 **Linking hydro-ecological sub-domains and broad hydrological regimes**

	Fresh Surface Waters		**Fresh Water Wetlands**					**Marine/coastal**				
	Riverine	Lakes/ ponds	Upland valley mires/ flushes	Lowland valley fens	Lowland fens & marshes	Natural floodplains	Controlled washlands	Sub tidal*	Inter tidal	Extreme tidal	Humid dune slacks	Estuaries & embayments
Ground water	Possible	Possible	Probable	Probable	Possible	Possible	Possible	Unlikely	Possible	Possible	Probable	Possible
Surface water	Probable	Probable	Possible	Possible	Possible	Probable	Probable	Unlikely	Possible	Possible	Possible	Probable
Tidal water	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Probable	Probable	Possible	Possible	Probable

Influence/impact key

- Probable
- Possible
- Unlikely

* Sub tidal domains are likely to be permanently inundated with sea water and receive a negligible freshwater contribution. It is accepted that localised specific freshwater inputs can exist but these are difficult to identify, quantify and apply within water resources regulation.

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Table 3.3 **Matrix linking hydro-ecological sub-domains and broad hydrological regimes**

Domain	Fresh Surface Waters		Fresh Water Wetlands					Marine/coastal				
Regime	Riverine	Lakes/ ponds	Upland valley mires/ flushes	Lowland valley fens	Lowland fens & marshes	Natural floodplains	Controlled washlands	Sub tidal*	Inter tidal	Extreme tidal	Humid dune slacks	Estuaries & embayments
Ground water												
Level	Probable	Possible	Probable	Probable	Probable	Probable	Possible	Unlikely	Possible	Possible	Probable	Possible
Flow	Probable	Possible	Probable	Probable	Probable	Possible	Unlikely	Unlikely	Possible	Possible	Possible	Possible
Quality	Possible	Possible	Probable	Probable	Probable	Possible	Unlikely	Unlikely	Possible	Possible	Probable	Possible
Surface water												
Level	Probable	Probable	Possible	Possible	Possible	Probable	Probable	Unlikely	Possible	Possible	Unlikely	Possible
Flow	Probable	Probable	Possible	Possible	Possible	Probable	Probable	Unlikely	Possible	Possible	Unlikely	Probable
Quality	Probable	Probable	Possible	Possible	Possible	Probable	Probable	Unlikely	Possible	Possible	Unlikely	Probable
Geomorphology	Probable	Probable	Unlikely	Unlikely	Unlikely	Probable	Probable	Unlikely	Possible	Possible	Unlikely	Possible
Tidal water												
Level	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Probable	Probable	Unlikely	Unlikely	Probable
Flow	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Probable	Probable	Unlikely	Unlikely	Probable
Quality	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Possible	Possible	Possible	Possible	Possible
Geomorphology	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Probable	Probable	Possible	Possible	Probable

Likely assessment requirement key

Probable | Possible | Unlikely

* Sub tidal domains are likely to be permanently inundated with sea water and receive a negligible freshwater contribution. It is accepted that localised specific freshwater inputs can exist but these are difficult to identify, quantify and apply within water resources regulation.

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Table 3.4 **Matrix linking sources (of impact) with hydroloical regimes (pathways for propogation/conveyance of impact)**

Source / Regime	Environment Agency – water resources function (or management): GW abstraction	Artificial Recharge or ASR*	SW abstraction	Raw water transfer**	Impound-ment**	Environment Agency – other (none water resource) functions: WQ discharge consents	IPC/RAS	Flood defence & land drainage*#	Navi-gation*#	Waste manage-ment*#	Water levels manage-ment plans*#	None agency activities/regulation: Site manage-ment	Mine & quarry activities	Planning	Agri/Aqua-cultural guidelines
Ground water															
Level	Probable	Probable	Possible	Possible	Possible	Unlikely	Unlikely	Possible	Possible	Possible	Possible	Possible	Probable	Possible	Unlikely
Flow	Probable	Probable	Possible	Possible	Possible	Unlikely	Unlikely	Possible	Possible	Possible	Possible	Possible	Probable	Unlikely	Unlikely
Quality	Possible	Possible	Unlikely	Unlikely	Possible	Possible	Possible	Possible	Possible	Probable	Possible	Unlikely	Probable	Possible	Probable
Surface water															
Level	Possible	Possible	Probable	Probable	Probable	Probable	Possible	Probable	Probable	Possible	Probable	Possible	Possible	Possible	Possible
Flow	Possible	Unlikely	Probable	Probable	Probable	Probable	Possible	Probable	Probable	Possible	Probable	Possible	Possible	Possible	Possible
Quality	Possible	Unlikely	Possible	Probable	Possible	Probable	Possible	Possible	Possible	Possible	Possible	Possible	Probable	Possible	Probable
Substrate	Possible	Unlikely	Possible	Possible	Probable	Possible	Possible	Probable	Probable	Unlikely	Unlikely	Unlikely	Possible	Possible	Possible
Tidal water															
Level	Unlikely	Unlikely	Unlikely	Unlikely	Possible	Unlikely	Unlikely	Possible	Possible	Unlikely	Unlikely	Unlikely	Unlikely	Possible	Unlikely
Flow	Unlikely	Unlikely	Unlikely	Unlikely	Possible	Unlikely	Unlikely	Possible	Possible	Unlikely	Possible	Unlikely	Unlikely	Possible	Unlikely
Quality	Possible	Unlikely	Possible	Possible	Possible	Possible	Possible	Possible	Possible	Possible	Unlikely	Unlikely	Possible	Possible	Possible
Substrate	Unlikely	Unlikely	Possible	Possible	Possible	Unlikely	Unlikely	Possible	Possible	Unlikely	Unlikely	Unlikely	Possible	Possible	Possible

Likelihood of influence

- Probable (or definite)
- Possible
- Unlikely (or very unlikely)

Highlights of responsibilities straddling functions or authorities

** Consenting responsibility may rest with Environment Agency but lie outside the water resource function.

*# Consenting responsibility may rest with an authority other than the Environment Agency

Note: Water quality impacts can cover a very wide range of possibilities and with respect to RoC could potentially cover chemical, sanitary, nutrient, toxicological, bacteriological, pathogenic, genetic disruptors, water borne diseases and foreign species related issues.

4 Assessment methods

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Environment Agency

NATURAL ENGLAND

Cyngor Cefn Gwlad Cymru
Countryside Council for Wales

4. Assessment methods

4.1 Introduction

This section provides a 'route map' to a range of available assessment methods (or techniques), details of which can be found on summary sheets in this document. These methods are available for use in assessments and the package of methods adopted should reflect specific site characteristics, the adequacy of available data for the site and the level (or sophistication) of assessment being undertaken. Selection of assessment methods should not be carried out without recourse to the relevant technical expertise.

The assessment methods are broken down into groups which may be used to:

- help characterise the site;
- interpret the processes which supply or influence freshwater supplies to the site;
- evaluate (quantify) impacts/effects.

Some guidance on assessment method selection is provided below within a framework which also considers the:

- **source – pathway – receptor** concept;
- ecological sensitivity of the receptor to hydrological impacts;
- adequacy of hydrological conceptualisation for the site;
- stage of assessment in the Habitats Regulations Review of Consent (or comparable) process.

All the assessment methods referred to should be applied following Environment Agency policies and procedures and following the relevant Work Instructions and guidance on the Environment Agency intranet system.

4.2 Guidance on assessment method selection

The selection of a method (or technique) for use in an assessment is dependent upon a number of important considerations. In outline, these can include:

- Does the hydrological characterisation (conceptualisation) for the site identify a potential **source – pathway – receptor** link? If not, or if any link is shown to be of very low consequence, there may be no need to undertake any further assessment work.
- If an assessment is considered necessary the approach to, or sophistication of, the methodology adopted should be commensurate with the:
  - Adequacy (confidence level) of understanding for both the hydrological and ecological characterisation/conceptualisation of the site.
  - The nature, proximity (with respect to the site/receptor) and size of the source/s of potential impact.
  - The conveyance of impacts along the relevant pathway/s (i.e. hydrological regimes) from the **source** to the **receptor**.
  - The ecological sensitivity of the key interest features at the receptor.
- Adopting a progressive, stepped and precautionary approach:
  - Starting with the simplest methods and progressing to more rigorous techniques as necessary;
  - Applying the precautionary principle in the light of uncertainties (in knowledge regarding hydrological characterisation or sensitivity of the interest features) and/or applied assumptions regarding hydrological characterisation of the site or the particular assessment methods adopted;
  - Undertaking assessments of impacts/effects progressively from single function through to multi-functional considerations, and also bearing in mind that in-combination effects may arise, such as the possibility of enhanced toxicity from a 'cocktail' of pollutants rather than consideration of individual toxicity from each individual constituent.
- If a refined approach is deemed appropriate also consider if there is a need for:
  - Further baseline investigations to improve site (hydrological or ecological) characterisation or specific understanding/provenance of a link between **source** and **receptor**.
  - Further research into the ecological sensitivity for certain interest features.

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4.3 Translation of hydrological impact to hydro-ecological effect

In all cases the significance of the predicted impact has to be assessed. This can only be done by translating hydrological **impact** (change in flow, water level etc) into hydro-ecological **effect**. The hydro-ecological effect depends on a range of ecological factors including what is known on the water requirements of the species or habitat and other pressures acting at the site in question. In most cases this will require local knowledge and access to expert opinion.

Very often there is a lack of information on which to base an assessment or decision on the significance of a predicted impact. Risk assessment frameworks can provide a useful tool in these circumstances. The methods should be precautionary (particularly where major uncertainty is involved) and can be used to assist in the identification of sites where risk is minimal (and hence can be eliminated from the assessment process) and to identify need for further investigations/ fieldwork.

4.4 Assessment methods

Following on from the introduction of hydrological regimes (the **pathway** for **source** to **receptor** impacts/effects) in Section 3.3 and potential links with types of activities which may provide the **source** of impacts/effects (Section 3.4), Table 4.1 sets out possible assessment methods applicable to these regimes. The assessment methods are divided into two main classes and include:

- Standard techniques to help characterise the site (typically covering field-based monitoring and baseline processing/interpretation of resulting data); and
- Various approaches which may be undertaken to assess hydrological impacts.

Table 4.1 also provides, for the assessment methods identified, an indication as to the:

- Type of method (whether used to provide baseline data, and site characterisation or enable impact assessment);
- Hydrological regimes under which the method is likely to (or may) be applicable;
- Typical cost/complexity of applying the method; and
- Further coverage of outline details for this method in these Guidelines (see Section 4.5).

Table 4.2 reproduces the full list of assessment methods previously identified in Table 4.1. The majority of these are provided with Assessment Summaries in Section 4.6 but in some cases where the selection of methods are not made primarily by the Water Resource function, e.g. water quality, no summary has been provided. When no summary has been provided then suggestions may be included (in Table 4.2) giving other references or organisations which might help.

4.5 Additional sources of information

Further information may be obtained from the following sources:

- 133_05 Work Instruction: (Appendix 4) Assessment of new Water Resources permissions under the Habitats Regulations.
- 134_05 (Appendix 4) Review of existing Water Resources permissions under the Habitats Regulations.
- 135_05 (Appendix 4) Stages 1 & 2 of the review of existing Water Resources permissions under the Habitats Regulations.
- 136_05 (Appendix 4) Stage 3 of the review of existing Water Resources permissions under the Habitats Regulations.

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Fish population surveys

Summary

Type of regime where applied
Riverine and lacustrine.

Applicability to groundwater or surface waters
Surface waters only.

Hydrological data requirements
Gauged flow data may be useful to explain or investigate migratory behaviour, distribution and impacts on fish populations

Ecological data requirements
River habitat survey may be used to link distribution to channel features

Can method be used on its own?
Yes, however, data are best interpreted against other environmental data.

Applicability to European interest features
Highly applicable, various survey techniques can be used to target particular species or groups according to habitat.

Resource requirement
Experienced/qualified surveyors required – minimum number to meet health and safety requirements varies according to specific task.

1. Background and applicability to species protected under the Habitats Directive

Fish population survey data have been routinely collected by the Environment Agency and its predecessor organisations for most river catchments in order to evaluate the distribution, abundance and status of fish species. Historically fish population data have been collected to provide information on the health of the river, both in terms of habitat and water quality, and in terms of the sport fishery. The collection of survey data has, in the past, varied between Environment Agency Regions and Areas, both spatially and temporally. Since angling has been a key driver for gathering fish population data, surveys have typically concentrated on the favoured coarse and salmonid fish species. Consequently, other species such as bullhead and lamprey have been under-recorded.

The provisions of the Conservation (Natural Habitats &c.) Regulations 1994 has highlighted the conservation status of species such as lampreys, bullhead and shads. As a result of this there has been increased emphasis on local targeted surveys for these species.

1 *European (fish) interest features include salmon, bullhead, allis shad, twaite shad, brook lamprey, river lamprey, sea lamprey, spined loach, powan and vendace*

Salmon are the only European (fish) interest feature that have historically been subject to extensive survey effort, with surveys targeting both the adult and the juvenile fish. Surveys have also been repeated at regular intervals, providing good historical data sets for many river catchments.

Bullhead, spined loach and lamprey have typically been recorded as present at sites if detected. However, the habitat preferences and behaviour of these species mean that specialist targeted surveys are required for quantitative studies, with routine surveys probably under-recording these species. Historical data for spined loach may be limited or unreliable due to lack of recording or mis-identification.

Shad species have rarely been monitored other than through specialist surveys as the adults are only present in rivers for short periods of time in Spring when general fish populations surveys are not usually undertaken. Most historical records are anecdotal based on observation of adult fish returning to spawn. Consequently no useful population estimates exist for this species, with the exception of the River Severn where there are 25 years of useful CPUE (Catch Per Unit Effort) data. However, the use of fixed station hydroacoustic counters is currently being evaluated on the River Wye.

Coregonids (powan, gwyniad, vendace) are confined to deep glacial lakes in generally upland areas of North West England and North Wales and have only been subjected to targeted surveys, principally by the Freshwater Biological Association and Centre for Ecology and Hydrology.

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2. Fish population survey methods

The variable morphology of water bodies throughout England and Wales means that a variety of different survey techniques have to be employed according to the width, depth, substratum, water conductivty and turbidity of the water being surveyed, also to purpose of survey and target species

Each of these techniques has certain limitations and they vary considerably in their selectivity and efficiency depending upon the survey site and prevailing conditions. A combination of techniques may be used at certain sites. The data from fish population surveys can be evaluated in association with environmental data, such as gauged flow data, River Habitat Survey (channel morphology) data, water quality data as described in summary to provide some explanation of variability in distribution or abundance, or to explain species behaviour.

The fishery survey methods most commonly used in England and Wales and their applicability to environments and species are summarised in the table below.

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Fish population survey methods

River Type	Method	European interest species	Comments
Upland, narrow, shallow streams	Backpack Electric Fishing	Salmon (juvenile), lamprey (juvenile), bullhead	-
Small to medium sized shallow rivers, upland and lowland	Wading (generator-based) electric fishing	Salmon (juvenile and adult) lamprey, bullhead, spined loach	Adult salmon seasonally only, electric fishing not recommended as a survey method
Deeper, medium to large rivers (upland and lowland), margins of lakes, canals	Boat-based hand-held electric fishing	Salmon (adult and juvenile), lamprey, bullhead, spined loach	Adult salmon seasonally only, electric fishing not recommended as a survey method. Lampreys, bullhead and spined loach in shallow margins only.
Large, navigable, slower-flowing rivers, lakes	Boom-boat electric fishing	Not applicable to any of European interest species	-
Medium to large, slow-flowing lowland rivers, large lakes, estuaries	Trawling	Shad, coregonids in lakes	-
Medium to large, slow-flowing lowland rivers, lakes, estuaries	Seine netting	Salmon (adult), spined loach, shad (juvenile)	Unlikely to be used for sampling adult salmon
Large lowland rivers and lakes, estuaries	Hydroacoustic survey (boat-based or fixed)	Coregonus species in lakes Shad and Salmon smolt	-
Small to large sized rivers and lakes, estuaries	Angler rod-catch Commercial net catch	Salmon (adult)	-

3. Brief descriptions of methods

3.1 Electric fishing

Electric fishing involves the creation of an electric field in the water around a set of electrodes in order to attract and immobilise fish so that they can be captured easily, enumerated and processed before being returned to the water with minimal risk of harm. Electric fishing can be carried out either by wading or from a boat, the power being provided usually by a portable generator, or in small shallow streams in sites with difficult access, a battery unit. The effective electrical field in water is generally only quite small, in the order of 2-3 metres around the electrodes, and so the method is of limited effectiveness in larger or deeper water bodies. There are considerable health and safety implications surrounding electric fishing and it must only be undertaken by trained and experienced staff, the number of whom are required varying according to the type of operation being mounted.

3.2 Netting

Although fish can be captured in a variety of broad types of nets, the chief methods used in English and Welsh waters for fish sampling are seine netting and trawling.

A seine net is typically 50 – 150 metres in length with varying depth (1.5 – 6 metres) and consists of a relatively small mesh size (15 – 50 mm). One end of the net is held on the bank whilst the rest of the net is set in a circle from a boat and the ends drawn together to form an enclosure around the area being fished. The whole net is drawn slowly towards the shore where the catch can be scooped out and placed in suitable containers for processing. Seine netting is impractical in waters which are very deep, have steeply shelving beds or are debris strewn, are weedy or where the water velocity is excessive. Seine netting is fairly manpower intensive although in ideal sampling conditions it is relatively efficient.

Trawling is undertaken from a suitably-powered vessel and involves the use of a bag-shaped net which can be rigged and weighted so as to sample either the bed of the water body or the pelagic layers. Long stretches of water can be sampled relatively rapidly although its relative efficiency is usually low and may be highly selective for species. The method is best suited to wide, deep waters with relatively smooth, clear bed.

3.3 Hydroacoustics

Hydroacoustic surveying of fish works by the transmission of a high-frequency sonic beam under the water which, when it encounters a fish or other underwater object, creates an echo that is detected by a receiver. The energy from the echo is transformed into a reading or visual image on a screen or paper chart. The modern split beam and dual beam hydroacoustic systems used by the Environment Agency and other scientific bodies incorporate very sophisticated software which enable high confidence in discerning fish from other objects, assessment of numbers and size of fish present and tracking of movement patterns of individual fish within the beam. Hydroacoustic surveys are generally conducted by boat although fixed location monitoring from the bank or a pontoon can be used. In the generally shallow (< 6m) deep waters the hydroacoustic beam is fired horizontally whilst in deep lakes it is transmitted vertically. The method enables long lengths of river or shoreline to be surveyed with modest manpower in a relatively short time, and has the advantage of being non-intrusive to the fish. Surveys are usually conducted between dawn and dusk when the fish tend to rise higher in the water column where they are more visible to the beam. Whilst the size of fish can be estimated, it is not generally possible to discern species.

3.4 Fish counters

Migratory fish species have presented their own challenges when trying to evaluate the characteristics of the adult spawning population. As a result of this fixed position counters have been deployed at various sites to count the number of fish migrating upstream and in some cases, downstream. These methods allow continuous recording of fish movement, subject to certain environmental conditions being met, and so can provide information not only on numbers of fish but patterns of behaviour.

Two techniques have routinely been employed:

- resistivity counters (where the fish interrupts an electrical field, the magnitude of the interruption being proportional to the size of the fish);
- hydroacoustic counters (where the fish swims through a sonic beam, influencing the returning signal, the magnitude of the returning signal being proportional to the size of the fish).

Both techniques are effectively 'blind', i.e. there is no easy way of establishing the identity of the fish other than to use a separate technique such as underwater video. Consequently there are certain inaccuracies associated with each method, which may also be influenced by other environmental factors such as macrophytes, algae, suspended solids, air bubbles etc. It is possible to calibrate systems so that fish size can be estimated, and fish numbers can readily be calculated unless the fish form dense shoals. This is a particular problem with shad, which makes enumeration problematic.

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Fixed position fish counters have been deployed on a number of the salmon rivers in England and Wales (11 of these provide reliable data). Consequently good data exist for some SAC rivers where salmon are an interest feature. In most cases fish migration data can be related to river flows to identify migration triggers. It is also possible to use counter data to enumerate the returning adult population. This can be related to spawning targets to establish the status of the fishery. Much research has been completed looking at the use of counters to evaluate stocks of salmon and sea trout. However, the value of these systems for evaluating shad migration is now being trialled, and work is being carried out to develop the systems further for this purpose.

3.5 Angler rod-catch and commercial net-catch.
Migratory salmonid rod licence holders and holders of licences for commercial salmon netting are required to submit to the Environment Agency details of their salmon catches including dates and methods used, hours fished etc. Rod-catch data are the most reliable data on runs of adult salmon in many rivers where there are no fish counters. The data are expressed as catch-per unit effort, i.e it can only provide a relative index of abundance although relationships between rod-catch and total run size have been established for some systems. Rod-catch data can also be used to draw inferences about the behaviour and distribution of adult salmon.

Additional information

General:

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EA Publication; 35pp.Bristol: Environment Agency, 2000

This document was withdrawn on 6 November 2017

Fisheries classification system (FCS)

Summary

Type of system where applied
Riverine.

Applicability to groundwater or surface water
Surface waters only.

Fish data requirements
Quantitative or semi-quantitative electric fishing survey data or angling match catch data

Hydrological data requirements
Historic naturalised and actual flow data may be useful for further investigations.

Ecological data requirements
Comparison with river habitat survey data may provide useful additional data on habitat preferences.

Can method be used on its own?
Uses fish population survey data plus map-and site-based data.

Applicability to European interest features
Uses UK reference sites for databases. Incorporate data on salmon, spined loach, bullhead and shads where these are present and can be sampled. Quantitative data only for salmon.

Resource requirement
Practitioners must be familiar with FCS software package and manipulation of fish population data including National Fish Population Database (NFPD).

Background

The Fisheries Classification System (FCS) was developed to enable objective assessment of fisheries, comparison of the status of fisheries from a local and national perspective, and communication of results, on a national basis.

The system was developed by compiling a database of fishery survey and simple environmental data from around 1000 river sites from around England and Wales and examining patterns of abundance of the various species and groups in relation to river width and river gradient.

Method description

FCS requires electric fishing survey outputs expressed as numbers of individuals per 100m2 for salmonids and biomass density (g/100m2) for coarse fish over 10 cm forklength (on the basis that fish less than 10cm in length cannot be sampled quantitatively, FCS can produce outputs for sites where fully quantitative electric fishing is not practicable and there is a module which can utilise angling match catch data.

Fishery survey data and site gradient and width data are entered into the model; the outputs for any given site are presented as grades according to a five-band classification system from the total range of values of fish density and biomass found across England and Wales. The system operates on four levels of detail through the use of a hierarchy of species aggregations, and, for each level of detail allows an absolute classification (how the fishery rates in relation to all others in the database) as well as a relative classification, which places the site in the context of other sites in the same broad habitat type (gradient and width category) in the database.

Applicability

At all levels of detail, 'minor' species such as bullhead, minnow, lampreys, coarse fish fry and the loaches is required only as presence or absence, hence FCS has limited applicability to most Habitats Directive species.

FCS uses only very basic habitat data as part of the evaluation process, which limits the sensitivity of the system for assessing species occurrence and abundance in relation to habitat. It is tailored towards species of angling interest and is a tool for National reporting and is easily translated to map-based outputs. Although FCS considers salmonids, the HABSCORE system provides a more robust tool for assessing salmonid populations in relation to habitat.

This document was withdrawn on 6 November 2017

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This document was withdrawn on 6 November 2017

HABSCORE

This document was withdrawn on 6 November 2017

Summary

Type of system where applied
Riverine.

Applicability to groundwater or surface water
Surface waters only.

Fish data requirements
Quantitative or semi-quantitative electric fishing survey data or angling match catch data

Hydrological data requirements
Historic naturalised and actual flow data may be useful for further investigations.

Ecological data requirements
Comparison with River Habitat Survey data may provide useful additional data on habitat preferences.

Can method be used on its own?
Uses fish population survey data plus map-and site-based data.

Applicability to European interest features
Uses UK reference sites for databases. Focuses on salmonids.

Resource requirement
Habitat and fish data must be gathered by trained practitioners. Users must be familiar with HABSCORE software package and manipulation of fish population data including National Fish Population Database (NFPD).

Background

HABSCORE is a system of salmonid stream habitat measurement and evaluation based on empirical models of fish density against combinations of site and catchment features. The system has been developed to aid the interpretation of fisheries data, with particular emphasis on the assessment of environmental impact. Indirect derivations of densities from the pristine HABSCORE sites feed into the production of spawning targets. HABSCORE is based on a series of empirical statistical models which predict population size of five salmonid species/age categories to observed habitat variables including site and catchment features.

The models were developed using fish population estimates obtained from 602 'pristine'sites in England and Wales.

Method description

The HABSCORE system uses a range of variables including catchment variables (e.g. altitude, slope), primary site variables (e.g. mean depth and width, shading) and derived site variables (e.g. surface area to volume ratio). The system produces two principal outputs:

- Habitat Quality Score (HQS): a prediction of the expected population at a site derived from habitat data.
- Habitat Utilisation Index (HUI): a measure of the extent to which the potential of the site is realised, i.e. the difference between the observed and the expected population size. The HUI is derived from habitat and fish data.

The comparison of observed with expected data using the HABSCORE model provides a useful tool for assessing the performance of the salmonid population at a particular site. A poor HUI indicates that the site holds fewer fish than would be expected on the basis of habitat features and hence that it might be impacted.

Because the HABSCORE system is empirically derived, there is not necessarily a direct causal link between the model variable and the predicted population. The system therefore has to be used with caution when trying to predict the consequences of habitat change. Therefore in those cases where the observed value falls below the predicted value, further investigation may be necessary to identify the factor(s) responsible for the deviation.

Applicability

HABSCORE has been designed to evaluate the habitat used by salmon and trout in upland rivers and streams and serves this purpose well, however its applicability in larger rivers where measurements of many of the variables used, is limited. The value of the method for other Habitats Directive fish species has not yet been validated.

Additional information

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FAME European Fish index (EFi)

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Summary

Type of system where applied
Riverine.

Applicability to groundwater or surface water
Surface waters only.

Hydrological data requirements
Historic Naturalised and Actual Flow data may be useful for further investigations.

Ecological data requirements
Comparison with River Habitat Survey data may provide useful additional data on habitat preferences.

Can method be used on its own?
Uses fish population survey data plus map and site-based data.

Fish data
Single-run electric fishing survey data.

Applicability to European interest features
Uses UK and European reference sites for databases. Incorporates data on salmon, spined loach, bullhead and shads where these are present and can be sampled but makes no specific reference in final score.

Resource requirement
Practitioners must be familiar with FAME software package and manipulation of fish population data including National Fish Population Database (NFPD).

Background

The FAME (Fish based Assessment Method for the Ecological status of European Rivers) methodology was developed to provide a tool for assessing Ecological Status of rivers for the purposes of complying with the European Water Framework Directive, using fish as one of the four elements which have been chosen as indicators of ecological status.

The method looks at the fish community rather than single species in isolation, and follows the concept of the Index of Biotic Integrity. IBI's work on the assumption that various aspects, or metrics of a biological system will change along a gradient of human interference or degradation in a predictable and quantifiable manner. Waters at High Ecological Status exhibit few or no signs of human degradation in the biotic communities they support, whilst those in the lowest of the five categories (Bad) have communities which are very highly modified from those occurring under pristine (reference) conditions. An EFi score of close to 1 indicates a high probability that the site is at reference condition.

The FAME database (FIDES) was developed on a European-wide scale and included over 15 000 samples from 8 000 sites from 12 countries. For each river type in each of 16 'eco-regions', characteristic fish communities have been identified by their composition in terms of reproductive and feeding 'guilds' that would be expected under near-pristine conditions.

Method description

The methodology involves five basic steps:

1. Classify river type – this is done on the basis of simple map and field based variables describing the basic environmental characteristics and geographical location of the site which are fed into the FAME model
2. Define reference condition – this is derived from the FIDES database by the model
3. Undertake survey and enter data into the model
4. Assess deviation from reference condition – this is the EFi score and is the output from the EFi software.
5. Assign quality status.

FAME uses data from single-run electric fishing survey, undertaken to strict criteria laid down in the FAME manual. Data from multiple catch surveys can be used, however only the first run catch is used in the computations. Fish caught are classified according to their membership of various guilds, which make up the ten fish metrics used to calculate the EFi. Some of the metrics are simply the presence or absence of certain species whilst others are densities of various fish groups.

Applicability

Whilst data on European Interest fish species is gathered and fed into EFi model, the resulting EFi scores only give a general indication of the ecological status of the site and are not suitable for investigating the status of particular species or the reasons for their status in any given site or reach.

Additional information

Schmutz, Stefan & Haidvogel, Gertrude (2004) *Development, evaluation and implementation of a standardised fish based assessment method for the ecological status of European rivers.*

FAME Group: 2004. Accessible from FAME webpage http://fame.boku.ac.at

FAME consortium (2004) *Manual for the application of the European fish index – EFI. A fish based method to assess the ecological status of European rivers in support of the water framework directive. Version 1.1 January 2005.*

This document was withdrawn on 6 November 2017

River Fish Habitat Inventory (RFHI)

Summary

Type of system where applied
Riverine.

Applicability to groundwater or surface water
Surface waters only.

Hydrological data requirements
Historic Naturalised and Actual Flow data may be useful for further investigations.

Ecological data requirements
Comparison with River Habitat Survey data and biological survey data may provide useful additional data on habitat preferences.

Can method be used on its own?
Uses fish population survey data plus map-and site-based environmental data.

Fish data
Can utilise fishery survey data of almost any type although quantitative electric fishing is most suitable for the present version of the model. Extremely flexible.

Applicability to European interest features
Current versions of RFHI have been developed for salmonids but the models are being trialled with other species groups and the approach could be used for other European Interest species.

Resource requirement
At present the model is not generally disseminated within the Environment Agency or externally and only staff from the Fisheries Stats and GIS group can apply the model.

Background

The approach was developed for the Environment Agency in order to integrate the basic Fisheries Classification System and HABSCORE (see earlier), producing a tool to enable Salmon Life Cycle Modelling and refine the setting of salmon Conservation Limits. The underlying models have been developed using a variety of catchment-based and site-based variables from pristine reference sites. The system uses contemporary statistical methods and high resolution GIS to produce maps displaying the quantity and quality of salmonid habitat in selected catchments. The model enables statistical comparison of the differences in observed and predicted fish abundance, and the approach can be used to help to identify possible factors limiting fish populations.

Method description

The models operate at two levels of detail; one based on map-based (GIS) variables only, and the other based on a combination of map and field-based variables from habitat surveys. The fish population models can be applied to quantitative and semi-quantitative data collected from the Environment Agency's national monitoring programme. Data from survey sites are used to interpolate and extrapolate fish abundance estimates throughout a catchment. The resulting maps provide a way of assessing spatial patterns in fish populations, and allow the estimation of population size at any spatial scale. A statistical comparison between the maps of fish abundance, and the maps of habitat quality, provides an assessment of where fish abundance is less than that expected from the habitat. This enables impacts affecting fish populations to be detected and quantified.

Applicability

The RFHI model has been used for salmon in relation primarily to Salmon Conservation Limits, however the model is being used to analyse data on coarse fish populations in some catchments. The model is both flexible and powerful and could be used to assess habitat quantity and quality for any species providing sufficient good quality data on relevant variables can be provided. However RFHI is not generally available as a user-friendly application and currently any enquiry about its use must be made via the Environment Agency's National Fisheries Technical Team.

This document was withdrawn on 6 November 2017

Additional information

Wyatt, R.J. 2002. *Estimating riverine fish population size from single- and multiple- pass removal sampling using a hierarchical model. Can. J. Fish Aquat. Sci. 59: 695–706.*

Wyatt, R.J. 2003. *Mapping the abundance of riverine fish populations: integrating hierarchical Bayesian models with a geographic information system (GIS). Can. J. Fish Aquat. Sci. 60: 997-1006*

WRc plc,Wyatt, R.J. & Barnard, S. (1997) *River fisheries habitat inventory (phase 1): scoping study. Environment Agency R&D Technical Report W95.* Publication Bristol: Environment Agency, 1997

Wyatt, R.J.(2005) *River Fish Habitat Inventory Phase 2: Methodology Development for Juvenile Salmonids. Environment Agency Science Report SC980006/SR.* Bristol: Environment Agency July 2005. ISBN Number 1844324591

This document was withdrawn on 6 November 2017

Impact of Groundwater Abstraction on River Flows (IGARF)

This document was withdrawn on 6 November 2017

Summary

Type of system where applied
Rivers.

Applicability to groundwater or surface water
To assess streamflow depletion impacts groundwater abstractions (including the length of river reach over which the impact may be spread, and the timing of the impact for 1 or 2 river systems).

Hydrological data requirements
Conceptual understanding of relationship between abstraction ('source'), aquifer and drift layering ('pathway') and river ('target'). Hydraulic parameters for predictive impact analysis (aquifer and aquifer-river), currently licensed groundwater abstraction locations (relative to the river), pumping rates (licensed and recent actual) and seasonal pumping profiles.

Ecological data requirements
None as such BUT can use the resulting impact estimates within the RAM framework in order to compare flows against ecologically based river flow objectives.

Can method be used on its own?
Must have a conceptual model first (part of IGARF guidance). Also groundwater abstraction impacts are unlikely to be the only influences on river flows (discharges, surface water abstractions etc.) so likely to be used in combination with the RAM Framework, unless it is to specify pumping tests as part of a new licence application (one of the purposes for which it was designed). If the abstraction is reasonably constant with time, there may be little to be gained in applying the IGARF spreadsheet analysis for the temporal re-distribution of seasonal abstraction stress. Always seek to back up any flow depletion predictions with evidence on the impacts to changes in historical groundwater abstraction rate.

Applicability to European interest features
IGARF is a programme of research led by the Environment Agency's Science Group which emphasises conceptual understanding first but includes some analytical spreadsheet solutions. As such it can be applied to any groundwater abstraction (GWABS) – river situation but is usually 'source' focussed, rather than water body focussed.

Resource requirement
Once the conceptual, abstraction and aquifer parameter information have been collated, simple flow depletion impact assessments for single sources may take minutes. However combining analyses for multiple boreholes on a river together with other flow influences could take much longer.

Figure 1 shows how the IGARF spreadsheets can be used to predict the length of river reach over which groundwater abstraction stream flow depletion impacts may be spread.

Background

The Environment Agency's Science Group has been running a programme of research into methods for understanding and predicting the Impacts of Groundwater Abstractions on River Flows ('IGARF'). These methods may be useful when considering groundwater dominated riverine sites.

Method description

The IGARF user manual emphasises the importance of establishing a good conceptual understanding upon which any impact predictions can be based (conceptual understanding for Habitats Directive purposes is considered in a separate summary sheet). A number of spreadsheet-based tools are also provided which enable the user to:

- Estimate how streamflow depletion impacts might be expected to develop in response to switching on abstraction (based on abstraction rate, distance to the river, aquifer parameters and river bed properties). This may be helpful in considering the design/duration required for a pumping test which aims to investigate stream flow depletion impacts.
- Estimate the profile of streamflow depletion upstream and downstream of the point of abstraction i.e. the length of reach over which the impact is spread (as shown in the Fig 1).

- Estimate the average monthly profile of streamflow depletion impacts, given an average monthly profile of abstraction. This may be helpful for considering the long term typical pattern of river flow depletion in response to a groundwater abstraction which is markedly seasonal in character (e.g. spray irrigation). However, the analysis is less worthwhile for abstractions which continue throughout the year at reasonably steady rates (e.g. many public water supply boreholes).
- Estimate the spatial distribution of impacts from one borehole on two or more river reaches, based on their distance, aquifer and river bed properties.

Use

IGARF approaches may form part of a Review of Consents assessment for a groundwater riverine habitat, particularly if it is influenced by strongly seasonal groundwater abstractions. Other techniques will also be required in order to account for other influences on river flows – IGARF may, for example, be used to define groundwater abstraction impacts as an input to a RAM Framework based assessment (described on a separate summary sheet). The IGARF analytically based spreadsheet tools should be applied with particular caution in hydrogeological situations where the characteristics of groundwater flow or groundwater – surface water interaction vary through the year (e.g. chalk winterbournes). If groundwater abstraction impacts are important in these or other hydrogeologically complex situations, it may be more appropriate to consider distributed groundwater modelling.

Further information

IGARF User Manual (Environment Agency Science Group).

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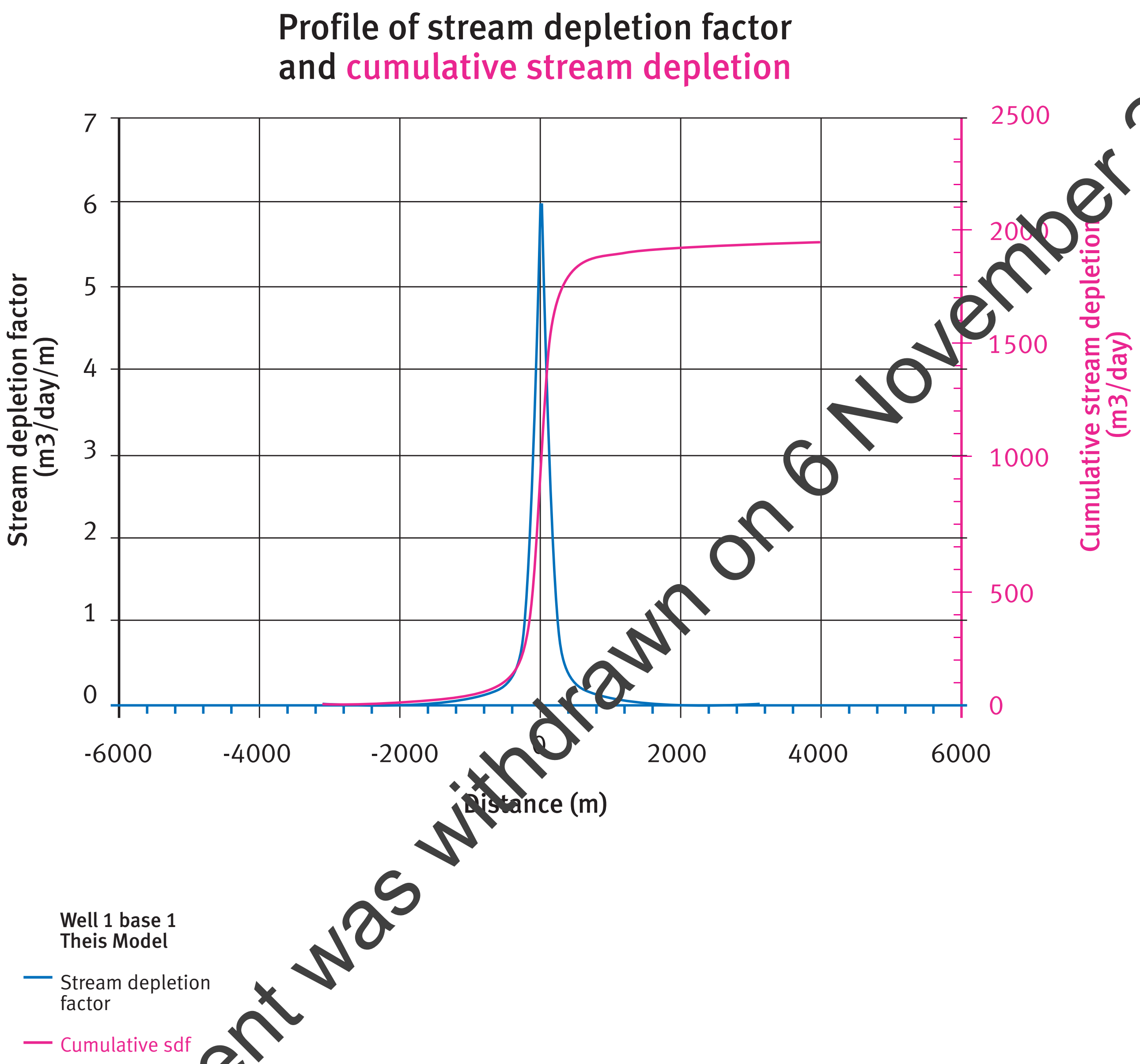
Figure 1 Example of output from IGARF spreadsheets: Analytical prediction of stream flow depletion profile associated with a groundwater abstraction



This document was withdrawn on 6 November 2017

Licence Accumulation Diagram (LAD)

Summary

Type of system where applied
Rivers, Lakes and Wetland.

Applicability to groundwater or surface water
Surface water and groundwater.

Hydrological data requirements
Estimates of the currently licensed abstraction impacts (e.g. groundwater level drawdown or flow reduction) on a water body.

Ecological data requirements
None as such BUT can usefully add an indicative hydro-ecological sensitivity or hydrologically significant threshold (HST).

Can method be used on its own?
Useful screening technique to identify total cumulative 'in combination' abstraction impacts, and the individual licences contributing to this total, ranked according to the size of the impact or the date of issue of the abstraction licence.

Applicability to European interest features
A standard hydrological technique which can be applied to any site.

Resource requirement
Once the impacts have been derived, a 'LAD' can be quickly put together in a spreadsheet, whether or not a HST has been determined.

Background

License Accumulation Diagrams (LADs) are graphical presentations of abstraction licence impacts – either groundwater level drawdown or flow reduction impacts. They can be prepared either for a wetland site (usually based on drawdown estimates from all surrounding groundwater abstractions, as in Figure 1), or for a lake or assessment point on a river (usually based on abstraction related flow depletion estimates from all upstream abstractions).

The LAD shows the impact of each licence individually and 'in combination' with those plotted previously on the diagram. The order in which the licences are presented therefore influences the shape of the LAD although the total impact of all the licences in combination will not change. Licences are commonly ordered either according to the size of impact (smallest ones first, largest last), to focus attention on those having the greatest impact, or according to the date of first issue (first one first, last one last) in order to reflect licensing precedence. Both these types of LAD may be useful when considering appropriate licensing options.

A 'Hydrological Significance Threshold' (HST) can be included on the LAD in order to highlight those licences which exceed this threshold, either individually or in combination, to provide a focus for further stages of impact assessment. Also, a 'triviality threshold' can be included to identify licences that can be excluded from further assessment due to the trivial nature of their individual impact. It is important to obtain agreement with our own technical staff and those from partner organisations on any thresholds that are used.

Method description

1. Carry out individual impact assessments for ALL licences relevant to the site (e.g. drawdown or flow reduction). When applying to flow impacts on a river assessment point take care to adopt appropriate consumptiveness assumptions and to make some allowance for the return of other discharges (e.g. sewage treatment works) which are also upstream.

2. Copy these results into a spreadsheet and sort according to size of impact on one sheet, and date of first issue on a second sheet.

3. Calculate cumulative impacts for both sheets and plot these, together with individual impacts as stacked bar plots (see illustration).

4. Add an agreed HST if available e.g. 5 cm drawdown has been used as a Stage 2 HST for groundwater fed wetlands in East Anglia.

5. If needed, add an agreed 'triviality' threshold e.g. 1mm drawdown has been used as a triviality threshold for groundwater fed sites in East Anglia.

Figure 1 shows a LAD for licensed drawdown impacts predicted at a wetland due to the licensed abstractions around it sorted according to the size of the predicted impact.

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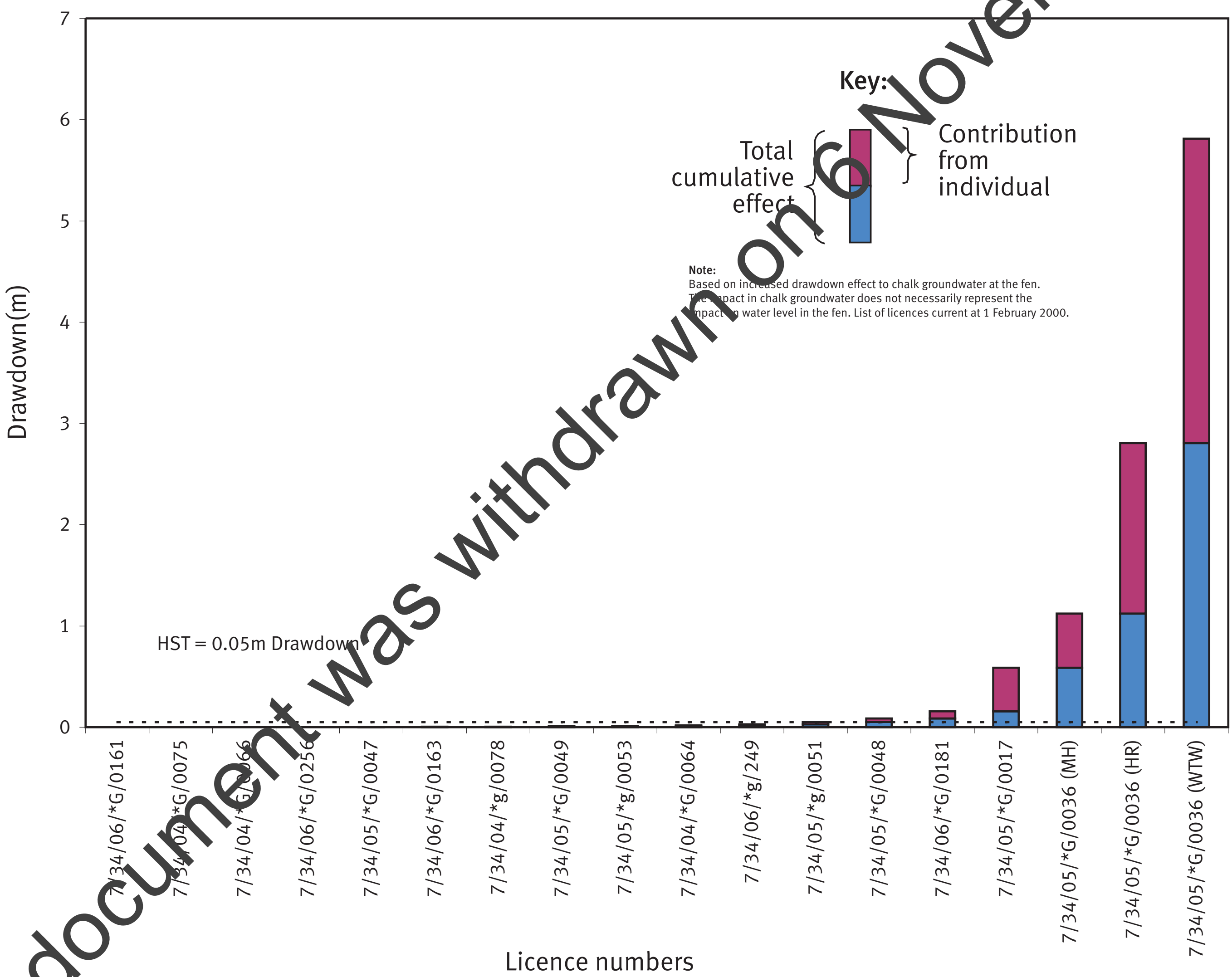
Uses

From the description above, LADs can be seen to provide a useful and comprehensive representation of licensed abstraction impacts for the purposes of screening and prioritisation.

Figure 1 Licence Accumulation Diagram of licenced abstraction drawdown impacts at a wetland based on a single layer analytical model



This document was withdrawn on 6 November 2017

Flow naturalisation

This document was withdrawn on 6 November 2017

Summary

Type of regime where applied
Mainly riverine or estuarine. Consider also for assessment of inflows to reservoirs/lakes, embayments and natural or artificial flood washlands.

Applicability to groundwater or surface waters
The technique is intended to evaluate naturalised river flow but requires both surface and groundwater influences to be taken into account.

Hydrological data Requirements
Gauged river flows. Surface and groundwater abstractions (both licensed and non-licensed). Surface and groundwater discharges (both consented and non-consented). Major impoundment operations.

Ecological data Requirements
None.

Can method be used on its own?
Yes this can be a stand alone process but is of little value in Review of Consents (RoC) unless incorporated with another application such as the Resource Assessment & Management (RAM) framework.

Applicability to European interest features
Interest features associated with regimes identified above.

Resource requirement
Depends upon level of flow naturalisation undertaken. Naturalised flows provide a benchmark and estimate of the natural flow regime. The methodology involves modifying a measured flow sequence by removing the impact of Artificial Influences (AI); these are impoundments, abstractions and discharges.

Overview

The effort applied to flow naturalisation can be dependent upon the specific application and the time/budget available for undertaking such assessments.

There are 5 stages for flow naturalisation:
Firstly, the flow sequence that is being naturalised should be assessed to determine whether it is of sufficient quality. If the data is of a poor quality then the naturalised time series may not be reliable, or fit for purpose. If observed data is not available and modelled data is used then an assessment of quality should also be carried out.

The flow record is then assessed to determine whether it is significantly influenced. If not significantly influenced then it may not be necessary to undertake any further work.

The next step is to develop an understanding of the nature and scale of the AI in the catchment. An understanding of the balance of AI in the catchment will identify those where further investigation is required. AI which have the dominant impact on the estimated natural flow will add to uncertainty.

Actual AI data is required for the timestep (daily or monthly) and time period that is being assessed. Where this is not available for specific abstractions, discharges and impoundments then estimates are made. These can be derived by applying average monthly usage profiles or using data from similar AI nearby.

The impact of the AIs on the final naturalised flow record is assessed at the next stage. The impact of each AI on the nearest river reach is also assessed to ensure that local impacts are sensible.

At this point the following data will now be available:

- An observed flow time series
- A time series of abstraction
- A time series of discharge

Naturalisation is now a simple arithmetical process.

Uses

Flow naturalisation enables the naturalised and actual (influenced) river flow regime to be compared and therefore the quantitative impact of different consents to be assessed. This is fundamental to the Review of Consents (RoC) assessments. During such assessments it may be necessary to examine the potential influence of AIs on the river flow by considering full licensed quantities rather than actual abstraction regimes. This approach is implicit in the RAM framework.

Additional information

Environment Agency, National Hydrology Group; *Good practice in flow naturalisation by decomposition (Version 2)*; April 2001 (Revised 15 June 2001).

Environment Agency, *Toolkit for flow naturalisation V1.0*; December 2005

Environment Agency, Anglian Region; Regional Good Practice Guideline; *The use of artificial influence data in flow naturalisation*; (undated).

Environment Agency, Midlands Region; *A guide to flow naturalisation (Version 3)*; September 1997.

Environment Agency, R&D; *A review of techniques of applied hydrology in low flow investigations; Technical report W6-057/TR; Sheet 12 – flow naturalisation*; W S Atkins; 2001.

This document was withdrawn on 6 November 2017

Low Flows 2000

Summary

Type of regime where applied
Riverine or Estuarine. Consider also for assessment of inflow regimes to Reservoirs/Lakes, Embayments and natural or artificial Flood Washlands.

Applicability to groundwater or surface waters
The technique is intended to estimate natural (and influenced) river flow statistics for ungauged catchments (or catchments with relatively limited gauging records).

Hydrological data requirements
Low Flows 2000 (LF2000) can be run by nominating a point on a GIS map or specifying a grid reference. The data underlying the system enabling estimates of natural flow include a digital terrain model, gridded hydrometeorological data, HOST soil class data and river network data. In order to generate influence data abstraction, discharge and impoundment data need to be added.

Ecological data requirements
None.

Can method be used on its own?
Yes this can be a stand alone process but is of little value in RoC unless undertaken to aid hydrological characterisation or impact assessment potentially required in the RoC process.

Applicability to European interest features
Interest Features associated with regimes identified above.

Resource requirement
Low Flows 2000 (LF2000) is the Environment Agency's standard methodology for estimating flow statistics at ungauged (or partially gauged) catchments enabling:

- Estimation of natural flow statistics for ungauged catchments (or catchments with very limited flow data availability);
- Estimation of the impact on flow estimates (from abstraction, discharge and impoundment activities). The impact on flows arising from such activities are commonly referred to as influences; and
- LF2000 has an extensive application throughout the Environment Agency as a means of estimating natural flow statistics for ungauged catchments. The comparable use for estimating influences on flow statistics throughout the Environment Agency is significantly less due to the need to first populate the system with artificial influence data.

Background

LF2000 was developed by the Centre for Ecology & Hydrology (CEH) for the estimation of flow statistics for ungauged catchments (or catchments with limited flow records) throughout England and Wales. The present system succeeds the Micro Low Flows V2.1 system developed by the Institute of Hydrology (component predecessor to CEH) and is the result of a joint R&D project between CEH and the Environment Agency. The system relies upon the development of the Region of Influence approach. This approach involves the derivation of catchment characteristics for the study catchment and relating these to 10 selected catchments for which natural (or near natural) statistical flow data are held within the LF2000 system and which possess the most similar set of characteristics. Estimates of flow statistics for the study catchment are then generated using a weighted assessment of flow statistics for the 10 selected (similar) catchments with the weighting allowing greater emphasis for those selected catchments which have the most similar characteristics to the study catchment.

In order to generate estimates of natural flow statistics the system is highly automated enabling natural flow statistics to be formulated very readily for any location in England and Wales on the 1:50 000 river network. The potential output is generated, with reference to discretised or mapped physical and hydrometeorological data (used to derive the catchment characteristics), on both an annual and individual monthly basis including:

- Mean flow; and
- Flow duration (percentile exceedence) values.

Standard output from LF 2000 includes;

- mapped generation of the catchment boundary and the relevant river network (which can be exported to ArcView);
- mapped generation of influence locations such as abstractions and impoundments (which can be exported to Arcview);
- tabular listings of standard physical and

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hydrometeorological parameter values (catchment characteristics) for the study catchment;
- plus generation of residual flow diagrams for any nominated stretch of river. Imminent enhancements of the system will allow this facility to be exported to ArcView.

If available flow data for study catchments includes a spot flow or a short gauged flow record these data can readily be compared with LF2000 output.

Incorporation of influence data for abstractions and discharges into LF 2000 can be quite time consuming if undertaken rigorously. The main driver within the Environment Agency giving rise to the systematic incorporation of influence data for catchments is the Catchment Abstraction Management System (CAMS) programme LF2000 output incorporating effects from influences includes:

- Modified mean flow (both annual and individual monthly).
- Flow duration values (both annual and monthly).
- Naturalised and Influenced longitudinal flow accretion diagrams representing a particular statistical flow condition such as the Q95 (the estimated flow exceeded for 95% of the time).

Strengths

The main strengths of LF2000 in the application of estimating natural flow statistics for ungauged catchments include:

- The available system is based on 'best practice' and forms the Environment Agency's standard method for statistical flow estimation in ungauged catchments with development fully supported by CEH;
- LF2000 benefits from a progressive evolution and benefits from considerable expertise held by CEH;
- A simple, extensive and efficient user interface, GIS based and compatible with other Environment Agency standard packages such as Excel, Word and ArcView;
- Extensive use across the Environment Agency and in particular for routine applications concerning abstraction licencing and discharge consenting assessments;
- The system benefits from extensive documentation and knowledge regarding strengths and weaknesses;
- Following initial investment in acquiring the system it's efficient user friendly interface leads to extensive use which makes it relatively cheap in the long term; and
- Wide use of the system means that a consistent approach is adopted throughout the Environment Agency.

Potentially, the strengths of utilising the LF2000 routines for estimating influenced flows are comparable to those for natural flow estimation but adoption of this component within the system has been much more patchy although it has been tied in with the CAMS priorities.

Weaknesses

The main weaknesses of using LF2000 for estimation of natural flow regimes are that:

- It is only possible to generate set statistical flow values and not a complete time series simulation of flow (as a hydrograph).
- There are serious some questionmarks regarding the reliability of low flow estimation (particularly in Chalk and Limestone dominated catchments otherwise the resulting flow statistics produced are generally regarded as reliable.
- There is a need to be vigilant regarding the automatic generation of catchment areas, using the DTM option, and in particular where:
  - drainage systems may be subject to artificial influence (i.e. diversions).
  - the area of interest incorporates low lying/relief zones where watersheds are difficult to depict without specific knowledge.

Where such complications are believed to occur use of the analogue option for catchment delineation may be more appropriate.

Additional weakness considerations with generation/ estimation of influences on flows includes:

- time consuming/onerous to populate the database with data on a rigorous basis.
- no allowance can be routinely made for possible routing processes involving attenuation applicable to non steady state surface water abstractions/ discharges.
- potential questionmarks over the incorporation of groundwater abstractions and their translation into river flow influences including:
  - inadequacies of the Theis-Jenkins technique. Most groundwater abstraction licences will have been loaded using this method, though since version 4.2.1 users can override this with their own calculations.
  - a need to recognise that surface catchment and groundwater capture areas may be quite different and therefore the automatic assignment of groundwater influences generated by LF2000 may require manual editing.

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The rigour with which influences are assigned in a LF2000 application may vary in accordance with the purpose, the nature of the catchment and available time/budget constraints for the study. For example, in a large catchment with a low baseflow index and where the dominant influence on the flow regime is from surface water abstractions there is probably no need to worry about variations between the surface catchment and groundwater capture zones or the translation of groundwater abstractions into impacts on river flow.

Uses

LF2000 is a very efficient system for generating estimates of natural flow statistics for an ungauged catchment (or catchment with very limited records). The method has widespread application across the Environment Agency. Output can be used to help inform hydrological characterisation and impact assessment for those sites involved in the RoC (or similar) process where inflows from a river system may be of significance such as in riverine, estuarine and controlled washland sub-domains as well as river fed lake/reservoir systems. Care should be exercised in generation/use of resulting output from groundwater dominated catchments (particularly incorporating Chalk or Limestone aquifers). Vetting of output by Area based Hydrologists/ Hydrogeologists is recommended and use of output should generally be limited to initial screening, and conservatively based, applications for the RoC.

LF2000 can also be used efficiently as a basis for scaling naturalised flows (derived from gauged records and incorporating removal of influence effects) for a gauged location to a non gauged location elsewhere within the same catchment. The process suggested involves:

- generating estimates of flows, covering a range of standard percentile exceedence values, for both the gauged and non gauged location of interest using LF 2000;
- normalising these estimated flows from cumecs to equivalent yield (l/s/km2);
- developing a variable conversion factor based on combining the ratios of both catchment area and normalised flow (equivalent yield) estimates to generate a factor which varies with flow percentile exceedence. A possible approach for this application is given in Ref 1;
- In general, LF2000 should be considered for RoC in study catchments where;
- the relevant database has already been populated with influence data for a CAMS (or other) study;
- the inflowing river to a site is ungauged and of relatively small proportions; and
- the river system is not baseflow dominated and influences on the river are predominantly from surface water abstractions (and/or discharges). Alternatively, in groundwater dominated catchments where influences are predominantly from groundwater abstractions an alternative, more conceptually based, approach is suggested possibly using IGARF (see the alternative Method Summary).

If the study requirement necessitates an assessment using time-series rather than statistical flow summaries then an alternative method is required enabling the natural riverflow for the river system to be simulated (see alternative Method Summary on Rainfall-Runoff Modelling).

Data requirements

Standard application of LF2000 for generation of natural flow estimates requires no data as the requisite needs are all integrated into the system. For study catchments including spot flow or short gauged records LF2000 can be populated with these data to enable comparisons between selective output and available data.

Utilisation of the influence procedures within LF2000 requires abstractions, discharges and impoundments data to be populated and routines have been developed enabling the automatic transfer of abstraction licence data and discharge consent data from standard output of the Environment Agency's NALD and WIMS respectively. However, this process is not straightforward and is likely to be time consuming for any significant catchment application although in some instances these data have already been incorporated particularly under the CAMS programme.

Applicability

LF2000 may provide useful output to aid RoC assessments particularly involving riverine and estuarine regimes and possibly involving shallow tidal embayments, reservoirs/lakes and natural/controlled flood washlands.

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Further information

Ref 1; 'Lookup details on *LF2000 scaling*'; Environment Agency – Anglian Region; Flow Institute of Hydrology; Low Flow Studies Report; 1980.

Institute of Hydrology; Low Flow Estimation in the United Kingdom; Report 108; 1992.

Environment Agency Internal Guideline; Implementation of Low Flows 2000 within the EA; (undated).

Centre for Ecology & Hydrology; Low Flows 2000; Quick Reference Notes 1 to 5; Various.
Note; further information on LF2000 is available to Environment Agency staff through the Intranet service under Solutions.

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Macro-invertebrate biotic indices

This document was withdrawn on 6 November 2017

Summary

Type of system where applied
Riverine.

Applicability to groundwater or surface water
Primarily surface water, but can be used to measure groundwater impacts.

Hydrological data requirements
Yes – Can be linked to gauged or modelled flow data.

Ecological data requirements
Possible to generate predictive data, but most useful when comparing actual data gathered through field survey. Most valuable comparison is observed long term data with historic flows.

Can method be used on its own?
Yes – possible to use the method in a variety of different ways to evaluate impacts. May need to be correlated to water quality, flow or RHS data to explain patterns due to low flow, quality or habitat impacts.

Applicability to European interest features
Only those associated with riverine systems. Useful for site characterisation and for defining the general sensitivity/status of the site in question.

Resource requirement
Time consuming, requiring data collection and processing. However, extensive data should already have been collected through water quality/water resource monitoring on riverine sites, so resource requirements may be reduced.

The scoring or ranking of macro-invertebrate assemblages on the basis of their sensitivity to changes in the environment, provides a useful means of identifying or predicting the effects of environmental stress. Biotic indices, such as River Habitat Survey (RHS), provide a useful means of identifying the effect of low flows on invertebrate communities. Other indices such as Biological Monitoring Working Party (BMWP) score or Average Score Per Taxa (ASPT) are primarily designed to assess organic pollution in a river, although these indices may also respond to flow variation.

Abstraction may impact on the macro-invertebrate community by reducing the dilution of pollutants, or by affecting the flow regime. Both changes can be assessed using macro-invertebrate indexing methods. Low flows, either as a result of abstraction or natural drought, cause habitat change through reductions in water depth, exposure of margins or midchannel habitats, and silt deposition. There may also be a decline in water quality though increased temperature, decreased dissolved oxygen and increased concentrations of pollutants. Changes in flow may also impact directly on flow-sensitive species, leading to changes in species diversity at a site. Engineered modification of riverine habitats may also adversely affect the colonising macroinvertebrate fauna and alter the natural response of this community to changes in flow.

Introduction

Benthic macro-invertebrates are widely regarded as the preferred group for assessing water quality. Sampling procedures for this group are well developed and there is a range of detailed identification keys available for most taxonomic groups. Most macro-invertebrates are relatively sedentary and exhibit a variety of different tolerances to environmental conditions, which means that they can be used to locally monitor environmental change over time.

Many macro-invertebrate species show a clumped distribution across a site in relation to the distribution of meso-habitats. Standard sampling techniques have been designed to compensate for this distribution, by covering all meso-habitats present and sampling each habitat present with an effort that is proportional to its occurrence. Consequently a single sampling technique usually provides a representative sample for a site.

A variety of sampling techniques are employed for collecting macro-invertebrates, the most widely used being the 'kick sample' using a hand net. Other techniques include benthic grabs, emergence traps and drift samplers. The last three methods are highly species/habitat specific and are not designed for general macro-invertebrate sampling. Further information on standard Environment Agency sampling techniques can be obtained from *Procedure for collecting and analysing river macro invertebrate samples,* Report no. BT001, Issue 2.0, (Environment Agency, 1999).

Method description

A number of biotic indices have been developed to assess water quality, which are based on the number and sensitivity of different macro-invertebrate taxa. In the UK the most widely used of these indices is the BMWP score. This scores each macro-invertebrate family present between 1 and 10, depending upon their perceived susceptibility to organic pollution. The most sensitive families, for example mayflies and stoneflies, are given the highest scores. The BMWP score is the total score for all families present in a sample.

If this score is divided by the total number of BMWP scoring taxa present in a sample, the Average Score Per Taxon (ASPT) is calculated. The ASPT has been found to be less influenced by the season or sample size than the BMWP score, and consequently provides a better indicator of water quality over a wide range of conditions. BMWP, and to a lesser extent ASPT, are influenced by habitat quality, and therefore this must be considered within any interpretation.

River Invertebrate Prediction And Classification System (RIVPACS) has been developed to evaluate environmental stress (water quality) as reflected in invertebrate communities. RIVPACS has two distinct components:

1. It offers site-specific predictions of the macro-invertebrate fauna based on environmental features and provides an indication of the fauna that might be expected at a site in the absence of environmental stress (comparison of the 'expected' fauna with the fauna observed at a site is the basis for a biological assessment);

2. It includes a system for locating sites of high biological quality within a national classification of sites, using macro-invertebrates.

The prediction system is built on a classification of running water sites. There are 35 classification groups based on the macro-invertebrate fauna recorded at 614 high quality reference sites distributed throughout Great Britain. A total of 637 macroinvertebrate taxa have been recorded at the reference sites. New sites of high biological quality can be placed within the existing site classification.

A recent development in the use of macro-invertebrate assemblages to monitor environmental change, is the development of the Lotic-invertebrate Index for Flow Evaluation (LIFE) methodology. Different taxa have been shown to have different flow sensitivities, which are categorised as follows:

I Rapid
II Moderate/fast
III Slow/sluggish
IV Flowing/standing
V Standing
VI Drought resistant

(Note ; Flow is used in the hydrological sense, to refer to river discharge, measured in volume/time. The LIFE score flow group weightings relate to perceived sensitivity to high/low velocity and silt/coarse substrata. In-river velocity is a product of both flow (discharge) and channel structure/habitat)

The index additionally considers the relative abundance of individual taxa, thus for a given site flow scores for the represented taxa are combined to produce an overall weighted average (the LIFE score). Higher antecedal flows produce higher LIFE scores.

RIVPACS predictions, alongside historic observed data, provide a means of both classifying the sensitivity of a site and standardising hydroecological information by means of observed to expected LIFE ratios. The analysis of LIFE against gauged flow data, provide a means of assessing a site over time and inferring the impact of low flows.

In addition, multivariate analysis tools may be used in ecological studies to provide a highly valuable way of linking observed changes in communities (either spatially or temporally) with environmental trends, where historic data exists or where large data sets have been collated.

Sensitivity

Aquatic invertebrates provide an extremely useful indicator of water quality and water quantity. Habitat quality can be inferred from biotic scores, but indices are not typically used as a habitat indicator. However, care needs to taken when using biotic indices as they may reflect the effect of a number of influences. For example an upland site may yield a low ASPT score because of a recent reduction in water quality (which may be linked to low flow) or because substrate compaction has occurred or a combination of the two. LIFE scores are a little bit more robust, but care also needs to be adopted when assessing data generated in this way. Consequently biotic indices may need to be considered with water quality, water quantity and RHS data when assessing cause and effect mechanisms.

In this context, recent work by CEH (Dunbar et al 2006) has shown strong links between habitat modification and LIFE score, with more modified sites having lower

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LIFE scores and a steeper slope of response of LIFE to flow. These findings may have far reaching implications for river management in the future.

LIFE scores are a key element of the Environmental Weighting component of the Resource Assessment and Management Framework. It may therefore follow that RAM is a useful tool to use alongside macro-invertebrate data.

Care needs to be taken when interpreting macro-invertebrate data, as at some sites the macroinvertebrate community appears to respond to the previous years summer flow and not the current year.

Application

As previously discussed, the relatively sedentary nature of benthic macro-invertebrates and the fact that they are sensitive to changes in environmental quality, mean that they are useful ecological indicators. The frequency at which the Environment Agency collects invertebrate samples means that data can only be used to detect trends over relatively long timescales, i.e. year on year and seasonal trends. Extensive historic data generally exists and can be used to assess the impact of low flows/abstraction.

As noted, LIFE scores may be used, in combination with other indices, to examine the effects of flow changes on the macro-invertebrate assemblage. RIVPACS allows predicted LIFE scores to be generated for sites based on certain morphological characteristics. Although these predictions should be treated with caution, they do provide a useful mechanism for assessing the effects of proposed abstractions, and the review of existing consents and authorisations.

This document was withdrawn on 6 November 2017

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MORECS/MOSES

Summary

Type of system where applied
All water body types (river catchments, lakes and wetlands).

Applicability to groundwater or surface water
Surface water and groundwater.

Standard applications
Site or catchment water balance assessments. Input time series or starting conditions for hydrological modelling (e.g. recharge or rainfall runoff models).

Ecological data requirements
None as such BUT can use the resulting impact estimates within the RAM framework in order to compare flows against ecologically based river flow objectives.

Applicability to European interest features
Interest features associated with regimes identified above.

Resource requirement
Standard outputs are available so resource requirements are minimal.

MORECS

MORECS (the Meteorological Office Rainfall and Evaporation Calculation System) operates on a 40 km grid square basis across the UK. The model runs on a daily timestep to produce weekly and monthly estimates of a number of water balance components (e.g. rainfall, actual evaporation, effective rainfall).

Climatic information from a network of stations is used to calculate potential evaporation (PE) including; sunshine; temperature; wind speed; vapour pressure; and albedo (which varies for different vegetation/land type). The Penman – Montieth Soil Extraction Model is then used to calculate actual evaporation for three broad classes of soil type (High, Medium and Low Water Availability) and a wide range of different crop types (including bare soil).

A wide variation of outputs are available from the MORECS model covering three soil types and a variety of vegetation and land use types. Of particular use are outputs for Grass and Real Land Use. The main outputs are:

- Soil Moisture Deficit (SMD), an indicator of the dryness of the soil at 09:00 on each day
- Actual Evaporation (AE)
- Hydrologically Effective Rainfall (HER) or Effective Rainfall (ER)

Data is calculated from 1961 to present.

MOSES

MOSES (Met. Office Surface Exchange Scheme) operates on a 5 km grid square basis across the UK and western Europe at an hourly timestep. The inputs are direct from the Met Office's Numerical Weather Prediction (NWP) model. Radar rainfall and other remotely sensed inputs are used instead of climate station data. The MOSES model is considered state of the art by the Met Office and will eventually replace MORECS.

A vast range of products are available from the MOSES model at an hourly and daily resolution. These include snow melt, actual evaporation and subsurface runoff for example. Soil Moisture Deficit is available but is not an explicit output from the MOSES model.

The Met Office has been running the MOSES model for a couple of years but it is not yet a commercially available product as MORECS currently is.

Outputs for the MOSES and MORECS models are not directly comparable given the inherent differences in model formulation, input datasets and the spatial and temporal resolutions.

Uses of MORECS/MOSES data

Uses of the MORECS/MOSES data are outlined below;

- As a broad estimate of ER inputs to a wetland site. This may need to be revised to account for local variations in rainfall as a result of topographical considerations.
- To assess evaporation demands (open water and specific land use) on a site, which can be compared with estimates of inflow (from surface or groundwater). The data can then be used to assess whether the site has the potential to become stressed in water balance terms.
- As an input into a rainfall runoff model. PE data and locally derived rainfall estimates can be used in the model to estimate river flow, rapid runoff, interflow and recharge to groundwater.
- As a direct input into a soil moisture / recharge model to calculate ER for use with groundwater models.

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This document was withdrawn on 6 November 2017

Rainfall – runoff modelling

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Summary

Type of system where applied
River catchments, inflows to lakes or online reservoirs and freshwater inputs to estuaries.

Applicability to groundwater or surface water
Surface water and groundwater where the requirement is to produce time series for a aquifer unit (effective rainfall) or catchment (river flow). Some models can produce recharge and baseflow time series. Where information is required on flows and levels over a wider area a distributed approach may be required. Please refer to the *Method Summary for Distributed Groundwater Modelling*.

Hydrological data requirements
The inputs to rainfall runoff models are time series (areally averaged or spatially distributed) of:

- Precipitation
- Potential Evaporation.

Other input time series can include:

- Abstractions (surface & groundwater)
- Discharges (surface & groundwater)
- Observed flow at calibration point(s).

Calibration parameters can be based upon physical characteristics of the following:

- Catchment Area
- Land Use types
- Soils
- Geology
- Topography
- Channel characteristics.

The type of model will determine the scale at which this information is used.

Ecological data requirements
None.

Can method be used on its own?
Yes, to assess/illustrate the inputs, outputs and storage changes in the water body. This assessment needs to be combined with an ecological assessment to determine whether changes in any of the water balance components impact on the ecological feature at the site.

Applicability to European interest features
Interest Features associated with regimes identified above.

Resource requirement
Depends upon nature and complexity of modelling undertaken.

Uses of rainfall runoff modelling
Rainfall runoff models are used by hydrologists, water resource planners, engineers and others *(CATCHMOD, Conceptual Rainfall Runoff Model, Technical User Guide & Software Manual for Catchod v4.03, Environment Agency, 2005)* to:

- extend existing time-series flow records (backwards or forwards in time) to include historic periods of drought or flooding, or bring a closed gauging station record up to date;
- infill gaps where part of a gauging station record is unavailable, due to performance or data transfer problems or temporary closure eg during refurbishment;
- estimate time-series flow data at ungauged sites, if flow estimates for calibration data can be made with confidence;
- estimate natural flows at gauged artificially-influenced sites, by calibrating the model with observed surface and groundwater abstractions and discharges;
- provide recharge time series for groundwater models.

Natural or artificially-influenced river flows, whether simulated or measured or a combination, are used for a variety of applications (*CATCHMOD, Conceptual Rainfall Runoff Model, Technical User Guide & Software Manual for Catchod v4.03,* Enviroment Agency, 2005) to:

- assess the impact of existing or proposed individual abstractions or discharges on river flow;
- assess the impact of different potential abstraction or discharge regimes;
- set abstraction licensing policies (through the Environment Agency's Catchment Abstraction Management Strategies – CAMS);
- estimate natural time-series of flow at a gauged location and transpose to ungauged locations;
- assess how water resource systems (surface and groundwater abstractions and reservoir control operations) behave under historic drought or flood conditions – to plan to meet water resource demands and set or amend the complex flow-dependent control conditions;
- forecast future water resource availability under different rainfall scenarios e.g. the impact of 60% rainfall over the next 6 months on river flow;

- assess the potential impact of climate change on rivers and reservoir inflow sequences e.g. using factors to produce scenario rainfall and PE series;
- calibrate real-time flood forecasting models off-line;
- calibrate flood estimates (flow and volume) feeding flood inundation and impact design studies (e.g. 100-year flood mapping);
- feed water quality and ecological impact assessments and policy making.

The use of rainfall runoff models needs to be proportionate to the objectives of the project, in some cases a more complex approach may be needed while in others a simpler approach could be used.

Types of rainfall runoff model

In general rainfall runoff models used in water resources fall into two broad conceptual categories:

- 'Lumped' Models;
- 'Distributed component' Models.

Single event models and linear transfer models have not been included in this document but are used in conjunction with the types of model above in flood risk management.

'Lumped' Models

'Lumped' Models generally incorporate a number of stores and functions to represent movement of water into, through and out of a catchment. Typically, storage fluxes may be estimated for the soil zone(s) and a number of groundwater zones. The total modelled hydrograph, depending on the model can be divided into different types of response, typically baseflow, inter-flow and rapid runoff.

Some of the main models commonly used in water resources include:

CATCHMOD: This is the Environment Agency's rainfall runoff model and currently the most used within water resources. Its main features are that the model:

- uses 3 conceptual stores representing soil moisture, upper and lower catchment storage;
- has a hydrological zone structure which allows the model to be run in parallel on up to 10 hydrologically similar zones (based on geology, topography or land use). Individual zones are summed to give total flow. The individual calibration of the zones allows water to pass through the stores at different rates;
- has a simple structure with only 5 physically-meaningful parameters per hydrological zone, with consistent meanings between zones. This makes the model easy to understand and restrict parameters to realistic values;
- is applicable to both baseflow dominated and flashy response catchments;
- can include abstractions from groundwater and river sources, and discharges to river;
- Rainfall, PE and artificial influence inputs may be zone-specific or common;
- Can be run at daily, hourly or 15 minute time intervals;
- has an optional channel routing (translation and attenuation) module for sub-daily mode.
- Does not allow auto-calibration of parameters to ensure user understanding and parameter realism, but manual changes are easily and rapidly implemented;

The model is available as an Excel spreadsheet to third parties to purchase from the Environment Agency.

HYSIM (Hydrological Simulation Model): This model was originally developed by Ron Manley and Severn Trent Water Authority. HYSIM incorporates a five store model which enables the combination of rapid runoff, interflow and baseflow components. The model uses 22 parameters, which can be automatically optimised. It also facilitates routing and can be undertaken for conventional and ponded river channels as well as impounded reservoirs. Large river basins can be divided into sub-catchments. The model is no longer widely used in the Environment Agency. If you wish to use this model, please contact the Water Resources Helpdesk so that the Hydrology and Hydrometry Policy team can discuss your needs.

IHACRES (Identification of unit Hydrographs And Component flows from Rainfall, Evaporation and Streamflow data): This is an Australian model which can produce both rapid and slow response components. The model is not widely used in the Environment Agency. If you wish to use this model, please contact the Water Resources Helpdesk so that the Hydrology and Hydrometry Policy team can discuss your needs.

MIKE-11 Rainfall-Runoff module: This model utilises four stores to represent responses from snow, the surface, the root zone and groundwater. It can model artificial influences and sub catchments. The model is relatively data and parameter intensive and cannot be used without other MIKE-11 modules. There is a perception that the model does perform well in groundwater dominated catchments with both high and variable aquifer transmissivities. Transmissibility is the rate of flow of water through the aquifer. MIKE 11 is not widely used in water resources but it is used in a small number of catchments in Anglian Region for flood forecasting.

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Additional models, such as the Stanford Watershed Model and the HEC HMS Model are available but are not used within the Environment Agency.

'Distributed Component' Models
These models describe each component of the hydrological cycle through complex mathematical equations. They are more resource intensive than 'lumped' models in terms of data requirements and the ability to successfully calibrate them. They require time series input data and calibration parameters for each grid point of the model, which can have a significant number of nodes on the finer gridded models. These models may be appropriate for certain designated sites where water movement is very complex but rely on the development of a conceptual understanding of the site through water balance assessments. It may also be appropriate to consider hydraulic models (ISIS, MIKE11 or more complex 2D and 3D models) in these terms.

MIKE-SHE: Developed by the Danish Hydraulic Institute, this model provides a very detailed 'physically' based hydrological modelling procedure potentially suitable for all types of catchments. The model enables integrated simulations of riverflow, subsurface (saturated and unsaturated) flow and over land flow. These models require a great amount of data input and can be challenging to calibrate.

SHE-TRAN: This model is essentially based on the same prototype as that used to develop

MIKE-SHE and has been further developed by the University of Newcastle Upon Tyne as primarily a research tool.

4R coupled with MODFLOW: MODFLOW is a well recognised and distributed groundwater model code developed by the USGS (US Geological Survey) and used for groundwater resource assessments. 4R is an interface developed by Entec to work in conjunction with MODFLOW. It provides a 'physically' based model for apportioning effective rainfall to rapid runoff, interflow and groundwater recharge (this component provides the recharge input to MODFLOW,) a routing mechanism for integrating runoff, interflow and baseflow (output from MODFLOW) and spatially accreting riverflow.

Modelling Lowland/Ponded River Systems
Special consideration may be required for the modelling of flows in river systems which transect lowlands and are ponded, such as those in the East Anglian fens and Somerset Levels.

These river systems, sometimes referred to as 'Highland Carriers' are usually embanked and held at retention levels. These levels are; invariably higher than surrounding lowland drainage system levels which tend to be pumped; and, much of the surrounding land levels. Along such embanked stretches some degree of seepage is likely to occur and this can be 'lost':

- if the lowland drainage system does not drain to (or is pumped back in) the source river; or,
- in summer, where such leakage may go to meet local 'riparian' demands.

In these circumstances careful selection of a distributed component model or hydraulic model will be required.

Further information

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This document was withdrawn on 6 November 2017

River Habitat Surveys (RHS)

Summary

Type of system where applied
Riverine – headwaters to tidal limit

Applicability to groundwater or surface water
Surface waters only

Hydrological data requirements
None

Ecological data requirements
River bank and channel morphological data collected for 500m reaches together with data on riparian and floodplain land use and map data. Incidental species data also recorded.

Can method be used on its own?
Yes, but best used in association with data collected using other techniques. A national database allows complex assessments to be carried out by comparing data with other sites.

Applicability to European interest features
Applicable for riverine interest features, where it may be possible to identify habitat interactions/relationships.

Resource requirement
The survey takes approximately 1 hour to complete. Rapid data input and standard reports have been developed for easy data extraction. Habitat quality and habitat modification scores are automatically calculated in the database.

River Corridors, which include the river, its banks and the adjacent land, may be surveyed using a variety of different techniques to identify and quantify the habitats that are present. River Habitat Survey is a technique that has been adopted routinely in recent years throughout England, Scotland and Wales. The technique involves the collection of a range of morphological, land use and habitat data along 500 m sections of river, the site data subsequently being compared with a national database comprising data from over 15 000 sites.

The large baseline data set used for carrying out analyses makes RHS an extremely useful evaluation tool. RHS is currently undergoing further development to improve its applicability over a range of functions.

Background

River Habitat Survey (RHS) is a technique used to assess the physical structure of freshwater streams and rivers based on a standard 500 m length sample unit. Although the technique does not require specialist geomorphological or botanical expertise, it does require the consistent recognition of features used in the assessment. For this reason all surveyors have to be accredited if the surveys are carried out for Environment Agency, Natural England, CCW or SEPA, or if the results are to be entered onto the national database.

Method description

RHS involves a walk-over survey of a 500 m section of river bank, recording various bank-side and in-channel habitat features using a standard recording form. At 50 m intervals throughout the survey section 'spot checks' are carried out: each spot check comprises an assessment of flow types, physical features, vegetation structure, land use and vegetation types. There is also an opportunity at the end of the survey to identify any features present that were not picked up during the spot checks. There is also a requirement to record various channel dimensions together with background map-based information.

The National RHS database is a repository of RHS data held by the Environment Agency, comprising more than15 000 sites across the UK. The data in the database can be used to compare habitat parameters from similar rivers nationwide, allowing an assessment to be made of the the habitat quality and habitat modification of a particular river. RHS methods have recently been reviewed and an updated methodology (RHS 2003) is now available.

A complementary module for RHS has been developed to collect detailed geomorphological and floodplain data. The methods for this were finalised in Nov 2005, pilot testing is currently being investigated.

Application

The national RHS database is continuously developing as more and more sites are completed and added to the database. This provides a significant quantity of baseline data from which sitespecific analyses can be made.

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For each river system RHS can be used to carry out an evaluation of habitat suitability for fish communities, using key parameters such as substrate and flow type. Previous analyses have been carried out by the Environment Agency on other river systems, for example the River Lune for salmonid fish. Analyses have also been carried out to identify other habitat associations, such as water vole on the River Arun in Sussex, and a pilot study on coarse fish communities in Midlands.

RHS could be applied to the analysis of habitat quality for any of the species interest features or their individual life stages, in those reaches considered to be affected by water resource operations. Survey data would be gathered for a representative range of sites and the various inchannel features, such as substrate type and flow type, could be compared to reference sites elsewhere within the catchment and nationally. Using these data in combination with ecological survey data, it should be possible to identify:

- optimal habitats for certain species or life stages;
- optimal habitats poorly utilised by certain species or life stages;
- sub-optimal habitat.

Where optimal habitat has been identified which is poorly utilised by a certain species, further investigations may be required to identify the causal factor, e.g. substrate quality or poor water quality.

Habitat Management Tools (HMTs) are in the process of being developed for some riverine Habitats Directive species such as bullhead (Cottus gobio (L.)). HMTs will provide statistical models of habitat suitability for species and communities. The aim will be to characterise habitat requirements of species and communities in terms of measurable parameters from the RHS database, and from expert knowledge derived from literature. They will also help to identify potential pressures acting on species and communities that may lead to a state of unfavourable condition allowing for possible mitigation of these pressures if necessary. Other applications being developed as 'bolt-ons' to RHS include floodplain and geomorphological components to the standard RHS methodology.

Sensitivity

The RHS methodology includes the outline evaluation of various habitat characteristics with a focus on patterns of erosion, deposition and geomorphology. Consequently the methodology can be used to identify the presence of combinations of features that are considered to be desirable for a particular species. However, the methodology is not carried out with sufficient resolution to allow an analysis to be made of the extent of useable habitat within a section of watercourse.

A major weakness of the current RHS system is that it includes very little data on the flow regime or species distribution/information/coverage within the channel, i.e. depth, width, flow velocity. Flow types do, however, give an approximation to froude1 number which can be used to coarsely assess flow diversity. Additionally, the new RHS Geomorphology and Floodplain Module will collect more detailed data in relation to flow and channel dimensions. It may be possible to overcome the flow-related weakness by combining the technique with flow accretion profiles to relate habitat features to the flow regime.

Applicability

In order to determine the effects of abstraction it may be possible to use RHS to identify habitats that are likely to be at risk through changes in the flow regime, e.g. side bars, riffles, wetlands.

However, it is more likely that the technique will be of most value when used alongside other methodologies, such as Resource Assessment and Management (RAM).

Further information

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'*River Habitats in England and Wales – A National Overview*' (1996) published by the Environment Agency. RHS National Centre, Environment Agency, Warrington.

1 The Froude number (Fr) is used by hydraulic engineers to describe types of flow. Fr can be thought of as the ratio of kinetic energy to potential energy. Fr values >1 describe shooting flow; Fr values <1 describe tranquil flow.

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River flows

Summary

Type of system where applied
River flow data is normally directly applicable to riverine systems but may also be fundamental to all surface water fed systems including lakes; estuaries and tidal embayments. For groundwater fed systems, river flow data may help characterise the inflow into (or residual flow from) a wetland system.

Applicability to groundwater or surface water
Of direct relevance to surface water fed systems but may also be important in some groundwater fed systems too.

Standard applications
Hydrological monitoring and conceptualisation. Conceptualisation requires various types of data manipulation and interpretation to assist the process.

Applicability to European interest features
Interest Features associated with regimes identified above.

Resource requirement
River Flows data monitoring and processing is a time consuming and costly undertaking.

River flows are collected for a variety of reasons including:

- for Environment Agency Water Resources and Flood Defence (including flood warning) functional activities
- due to obligations on Consent holders to undertake flow monitoring, typically:
  - Water Companies (or other major users of water or dischargers to rivers)
  - Non Environment Agency Drainage Authorities (such as IDBs)
  - Mining/quarrying operators
  - Operators of water management schemes.
- as a requirement of large civil engineering schemes such as, impoundments/reservoirs, channel diversions and interbasin transfers.

Availability of river flow data

Within the Environment Agency, river flow data is available from the National Archive – WISKI. This is accessible from Area/Regional offices. Environment Environment Agency Area Hydrometric Registers, Operational Drought Monitoring Reports (covering the droughts of the early and mid 1990's) and other reports may provide additional river flow data.

As well as the Environment Agency other potential sources of River Flows data include:

- Centre for Ecology and Hydrology (CEH, see also the Hydrometric Register and Statistics reports).
- British Waterways
- Water Companies (as water and sewage effluent undertakers)
- Environmental Impact Assessments for site-specific schemes (both for investigations and operations)
- Universities specialising in hydrological or associated research

Measurement of river flows

River flows are measured continuously (every 15 minutes) at gauging stations. There are several types of gauging station including:

- weirs or flumes
- ultra-sonic
- electromagnetic
- adapted sluice (or other river) structures which are primarily intended for river control purposes
- natural bed control sites which have rated sections (empirical stage – discharge calibration)

At ultra-sonic and electromagnetic gauging stations river flow is measured directly. At weirs, flumes and rated sections, flow is calculated from the measurement of river depth or head/stage. Conversion from stage to flow is determined through a stage – discharge relationship.

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Further information

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Species abundance and distribution data

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Summary

Type of system where applied
All aquatic and terrestrial systems.

Applicability to groundwater or surface water
Sites influenced by groundwater and surface water.

Hydrological data requirements
Flow, level, rainfall, groundwater (borehole) data etc may be linked to abundance and distribution to explain variance.

Ecological data requirements
Appropriate methodologies need to be employed to collect survey data. Survey programmes need to consider the number of samples required to generate useful data.

Can method be used on its own?
No – needs to be interpreted against other environmental data to explain variability in abundance and distribution. Historical data required to identify trends.

Applicability to European interest features
Highly applicable if appropriate, targeted survey technique used.

Resource requirement
Experienced/qualified surveyors required.

An important first step in understanding the relationship between species and the habitat(s) in which they are found is identifying the distribution and abundance of those species. Even in a pristine system, species will vary in abundance between sites, this variability being attributable to a range of factors including water quality, habitat quality, competition, food availability, predation and disease. Understanding the reasons why species vary in abundance and distribution is critical if the effects of abstraction are to be accurately predicted, and this can only be achieved through carefully designed survey work or analysis of existing data if available.

Although there is obvious value in collecting distribution and abundance data for the European interest features present at a site, a lot of useful information can be obtained by looking at other species, particularly those with a known sensitivity to changes in environmental conditions e.g. many freshwater invertebrate species. The sensitivity of certain species to different environmental conditions means that their presence is often indicative of a certain habitat type or quality. Consequently the presence or absence of chosen indicator species can be used to assess the suitability of a habitat to support particular European interest features.

Background

Historically, species-specific survey data have been collected for SACs and SPAs by a range of organisations, including the Environment Agency, Natural England, the Wildlife Trusts, and local naturalist groups. Sites of European importance are generally well studied, with certain species, such as otter, crayfish and great crested newt, generally being well recorded. However, other species, such as invertebrates and bryophytes, have probably been under-recorded.

The value of survey data is dependent on a number of factors, including the accurate recording of data, location, surveyor, method, site conditions, together with some form of quality control. In most cases this will entail the validation of the surveyors' technical competence.

The value of data is also linked to the purpose for which those data are to be used. For example, a single appropriately timed site survey would be adequate to establish presence or absence of certain species, such as macrophytes and some invertebrates. However, the success of such a survey may be dependent on the seasonal timing of the survey, weather conditions etc. For other species, such as great crested newt, a single survey may be insufficient to establish presence, and multiple visits may be required. It should be noted that presence/absence surveys would not be very informative in isolation for appropriate assessments carried out under the Conservation (Natural Habitats &c.) Regulations 1994, and may need to be complemented with other survey work.

If the objective of a survey is to establish the status of a population (i.e. stable, improving or declining), multiple surveys will be required over a specified time period. For short-lived species the survey period may only need to be relatively short, whereas for long-lived species a much longer temporal data set may be required, possibly extending over many years. To link water quantity / abstraction to species abundance and diversity, the period of monitoring must include a representative range of water levels or flows. The greater the temporal extent of the data, the more robust the analysis is likely to be when examining trends linked to environmental change.

Method description

Survey design may vary considerably depending upon the species or habitat that is being targeted, and the site where the surveys are to take place. Consequently survey design should consider a number of factors including:

- Geographical extent of the survey area (whole SAC or SPA or a component habitat)
- Weather conditions
- Season and time of day
- Sampling methodology, e.g. observation, trapping
- Site selection
- Survey objectives, e.g. presence/absence, abundance, population trends
- Sampling frequency
- Recording of supporting environmental variables

There are a number of survey techniques that are currently accepted as the standard data collection methods for various taxonomic groups and habitat types. These are summarised in Table 1.

Application

As highlighted above surveys may be used to provide data for a range of purposes, including:

- To determine presence/absence
- To establish status, i.e. stable, declining or improving
- To assess recruitment, age structure and growth rates in a population
- To assess population change due to emigration, immigration or mortality
- To provide a measure of habitat quality or suitability

In the context of determining the likely effect of abstraction on species and habitats, it is important that surveys are designed to meet the requirements of the site being assessed.

Sensitivity

In order to generate useful, technically robust data, there is a need to select an appropriate survey methodology and to design the survey programme incorporating appropriate spatial and temporal survey coverage.

Some species have very specific habitat or water quality requirements, and so survey data can readily be linked to changes in habitat quality. Other species are much more tolerant of a range of environmental conditions, which potentially makes it more difficult to link distribution and abundance to habitat variability.

Ultimately the value of survey data lies in the ability to relate them to other data, e.g. macroinvertebrates and water quality/quantity (RIVPACS/LIFE); salmon and flow/habitat (HABSCORE). River Habitat Survey may be used to link habitat quality with species presence or abundance data, as the database contains information on a wide range of habitat variables across a large number of sites.

Additional information

Gilbert G, Gibbons D and Evans J, (1998). *Bird Monitoring Methods*, RSPB, BTO, WWT, JNCC, ITE and the Seabird Group.

Sutherland W, (1999). *Ecological Census Techniques*, Cambridge University Press. (Refer to Table 2).

Guidance for Assessment: 'Hydrological Requirements of Habitats & Species' *Assessment Method Summary Macro Invertebrate Biotic Indices*

This document was withdrawn on 6 November 2017

Table 1 Selection of survey technique for SAC/SPA species and habitats species survey method habitat survey method

Species	Survey method	Habitat	Survey method
Allis shad	Electrofishing;catch data; hydroacoustics; LIFE in UK rivers methodology	Alkaline fens	National Vegetation Classification
Atlantic salmon	Electrofishing; catch data; LIFE in UK rivers methodology fish counter; redd counts; smolt traps	Alluvial forests	National Vegetation Classification
Barbastelle	Barbastelle forest survey (BCT) - tailored bat detector survey	Alpine pioneer formations of the Carician bicolorisatrofuscae	National Vegetation Classification
Birds of lowland freshwaters and their margins	WeBS low tide and high tide counts (marine); species specific observation surveys	Atlantic salt meadow	National Vegetation Classification /biotope mapping
Birds of lowland wet grassland	Species-specific observation surveys	Blanket bog	National Vegetation Classification
Brook lamprey	Electrofishing	Bog woodland	National Vegetation Classification
Bullhead	Electrofishing; Kick sampling bycatch;	Calcareous fen	National Vegetation Classification
Creeping marshwort	Species-specific surveys	Coastal lagoons	National Vegetation Classification
Desmoulin's whorl snail	Species-specific surveys	Depressions on peat substrates	National Vegetation Classification
Fen orchid	Species-specific surveys	Estuaries	National Vegetation Classification /biotope mapping
Floating water plantain	Species-specific surveys; MTR survey; WFD lake macrophyte survey	Hard oligo-mesotrophic waters	National Vegetation Classification
Geyer's whorl snail	Species-specific surveys	Humid dune slacks	National Vegetation Classification
Great crested newt	Bottle trapping; torchlight surveys; netting; egg search	Inland salt meadow	National Vegetation Classification
Marsh fritillary	Species-specific surveys	Large shallow inlets and bays	National Vegetation Classification /biotope mapping
Marsh saxifrage	Species-specific surveys	Mediterranean temporary ponds	National Vegetation Classification
Narrow-mouthed whorl snail	Species-specific surveys	Molinia meadows	National Vegetation Classification

This document was withdrawn on 6 November 2017

Table 1 Selection of survey technique for SAC/SPA species and habitats species survey method habitat survey method *(cont.)*

Species	Survey Method	Habitat	Survey Method
Otter	Vincent Wildlife Trust methodology; LIFE in UK rivers	Mudflats and sandflats	National Vegetation Classification /biotope mapping
Pearl mussel	Species-specific surveys; LIFE in UK rivers	Natural dystrophic lakes and ponds	National Vegetation Classification
Petalwort	Species-specific surveys	Natural eutrophic lakes	National Vegetation Classification /Predictive System for Multimetrics
River lamprey	Electrofishing; LIFE in UK rivers	Northern wet heath	National Vegetation Classification
Round-mouthed whorl snail	Species-specific surveys	Oligotrophic to mesotrophic standing waters	National Vegetation Classification /Predictive System for Multimetrics
Sea Lamprey	Electrofishing; LIFE in UK rivers	Oligotrophic waters of sandy plains	National Vegetation Classification
Slender green feather moss	Species-specific surveys	Raised bogs	National Vegetation Classification
Southern damselfly	Species-specific surveys; kick sampling (larvae); LIFE in UK rivers	Salicornia and other annuals colonising mud and sand	National Vegetation Classification /biotope mapping
Spined loach	Electrofishing; Kick sampling bycatch; EA spined loach survey	Spartina swards	National Vegetation Classification /biotope mapping
Twaite shad	Electrofishing; LIFE in UK rivers	Temperate wet heath	National Vegetation Classification
White-clawed crayfish	Kick sampling bycatch; substrate search; torchlight surveys; trapping; LIFE in UK rivers	Transition mires	National Vegetation Classification
		Watercourses of the plain to montane levels with Ranunculion fluitantis and Callitricho-batrachion vegetation	National Vegetation Classification /Mean Trophic Rank

This document was withdrawn on 6 November 2017

At sites without a gauging station, one off, individual river flows measurements ('spot' flow measurements) are taken by:

- Current metering (mechanical or other)
- Rising air bubble technique
- Floats
- Dilution gauging

Processing river flow data

Archiving raw river flow measurement data follows well-established formal processes. Measurements of river stage taken at 15 minute intervals are converted to flow, quality assured and archived. Flows are normally presented as a daily mean.

To in-fill gaps in river flow data, record interpolation, possibly aided by correlation, can be used for very short gaps (say ‹ 7 days). Otherwise guidance given in the Method Summary for Rainfall – Runoff Modelling should be referred to for extending river flow data records or infilling more significant data gaps.

Presenting river flow data

Daily Mean Flows (DMFs) are normally displayed as a time series hydrograph. It can be useful to present more than one hydrograph on one plot to demonstrate seasonal differences in response, identify trends or to demonstrate the effects of catchment geology i.e. baseflow or surface runoff dominated catchments. Daily mean flows can also be presented as flow percentile exceedence graphs or flow duration curves.

DMF's are commonly summarised as monthly and annual values (mean, max & min). They are used to calculate the catchment Base Flow Index (BFI) – the relative proportions of total flow that comes from baseflow. Another common use is to calculate extreme minima or maxima (annual or above/below a threshold).

Verifying river flows

River flows can be checked through comparison with another set of river flow data to ensure that the relationship between the two sites remain the same. This can be done with a Double Mass Plot. Double mass analysis, tests the consistency of the record at a station by comparing its accumulated annual runoff with the concurrent accumulated runoff for a group of similar nearby stations. Any significant variations in the relationship should reveal any periods of potentially suspect data or unexpected influences on one of the data sets.

River flow data analyses

Some of the most common type of analysis include:

- Flow normalisation (reducing flow records to $l/s/km^2$ or similar) which is useful in making yield comparisons between catchments or to compare catchments of different size or geology for example.
- Baseflow recession analysis, where the relative contribution of groundwater and surface water in individual river flow events is calculated to help improve our understanding of the processes involved.
- Flow Naturalisation (*see Method Summary – Flow Naturalisation*).
- Flow Accretion Diagrams. Where gain or loss in flow along the course of a river can be shown as a long profile. To aid interpretation, long profiles should show positions of tributaries; abstractions; discharges; and, possible hydrogeological controls.

River Flows data is an important means of calibrating hydrological models (see separate Method Summaries for both Rainfall – Runoff Modelling and Distributed Groundwater Modelling).

Application to wetland sites

The river (or spring) flow regime into a wetland site may be very important to the characterisation of the site and the requirement of the Interest Features.

If low flows are considered critical to the favourable hydrological condition then attention should be given to an assessment of low flow regimes and factors which may impact that regime such as abstraction.

If high/flood flows are critical, such as in washland sites, then focus should be given to factors which may impact the favourable inundation of the site. In this instance, it is very probable that issues such as changes in landuse will have more affects on river flows than licensed abstractions.

In order to undertake the required assessments for the Review of Consents the following will need to be included:

- Flow hydrograph (time series) plots.
- Flow percentile exceedence tables or graphs.
- Tabular seasonal and/or monthly flow statistics.

There are other analytical and interpretative hydrological techniques that can be applied to river flow data that may be used to inform Review of Consents studies. These techniques are addressed within the relevant Method Summaries.

This document was withdrawn on 6 November 2017

Table 2 Information sources for standard survey techniques

Taxonomic group	Survey methodology	Reference
General	LIFE in UK rivers methodologies	A full range of Life in UK Rivers publications can be ordered from: The Enquiry Service Natural England
Plants/habitats	J NCC Phase 1 and 2 habitat surveys National Vegetation Classification *Mean Trophic Rank*	'Handbook for Phase 1 habitat survey' JNCC (1993);'*British Plant Communities – Volumes 1 -5*' Rodwell (2000); '*Mean Trophic Rank – A User's Manual*' EA Technical Report E38
Invertebrates	3 minute kick sampling	'*RIVPACS III – User Manual*' IFE/EA (1997) Agency Guidelines
Mammals	Survey of field signs (otter) Bat detector surveys	'*Otter and river habitat management*' EA (1999) Bat Conservation Trust (http://www.bats.org.uk/)
Birds	WeBS low tide and high tide counts for wintering birds; species-specific surveys	British Trust for Ornithology (http://www.bto.org/survey/webs/)
Amphibians	Bottle trapping/torching/netting	'*Great crested newt mitigation guidelines*' English Nature (2001)
Fish	Electrofishing Hydroacoustic/resistivity counter Fish traps Catch data (angler and net)	Environment Agency guidelines/work instructions Environment Agency R&D (http://publications.environment-agency.gov.uk /epages/eapublications.storefront)

This document was withdrawn on 6 November 2017

Trophic status assessments

This document was withdrawn on 6 November 2017

Summary

Type of system where applied
Riverine.

Applicability to groundwater or surface water
Flowing surface waters only.

Hydrological data requirements
None.

Ecological data requirements
Macrophyte or diatom data collected using standard survey methodologies.

Can method be used on its own?
No – used to assess trophic status so needs to be evaluated in association with flow and water quality data.

Applicability to European interest features
Useful for evaluating secondary effects of flow changes on water quality. Supplementary data only. Should only be used where linked concerns exist regarding water quality and potential impact of abstraction.

Resource requirement
Time consuming requiring data collection and processing. Data may already exist from Urban Waste Water Treatment Directive (UWWTD) studies.

The Mean Trophic Rank (MTR) and the Trophic Diatom Index (TDI) have been developed to provide qualitative assessments of whether a site is impacted by eutrophication or has undergone changes in trophic status. Such changes may occur indirectly as a result of abstraction, which may lead to reduced dilution and increased residence time of point or diffuse source inputs. MTR and TDI should only be used to compare the trophic status of physically similar sites.

MEAN TROPHIC RANK

Background

Mean Trophic Rank (MTR) is a technique used to assess the trophic status of freshwater streams and rivers based on a standard 100 m length sample unit. The technique requires specialist botanical expertise to identify a range of macrophyte species, each of which has been ranked according to their nutrient sensitivity.

Method description

MTR involves a detailed botanical survey and assessment of the physical character of a 100 m section of river bank. All macrophytes present are recorded, together with an estimate of percentage cover. Macrophyte species are assigned a number between 1 and 10 on the basis of their tolerance to nutrient enrichment. These values are then multiplied by the cover value scores for each species, a mean value calculated and multiplied by ten to provide the MTR.

Scores for sites are then interpreted on the basis that scores greater than 65 are unlikely to be eutrophic, scores less than 25 are badly damaged either by nutrient enrichment, toxicity or physical degradation, and scores in-between are eutrophic or at risk of becoming eutrophic. The MTR score is influenced by habitat type and therefore it is most useful to interpret the score alongside physically similar sites of known high water quality. Initially MTR was only used to study spatial changes within a reach, with a change in MTR score of 15% considered to be significant. Therefore consideration needs to be given to the use of MTR on temporal scale.

Application

MTR has principally been developed to assist in the designation of 'sensitive reaches' under the Urban Waste Water Treatment Directive. However, the ability to characterise watercourses in this way is considered to be useful supplementary information when assessing the direct and indirect effects of abstractions on European interest features, but only where concerns exist regarding the interaction of WQ and abstraction impacts.

Sensitivity

The calculation of MTR scores involves the scoring of over 130 different taxa, all of which have been attributed a score between 1 and 10 to reflect their sensitivity to nutrient enrichment.

Consequently the technique can be applied across a range of stream and river types, but may be influenced by variability between surveyors and habitat variability. In addition there may be some natural background variation in MTR depending upon the survey season and the physical comparability of sites, however, the methodology is designed to minimise this variation.

Applicability

In order to determine the effects of abstraction it may be possible to use MTR to identify sites at risk from eutrophication. Abstraction in or near such sites may reduce dilution volumes, further compounding the effects of nutrient enrichment. This technique may be directly applicable to some SAC interest features, however, it is more likely that it will be of general value in characterising watercourses. The method should only be considered where abstraction and water quality are considered to be inter-linked. Ideally there should be a minimum of 1 survey over 3 years for useful interpretation to be carried out.

Further information

EA R&D '*Mean Trophic Rank – A User's Manual*' Technical Report E38.

EA R&D '*Assessment of the trophic status of rivers using macrophytes: Evaluation of MeanTrophic Rank*' Technical Report E39.

EA R&D '*Assessment of the trophic status of rivers using macrophytes: Supporting documentation for the evaluation of Mean Trophic Rank*' Technical Report E1/i694/1.

TROPHIC DIATOM INDEX

Introduction

As with Mean Trophic Rank, the Trophic Diatom Index was developed to assist in the monitoring of rivers in response to the requirements of the Urban Waste Water Treatment Directive. The method uses benthic diatom communities to assess water quality, with particular emphasis on nutrient enrichment. Trophic status is derived on the basis of the taxa present within a sample, with certain taxa being more sensitive than others to nutrient enrichment. TDI does not really define trophic status, but allows a comparison to be made spatially between sites and to make the conclusion that one site is more enriched than another.

Method description

Benthic diatom films are collected from either natural or artificial substrates within the sample site, each site comprising a 10 m reach of river. The favoured method, in terms of ease, is to use natural substrates, as artificial substrates require multiple site visits. Slides of the diatom sample are analysed in the laboratory and the taxa present identified, together with an estimate of relative abundance. The Index is then calculated from the data gathered.

Application

As with MTR, TDI has principally been developed to assist in the designation of 'sensitive reaches' under the Urban Waste Water Treatment Directive. However, the ability to characterise watercourses in this way is considered to be useful supplementary information when assessing the direct and indirect effects of abstractions on European interest features. As with MTR, TDI should only be considered where abstraction and water quality concerns are inter-linked.

Sensitivity

The TDI has been developed using 86 taxa that are sensitive to nutrient status. Each individual taxon is assigned a value between 1 (favoured by low nutrient concentrations) and 5 (favoured by very high nutrient concentrations), with TDI values ranging from 0 (indicating very low nutrient concentrations) to 100 (indicating very high nutrient concentrations). The method is therefore applicable to the assessment of trophic status, but has no proven application for assessing flow derogation *per se*.

This document was withdrawn on 6 November 2017

Applicability

TDI is considered to be an alternative to or complementary to MTR, when determining the effects of nutrient enrichment as a result of abstraction. Abstraction in or near European sites may reduce dilution volumes, further compounding the effects of nutrient enrichment. This technique may be directly applicable to some SAC interest features, however, it is more likely that it will be of general value in characterising watercourses.

Further information

Trophic diatom index Project Number 0618.

The Trophic Diatom Index: A User's Manual Reference Number TR E2.

Note:
New ecological status classification tools, using macrophytes and diatoms, have been developed for the purposes of the Water Framework Directive, and these will be in use from 2007 onwards. These new tools are essentially improved and refined versions of the existing MTR and TDI methods, based on more extensive data analyses, and as such will probably be widely adopted for assessment of nutrient impacts.

This document was withdrawn on 6 November 2017

Water balance assessment

This document was withdrawn on 6 November 2017

Summary

Type of system where applied
River catchments, lakes & wetlands.

Applicability to groundwater or surface water
Surface water and groundwater.

Hydrological data requirements
To reach a conceptual understanding of a water body there is a need to assess its water balance. This is a volumetric assessment of the inputs, outputs and the changes in storage of the water body.

The main components of the natural water balance which can be measured or estimated are:

- Precipitation (rainfall/snowfall)
- Evaporation (including transpiration)
- Effective Rainfall
- Soil Moisture
- Water or groundwater level
- Riverflow and other outflows.

Water balances also need to consider artificial influences (AI's) including:

- Abstractions
- Discharges
- Mains/sewer leakage
- Water transfers.

Other data which may support a water balance assessment includes:

- Topographical catchment definition
- Groundwater catchment definition from groundwater level contours
- Aquifer storage and transmissivity values
- Level storage relationships.

Ecological data requirements
None.

Can method be used on its own?
Yes to assess/illustrate the inputs, outputs and storage changes in the water body. This assessment needs to be combined with an ecological assessment to determine whether changes in any of the water balance components impact on the ecological features at the site.

Applicability to European interest features
Interest features associated with regimes identified in the previous questions identified above.

Resource requirement
Can be scaled depending on the level of assessment required.

Water balance assessments

Water balance assessments can be used to:

- Quantify or estimate the main inflows, outflows and changes in storage in a particular water body. Over a period of time the water balance assessment can determine the sustainability of the water body in terms of whether inflows are, in fact, balanced by outflows and changes in storage.
- Estimate one of the components of the water balance which has not been measured or assessed. In this case, inflows into a water body (i.e lake) can be estimated over time from the measurement of the change in storage in the water body (i.e lake level), and the outflows from the water body (i.e abstraction, or compensation flow or spill).

Similarly for Habitats Directive Review of Consents (RoC) purposes, the assessment should focus upon the designated site, or that part of it where the designated ecological features are located (e.g. if the wetland feature is fed by groundwater discharge, the water balance may exclude inputs from surface water runoff to adjacent ditches). To fulfil the RoC objectives the water balance assessment should consider:

- 'natural' conditions (no artificial influences of abstractions or discharge);
- 'recent actual' conditions (abstractions and discharges as they are currently and have been in the recent past)
- 'licensed' conditions (abstractions assuming full licensed uptake and appropriate discharges).

The timestep at which water balance assessments are undertaken is often determined by the resolution of the estimated or measured data available and by its intended use. This could range from a daily, monthly or yearly (usually a water year i.e. 1^{st} October to 30^{th} September, to minimise changes in storage) timestep to long term average values. Typically water balance assessments of designated sites may focus on a representative year and upon a dry year.

Consistent units should be used to quantify all inflows, outflows and changes in storage. These can be expressed as Ml/d or mm.

Methodology

A water balance must be formulated on the foundations of a sound conceptual model that describes the processes involved in the movement of water through the catchment. Like any good conceptual model, it may be subject to refinement and improvement as understanding develops. It is sensible to look at the water balance of each water body type separately if the designated site is dependent on more than one. For example, a water balance for a particular wetland, aquifer type (e.g. shallow drift gravel and deeper chalk) or river catchment. The conceptual model should assist in determining which discrete water bodies require a water balance assessment.

Components of a water balance may include:

Inflows
- Precipitation (rainfall/snowfall)
- Effective Rainfall (surface and subsurface/recharge)
- Effluent discharges
- Outflows from the water bodies (e.g. based on estimates of recharge to groundwater catchment areas, or based on simple calculations of hydraulic gradient and confining layer permeability assumptions)
- Mains/sewer leakage
- Water transfers

Outflows
- Evaporation (including transpiration)
- Riverflow
- Inflows to other water bodies
- Abstractions
- Water transfers

Changes in storage over the water balance period can be assessed for each water body by looking at changes in:

- Groundwater levels,
- Soil moisture deficits,
- Riverflows
- Lake levels

When assessing licensed surface water and groundwater abstraction impacts on a water balance it is important to consider the licence constraint conditions written on the licence, as these may include cessation clauses to limit low flow impacts. It is also essential that the consumptiveness of the abstraction is taken into account in terms of the water locally returned to the catchment, and that the impacts of other discharges not locally associated with an abstraction (e.g. sewage treatment works) are also included. The Environment Agency's 'Good practice in flow naturalisation' and 'RAM Framework' provide more details.

Visualising the water balance

Results can be expressed graphically for each separate water body in a number of ways:

- diagrammatically as a series of stores and flows/or fluxes
- as maps containing equivalent recharge circles around abstraction sources. The 'RAM framework' provides more details (as illustrated in Figure 1)
- as a pie chart of typical inflows/outflows to the site (as illustrated in Figure 2). Determining percentage contributions of artificial influences (in particular abstractions) will help determine the magnitude of their impacts upon the water balance.

These illustrations can be produced for a representative year, a dry year, or a long term average for natural, recent actual and fully licensed conditions.

Uses

Water balance assessments focus on quantifying the most important component(s) of the designated feature and the impact on this of licensed abstractions and consented discharges. Once changes have been quantified further analysis will be required to assess how these may translate into habitat parameters (such as water depth, wetted perimeter and flow velocity) and whether these are responsible for an adverse ecological impact.

Further information

Standard hydrological text books

Entec, 2002, *'Resource Assessment and Management Framework – Report and User Manual – Version 3' R&D Manual W6-066M Version 3*, for the Environment Agency.

Environment Agency (2001); *Good Practice in Flow Naturalisation by Decomposition (Version 2)*; National Hydrology Group April 2001 (Revised 15 June 2001).

Environment Agency (2005*), Toolkit for flow naturalisation V1.0*; December 2005

This document was withdrawn on 6 November 2017

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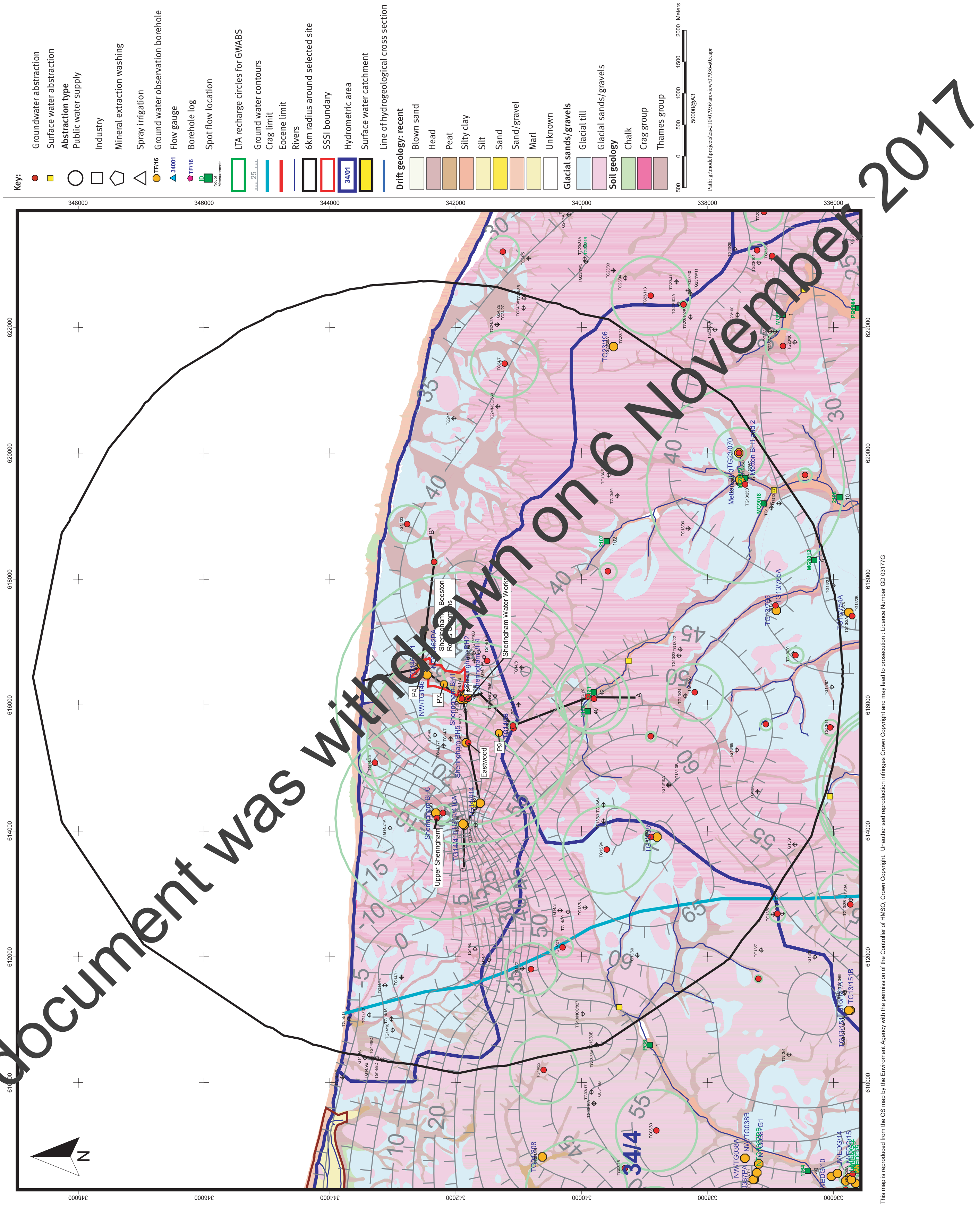


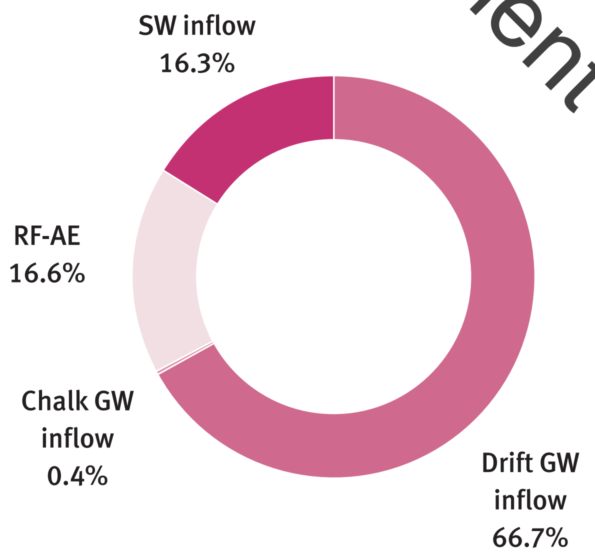
Figure 1 Geology, abstractions, hydrometic observations and line of cross section

This document was withdrawn on 6 November 2017

Figure 2 Inflow estimates into Sheringham and Beeston Regis SSSI

Long term average natural inputs

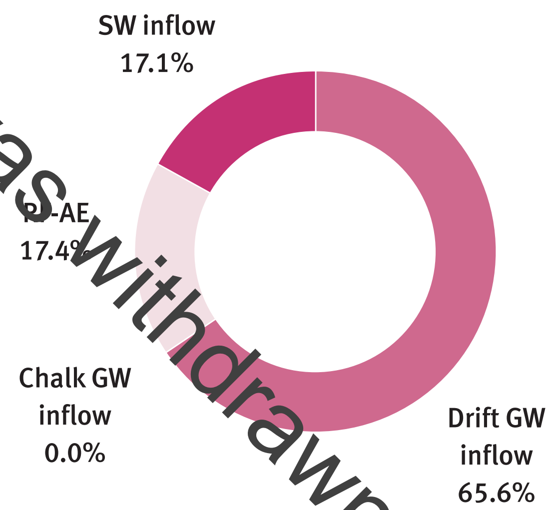
Total inputs 0.68 M/d



LTA Inputs	mm/a	Ml/d	% inflow
RF - AE	171	0.112	17%
SW Inflow	29	0.110	16%
Drift GW Inflow	688	0.450	67%
Chalk GW Inflow	5	0.003	0.4%
TOTAL INFLOW	**893**	**0.675**	**100%**

Current inputs

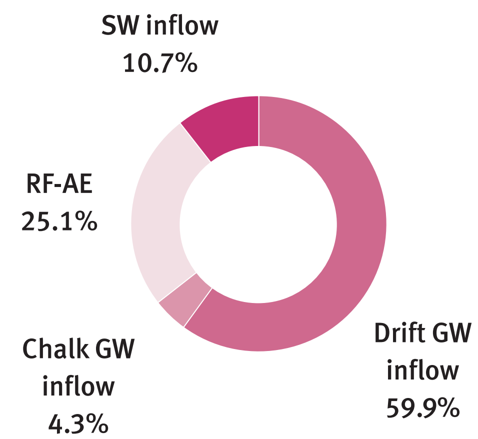
Total inputs 0.64 M/d



Current Inputs	mm/a	Ml/d	% inflow
RF - AE	171	0.112	17%
SW Inflow	29	0.110	17%
Drift GW Inflow	646	0.423	66%
Chalk GW Inflow	0	0.000	0.0%
TOTAL INFLOW	**846**	**0.644**	**100%**

1975/1076 natural inputs

Total inputs 0.28 M/d



Drought Inputs	mm/a	Ml/d	% inflow
RF - AE	107	0.07	25%
SWInflow	8	0.03	11%
Drift GW Inflow	256	0.17	60%
Chalk GW Inflow	18	0.01 4%	67%
TOTAL INFLOW	**893**	**0.675**	**100%**

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Groundwater levels

Summary

Type of system where applied
Groundwater Fed Wetlands. May also be relevant to headwater locations on riverine systems.

Applicability to groundwater or surface water
Only of direct relevance to groundwater fed systems. In special circumstances Groundwater fed wetlands may include coastal as well as inland sites.

Standard applications
Hydrogeological monitoring and conceptualisation with the latter usually requiring various types of data manipulation and interpretation to assist the process.

Applicability to European interest features
Interest Features associated with regimes identified above.

Resource requirement
Groundwater level data monitoring is fundamental to the water resource function of the Environment Agency. Site specific groundwater level data are also required for the Environment Agency's Waste Management (Landfill Licensing) function and occasionally for flood defence schemes or conditionally for certain operational schemes. Groundwater level data monitoring and processing is a time consuming and costly undertaking.

Groundwater level data are monitored for a variety of reasons including:

- Environment Agency Water Resources and Waste Management functions;
- In connection with Section 32/3 pumping tests which are typically undertaken to support an application for a new/varied groundwater abstraction licence;
- Environment Agency Groundwater Investigation requirements and operational monitoring obligations;
- Obligations on Consent holders to undertake monitoring typically including Water Companies (or other major users of water); landfill operators; mining/quarrying operators; and operators of water management schemes; and
- In connection with large civil engineering schemes involving earthworks groundwater level monitoring may well be required such as for tunnelling, large cuttings, impoundments/reservoirs and dewatering operations.

As well as the Environment Agency other potential sources of groundwater level data include:

- British Geological Survey (through well records etc).
- County Councils (through Mineral Planning and Highways functions).
- Site specific schemes (both for investigations and operations). In this respect allied Environmental Impact Assessments may provide a useful guide to potential data availability.
- Universities specialising in hydrogeological or allied research fields.

Groundwater level monitoring may be undertaken using a number of facilities such as:

- Purpose constructed observation boreholes and/or piezometers.
- Utilising abandoned abstraction wells, boreholes, mine shafts and adits.
- Via excavations penetrating beyond the water table.
- Where groundwater naturally emanates to the surface as springs or seeps.

Groundwater levels are typically monitored:

- By means of an electrical contact dipper for occasional spot readings down boreholes or piezometers.
- Via gauge board installations in excavations or in discrete springs for occasional spot readings.
- By means of 'continuous' monitoring made via a sensor and recorder. Traditionally, these included floats suspended over a pully driving an autographic recorder. Typically, they now incorporate either a shaft encoder (float/pully driven) or pressure transducer sensor coupled to a data logging device.
- Where artesian groundwater levels are encountered heads may be recorded using a pressure gauge or manometer.

Background

The processing of raw monitoring data to a formal archive will normally include a number of quality checks such as:

- Levels within expected range;
- Difference since last recording within anticipated range or change in level (up or down) is as anticipated;
- Type of recording device as anticipated; and some form of verification.

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The standard processing and presentation for groundwater levels is to prepare them singly as a time series hydrograph. In some instances two or more groundwater level hydrographs may be shown on one plot to reveal trend comparisons or changes to response (such as in a pumping test).

Groundwater levels are also commonly plotted spatially and represented as a contoured plot for a specific time. Such plots are used to help interpret:

- Groundwater flow paths.
- Groundwater flow gradients.
- Groundwater capture zones to an abstraction or discharge.

Groundwater level data are essential to help inform the hydrogeological characterisation of aquifer systems. Singly these data show level response to natural and artificial recharge and discharge (including abstraction driven) processes/mechanisms. In conjunction with other data (particularly discharge and/or abstraction) level data can be used to interpret standard hydraulic properties of aquifers including transmissivity and storativity (or specific yield).

Application to wetlands

Groundwater level data may help in the characterisation and assessment of wetland sites in a number of important, and sometimes fundamental, ways including:

- A sufficient network of groundwater level data may enable the groundwater capture zone supplying groundwater flow to the site to be defined through compiling and interpreting a groundwater level contour plot.
- A nest of piezometers (or boreholes) into successional geological horizons underlying a wetland site should help reveal if the hydraulic potential for groundwater flow is upward (discharging), downward (recharging) or neutral.
- A transect of piezometers (or boreholes) across a wetland site may reveal local variations in piezometric level and these can be compared to site topography to provide a spatial picture of depth to water table across the site. In addition, the variation in water levels across the transect may potentially allow hydraulic relationships to be drawn with on-site features (such as springs) or off-site stresses (such as from abstractions or tidal effects etc).
- In some instances discrete time series groundwater level data recorded at or close to a wetland site may reveal a specific response attributable to an individual abstraction operation (or some other stress). This may be especially noticeable where the abstraction is subject to distinct temporal variations (such as significant seasonal or diurnal variations in abstraction rate). Where relatively steady state abstractions are suspected to cause an impact on a site, purpose designed tests (often referred to as 'Signal Tests') may be undertaken to disrupt or alter the steady state abstraction pattern so as to generate the potential for a variation in groundwater level monitored at the site. In this way 'Signal Tests' may prove valuable for identifying hydrological characteristics at a site as well as indicating the possible scale of impacts.
- Where sufficient groundwater level data are monitored at a designated wetland site the information should, when combined with topographic and ecological data for the site, help confirm whether or not favourable hydrological conditions are achieved relative to the specific water resource requirements of the Interest Features.

Further information

Environment Agency, Anglian Region; *Strategy for Groundwater Investigations and Modelling; Interpretation of Groundwater Levels*; Entec; August 2000.

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Numerical groundwater modelling

Summary

Type of system where applied
Rivers, lakes & wetlands.

Applicability to groundwater or surface water
Worth considering where seasonal or geographically localised impacts of groundwater abstraction are important. For example, modelling changes in groundwater levels, groundwater flows into wetlands or lakes or baseflow to rivers.

Hydrological data requirements
A conceptual understanding of natural groundwater recharge, flow and discharge and abstraction impact mechanisms which is appropriate to the level of assessment and includes the water body supporting the ecological feature plus all potentially impacting abstractions. This depends on collating, integrating and understanding a range of meteorological, geological, topographical, river flow, groundwater level and hydrochemical information. Aquifer boundaries and hydraulic parameters for groundwater flow, storage and interaction with streams/rivers. Historic recharge and abstraction estimates plus observed groundwater levels and river/stream flow estimates (for historic or steady state calibration). Fully licensed and recent actual groundwater abstraction rate assumptions for predicting licensed impacts compared with 'natural' (zero abstraction) scenario.

Ecological data requirements
None, however, to draw a conclusion from the modelling results regarding ecological effects, targeted ecological data are required to demonstrate ecological change.

Can method be used on its own?
Within hydro-ecological impact assessments, groundwater modelling will usually be used as part of a wider study including ecological studies and options appraisal. The wider study will set environmental outcomes which will determine the scope of the modelling work.

A conceptual model taking account of the water supply mechanisms critical to the ecology is required before modelling (see conceptual model technique sheet). For wetlands, model results should be prepared in consultation with ecologists and impacts assessed with reference to hydro-ecological guidelines which define the favourable water level or flow regime required by the wetland features. For rivers, results should be compared with the Resource Assessment & Management (RAM) Framework or Natural England – Favourable condition Table (FCT) -based RiverFlow Objectives.

Applicability to European interest features
Standard hydrogeological assessment techniques which can be applied for any location/wetland but can only be interpreted in terms of potential 'ecological effects' if combined with other techniques.

Resource requirement
A 'simple' numerical model to consider groundwater abstraction impacts on a wetland may be built and used to give indicative results within a few weeks. A more complex model of a larger catchment can take a few years and cost several hundred thousand pounds.

Figures 1 and 2 include modelled groundwater level output superimposed on a hydro-ecological water level regime prescription for a wetland feature, and modelled water balance output showing variations in flows into and out of a wetland, respectively.

Background

A numerical groundwater model is used to understand and quantify the groundwater flow system to ensure that an adequate balance between recharge (water entering the aquifer) and abstraction (water being pumped out of the aquifer) is maintained. A model usually simulates the spatial distribution of groundwater recharge, flow and discharge across a grid of 'cells' representing the aquifer and river network and can also show how groundwater levels and flows change with time in response to recharge and abstraction stresses. Such a model can provide the 'best available' tool to assess the impacts of groundwater abstraction on river baseflow, spring flow, drain flow or groundwater levels. Predictions of both recent actual and fully licensed impacts can be made using a model which has been credibly calibrated against historic records of river flow and groundwater level variations. These predictions can focus on critical drought, average or high groundwater level periods as appropriate.

However, distributed groundwater models can also take much time and money to build and will only ever be as good as the information and conceptual understanding upon which they are based. Before building such a model it is always worth trying other, simpler approaches, as described on separate summary sheets:

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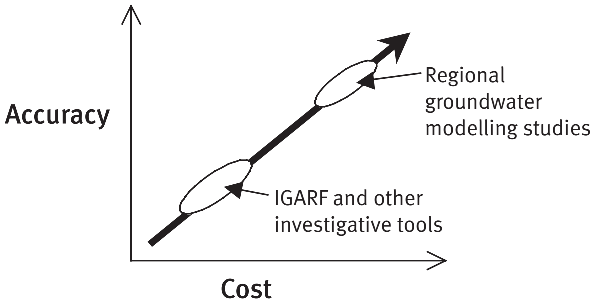
- Conceptual understanding;
- Simple water balance approaches;
- Radial flow based drawdown methods, together with licence accumulation diagrams;
- IGARF; and/or
- The RAM Framework.



For the purposes of any hydroecological investigation it is essential to work with ecologists to 'translate' the output from any groundwater model into a format which is relevant to the ecological interest features on the site. It is important to separately consider whether the predicted impacts will result in an adverse ecological effect.

For example:

- modelled groundwater levels at a wetland cell representing the piezometric head (in m AOD) within the main aquifer may have to be 'translated' to indicate the behaviour of the near surface water table (in m bgl) and to allow this to be compared with a prescribed water level regime for a 'wet grassland' feature on the site itself. The duration and frequency of ***changes*** in groundwater levels in relation to the growing season need to be considered.
- Seasonal changes in the direction and size of groundwater flows need to be considered. Maintenance of flushing flows into a wetland, or an upward hydraulic gradient may be critical to some vegetation interest features. The frequency, duration and timing of any gradient reversals is also important.
- The duration, frequency and timing of any reductions in baseflows to rivers and lakes.

Method description

Following a 'source – pathway – receptor' model, the first step is to establish an appropriate level of conceptual understanding. This will include some simple water balances and an appreciation of the sources of impact (e.g. pumping by groundwater and surface water licensed abstractions), flow mechanisms (pathways) and vulnerability mechanisms of the designated ecological features (receptors).

Once a conceptual understanding has been developed, numerical groundwater modelling may be used. It is a specialist activity to be undertaken by groundwater professionals. It is important to keep the numerical model as simple a representation of the conceptual model as is credibly possible in order to avoid having too many, or inappropriate, model parameters. This may lead to unrealistic expectations/aspirations for the model results.

Calibration and validation of the distributed model against observation data acts to test and increase confidence in the conceptual model. During the development of the distributed model it may be necessary to revisit and modify the conceptual model before continuing.

Model layers

A single layer model provides the capability to incorporate recharge, control by rivers and drains, regional gradients, storage and abstractions. It also permits spatial variations in aquifer transmissivity or specific yield to be incorporated. This will permit time variant changes in groundwater discharge rates to be determined and may be adequate for some rivers and wetlands which are generally considered to be in good hydraulic connection with the underlying aquifer.

However, in the presence of significant drift deposits such a model may not provide an adequate simulation of changes in water level near the surface of a wetland. It may also be difficult to compare the predictions of the model with the results of field observations if these comprise only levels. Furthermore, even where the geology beneath a wetland is apparently simple, with no drift and good connection to the underlying aquifer, there is often some degree of layering, possibly related to fissure flow within the aquifer itself. In these situations pumping signals may travel greater distances whilst near surface drawdown is less marked. For these reasons it is unlikely that a single layer model would provide an adequate representation of many wetlands, where two layers or more may be required.

A model with two layers in the vicinity of a wetland permits vertical gradients in the wetland to be defined, and provides a basis for more realistic simulation of heads in the wetland. The effect of horizontal/vertical anisotropy in the regional aquifer can be modelled by changing vertical conductance terms. The results are more readily comparable with those from field investigations, leading to more confidence in the appropriateness of the model calibration.

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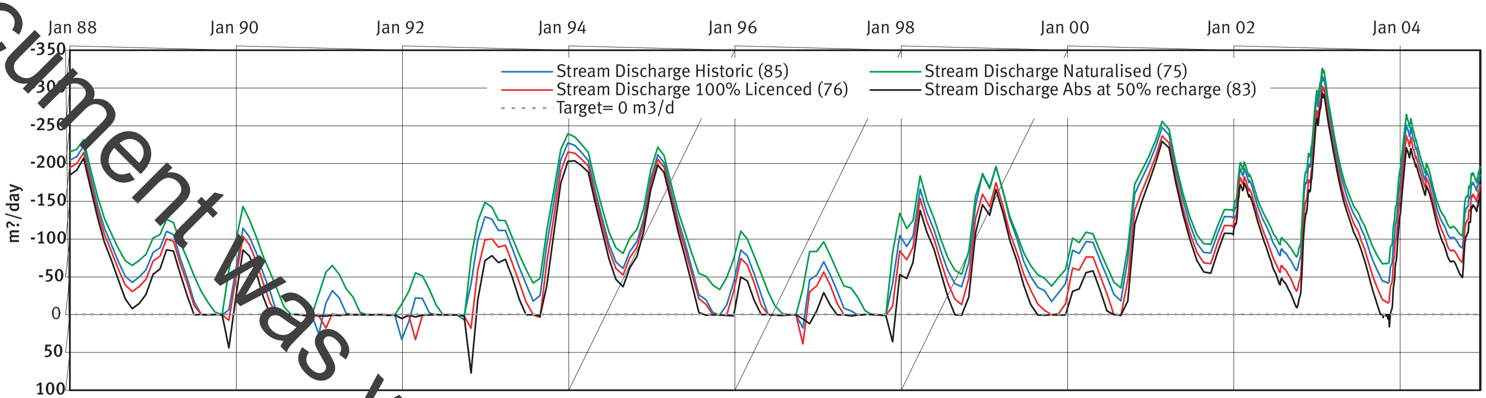
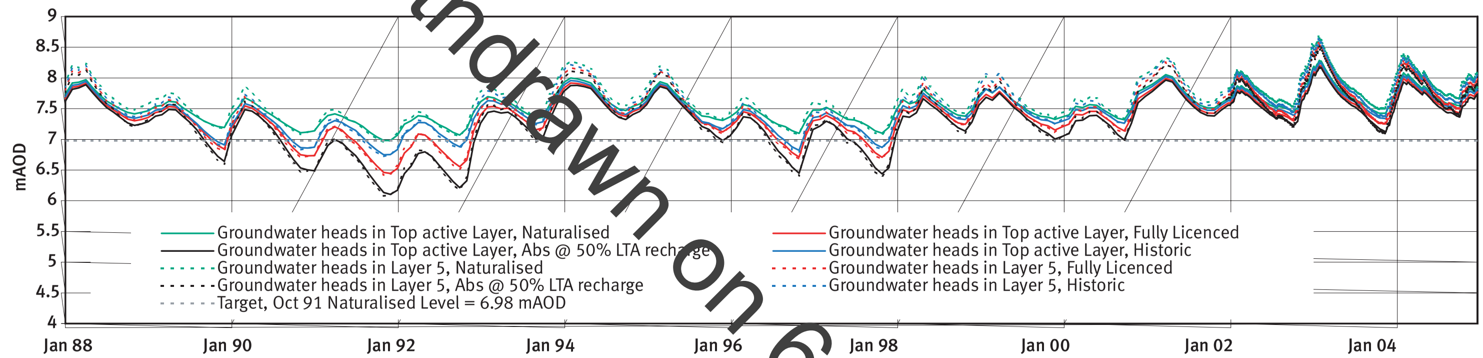
Figure 1 Appraisal of abstraction scenarios for a model cell at a groundwater fed fen.

Discharge to stream



Note differing chart scales

Groundwater heads in top active layer and layer 5



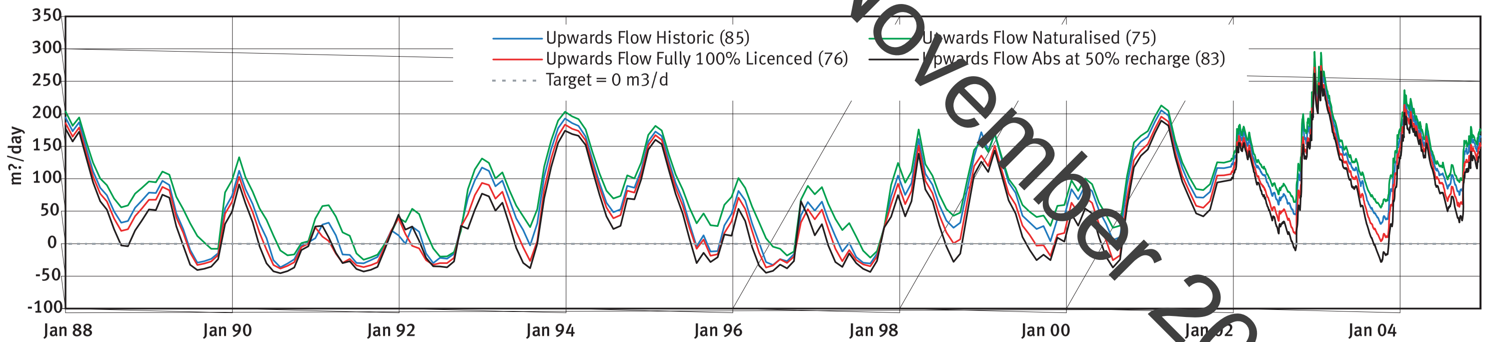


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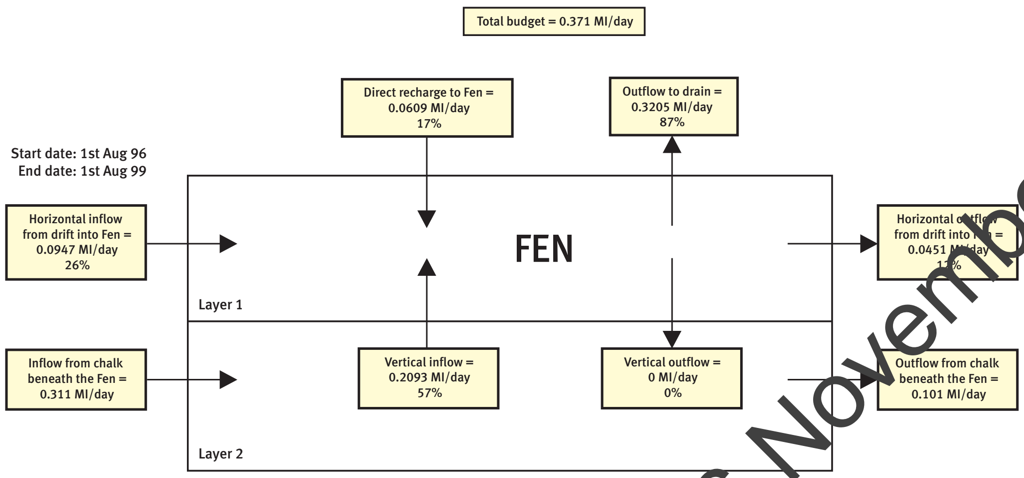
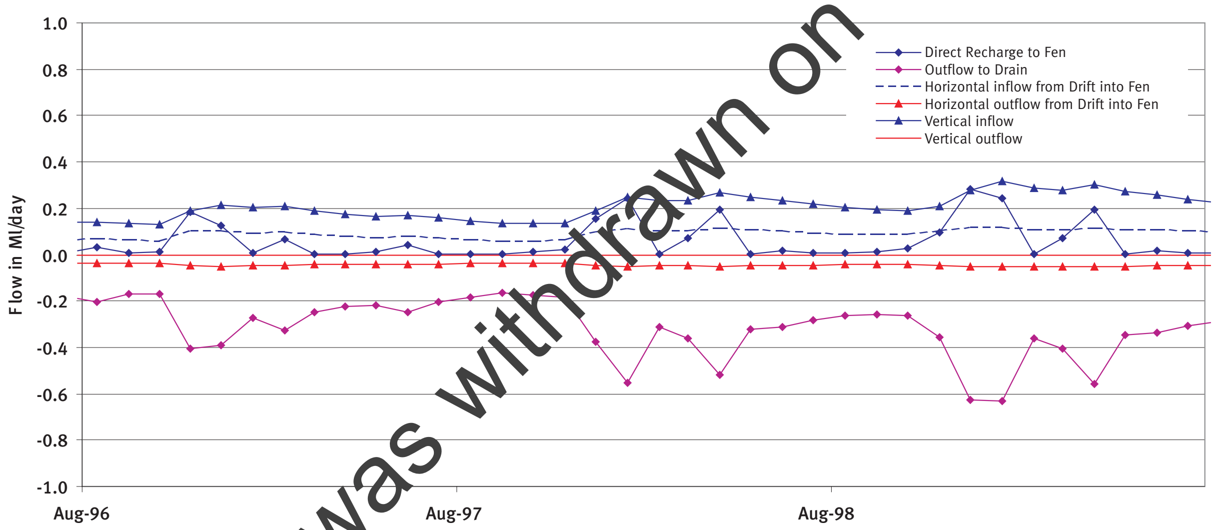
Figure 2 Components of modelling water budget and modelling groundwater levels

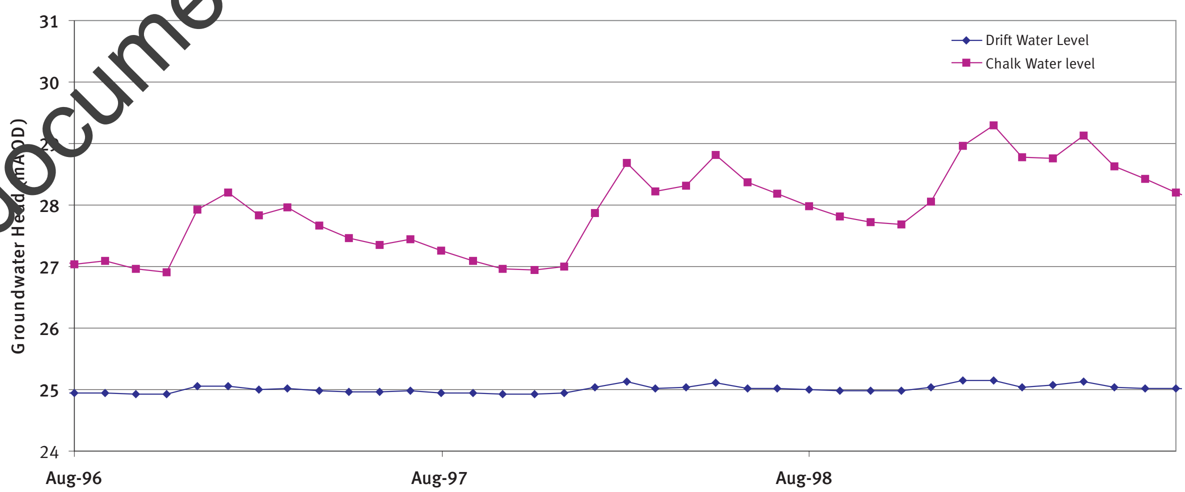
Components of the modelling water budget for a groundwater fed fen between Aug 1996 and Aug 1999



Components of flow budget in Fen



Modelling water levels at the Fen



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Numerical model design, construction and refinement

Boundaries of the modelled area should be defined from the conceptual model including its piezometric surface map. In order to adequately consider the impacts of abstractions on both the site of interest and other surface water features, and to allow comparison of output against river flow gauges which may not be local to the site, it is likely that the boundaries will have to be set at some distance away from the site. Models are thus likely to be at the sub-catchment or small regional scale, rather than finely focussed on the designated site itself.

Steady state simulations may be useful in the early stages of model development and validation but, if consideration of critical low flow periods is required, the model should be refined through comparison with available data in transient mode. It should incorporate historic actual abstractions and meteorology for this purpose – in most cases a monthly stress period should be adequate.

The purpose of constructing the numerical model is to demonstrate the impact of groundwater abstractions using a simplified but credible representation of the 'source, pathway, receptor' understanding presented in the conceptual model (see separate summary). Although it is important to show that the model representation is reasonable, it is strongly recommended that the model is used to review the impacts of abstraction from a very early stage in its development – well before it might be considered to be robustly calibrated according to general practice in the development of a groundwater model. Running 'no abstraction' and 'fully licensed abstraction' scenarios and reviewing the results will help to highlight any errors in model construction and will provide an early estimate of the possible magnitude of impacts, thereby indicating the likely value and benefits of further time spent in refinement.

Demonstrating the impact of consented groundwater abstractions

In general, predicted impact is defined as the difference between calculated model behaviour in the absence of consented activities, and in the presence of consented activities. More confidence exists in the calculated difference, than in the absolute values. The intention is to review consented abstractions, therefore the scenarios should examine all licensed abstractions at maximum consented rates regardless of whether or not this can be taken using the installed pumps, pipes etc.

The sequence of steps will thus be to establish a relatively rapid dynamic calibration using actual abstraction data, to produce from this a 'no abstraction baseline' by turning off all abstractions, and then to calculate impact by turning on all abstractions at the licensed rate. If an impact is demonstrated (see below – Presentation and Review of Model Output), then additional work is necessary to identify the abstractions causing the impact, and the approximate proportion of the impact caused.

Presentation and review of model output

Model output should be presented to:

- Demonstrate that the simplified model representation of the designated site, sub-catchment and groundwater abstraction impacts are credible; and
- Predict the impacts of fully licensed groundwater abstraction. Calibration should be demonstrated by areal and time series plots of water level, by time series plots of flow data where available, and by statistical summaries of both levels and flows.

Dynamic model flow budget output can also be helpful for the whole model area, subcatchments drawn to flow gauges, and the cells representing the designated site itself.

Ways to present hydrological impacts and review their hydro-ecological significance against the feature prescriptions should be discussed with ecologists from the Environment Agency and Natural England early on in the model development process. Options include:

- Annual cycle plots of depth to groundwater level (with a single year range on which values from all years are plotted) including: the monthly tolerance ranges suggested by the hydroecological prescriptions for the 'most sensitive feature'; any observed depths to water from near surface piezometers on the site; simulated depths to water from the no abstraction and full licensed runs, an example is shown on Figure 1;
- Time series plots of both no abstraction and fully licensed abstraction scenarios on groundwater levels and drain or river discharge flows, and of the difference between them. Time series plots of wetland drain discharge flows simulated by the full licensed scenario as a percentage of those from the no abstraction scenario may also be helpful;
- Level-duration, river flow-duration, and drain or

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- spring flow-duration curves for both scenarios, with tabulated differences at key percentiles – particularly the 95 percentile which is commonly as a low flow parameter for rivers; and
- Indicative drawdown maps at key times (e.g. selected drought years) focusing on the uppermost layer of the model.

In many cases, the ecological effect of the impact produced will not be clear cut and assessment of the significance of the effect will require discussion with the Environment Agency and Natural England.

In some cases it may be possible that the depth to water ranges predicted for the 'no abstraction' scenario lie outside the tolerances suggested for ecological features present on the site. If existing monitored depths to water plot within the tolerance range, such 'no abstraction' predictions may imply that the actual existence of these ecological features is in part related to the current groundwater abstraction stresses. However, both 'no abstraction' and 'fully licensed' scenario predictions should be viewed with some caution as they may take the model beyond its historically calibrated range and groundwater – surface water interaction mechanisms may not be reliably simulated.

Uses

Groundwater models have been used for many years as part of investigations into low river flow alleviation or wetland restoration projects (e.g. the Wylye model on the Hampshire Avon SAC and the model used for relocation of the Redgrave abstraction as part of Fen restoration in Suffolk). There has been a recent increase in their application to groundwater abstraction impact issues for Habitats Directive assessments (e.g. the River Itchen SAC, the Bourne/Upper Avon SAC, many wetlands in East Anglia). But it is important to remember that all of these studies also involved significant collection and analysis of hydrometric data and field evidence.

Without such evidence, and the structured process required to produce a conceptual understanding of the system which is agreed by the main stakeholders (especially the Environment Agency, the water companies/abstractors, and Natural England), a distributed numerical model may be a misleading and costly distraction.

Furthermore, although the existence of a credible and accepted model should take much of the argument out of hydrological impact predictions (i.e. stream flow depletion, water table drawdown etc), uncertainties regarding the effects of these impacts on the ecology will still have to be grappled with.

Further information

Guidance for the Appropriate Assessment of Impacts from Licensed Abstractions on the Hydrological Regime of Groundwater Fed Wetlands. Entec Technical Note for Environment Agency Anglian Region.

Manual of Notes on Groundwater Modelling, Environment Agency National Groundwater & Contaminated Land Centre.

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Groundwater abstraction drawdown methods (based on radial flow assumptions)

Summary

Type of system where applied
Groundwater Fed Wetlands.

Applicability to groundwater or surface water
To assess groundwater abstraction drawdown impacts related to Licensed or Recent Actual pumping rates.

Hydrological data requirements
Conceptual understanding of relationship between abstraction ('source'), aquifer and drift layering ('pathway') and near surface wetland water table ('target'). Assessment of historic groundwater level and groundwater abstraction time series relationships, including signal or pumping test results, plus appreciation of other factors influencing groundwater levels (e.g. site drainage, riparian evapotranspiration). Hydraulic parameters for predictive impact analysis, currently licensed groundwater abstraction locations (relative to the wetland), pumping rates (licensed and recent actual) and seasonal limits, pumping duration and recharge assumptions.

Ecological data requirements
None as such BUT can compare drawdown predictions with observed water levels in the context of hydro-ecological water level regime prescriptions for wetland features. See *Ecohydrological Guidelines for Lowland Wetland Plant Communities* on Environment Agency website.

Can method be used on its own?
Must have a conceptual model first, then can usefully be applied to all groundwater abstractions (GWABS) within 5 km of a wetland at once and combined with Licence Accumulation Diagram (LAD) format output to provide total 'in-combination' drawdown predictions, plus the contribution of each abstraction to the whole. But further ecological 'effect' interpretation will still be required to determine adverse effect for Habitats Directive sites.

Applicability to European interest features
Standard hydrogeological techniques which can be applied to any wetland or location – only relevant to those wetland Habitat Directive (HD) features which depend on a groundwater level regime.

Resource requirement
Once conceptual understanding, aquifer parameters and abstraction data are collated, simple 'first pass' application of analytical solutions like Theis, Hantush or Neuman can provide aquifer drawdown estimates and associated LADs within a few hours. Application of more sophisticated techniques seeking to determine near surface water table drawdown in response to pumping signals deeper in the aquifer (e.g. layered radial flow modelling) may take a few days.

Figure 1 shows alternative analyses and models for the prediction of drawdown due to groundwater abstraction including simple Hantush (leaky aquifer) and Neuman (unconfined aquifer) approaches. Figure 2 shows a more involved layered radial flow model (to predict drawdown at shallower depths).

Background

Wetland ecological features may be sensitive to changes in the shallow water table regime resulting from groundwater abstraction drawdown impacts. A key part of Review of consents (RoC) Appropriate Assessments for groundwater fed wetlands therefore includes estimation of drawdown impacts, relative to a natural baseline, associated both with current rates of abstraction and with fully licensed abstraction. These estimates must be based on a sound conceptual understanding of the relationships between the open or screened section of abstraction borehole where the stress is applied (the 'source'), the aquifer and any drift layers through which the signal must be transmitted (the 'pathway') and the ecological feature dependent on the shallow water table depth regime (the 'receptor'). This source – pathway – receptor type of conceptual model for Habitats Directive assessments is described in a separate sheet. They must also maximise the use of any monitoring evidence of abstraction related drawdown (e.g. from comparison of historic abstraction rate changes and water level fluctuations, from pumping tests carried out during licence determination, or from more recent 'signal tests' on operational sources.

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However, in order to assess the impacts of full licence uptake, predictive techniques are likely to be required. A wide range of approaches can be attempted from simplistic confined aquifer analytical solutions (e.g. Theis), to more complex leaky or unconfined aquifer assumptions (e.g. Hantush or Neuman), layered radial flow numerical models or distributed numerical models. Distributed numerical models are described in a separate sheet. This sheet focuses on analytical and numerical radial flow approaches which can be applied to determine drawdown impacts from all of the licensed abstractions within a given radius of the wetland (e.g. within 5 km). The output from these analyses are most effectively represented in Licence Accumulation Diagrams (LADs) which are also described on a separate sheet.

Time and parameter requirements for these radial flow based techniques increase as they become more sophisticated and a progressive screening approach is recommended. Simple analyses should be tried first (e.g. Theis) on the understanding that they should represent conservative, precautionary estimates of drawdown. More complexity can then be introduced to better represent the conceptual model until the site is either clearly moved forward to the next RoC stage (on the basis that a significant drawdown impact is likely), or dropped from the process (because the total drawdown is predicted to be less than agreed thresholds). In some cases significant uncertainty will remain which further, more sophisticated analysis will not remove – these sites will also be moved forward together with recommendations for further investigations or monitoring to improve confidence.

Method description

Analytical Drawdown Estimates (e.g. Theis, Hantush or Neuman)

An initial screening assessment of drawdown at the wetland associated with all the surrounding groundwater abstractions can be made using the **Theis** equation. This is most readily achieved by collating all the abstraction licence information in a spreadsheet (including locations, licence numbers, annual limits, assumed distributions of abstraction stress between multiple location licences which are conservative with respect to the wetland itself, etc.) together with the Theis function and aquifer parameter assumptions. Use of the 'Aquifer Win32' radial flow analysis package is also an appropriate alternative. The drawdown from each abstraction can be calculated based on both the licensed annual abstraction rate and the daily maximum limit with aquifer parameters T and S specified as uniform but subject to sensitivity across a very broad range of values, e.g. after an assumed pumping period of 200 days (a 'long period' without recharge).

Theis calculations of drawdown in the pumped and confined aquifer, with no recharge, based on a daily maximum abstraction rate and based on aquifer parameters on the outer bounds of credible ranges are deemed worse case. They are then assumed to result in conservative over-estimates of the drawdown which would actually occur near the ground surface of the wetland. This is particularly the case when considering water level impacts in the upper, unconfined, discharging layer of a layered Drift-aquifer system which is typical of many wetlands.

For wetlands where analytical models other than Theis are deemed to be more appropriate (but still relatively simple) then alternative drawdown calculations can be made. It must be stressed that an appropriate conceptual model of the site is established to inform aquifer parameters used in calculations. This might also involve the use of spreadsheets or packages such as Aquifer Win 32 to estimate unconfined aquifer (**Neuman**) or leaky aquifer (**Hantush**) drawdown and then simply assuming superposition of these impacts at the wetland.

This represents 'one step beyond' the Theis calculations and it is recommended that the same time period (e.g. 200 day) is assumed but that abstraction rate and main aquifer parameter assumptions are more credible than the extremes previously adopted. In all cases it is expected that the predicted drawdown (which is still in the pumped aquifer rather than any overlying layer) will be less for the leaky aquifer than the Theis estimates and, in some cases, may fall below the total combined drawdown threshold chosen to represent a 'negligible impact'.

If drawdown at the site can be demonstrated to be sufficiently small, the hypothesis of impact can be rejected. If the site is unconfined, 'sufficiently small' is likely to be defined with respect to the natural variation of water level in the wetland considering the assumed tolerance of the features present, if data are available. If the site is leaky, it is more likely that the hydrology of the wetland is defined by the hydraulic gradient causing leakage, than by the absolute level of the piezometric surface. In this case, 'sufficiently small' will need to be evaluated with respect to the known range in gradient. It will be particularly significant if the drawdown is sufficient to change the sign of the gradient whereas the existence of a consistent upward gradient under high artesian pressure might suggest a strongly restricted pathway and negligible potential impacts.

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A 10cm drawdown threshold has been generally adopted for Stage 2 Assessments (as this was recommended in TRAG as a default value). However, a more cautious 5 cm drawdown threshold is recommended in TRAG for fen/mire communities. These thresholds may also provide an appropriate screen for Stage 3, although this needs to be agreed with Natural England/CCW (where appropriate) and the Environment Agency –more specific thresholds for different features may need to be considered, based on their tolerance in different seasons or months, as evident in the hydro-ecological prescriptions. As this level of simple analysis is precautionary relative to subsequent, more sophisticated, layered approaches, it is reasonable to review results against the chosen threshold and, if appropriate, use them to justify a statement of 'no adverse effect' without further work.

In addition to calculation of a total drawdown at the site through superposition, the contributions from each abstraction can be tabulated and plotted in revised LADs. It may also be useful to map the results as a series of overlapping 5 cm drawdown circles, drawn around each source – the Aquifer Win32 analysis will generate a drawdown map as an alternative.

Application of these approaches should take a few hours only for each site, including the provision of some time to investigate the sensitivity of the final answer to a variety of credible assumptions regarding aquifer parameters.

Layered, Radial Flow Model Drawdown Estimates
If the simple approaches described above indicate that possible abstraction impacts may be above agreed threshold levels, the application of more sophisticated radial flow models should be considered. These models will provide an estimate of drawdown in an upper, unpumped aquifer, in response to abstraction stresses applied to a lower layer – a conceptual arrangement which is of relevance to many of the wetlands under consideration. However, it is important to note that they will not take account of the near-surface influences of ditch or river drainage/recharge boundaries which will tend to reduce the amplitude of both seasonal and abstraction related water level fluctuations. In this respect it is reasonable to consider the resulting drawdown estimates as conservative relative to a regional flow model which includes these boundaries.

A version of MODFLOW transformed to operate on radial flow assumptions can be applied (or any other appropriate radial groundwater flow model). In many cases it is likely that a three layer model (possibly representing pumped aquifer – aquiclude – wetland aquifer, depending on the conceptual model) should be adequate for the level of analysis. The thickness and parameterisation of the layers and the conductance between them should be derived from the data integration and conceptual understanding and informed by previous analytical approaches. In line with these approaches a prediction of the radial distance – drawdown curve can be made for all layers assuming 200 days abstraction with no recharge.

The radial flow model may then only be run once for each of the main aquifers from which abstraction occurs, with the resulting distance – drawdown curve copied into a spreadsheet where it is used to determine the drawdown in the upper wetland layer due to each abstraction in turn, based on distance from the wetland and scaled according to abstraction rate.

Once again it is probable that the upper, wetland layer drawdown estimates from such models will be smaller than any simplified leaky single layer analysis previously carried out. As before these drawdown predictions for the wetland layer should be compared against the same threshold values and hydro-ecological prescriptions to determine whether a statement of 'no adverse' effect can be justified or whether further appropriate analysis (possibly using time variant distributed models) is required.

Application of the radial flow modelling approach should be based on the aquifer parameters found to suggest the largest credible drawdown estimates in previous analytical sensitivity analysis. By choosing such conservative parameter combinations, the need for extensive sensitivity analysis using the radial flow model can be minimised so that results should be obtainable within a day.

Uses

Apply these techniques where the ecological feature is dependent on a shallow water table 'depth to water' regime which may be impacted by groundwater abstraction i.e. groundwater fed wetlands.

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Further information and references

Local hydrogeologist with experience in developing ideas and conceptual models using disparate data. Entec have developed spreadsheets to streamline all of these analyses for application to Anglian groundwater fed wetlands. Entec would be happy for these to be adapted for use more generally across the country although this would require further resources possibly with associated training. Calculations should be carried out by persons with hydrogeological knowledge to avoid misapplication of the spreadsheets, preferably with experience of the particular aquifer in question.

Standard pumping test analysis texts (e.g. Krusemann & de Ridder).

User Manual for Aquifer win32.

Environment Agency Internal Document; Habitats Directive Stage 2 Review – Water Resource Authorisations; '*Practical Advice for Agency Water Resource Staff*' Version 2; March 2001.

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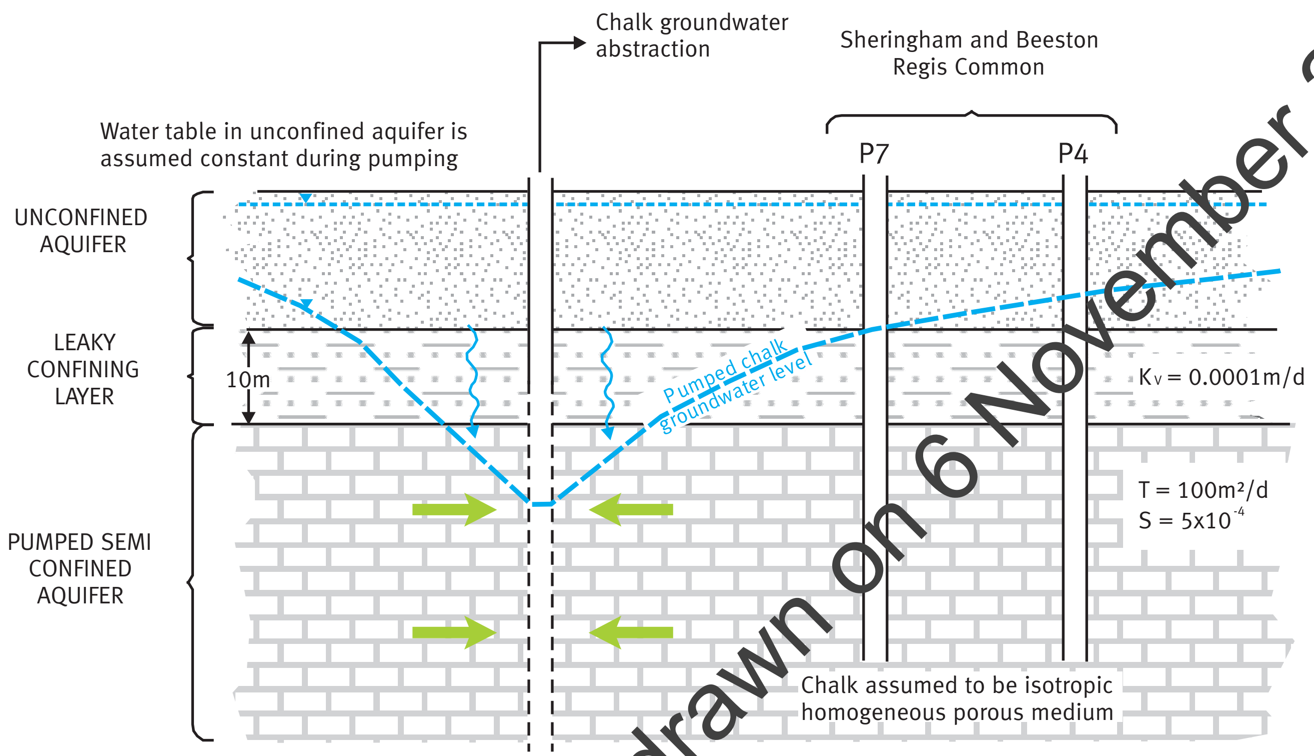
Figure 1 Simple analytical models for Hantush and Neuman

Confined – leaky aquifer approach (Hantush)



Confined – leaky aquifer approach (Neuman)

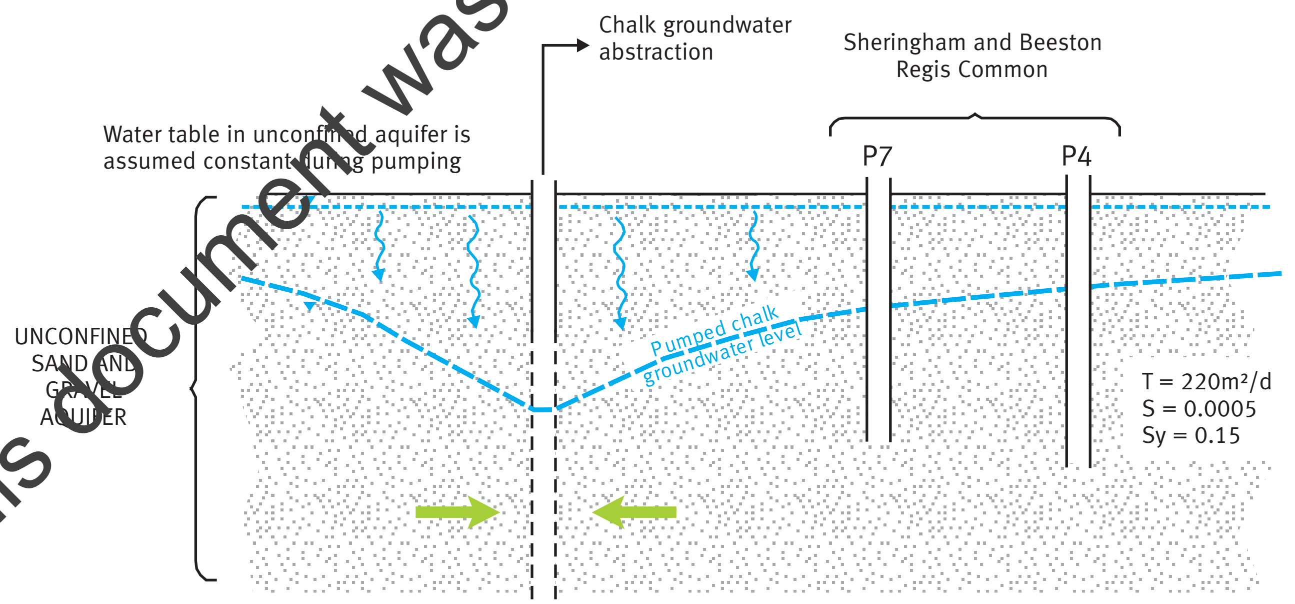


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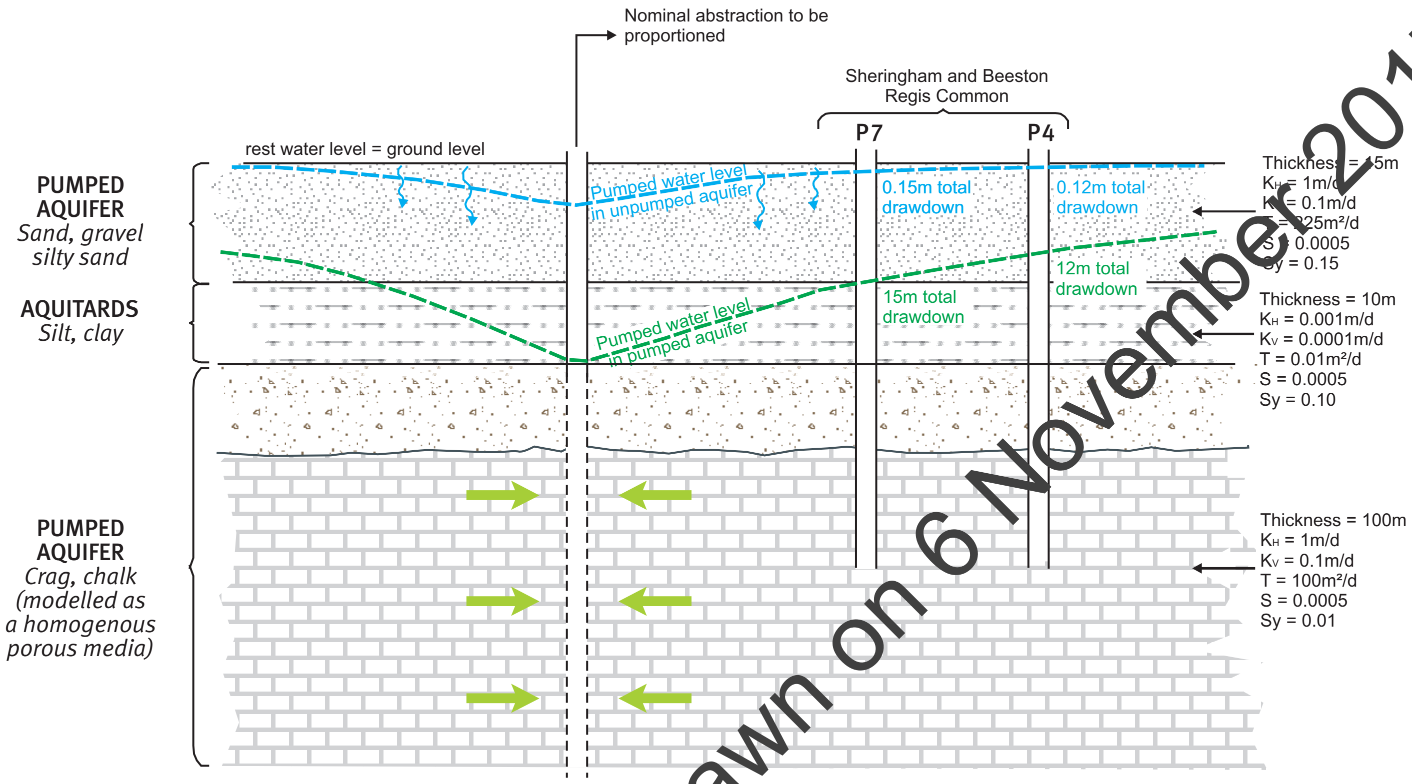
Figure 2 Three layer numerical redical flow model



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Conceptualisation for Habitats Directive Appropriate Assessments

Note: this approach can be tailored to suit any hydro-ecological investigation irrespective of the legislative driver

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Summary

Type of system where applied
All.

Applicability to groundwater or surface water
Surface water and groundwater.

Hydrological data requirements
Integration of a wide variety of hydrological, hydrogeological, water quality, and meteorological data to develop an understanding of water supply and quality influences on the water dependent site concerned. Information should also be gathered on the size and location of artificial influences (abstractions & discharges) thought to affect the water supply to the site.

Data needed may include rainfall & evaporation, or MORECS/MOSES hydrologically effective rainfall, recharge, abstractions and discharges, local geology, topographic or groundwater level contours, measured river flow hydrographs, groundwater level hydrographs, water quality distribution, river flow accretion data.

Ecological data requirements
Habitat type and species data. Habitat type NVC survey data, or other vegetation mapping, should show the extent of particular communities of interest. Target notes may provide some qualitative information on the condition of the communities and the presence/absence of positive and/or negative indicator species.

Survey data for particular species will provide an overview of the distribution, abundance and conservation status.

The relevant species/habitats pages within section 2 this document will help develop an understanding of the vulnerability and sensitivity of ecological features to changes in water supply. Hydro-ecological prescriptions can then start to be established.

Can method be used on its own?
Establishing a sound conceptual characterisation is a vital first step for any Appropriate Assessment or other hydro-ecological assessment technique. Conceptualisation should be refined iteratively throughout the process.

Applicability to European interest features
Applies to them all.

Resource requirement
Can be very quick and based on expert elicitation/brainstorming or can be based on analysis and integration of large volumes of data. Resource requirements will be determined partly by available information, current understanding and the status of the site under investigation.

Figure 1 is a conceptual cross section drawn through the River Itchen cSAC to show mechanisms of groundwater abstraction impacts on river flows.

Background

As a pre-requisite to applying any assessment it is essential to establish a sound conceptual understanding of:

- the natural water supply and water quality regime of the site;
- the way in which this has been modified by the actual influences of Environment Agency granted consents;
- the extent to which these impacts might be exacerbated if the consented activities were to increase to their maximum allowable limits; and
- the other factors which may also influence the designated ecological features.

The aim of a Habitat's Directive Appropriate Assessment is to ascertain there will be **no adverse effect on the integrity of the European site.**

The 'source-pathway-receptor' paradigm is recommended as the framework for developing conceptual models to support Appropriate Assessments, which in this context becomes 'consent-mechanism-ecosystem' approach. An adverse impact can exist only if there is a consent (given), a vulnerable ecosystem, and a mechanism by which the consent can effect the ecosystem. The presence of a vulnerable ecosystem is a given at most (but not all) sites, and therefore the thrust of demonstrating no impact will lie in demonstrating either that there is no mechanism, or that the hydrological or water quality impact via such a mechanism is negligible (or not significant).

A robust determination is required based on a sound conceptualisation of the mechanisms involved, but a degree of pragmatism is also imposed by constraints of available data, as well as by time and resources. Full understanding of most of the sites concerned is unlikely to be possible from the available dataset. Determinations may be conservative, but not unreasonably so. An impact that is too small to detect can be discounted under triviality.

Within these constraints, methods of calculating impact should take sufficient account of the site conceptual model to be defensible, and should assess the effect of simplifications made, demonstrating either explicitly or by reference that these simplifications are conservative with respect to calculating impact.

It is unlikely that any determination of impact will be the final statement on the matter.

However, any determination of no significant impact or adverse effect will be a final statement.

A useful principle is that simple approaches should be tried first, but that if the possibility of impact cannot be eliminated, then more complex approaches may be tried. The work is complete once:

- it is clear either that there is negligible or none significant impact; OR,
- that there is a possible impact, the size of which has been determined and apportioned to the causing consents; OR
- that it is impossible to prove given the present state of knowledge that there is no impact (which is by default a determination that there is a possible impact).

Thus if, after 'more complex' assessments, risk of impact still cannot be excluded, the site will be carried forward to where further detailed studies of remedial actions may be necessary.

Method description

Conceptual models may be developed at a variety of scales and degrees of sophistication, based on extensive data analysis or more rapid expert elicitation. The following summary description is an EXAMPLE which focuses on trying to understand the effects of groundwater abstraction ('source') drawdown and flow impacts, as propagated through the intervening aquifer ('pathway'), on the shallow water table and drain system of a wetland habitat ('receptor'). It is hoped that the reader will be able to make analogies with other types of Review of Consent problems.

Data collation and integration

Collate information on the current '**sources**' around the wetland which may be causing impacts:

e.g. licensed and unlicensed abstraction locations within 5 km of the site, historical, current and licensed rates of pumping including (for the largest) depths of screened or open sections.

Collate information to provide an understanding of the '**pathways**' from the sources to the near surface wetland: e.g. geological layering, historic responses of groundwater levels to changes in abstraction and recharge stresses (including the results of any 'signal' or pumping tests), aquifer properties (horizontal and vertical layering)and hydrochemical data.

Collate information to provide an understanding of the designated ecological features – the '**targets**' for the analysis: e.g. distribution, abundance and vulnerability mechanisms.

Collate information on the other, 'non-consented factors' which may also influence the ecological features: e.g. site drainage, physical habitat management etc.

Schematic maps and sections

Prepare plans and hydrogeological cross-sections including source, pathway and target and illustrating the main features including:

- the main watercourses;
- the locations of consented abstractions and discharges from groundwater and surface water and any protected rights (these will be shown in plan, with key abstractions in section as appropriate);
- sections through the main wetlands;
- sections through other points of interest such as springs, IDB drains, etc.

The area considered should be large enough to include all consents expected to affect the site.

The plans should identify the rough line of cross-sections.

The preparation of the working plans and cross-sections should be viewed as a way of facilitating three-dimensional visualisation of the hydrological system. The schematic cross-sections should draw together on one diagram details of the following:

- the geological framework, including the shallow geology and any Quaternary deposits;
- an indication of topography;
- factors affecting groundwater recharge;
- controls on surface water levels, e.g. ditches, rivers and IDB drains and their sluices should be identified and tied in to sections;

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- location of ecological features;
- sections through public water supply or spray irrigation boreholes as appropriate showing the position of the open section so abstraction horizons are established and an indication of transmissivity and storage characteristics of the deposits;
- an indication of the behaviour of groundwater levels within the area and for the different geological units represented by the schematic cross-section, or an indication of how we anticipate the piezometric levels at different depths are behaving both naturally and in response to hydrochemistry – we need to gain an understanding of the horizontal and the vertical flows;
- an indication of the hydrochemistry; and
- an indication of the flows and factors which control surface water levels in watercourses.

The cross-sections should indicate the hypothesised flow of water from the ground surface through the unsaturated and saturated aquifer system within and across the boundaries of the hydrological domains. The unsaturated and saturated zone flow processes should be indicated, with emphasis on the dominant processes within any domain. The degree of surface water/groundwater interaction should be given particular consideration. From the available field evidence, and from our previous experience, what do we think the processes are?

Basically, what are the inflows and the outflows, what are the pathways along which water will flow, and which pathways are abstraction horizons likely to be affecting?

Assessment of vulnerability mechanisms

For effective analysis of hydrological impact there must be an assessment of how impacts may arise at the ecological level. Key parameters are one or more of:

- Water level regime;
- Water flow regime (velocity or volumetric rate); and
- Water quality regime.

Conceptual understanding and uncertainty

A conceptual understanding of the groundwater and surface water flow system should be drawn from the schematic maps, sections, and water balances with particular reference to the hydroecological vulnerability mechanisms and 'source – pathway – target' philosophy.

This understanding should extend beyond the wetland to identify other surface water features which are also thought to be dependant on groundwater discharge and may therefore also be impacted by groundwater abstraction.

The limits of the current conceptual understanding and major uncertainties should be indicated.

These uncertainties may include geological uncertainties. The extreme plausible conceptual model leading to the greatest impact should be identified and defended with robust argument. If such an identification cannot be made or defended, sensitivity testing will be needed at a later stage to demonstrate a conservative assessment. Iteration, refinement and development are essential components of the conceptual modelling process.

Application

A conceptual model of the type described above can be applied to make quantitative assessments of impact according to a variety of techniques which are separately described (including water balance assessments, groundwater level drawdown estimates, Impacts from Groundwater abstraction on River Flows (IGARF) type assessments, distributed groundwater models etc).

Sensitivity

Conceptual models need to be tested quantitatively to understand how sensitive they may be to assumptions which are inevitably required in the face of conceptual or parameter uncertainty.

Applicability

Some form of conceptual description should be possible and essential for any Appropriate Assessment.

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Further information

Ecohydrological Guidelines for Lowland Wetland Plant Communities
'*Resource Assessment and Management Framework – Report and User Manual – Version 3*' (2002), R&D Manual W6-066M Version 3, published by Entec on behalf of the Environment Agency.

Various Environment Agency documents (particularly from the NGWCLC including the IGARF Manual).

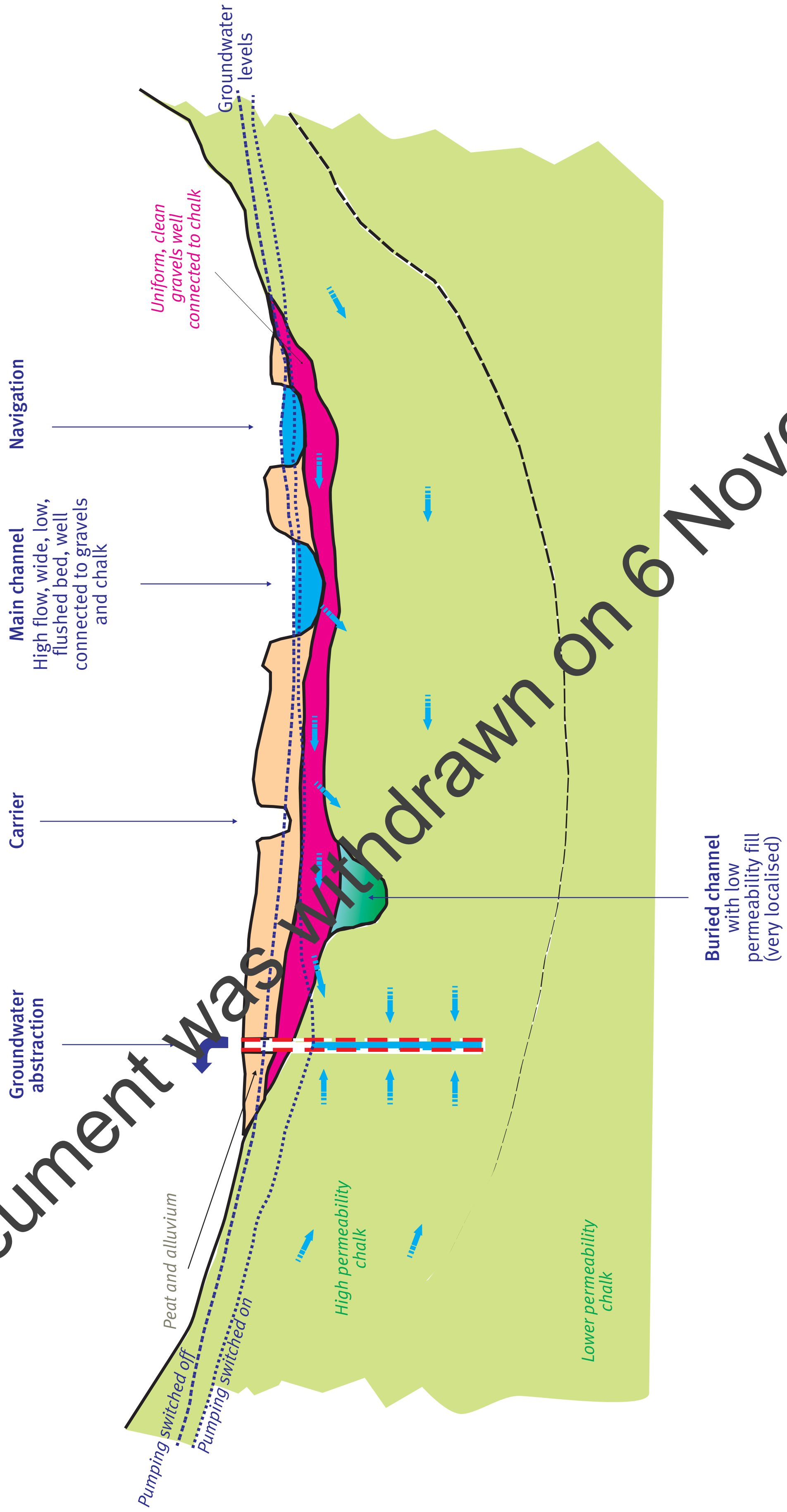

Figure 1 Conceptual understanding of the impact of groundwater abstractions on river flows

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Flood inundation modelling

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Summary

Type of system where applied
Riverine or Estuarine. Consider also for assessment of flood flows and flood storage within Reservoirs/Lakes, Embayments and natural or artificial Flood Washlands.

Applicability to groundwater or surface water
The technique can be used to estimate flow volumes and velocities, extent, depths and duration of flooding in flood washlands, depths of flow within rivers and associated floodplains under flood conditions of varying probability. More complex 2D models can be used within extensive floodplains and estuaries while 3D models are usually only used in large estuaries.

Hydrological data requirements
These depend on the type and complexity of the model. All models will require data on channel topography (or estuary bathymetry), and channel roughness. Flood flows can be estimated using Flood Estimation Handbook (FEH) techniques while tidal levels can be estimated from extreme tidal datasets.

Ecological data requirements
None, although more sophisticated techniques are evolving to model natural river regimes including vegetated channels.

Can method be used on its own?
It needs to be combined with Flood Estimation methods and some form of Digital Elevation Model (DEM) where large out-of-bank flows are forecast.

Applicability to European interest features
This method relates primarily to wet grassland sites (usually designated for their bird species) where depths and duration of winter flooding are of concern, or washlands where water level management under extreme flow conditions is required. Flood and tidal modelling is also applicable to coastal sites where habitats may be vulnerable to increased levels or flow velocities.

Resource requirement
Depends upon nature and complexity of modelling undertaken.

Background

Flood inundation modelling provides a methodology for estimating flood flows, velocities and depths of flow in rivers and associated floodplains under flood conditions as well as depths and durations of flooding in washlands. Coastal and estuarial models can be combined with coastal process models to estimate impacts on coastal and estuarial habitats, as well as transitional wetlands.

Increasingly such models are also being used to investigate hydrological impacts under climate change using sensitivity analysis (e.g. increasing flood flows by 20%).

The level of sophistication applied to modelling can vary widely depending upon the specific application and the time/budget available for making the assessment. Flood models can be subdivided into the following categories: -

- 1D models (e.g. HEC-RAS, MIKE 11, ISIS) – typically used for river modelling where floodplains are reasonably contained, although may be applied in a quasi-2D form to simulate complex floodplain hydraulics.
- 2D models (e.g. MIKE 21, DIVAST) – becoming more widely used and applicable to situations where floodplains are very wide and in wide estuaries or embayments.
- 3D models (e.g. MIKE 3, TRIVAST) – require a significant input of resources and are more normally used for research purposes.

Models can be run in steady-state or time variant mode. Steady-state models are used where a single simulated flow and corresponding water level are required. They take no account of storage effects or time-variant boundary conditions such as tidal cycles. As a result flood extents may be conservative and are usually used where a quick precautionary assessment is required for little financial or temporal outlay. Where storage effects are significant or time-variant effects such as duration and variation in level are important then time variant or hydrodynamic models are used.

General data requirements

General data requirements for flood modelling include:

- estimate of flood peak flows or flood hydrographs; in tidal regimes this would also include extreme tidal levels and tidal cycles (see below);
- evaluation of river geometry or estuarial bathymetry and associated surface roughness for input into channel hydraulics; and

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- some form of Digital Terrain Model (DTM) or Digital Elevation Model (DEM) covering the floodplain onto which predicted flood levels can be mapped to predict flood extents under floods of varying magnitude and/or temporal characteristics.

Flood estimation

Flood estimation can be carried out on un-gauged and gauged catchments using flood estimation techniques based on the Flood Estimation Handbook (FEH). Where gauged records exist statistical analysis can be carried out using series of annual maxima or peaks over threshold (POT) to estimate peak flows. An alternative approach uses rainfall-runoff methods to generate flood hydrographs. For ungauged sites or sites where there are insufficient observed data, methods exist to pool data from 'pooling groups' of gauged sites in nearby or hydrologically similar catchments.

In estuarial situations it may be necessary to assess extreme levels based on a combination of tidal conditions and extreme flood flows. This is normally carried out using joint probability techniques.

1D hydrodynamic models

- HEC-RAS
  - Steady and unsteady 1D flood flow simulation in river networks. Produced in the US by the Army Corps of Engineers, widely used particularly by smaller consultancies.
  - Website: http://www.hec.usace.army.mil/software/hec-ras/hecras-hecras.html
- MIKE 11
  - Steady and unsteady 1D flood flow simulation in river networks. Also simulates sediment and water quality. Produced in Denmark by DHI Software, and widely used around the world. Has an integrated rainfall-runoff simulation, including FEH methods.
  - Website: http://www.dhisoftware.com/mike11/
- ISIS
  - Steady and unsteady 1D flood flow simulation in river networks. Also simulates sediment and water quality. Produced in the UK by HR Wallingford Group. Has an integrated rainfall-runoff simulation, including FEH methods.
  - Website: http://www.wallingfordsoftware.com/products/isis.asp

2D hydrodynamic models

- MIKE 21
  - Unsteady 2D simulation of rivers, estuaries and coastal waters. Also simulates sediment, water quality and waves. Produced in Denmark by DHI Software.
  - Website: http://www.dhisoftware.com/mike21/
- DIVAST (Depth-Integrated Velocities and Solute Transport)
  - Unsteady 2D flow and contaminant transport estuarine/coastal model. Produced by the Environmental Water Management Research Centre (at Cardiff University).
  - Website: http://www.cf.ac.uk/engin/research/water/2.1/2.1.1.6/erdf2.1.1.6.html

3D hydrodynamic models

- MIKE 3
  - Unsteady 3D simulation of rivers, lakes, estuaries, bays, coastal waters and seas. Takes into account density variations, bathymetry, meteorology, tidal elevations and currents. Produced in Denmark by DHI Software.
  - Website: http://www.dhisoftware.com/mike3/
- TRIVAST
  - Unsteady 3D simulation of hydrodynamics (3D extension of DIVAST, see above). Makes a hydrostatic assumption in the vertical plane.
  - Website: http://www.cf.ac.uk/engin/research/water/2.1/2.1.1.6/erdf2.1.1.6.html

Link to sediment transport/coastal process models

Flood inundation models can be linked to sediment transport models and various packages are available, often as additional modules within an overall modelling package. Examples include MIKE 11, MIKE 21, MIKE 3, ISIS, DIVAST and TRIVAST.

Lidar terrain mapping

Summary

Type of system where applied
A method of obtaining topographic data which is applicable to site characterisation and as an aid to the interpretation of hydrological impacts into effects.

Applicability to site
Relevant to interest features associated with regimes identified above.

Standard applications
Topographic data are integral to the water resource function of the Environment Agency, in particular flood plain and drainage mapping, coastal zone monitoring, flood risk analysis, hydraulic and groundwater modelling and monitoring.

Resource requirement
Relatively inexpensive process requiring airborne laser scanning and subsequent truthing and filtering. In many cases more costs effective than high-resolution ground based topographic survey.

Introduction

LIDAR (Light Detection and Ranging), also known as airborne laser scanning, is a relatively new remote sensing technique for cost-effective topographic terrain mapping. It is ideally suited for mapping extensive areas where accurate elevation data are rapidly required.

The Environment Agency, Infoterra, and Ordnance Survey are together promoting this technique. It was first flown by the Environment Agency in 1998 and is rapidly developing with constant improvement in methods of data acquisition and processing. For instance, new equipment has meant that sites flown from 2000 no longer have the 'white space' problem due to absorption of the laser pulses by water and tarmac.

Method Description

The system operates on a principal similar to radar in that a laser ranger (ALTM – airborne laser terrain mapper) transmits a series of pulses, these are reflected back from the ground and used to measure the distance between the ground and the aircraft. The aircraft fixes its position to coincide with each pulse by an integrated on-board Global Positioning (GPS) and an Inertial Navigation (INS) system. Areas are generally flown in winter when there is less ground cover.

The output is in the form of contours and terrain models, which can be:

- Digital Elevation Model (DEM) representing the topographic surface and includes features such as buildings, trees etc (often referred to as clutter).
- Digital Terrain Model (DTM) representing the ground surface. It is processed by filtering out the 'clutter' from the DEM.

There are currently three methods of filtering the data to remove features and vegetation. In order of increasing sensitivity these are:

- Automatic (generally used);
- Semi-automated/ supervised (on request);
- Terrascan (as required).

The point elevations are acquired at 1 m or 2 m spatial resolution, to a vertical (z) accuracy of Ŷ0.15 m or even Ŷ0.10 m depending on plane altitude, and a plan (x & y) accuracy of better than 1/2000 x altitude. Independent ground truthing commenced in 2000 and now each polygon is automatically ground truthed when flown.

Data is available at a variety of postings between 0.5 – 2m although data at 0.15m posting is occasionally captured in areas where higher detail is required to identify smaller features

The Environment Agency can provide the data as a series of tiles, either 5 x 5 km or 2 x 2 km, and these are available on CD as both DEM and DTM models. They can be processed in ARCView using spatial analyst to produce high-resolution topographic surfaces in plan, section, and 3D.

Application

Applications include:

- Flood plain and drainage mapping;
- Coastal Zone monitoring;
- Flood risk analysis;
- Hydraulic modelling;
- Landform monitoring;
- Forestry management;

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- Landfill site assessment;
- Pipeline routing;
- Cartography.

The main advantage is that the method can be used to map areas of difficult terrain where accurate elevations are rapidly required by remote sensing and under most weather conditions.

Research is on-going into methods of improving the product, its accuracy, and its use in conjunction with other techniques, such as digital photogrammetry, image analysis, synthetic aperture radar (SAR) and land-form profiles.

Further information

Environment Agency: Science Enterprise Centre, Twerton.

Ordnance Survey website (www.ordnancesurvey.co.uk).

Infoterra website (www.infoterra-global.com).

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Topographic surveys

This document was withdrawn on 6 November 2017

Summary

Type of regime where applied

A method of obtaining topographic data which is generally applicable to site characterisation and as an aid to the interpretation of hydrological impacts into effects.

Applicability to site

Relevant to interest features associated with regimes identified above.

Standard applications

Topographic data are integral to the water resource function of the Environment Agency, in particular flood plain and drainage mapping, coastal zone monitoring, flood risk analysis, hydraulic and groundwater modelling and monitoring.

Resource requirement

Time consuming but relatively cheap process requiring data collection and processing.

Introduction

A topographical survey is used to spatially locate any point or series of points for position and height by defining the x and y co-ordinates (easting and northing) and z direction (elevation) in relative or absolute terms. These surveys used to be carried out using a theodolite and staff and the Ordnance Survey (OS) benchmark system, which was based on a series of observations dating back to the 1700s. However, this was declared redundant in 2002 due to inherent inaccuracies and surveys are now done using the Global Positioning System (GPS) and a series of OS electronic stations set up around the country.

Method description

Primary (E1) control stations are established, these require a minimum of six hours observations in conjunction with the OS Active GPS Network. Secondary (E2) control stations are established with a minimum of 1 hour's observation tied in to the local E1 station.

Tertiary (E3) stations are then established using GPS RTK (real-time kinematic) in some 5 to 10 minutes for local control.

- The Environment Agency recommends the following spacings:
- Linear Surveys: E1 station every 5 km, E2 stations every 1 km, and E3 as section controls between the E2s.

Area Surveys: An E1 station will give a coverage of 2.5 km in all directions, which equates to the distance of the radio telemetry links on the GPS equipment. E2 and E3 stations are at similar spacing described for the linear surveys.

Further readings are then taken using a GPS receiver and antenna on a pole and automatically adjusted to real time co-ordinates by reference to a control station. In places where there is inadequate satellite coverage, such as woods, readings are obtained using spirit level and staff and closing back (closed loop) onto the nearest control station.

The data are then processed to produce ETRS89 geodectic co-ordinates, which are currently transformed to OSGB36 via OSTN02 and to ODN (Ordnance Datum Newlyn) via OSGM02. The order of accuracy of the 2002 co-ordinate conversion is:

- standard error in plan (x & y) of the OSTN02 transformation is 0.10 m; and
- standard error in height (z) of the OSGM02 conversion is 0.02 m.

New surveying methods utilising virtual base stations e.g. SmartNet are facilitating cheaper and quicker surveys. In addition they are reducing the requirements for E2 and E3 stations as measurements to E2 accuracy's can be made in a matter of a few seconds.

As more active stations are set up by the OS and its partners, surveying with virtual base stations will become the norm

Application

The data form part of the fundamental information database for characterisation of any single point or site and fixes its spatial location in the continuum in either relative or absolute terms, depending on the datum.

The results have many varied applications. In the environmental field measurements on boreholes, gaugeboards, weirs, and dams are often used to relate water levels between these features and determine hydraulic gradients. Profiling is another common usage in the design of water-retention or measuring structures, such as dams and weirs, and for ecological and geological mapping. These data can also be contoured to produce topographical and piezometric plans as part of the broader picture.

Further information

Environment Agency National Standard Contract and Specification for Surveying Services, Version 2.2 (and subsequent amendments).

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Resource Assessment and Management (RAM) framework

Note: This method summary relates to RAM V.3 and will be superseded by RAM V.4 in March 2008.

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Summary

Type of system where applied
Riverine (potentially as a stand alone screening tool).

Components from RAM can also be used to assist assessments for other (non riverine) hydrological domains.

Applicability to groundwater or surface waters
Surface water and groundwater abstraction impacts on river flows – at a sub-catchment 'screening scale' (Flow Duration Curve (FDC) analysis in CAMSLedger.xls and daily flow hydrographs in RivDay.xls), plus detailed accretion profiling where required (in AccProf.xls). Also within RAM the Aquifer Response Function can be used to assist in initial characterisation of groundwater fed habitats served by large recharge capture areas.

Hydrological data requirements
Natural flow duration curves for a number of sites, gauged flow data, licensed & recent actual abstraction and discharge datasets (CAMSLedger), daily river flow hydrographs (RivDay), spot flow survey data and natural flow output from Lowflows 2000 (AccProf).

Ecological data requirements
Benchmark macro-invertebrate and macrophyte data, plus assessments of physical habitat and fisheries. Used within the Environmental Weighting (EW) System to derive River Flow Objectives (RFO) and assess actual ecological departure from the benchmark.

Can method be used on its own?
Yes (for riverine domains) – may require comparison with other river flow targets (e.g. those determined by Natural England/CCW), in addition to the Environmentally Weighted - River Flow Objectives (EW RFOs) derived within RAM Framework.

Applicability to european interest features
Mainly those associated with riverine systems; care required when interpreting data due to method sensitivity. See separate report on applicability (Environment Agency; 2003).

Resource requirement
Time consuming, requiring collation and processing of (generally) voluminous datasets. However, under the CAMS programme, necessary data sets will become increasingly established.

Figures 1 and 2 show the flow duration curve analysis, which lies at the heart of long term River AP resource assessment, and an example of an accretion profile which can be used to improve understanding of the distribution of abstraction and discharge impacts in between River Assessment Points (Aps).

The Resource Assessment and Management Framework currently provides the most appropriate tool for estimating the amount of surface water available within a river for abstraction relative to the ecological requirements of the watercourse, and for quantifying the Licensed and Recent Actual abstraction and discharge impacts on river flows (including groundwater and surface water consents). It can also provide an assessment of predicted recharge and discharge rates from any aquifers at a sub-catchment scale (e.g. aquifers draining to large coastal wetlands) and therefore be used to help characterise certain groundwater fed sites and assess impacts related to groundwater abstraction. However, the RAM Framework is not considered a suitable tool for evaluating local groundwater balances (e.g. in the vicinity of smaller inland wetlands) as the capture zones to such sites are often subject to significant temporal/seasonal variations and/or main aquifer interaction with the near surface is complicated by the near surface (drift) geology to the extent that the methods utilised in the RAM Framework are sometimes not considered appropriate.

The method, which applies to riverine systems with or without a groundwater influence, uses naturalised flow data as a benchmark to define ecologically desirable flow regimes on a reach-by-reach basis in the catchment, depending on the sensitivity of the ecology within the reach to abstraction related flow reductions. The ecologically desirable flows are compared with estimates of actual flows and flows predicted for fully licensed uptake to indicate the abstraction status of each reach. Care should be taken when applying the Environmental Weighting system (which is a component of the RAM Framework) to particularly sensitive species and habitats, as the sub-catchment resolution of the system may not be sufficient to achieve the desired level of confidence for Habitats Directive purposes.

Background

The river flow Resource Assessment and Management Framework compares the ecologically desirable flow in a river system with the denaturalised flows predicted for recent actual or fully licensed abstraction scenarios. This is achieved in five main stages:

- The natural flow regime at a number of locations ('assessment points') is established by, for example, use of Low Flows 2000, naturalising gauged flow based on abstraction and discharge data, or modelling;
- The sensitivity to abstraction related flow reductions (the 'environmental weighting band') for each assessment point is determined based on four ecological indicators: physical habitat, macrophytes, macro-invertebrates and fisheries;
- A minimum ecologically desirable flow regime (the 'river flow objective' – RFO) is hung from the natural flow duration curve based on the environmental weighting band. The more sensitive the ecosystem the closer the ecological RFO is to the natural flow. The appropriateness of the RAM Framework EW RFO for Habitat's Directive purposes (in comparison with Natural England's 'within 10% of natural flow' default Favourable Conditions Table Target) has been subject to separate review (Environment Agency; 2003);
- The natural flow is denaturalised by application of the abstraction and discharge dataset to produce an estimate of what the flow regime currently is based on recent actual abstraction and discharge impacts, and what it would be if all abstractions were increased to fully licensed rates. Where the recent actual flow is lower than RFO over much of the lower flow range, the reach may be given an 'over-abstracted' status. If this is the case only for the licensed scenario flow, the reach may be deemed 'over-licensed'. Where not over-licensed RAM provides an indication of surplus water above the RFO, which may be available for further abstraction licensing abstraction; and
- The denaturalised recent actual flow should be compared to gauged flow data to check that the assumptions underlying the natural flow regime and assigned influences for abstraction and discharge appear credible.

The RAM Framework EW system includes a further 'ground truth' check to investigate whether those reaches deemed to by 'over-abstracted' are showing signs of actual ecological stress.

How far away from the 'benchmark' or natural status are they, and, if ecological integrity appears to be impaired on the basis of monitoring data, is this due to the effects of flow reduction, or other factors (e.g. poor water quality or physical channel modifications).

The groundwater component of the RAM Framework uses estimates of recharge and discharge combined with aquifer properties data to evaluate the abstraction status of groundwater bodies, which may also be in various degrees of surplus, over-licensed or over-abstracted. Empirical evidence of groundwater problems or local techniques may also be applied as part of the groundwater tests. These groundwater resource analysis may have some value for the assessment of GW fed wetland habitats dependent on groundwater discharge served by large recharge capture zones. In fact, components from RAM are being used in ongoing Habitats Directive Review of Consents assessments for the North Norfolk Coast.

Uses

The RAM Framework was designed for application within the Agency's Catchment Abstraction Management Strategy process and is supported by some spreadsheet tools:

- CAMSLedger: flow duration curve analysis at River Assessment Points (APs), plus groundwater resource assessment for groundwater management units (GWMUs);
- RivDay: Daily river flow hydrograph analysis at 'critical' River APs;
- AccProf: River flow accretion profile analysis to identify abstraction impacts between River APs;
- GWMon: Monthly groundwater outflow analysis for critical GWMUs.

It is useful as a screening tool for identifying abstraction impacts and where water may or may not be available for further licensing at a sub-catchment scale. It can be used as an initial screening tool for new licences, but does not negate the need for a detailed local appraisal of any licence application and its effect on local water features and other water users to be undertaken.

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Although the accretion profile options will also be helpful in identifying smaller scale river reaches which are critically flow depleted the RAM Framework should be applied with caution when assessing effects on European habitats and species at this scale, as it is designed to be used as a screening tool. It provides a useful method of assessing impacts on these features but other techniques are also likely to be required for further analysis.

Data requirements

The RAM Framework is generally data intensive - it requires collection of considerable hydrological, ecological and abstraction and discharge data. Data requirements may be reduced by focusing efforts on major artificial influences or particularly sensitive river reaches.

Typical data required for riverine analysis include natural flow duration curves (Low Flows 2000, modelling etc), licensed quantities and actual abstraction data, discharge data (typically in the form of actual or consented dry weather flows). Many of these data are fairly readily available from existing Environment Agency databases although abstraction and discharge information often requires significant manipulation before input into the RAM Framework spreadsheets. For the groundwater assessment estimates of recharge, aquifer properties, and other groundwater parameters may be used, depending on the resolution of the resource assessment required. In some cases potentially useful datasets, for example abstraction returns, may be flawed or unavailable and simple but justifiable estimates must be made using, for example, uptake factors.

The RAM spreadsheets limit the number of River assessment points in any given river system to 20, and guidance suggests that the minimum catchment to an assessment point should be of the order of 50 km2 (although accretion profiles may be extended further upstream if required).

Applicability

The RAM Framework's intended use is as a high level screening methodology with the option of more detailed river flow accretion profiling where required. It can indicate where there is the potential for ecological impact or where abstraction *may* be increased without adversely affecting the ecosystem. Further investigation would be required on a site specific, more detailed, level to determine whether an interest feature (of a Habitats Directive site for example) is impacted by over abstraction and what changes are required to adequately mitigate effects.

Further Information

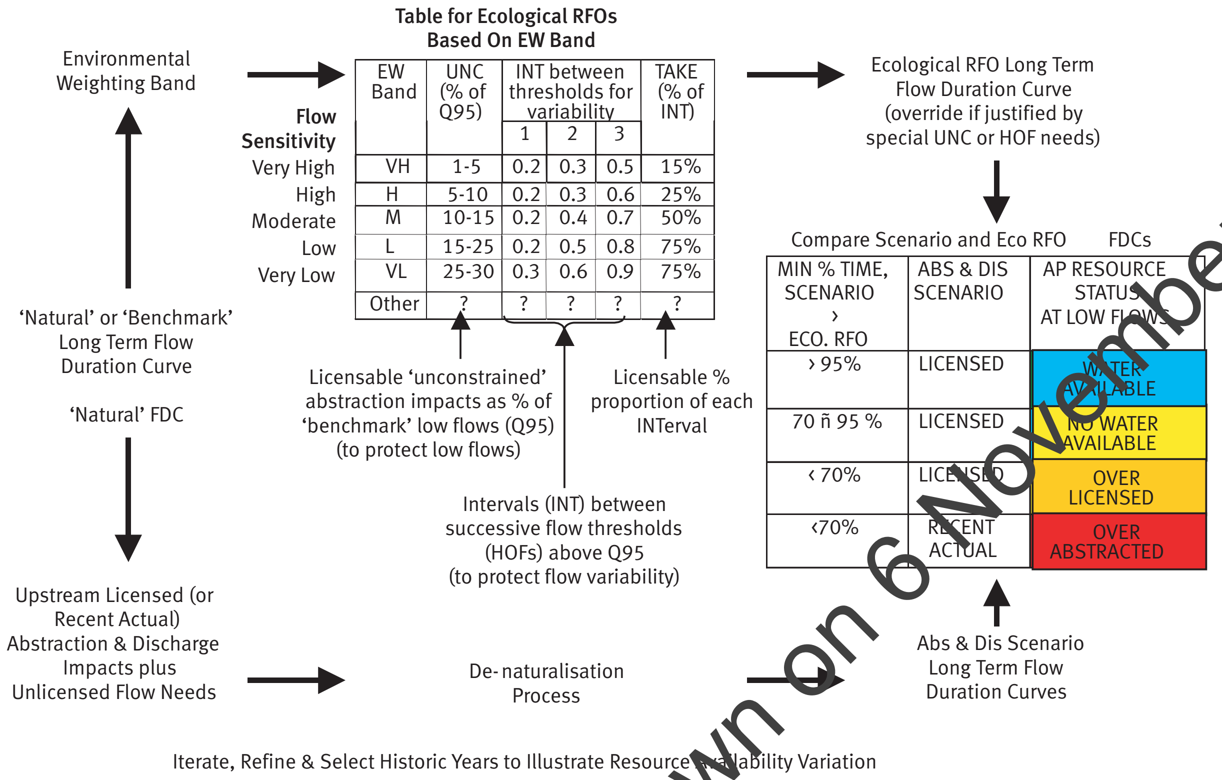
'Resource Assessment and Management Framework – Report and User Manual - Version 3' (2002), R&D Manual W6-066M Version 3, published by Entec on behalf of the Environment Agency.

(Environment Agency; 2003) *RAM Framework; An Appraisal of the EW System for Assessing Impacts on Habitats Directive Interest Features (currently in Draft);* Entec; December 2002.

This document was withdrawn on 6 November 2017

Figure 1 River AP resource assessment process (a), and example of long term flow duration curve analysis

a)



EW Band	UNC (% of Q95)	INT between thresholds for variability 1	2	3	TAKE (% of INT)
VH	1-5	0.2	0.3	0.5	15%
H	5-10	0.2	0.3	0.6	25%
M	10-15	0.2	0.4	0.7	50%
L	15-25	0.2	0.5	0.8	75%
VL	25-30	0.3	0.6	0.9	75%
Other	?	?	?	?	?

MIN % TIME, SCENARIO › ECO. RFO	ABS & DIS SCENARIO	AP RESOURCE STATUS AT LOW FLOWS
› 95%	LICENSED	WATER AVAILABLE
70 ñ 95 %	LICENSED	NO WATER AVAILABLE
‹ 70%	LICENSED	OVER LICENSED
‹70%	RECENT ACTUAL	OVER ABSTRACTED

b)

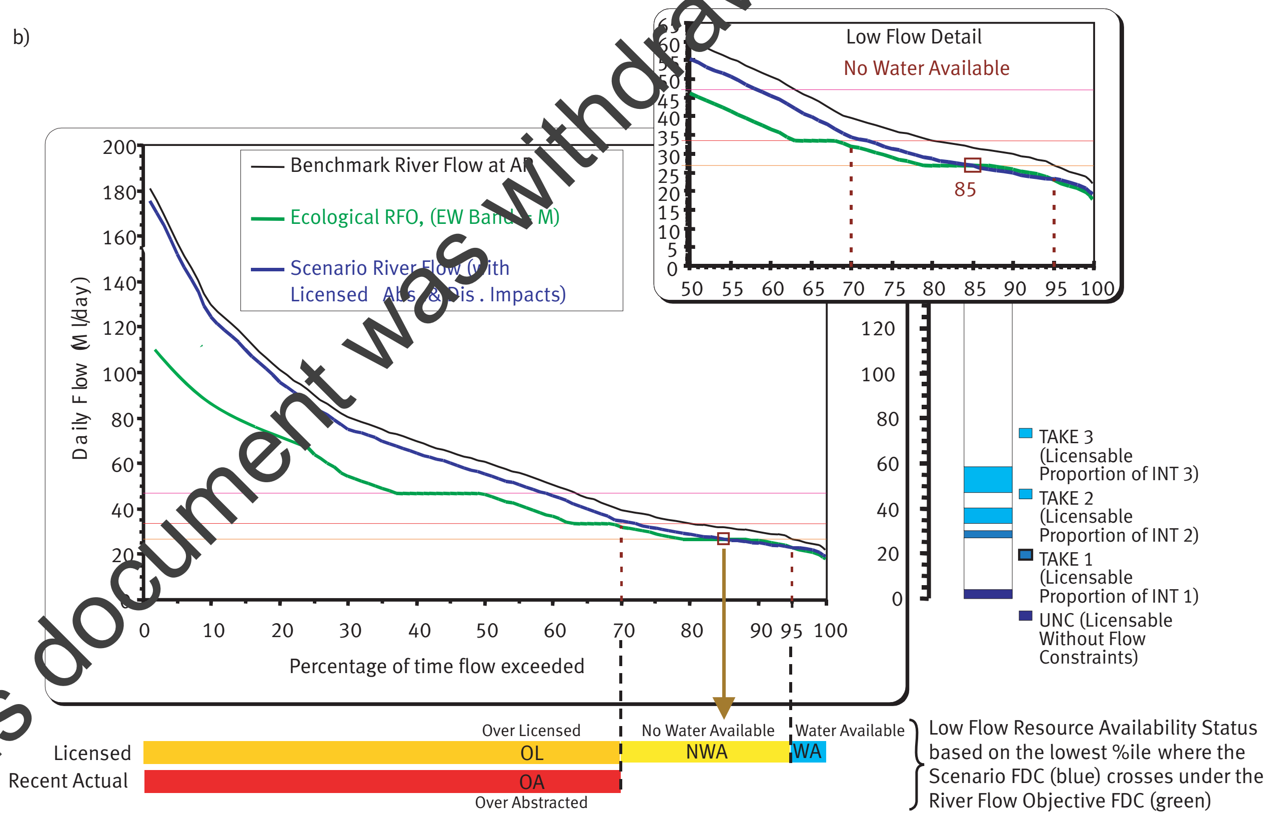


Figure 1.7

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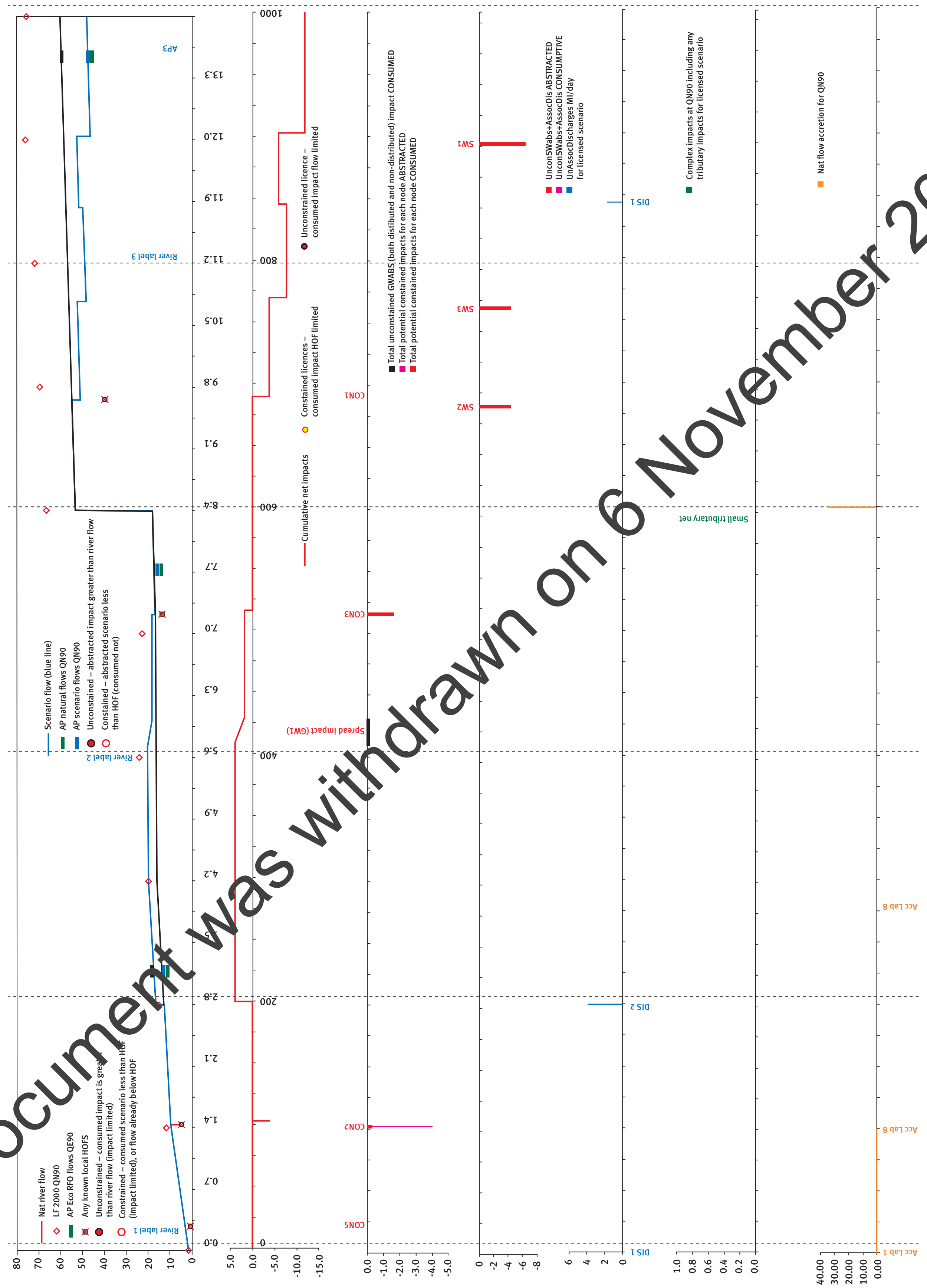

Figure 2 Accretion profile for the licensing working example of the CAMSLEdger – plotting flows and impact at Q90

Risk Assessment protocol

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Summary

Type of regime where applied
The Risk Assessment protocol is intended to provide a risk assessment framework for any form of Environmental Impact. As such it is applicable to all regimes relevant to RoC.

Applicability to sites
The protocol provides a framework allowing hydrological impact (at the receptor) to be translated into hydro-ecological effect to the Interest Features.

Standard Applications
All forms of Environmental Impact Assessment.

Resource requirement
The Risk Assessment protocol can not be undertaken in isolation.

Sites require; characterisation (hydrologically and ecologically); evaluation of hydrological impact; determination (or knowledge) of the water resource requirements (and sensitivity) of the Interest Features; before the Risk Assessment can be undertaken.

Introduction

The risk assessment procedure suggested for the Review of Consents (RoC)1, and in routine Licence Determination, is one which broadly follows the protocol given in the '*Guidelines for Environmental Risk Assessment and Management*' produced by the DETR (2000). It is considered difficult to formulate a procedure that is highly definitive, particularly in the early stages of the RoC process. The method should be precautionary (particularly where major uncertainty is involved) and should initially aim to:

- Assist in the identification of sites at which there is clearly minimal risk and which can therefore be eliminated from the RoC process.
- And depending upon the stage in the RoC process either:
  - as in the early stages of RoC identify the need for further investigations/assessments at those sites considered to be at significant risk; or,
  - at latter stages of the RoC process identify the activities which are considered to give rise to significant risk on the site necessitating some action to be undertaken to mitigate (or further clarify) the situation.

As noted in the DETR guidelines, 'risk' is a combination of the probability, or frequency, of occurrence of a defined hazard (through the **source-pathway-receptor** mechanism) and the magnitude of the consequences of the occurrence. Following this principle, a 'risk matrix' is required which can be used to ascribe values of potential risk based upon the perceived

1 Required under Regulation 50 of the Conservation (Natural Habitats &c.) Regulations 1994

This (or a similar) approach is required for each category of consents to be reviewed. However, in addition the review procedure should also:

- Be iterative and take on increased refinement through the staged RoC process.
- Consider impacts from consents both singly and in-combination (remembering that the combined effect from a 'cocktail' of impacts maybe significant whereas the individual impact/effect evaluated for specific activities/functions may not be considered significant) with the in-combination assessment covering both:
  - a group of single type consents (i.e. abstraction licences);
  - a mixture of consent types (i.e. a multi-functional assessment).
- Consider related management strategies such as:
  - CAMS for abstraction licences;
  - Catchment Flood Management Plans for flood defence;
  - Target River Quality Objectives which govern/influence discharge (water quality related) consents;
  - Shoreline Management Plans which influence coastal sea defence and environmental regimes;
  - Future assessments which will be required (and are being planned) for the Water Framework Directive.

The Risk Assessment methodology is highlighted as follows in a Stage 2 Case Example undertaken for the Nene Washes below.

The possible effects on the water supply to the site were initially ranked according to the nature and magnitude of the hydrological impact as summarised opposite.

Ranking description of potential hydrological impacts

Ranking		Description of potential hydrological impacts
HIGH	L1	Major reduction (i.e. well above HST) in wetland groundwater levels due to one or more individual licensed abstractions.
	C1	Major reduction in wetland groundwater levels as a result of combined abstraction from multiple licensed abstractions
	F1	Major interception of surface water and/or groundwater flow to the wetland
	Q1	Major reduction in the quality of water supply to the wetland
MEDIUM	L2	Moderate reduction (i.e. around HST) in wetland groundwater levels due to one or more individual licensed abstractions
	C2	Reduction in groundwater levels due to combined effects of multiple licensed abstractions
	F2	Reduction in surface water and/or groundwater flow to the wetland
	Q2	Licensed abstraction will lead to a reduction in the quality of the water supply to the wetland
LOW	L3	Very Low reduction (i.e. well below HST) in wetland groundwater levels. The response to pumping by individual abstractions is unlikely to be observed, but a general reduction in groundwater levels may occur due to cumulative effects of pumping from multiple licences.
	C3	Very low reduction in groundwater levels due to combined effects of multiple licensed abstractions
	F3	Minor interception of surface water and/or groundwater flow to the wetland
	Q3	Minor change in the quality of the water supply to the wetland.

These rankings were converted into assessments of potential 'hydro-ecological' effect, based on considerations of the freshwater dependence of the key European interests and their vulnerability to the hydrological impacts. It is these potential effects which are combined with likelihood of occurrence within the risk matrix to define overall risk.

The Magnitude of the Potential Effect is ranked as follows (see Table 1):

High, Medium, Low, Very Low, Negligible.

The likelihood of occurrence of risk is ranked as follows:

Certain, High, Medium, Low, Very Low, Negligible, Not Known.

The ratings of Risk that are used in the resulting assessment were as follows:

- High, Medium, Low (classed as **significant**)
- Very Low, Negligible (classed as **not significant**)
- If the risk is not known (then the likely default is that it should be classed as **significant).**

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Table 1 Risk matrix

Magnitude of potential effect					
HIGH	Low	Medium	High	High	High
MEDIUM	Low	Low	Medium	High	High
LOW	Very low	Low	Low	Medium	High
VERY LOW	Negligible	Very low	Low	Low	Low
NEGLIGIBLE	Negligible	Negligible	Negligible	Negligible	Negligible
Likelihood of occurence	**VERY LOW**	**LOW**	**MEDIUM**	**HIGH**	**CERTAIN**

The Level of Confidence in the assessment also need to be ranked as follows:

High	The assessment has been based on a large quantity of good qualitydata.
Medium	The assessment is based on a limited amount of data, but these are of good quality and are directly relevant to the site.
Low	Only a limited amount of poor quality data are available. Conditions on site have been inferred using data from other sites in the locality.
Very Low	No relevant data are available.

Potential risk resulting from licensed abstractions
The potential risk to the Nene Washes as a result of Environment Agency Water Resources licensed abstractions is shown in Table 2.

The Potential Hydro-ecological Effect on the European features is based upon the potential hydrological impacts described in the previous section. In addition it incorporates expert judgement of:

- the freshwater dependence of the site's key ecological interests (European features);
- the significance of specific hydrological components (surface and/or groundwater) to the site;
- the vulnerability of the ecological interests to hydrological change/impact.

When undertaking this assessment, particular attention is given to situations where the original hydrological impact ranking is 'Low', to see if this should be translated to a 'Very Low' or Guidance for Assessment: 'Hydrological Requirements of Habitats & Species' Page 5 of 6 'Negligible' hydroecological effect on the Risk matrix, as this can be a key factor in deciding whether or not a site progresses to the next stage of the RoC process.

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Table 2 Potential risk due to Environment Agency licensed abstractions and strategic water resources management *(extract from Stage 2 assessment for the Nene Washes)*

Hazard	Nature and magnitude of potential effects on the water supply to the site	Potential impact on the overall water supply to site	Likelihood of occurrence	Consequent risk to European features (preliminary assessment only)	Level of confidence
Mortons Leam and the Washes					
Licensed surface water abstractions	F2 (S) F2(W)	Medium (S) Medium(W)	Low[1](S) Medium(W)	Low[1](S) (S)	High(S) Medium(W)
Non Licensed surface water abstractions	F1(S)	High(S)	Low[1](S)	Medium[1](S)	High(S)
Strategic catchment management	F2(S) (S 6.1)	Medium (S)	Low[2](S)	Low[2](S)	High(S)
Licensed surface water abstractions	L2, F3 (S6.3.1)	Medium	Low	Low	Medium

[1] Controlled by the Lower Nene Summer Operating Policy
[2] The strategic Wansford mcf limits effects and overall abstraction/discharge effects contribute positively to the low-flow regime of the Nene at Orton.

(S) Summer Effect controlled by Operating Policy
(W) Winter Effect possibly attributed to AWS Wansford abstraction.

It must be noted that the risk assessment presented in Table 2 relates only to the conditions prevailing when the relevant assessment was prepared. The potential risk that may result from any future abstractions (or variations) must be assessed independently as and when such changes arise.

The likelihood of occurrence takes into account any mitigating factors that may operate to reduce the potential impact on the site. The Level of Confidence that has been attributed defines the degree to which these factors are known.

The broad methodology suggested for assessment of a riverine domain is set out schematically in Figure 1. This identifies the undertaking of assessments for both:

- groups of abstraction licences; and,
- multi-functional consents.

The process also highlights the possibility of incorporating an auditing process, regarding the adequacy of assessment both for ongoing and future needs, within the RoC process.

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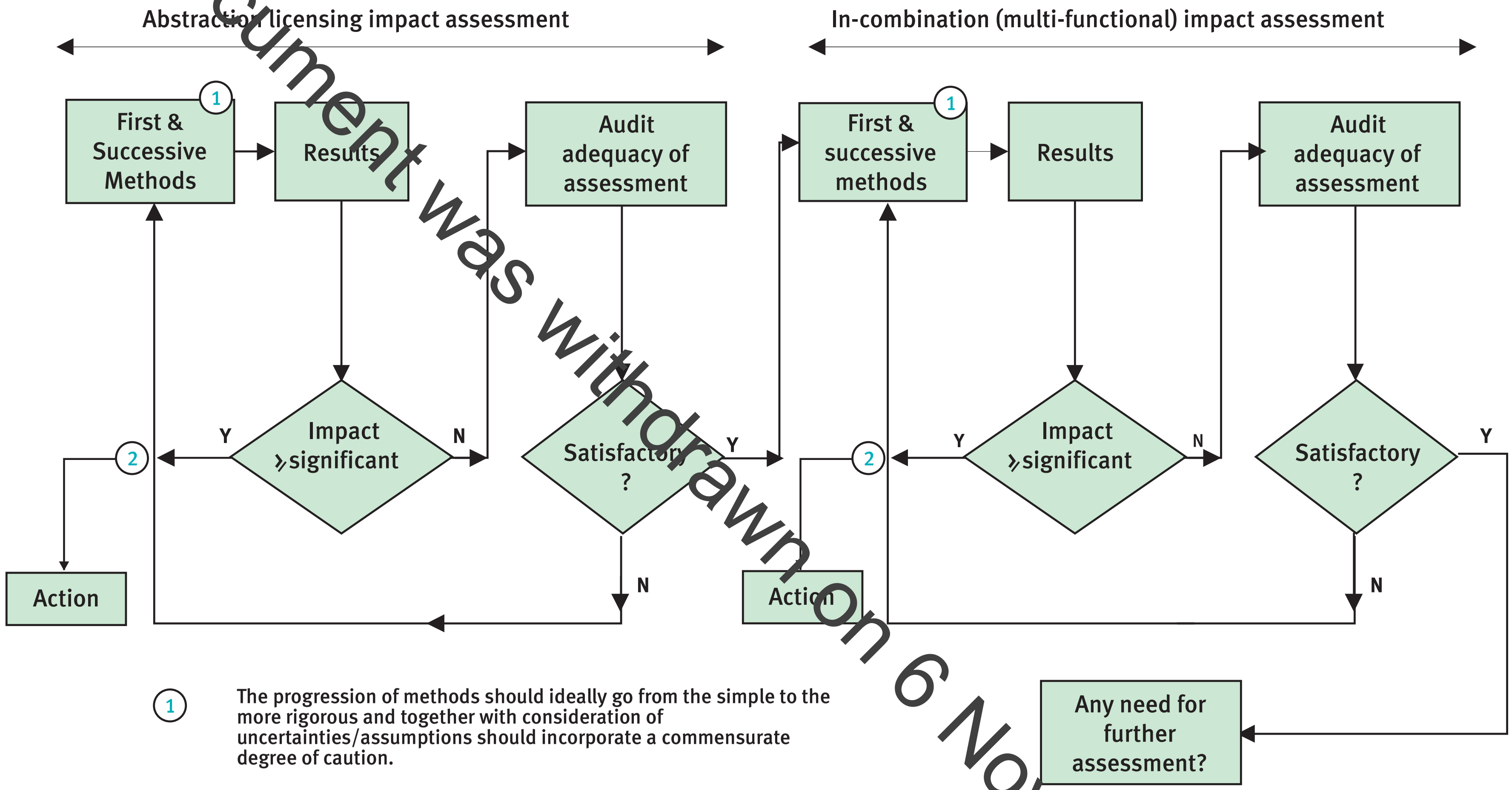
Figure 1 Indicative framework for HD RoC – Single function and multi functional assessments



1. The progression of methods should ideally go from the simple to the more rigorous and together with consideration of uncertainties/assumptions should incorporate a commensurate degree of caution.

2. If the 'final' assessment of impact › significant then some positive action to mitigate effects will be required.

5 Case studies

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Environment Agency

NATURAL ENGLAND

Cyngor Cefn Gwlad Cymru
Countryside Council for Wales

5. Case studies

5.1 Introduction

The list of case example assessments and the hydrological domains to which they belong is outlined in Table 5.1. (It is intended that these will be added to and revised on a regular basis as more information becomes available).

The range of assessment methods undertaken in studies to date to inform impact assessments (including; interpretation and site characterisation aids; water quality assessments; and, hydrological impact assessments;) for these selected case examples is summarised in Table 5.2.

Table 5.1 Selected case examples

Hydrological sub-domain	case example
Riverine	River Itchen
Lake/Reservoir	Rutland Water
Lowland Valley Fen	East Walton Common
Lowland Valley Fen	Great Cressingham Fen
Natural Flood Plain	Portholme Meadow
Controlled Washland	The Nene Washes
Estuarine	The Stour Estuary
Extreme Tidal - Humid Dune Slacks	Gibraltar Point
Marine Transition & Inter-tidal	The North Norfolk Coast
Tidal Embayment	The Wash

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Table 5.2 **Case examples given for selected hydro-ecological sub-domains**

Hydrological sub-domain	Case examples	Interpretation and site characterisation aids									Water quality
		Low Flows 2000	Geological & hydro-geological	Schematic concept-ualisation	Flow naturalisation	Water balance assessment	Rainfall-runoff model	Flood inundation model	Lake hydro-dynamics	Tidal hydro-dynamics	Assessments
Riverine	The River Itchen		Y	Y	Y	Y	Y				Y
Lake	Rutland Water			Y		Y					Y
Lowland valley fen	East Walton Common		Y	Y							
Lowland valley fen	Great Cressingham Fen		Y	Y		Y					Y
Natural floodplain	Portholme Meadow		Y	Y	Y			Y			Y
Controlled washland	The Nene Washes	Y	Y	Y	Y	Y		Y			Y
Estuarine	The Stour Estuary			Y	Y					Y	Y
Marine transition & inter-tidal	The North Norfolk Coast		Y	Y	Y	Y				Y	Y
Extreme tidal-humid dune slacks	Gibraltar Point		Y	Y						Y	Y
Tidal embayment	The Wash	Y		Y	Y					Y	Y

Assessments undertaken in Stage 2 of RoC Process (more detailed/rigorous assessment may be undertaken for Stage 3)

Assessments proposed or undertaken in Stage 3

* Use of RAM in N Norfolk Coast concerns the estimate for minimum GW outflows to the site

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Table 5.2 **Case examples given for selected hydro-ecological sub-domains** continued

Hydrological sub-domain	**Case examples**	**Impact assessment methods**							
		GW abstraction drawdown methods	LAD (Licence Accumulation Diagram)	IGARF (Impact of GW Abs on River Flow)	RAM (Resource Assessment Management)	Distributed GW Model	PHabSim	Hydro-dynamic Estuarine model	Risk Assessment protocol
Riverine	The River Itchen				Y	Y			
Lake	Rutland Water								Y
Lowland valley fen	East Walton Common	Y							Y
Lowland valley fen	Great Cressingham Fen	Y	Y			Y			Y
Natural floodplain	Portholme Meadow	Y							Y
Controlled washland	The Nene Washes	Y							Y
Estuarine	The Stour Estuary								Y
Marine transition & inter-tidal	The North Norfolk Coast				Y*	Y			Y
Extreme tidal-humid dune slacks	Gibralter Point	Y							Y
Tidal embayment	The Wash								Y

Assessments undertaken in Stage 2 of RoC Process (more detailed/rigorous assessment may be undertaken for Stage 3)

Assessments proposed or undertaken in Stage 3

* Use of RAM in N Norfolk Coast concerns the estimate for minimum GW outflows to the site

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The River Itchen

Undertaken/planned investigations

Ecology

Site type
Riverine SAC (and fringing Wetland)

Area of SSSI
309.26 ha

SAC features
River Itchen cSAC

- Otter
- Salmon
- Bullhead
- Brook Lamprey
- Crayfish
- *Rananculus* (Water Crowfoot)
- Southern Damselfly

Fringing Wetlands

- Desmoulin's Whorlsnail
- Fen Habitats
- Wet Grasslands
- Bog Woodlands

SPA features
- None

Water resources

See Schematic Figure overleaf.

Geology/hydrogeology
The essential geology of the Itchen catchment is Chalk with Tertiary deposits in the lower (southern) section of the catchment. Flow in the Itchen is ground water dominated with runoff only having any significance in areas covered by Tertiary deposits and also through drainage modifications in urban areas such as Winchester and Alresford.

Source(s) of water supply
The river is essentially spring fed from the Chalk aquifer and the wetland areas depend upon aquifer-river-flood plain interaction and artificial water management too.

Level of confidence in the conceptual understanding site
The general conceptualisation for the site is considered to be very good.

Relationship between ecology and water resources

Relationship between european features and water supply
Riverine SAC: There are reasonably clear hydrological requirements set out for many of the Interest Features. It should be noted that these requirements equally comprise quality and geomorphological regimes as well as those related to quantity (discharge, velocity and level). Additionally, the multifunctional (sustainable) dimension is very important to the Itchen with effluent discharges, land use, land drainage and river management having comparable significance to the favourable condition of the riverine domain as abstractions. The habitat is dependant upon the river flow regime which is ground water dominated.

Fringing Wetland: The hydrological regime of the fringing wetland is more directly dependant upon the ground water table regime and local water management, rather than the direct quantity regime of the River Itchen and tributaries.

What are the potential effects on the site and how are they evaluated

A standard RAM assessment for the River Itchen shows that actual gauged flows, measured at Highbridge and Allbrook, fall significantly below the 'target' river flow objectives evaluated using the Environmental Weighting method. If abstractions and discharges were to develop to full consented limits this 'deficiency' would be even more marked as revealed on the RAM output extract. The predominant abstraction development in the catchment is made from the Chalk aquifer particularly for PWS and the RAM results reveal significant flow depletions, compared to the naturalised regime, for the river. Comparable results derived from Distributed Ground water Modelling for the Itchen (developed using MODFLOW) reveal, when compared to the modelled naturalised flow regime, 33% and 43% reductions in flow at the Q95 for scenarios which represent the present actual and potential (fully licensed) abstraction regimes respectively. All the RAM and Ground water Model results described above make due allowance for residual effluent returns to the river.

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Hydrological impacts to the flow regime of the Itchen have not been translated into an assessment of ecological effects within this case study but a series of investigations and assessments were commissioned for the appropriate assessment. These assessments are not merely restricted to requirements under the HD RoC but are also driven by the AMP-NEP (and are therefore considering non European designated Interest Features too) as well as aiming to satisfy the holistic/sustainable approach underpinning the Water Framework Directive requiring a multi-functional approach for impact assessment and future improved management of this site.

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Potential risk (Indicative only) due to Environment Agency licensed abstractions

Hazard (River Itchen and fringing wetlands)	Nature and magnitude of potential effects on the water supply	Potential impact on the overall water supply	Likelihood of occurrence	Consequent risk to European features (preliminary assessment only)	Level of confidence
River Itchen cSAC SW Abstractions	Flow	Low[1]	Medium	Low	Medium
River Itchen cSAC GW Abstractions	Flow	High	Medium	High	High
Fringing Wetland SW Abstractions	Flow	Very low[1]	Low	Very low	Low
Fringing Wetland GW Abstractions	Flow	Medium	Low	Low	Medium

[1] The most significant surface water abstractions are non consumptive made for fish farms.

River Itchen steering group proposals at scoping stage

A scoping report was complied by Halcrow (dated Oct. 2000) which set out a three phase programme of work summarised as follows:

A. Phase 1 Baseline studies and reviews (complete)

- Hydrogeological SI and conceptual model refinement.
- Review/analyse hydrological data.
- Recharge and ground water model development.
- Review existing water quality data and potential modelling requirements.
- Define Target species and Favourable Condition status.
- Review fisheries and related study requirements.
- Assess potential/actual substrate issues (particularly siltation).
- Review past/present river operations and consult riparian owners.
- Review land use/management information.
- Review ecological modelling requirements and approach.
- Investigate wetland components of site.
- Establish general protocols including QA.

B. Phase 2 Validate and setup a series of integrated models and conduct allied studies

- Ground water model.
- River (hydraulic) model.
- Water quality model.
- Fish migration model .
- Ecologically based interpretation and assessment.
- Consultation/Reporting.

C. Phase 3 Investigation and development of possible alternative management strategies

- Develop sustainable management strategy options.
- Consultations.
- Reporting (including recommendations on further research).

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Conceptual understanding of the Impact of groundwater abstractions on river flows

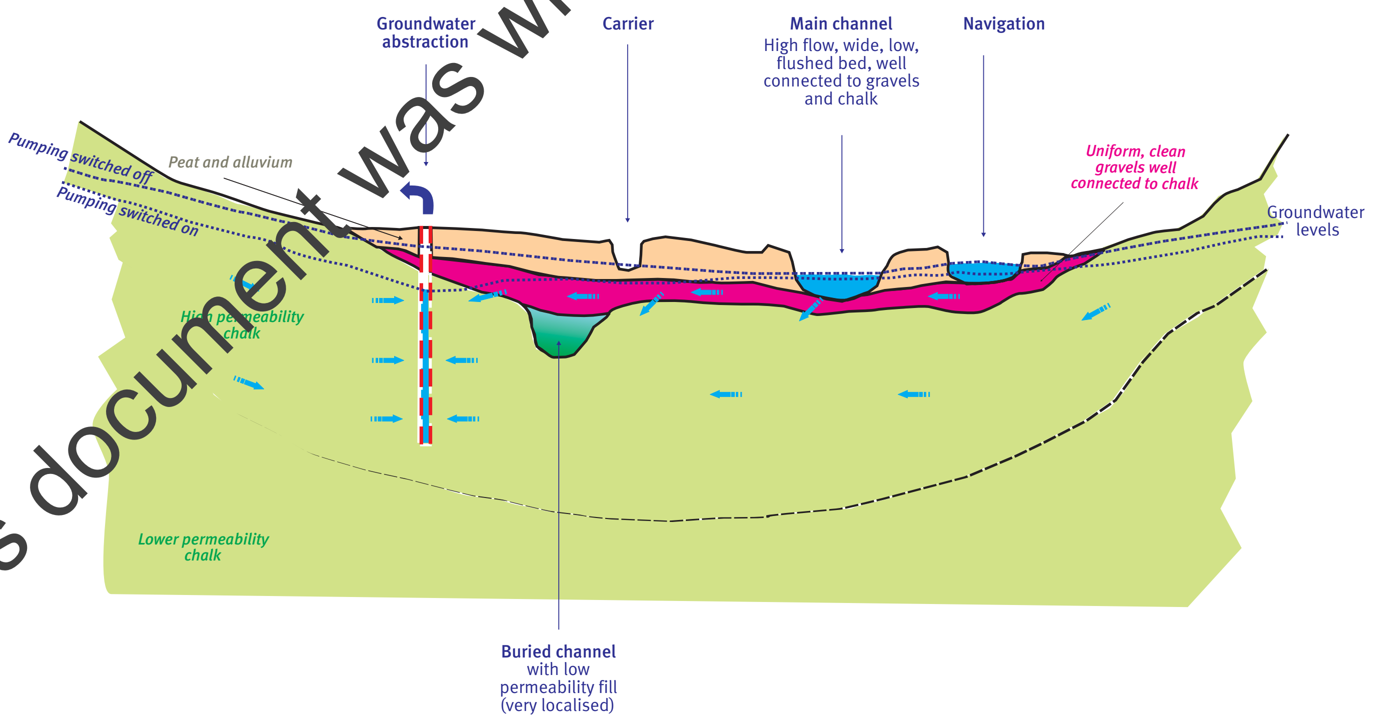


Figure 1. Assessment points, catchments and surface and groundwater abstractions

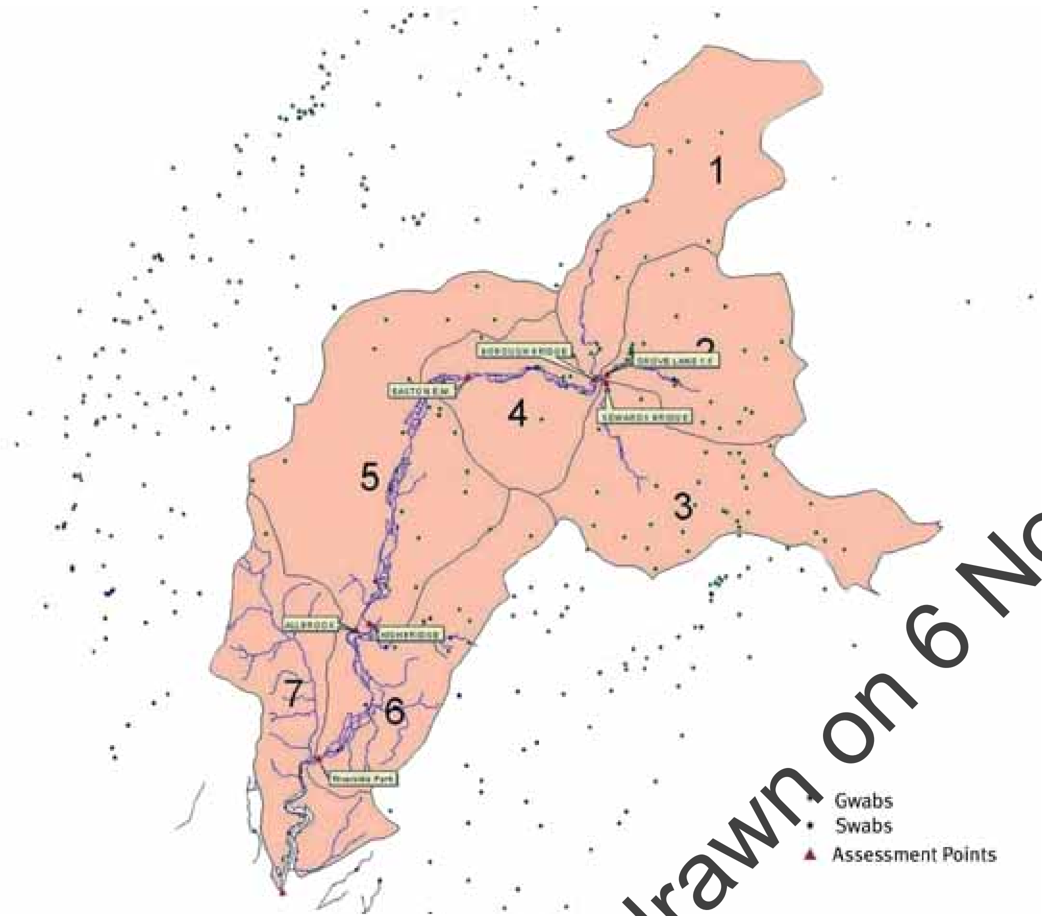
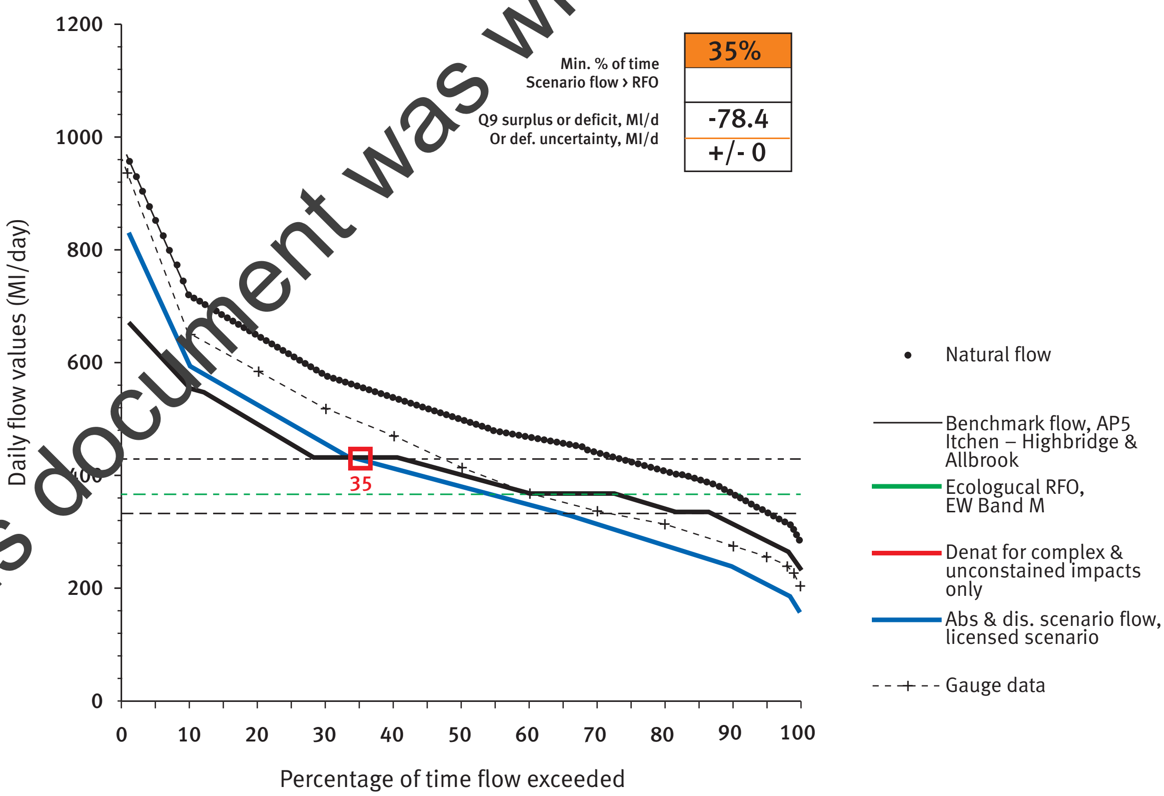


Figure 2. APS Itchen – Highbridge & Allbrook



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Rutland Water

Stage 2 Assessments (and Stage 3 Proposals)

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Site description

Rutland Water is a man-made pump storage reservoir that was created in 1975 when the Gwash Valley was dammed. Rutland water was designated as a SSSI in 1981, principally as a result of supporting exceptional numbers and diversity of passage and wintering waterfowl. Habitats within the SSSI include open water, islands, mudflats, lagoons, reedswamp, pastures, meadows, scrub and mature woodland.

Ecology

Area of SSSI

1,540 ha

SPA features

Regularly occurring migratory bird species of international importance:

- wintering gadwall
- wintering shoveler

Assemblage qualification: A wetland of International importance:

- by regularly supporting greater than 20,000 waterfowl during winter

Existing ecological monitoring

No formal regular monitoring of habitats, but occasional monitoring of macrophytes. Regular monitoring of macro-invertebrates.

Bird counts are carried out annually as part of the Wetland Bird Survey (WeBS) Core Counts.

Water resources

Geology

Most of Rutland Water is underlain by the Whitby Mudstone. The Lincolnshire Limestone and and the Northampton Sand also occur.

Existing surface water and ground water monitoring

Water levels (absolute and percentage fill) and abstraction volumes are recorded by AWS

Source(s) of water supply

The inputs to Rutland Water are: flow from the upstream catchment; abstraction from the River Welland at Tinwell; abstraction from the River Nene at Wansford, and direct rainfall. By far the largest input comes from abstraction.

Level of confidence in the conceptual understanding of the site

High. Hydrologically the inputs, outputs and processes at Rutland water are relatively simple.

Relationship between ecology and water resources

Relationship between european features and water supply

Relationship Between European Features and Water Supply SPA: The SPA qualifying bird species require the following habitats: open water with shallow margins; stable littoral invertebrate and macrophyte communities; and open grassland and wetland habitats around the shoreline. The location and extent of these habitats is dictated mainly by the current water management regime within the reservoir, which comprises pump storage and abstraction (supply) operations.

Historical bird count data for the reservoir shows that the population grew rapidly following commissioning of the reservoir, and has remained relatively stable ever since (within year-to-year fluctuations). There is no evidence that the current management regime is having a detrimental effect on the bird assemblage or any of the individual species present.

The current management regime results in the seasonal draw-down of reservoir water levels. The effect of this is to create an impoverished flora and fauna within the littoral zone (based on the high water mark). High nutrient levels in the reservoir are thought to compound these effects by affecting macrophyte and algal diversity and abundance. However, the significance of these effects on the bird assemblage is not fully understood.

Do any european features have a specific requirement for ground water

No.

Are any of the features supported by ground water inputs

No. Rutland Water is a pump storage reservoir.

What are the potential effects on the site

The potential risk to Rutland Water as a result of the AWS abstractions at Wansford, Tinwell and Rutland Water is shown in Table 1. The potential impact of surface water abstraction on Rutland Water and the likelihood of this impact occurring, have been ranked as High on the basis that the existing abstraction regime allows regular and sustained draw-down to occur within the reservoir. Both draw-down and refilling may lead to relatively rapid changes in water level that exceed the rate of invertebrate movement and/or macrophyte growth. Linked to this some deterioration in water quality is likely, particularly as the reservoir is eutrophic and regularly suffers algal blooms.

The level of risk is considered to be Medium as, although there is no evidence to suggest that the current operating regime is impacting upon the birds present, this is probably the consequence of inadequate monitoring. Bird count data suggest that populations of individual species are generally stable, following an initial rapid increase after the completion of the reservoir. Although the bird population appears to be relatively stable, it is unclear how this reflects the general health of the habitat supporting those birds. The ecological interactions occurring at Rutland Water are complicated by the fact that water levels, and hence the littoral zone, fluctuate throughout the year. This, together with a high nutrient burden which affects macrophyte and algal abundance and distribution, results in a system that is constantly changing.

The level of Confidence is considered to be Low/Medium as very little data are available on the effect of draw-down on the prey species being exploited by the birds. Consequently it is possible that the current regime may be impacting on the food resource used by the birds, resulting in a gradual decline in prey availability. This may manifest itself as a gradual decline in the bird population that is currently masked by the natural variability of the populations present.

Table 1 Potential risk to Rutland Water due to AWS abstractions

Hazard	Nature and magnitude of potential	Potential impact on the overall water supply	Likelihood of occurrence	Consequent risk to european features (preliminary assessment only)	Level of confidence
AWS abstractions	F1. The abstractions provide the majority of water to the site and control how it is released	High. The way the abstractions are managed largely dictates how water levels and chemistry in the reservoir change.	Medium	Medium/High. Habitat/prey supporting interest features are impacted by operational regime, however, significance of this is not fully understood.	Low/Medium

Stage 3 Proposed/ongoing work

At the present time Anglian Water Services are unable to abstract their full licensed amount as there is insufficient capacity at Wing Water Treatment Works. AWS are proposing to increase the capacity of this WTW, and this has led to the commissioning of a series of Environmental Impact Assessment for the proposed scheme. Although some results have been published, further work is in progress and areas of additional research have been identified.

Although there is no evidence that the current operating regime is having a negative effect on the bird assemblage, limited data are available on the condition of the habitat supporting those birds. Further research is recommended as follows:

- An investigation of how macro-invertebrates and macrophytes respond to changes in the water level, with consideration given to the duration and speed of draw-down events and the speed of refilling.
- An investigation of bird behaviour focussing on the identification of feeding areas and food sources. This should include an assessment of new feeding sites as water levels within the reservoir change throughout the year.

This research will allow the impact of draw-down on invertebrate and plant populations to be assessed, together with the recovery of these populations following refilling of the reservoir.

This document was withdrawn on 6 November 2017

Figure 1 Rutland Water SPA

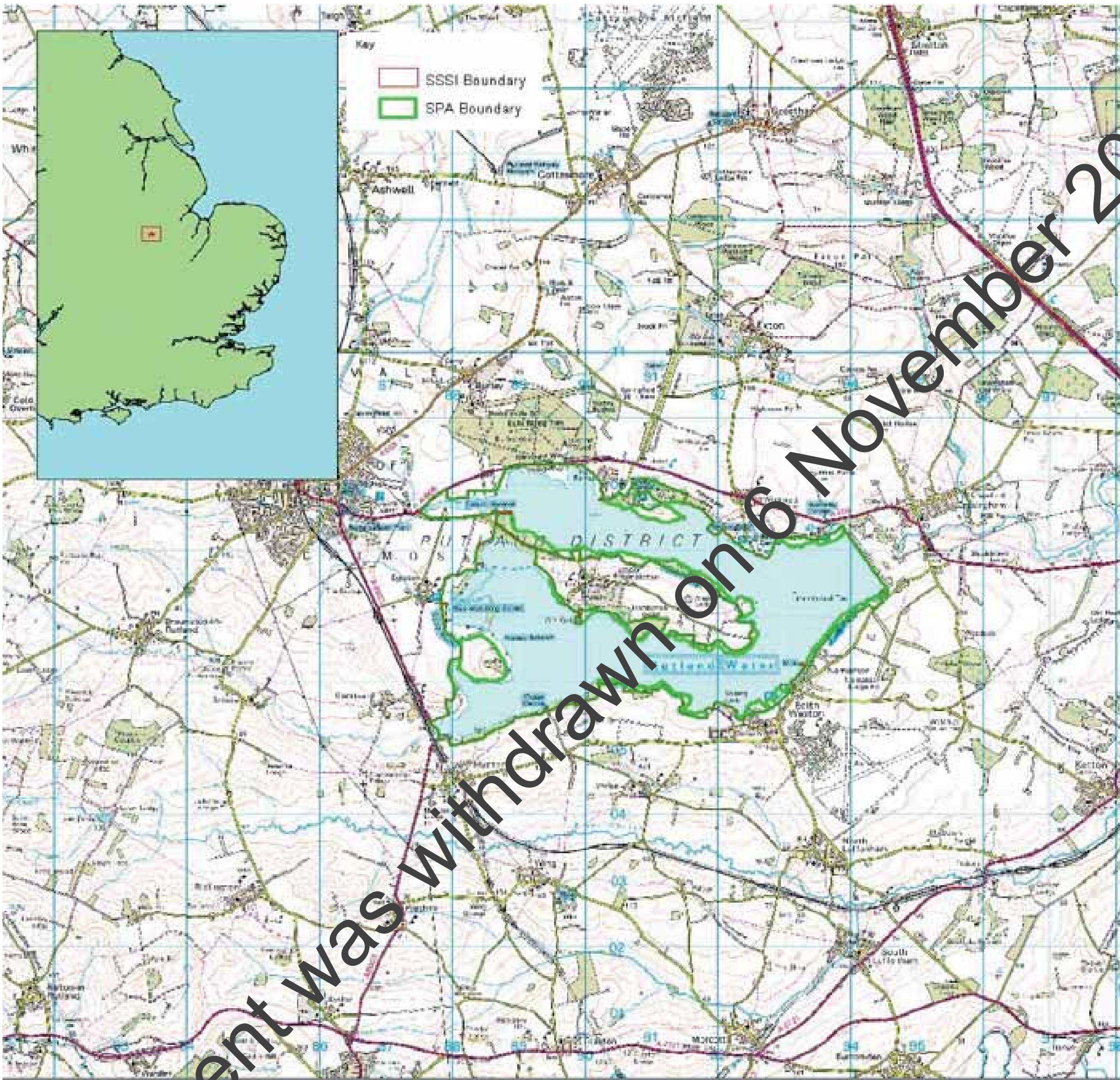

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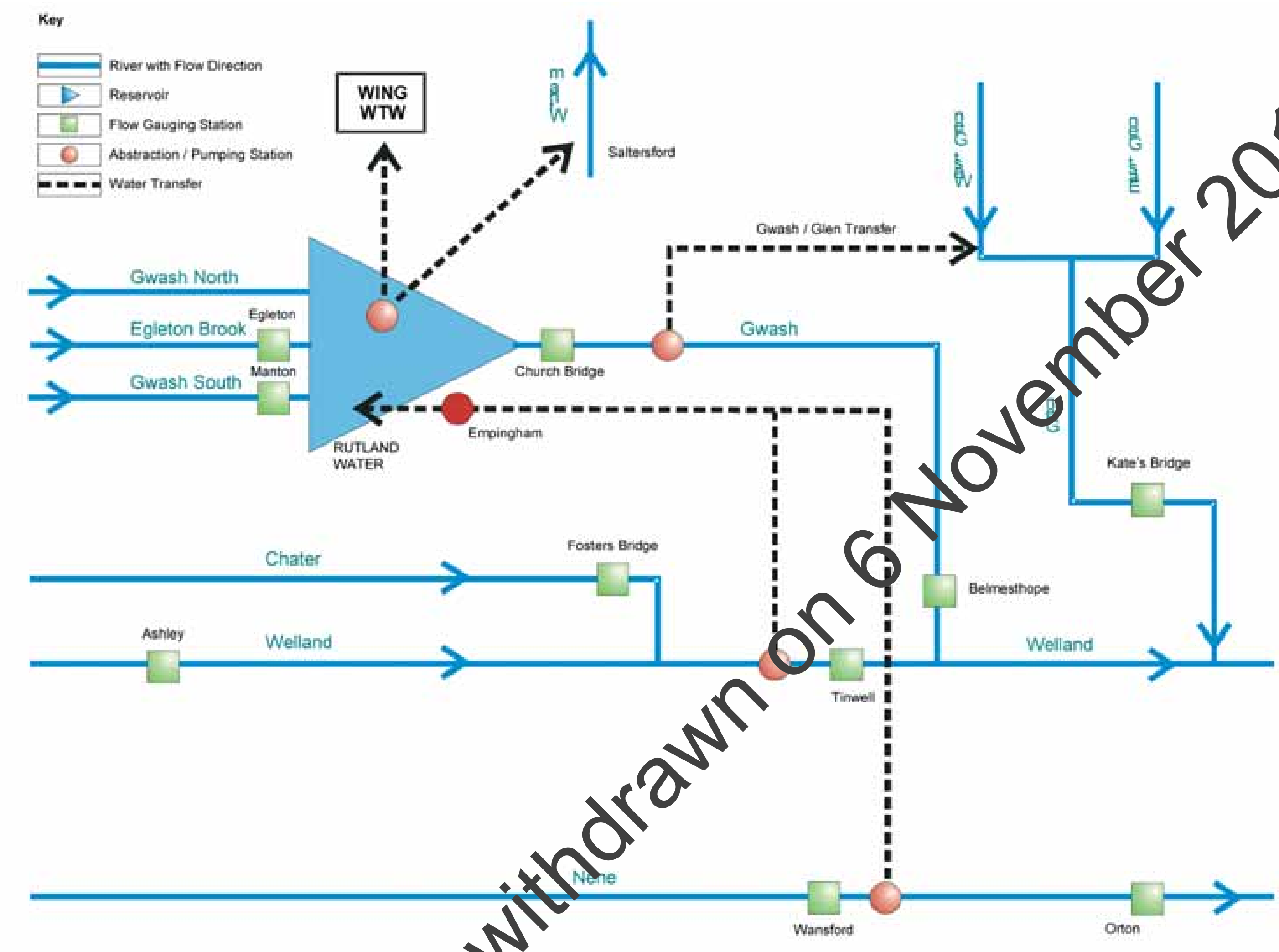
Figure 2 Simplifed conceptual schematic of Rutland water system



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East Walton Common

Stage 2 Ongoing (& Stage 3 Assessments)

Site description
Combination of 2 distinct but nearby sites (East Walton and Adcock's Common) with similar physical and ecological characteristics.

Ecology

Area of SSSI
62.9 ha (49.7 ha for East Walton and 13.2 ha for Adcock's Comon)

SAC features
Alkaline fens (M9, M13);

Habitats for the population of Desmoulin's whorl snail (*Vertigo moulinsiana*);

Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (W6);

Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae* (S2 and S25);

Molinia meadows on calcareous, peaty or clayey-silt-laden-soils (M24); and

Semi-natural dry-grasslands and scrubland facies: on calcareous substrates (CG2).

SPA features
- N/A

Existing ecological monitoring
Wetland plant communities surveyed as part of Valley Fen Survey (1993). Locations of ground depressions were mapped using GPS in 2000. Plant species lists have been produced in 2000 during compilation of a Millennium Report for the site, but communities were not identified or mapped.

Invertebrate species lists have been compiled from surveys in 2000, undertaken for the Millennium Report, and previous data. The birds on site were surveyed informally throughout 2000.

Water resources
See schematic figure overleaf.

Geology

Superficial sands/clays:	variable(3 m thick)
Lower Chalk	absent to 30 m thick
Gault Clay	~10 m thick
Upper Chalk	

Existing surface water and ground water monitoring
2 Gaugeboards installed in depression ponds. No monitoring at Adcock's Common.

2 piezometers installed by HSI in 1996 near the eastern perimeter of the East Walton site and completed into the Chalk and superficial deposits.

Source(s) of water supply
The site is supported by springs and emergences from the Chalk strata.

Regionally the superficial deposits and Chalk are hydraulically continuous. Locally the situation is complex and dictated by minor variations in lithology which causes variability of water levels across the site.

Level of confidence in the conceptual understanding of the site
Moderate. A reasonable record is available for ground water monitoring piezometers in the eastern part of the East Walton site. No data are available for the Adcocks' Common site although the hydrogeology is comparable.

There is a case for more detailed measurements to understand local variations.

Relationship between ecology and water resources

Relationship between european features and water supply
The alkaline fen, calcareous fen and habitats that support Desmoulins whorl snail all require high water tables maintained throughout the summer and are vulnerable if subjected to relatively small reductions. Alder woodland requires at least winter-wet conditions but can tolerate more variation. M24 requires a moderate water level and is less critically affected by variations but is still vulnerable to drying in the longer term. Semi-natural dry grasslands require rainfall and do not need high water levels.

Do any european features have a specific requirement for ground water
SAC: Yes. M13 is critically dependent upon the supply of base-rich ground water.

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Are any of the features supported by ground water inputs

Yes; The dominant supply to the alkaline fen, calcareous fen, alder woodland and habitats that support Desmoulin's whorl snail is ground water.

What are the potential effects on the site

Conceptual model of water supply

The hydrological regime at East Walton is shown schematically in the Figure overleaf. Both the East Walton and Adcocks components of the site can be considered as ground water fed by springs and seepages resulting from the lateral flow of Chalk ground water from the east of the sites. Both sites are located on the edge of the Chalk which is underlain by the Gault Clay aquiclude. Overlying sandy drift deposits, generally, are in hydraulic continuity with the Chalk although the location of springs at East Walton appears to correlate with the Chalk/drift boundary.

Impacts from surface water abstractions

There are no surface abstractions that are considered to present a risk to the site.

Impact from ground water abstractions

Estimated drawdowns have been made using AQUIFER-WIN32 and the Neuman method assuming 200 days without recharge. The resulting values are within the range 0.5 and 1.0 m, with the greater drawdowns occurring at Adcock's Common rather than at East Walton Common. This level of potential impact is considered significant although uncertainties with the assumptions which underpin the assessment in comparison to the true hydrogeological regime for the site must be borne in mind.

This document was withdrawn on 6 November 2017

Potential risk due to Environment Agency licensed abstractions and strategic water resources management

Hazard	Nature and magnitude of potential hydrological impacts	Potential hydro-ecological effect	Likelihood of occurrence	Consequent risk to interest features (preliminary assessment only)	Level of confidence
Surface water abstractions	River flows	N/A	N/A	N/A	High
Ground water abstractions	GW levels & flows)	High	Medium	High	Low

Stage 3 Proposals

Appropriate assessment is considered essential for the site and Baseline investigations/assessments recommended are outlined below:

Part 1. Review of permissions

Improved understanding of the ground water system and impact assessment of ground water licences.

Part 2. Ecological, water quality and level surveys

- Ecological survey to confirm the nature, extent and composition of alder woodland, calcareous grassland and habitats that support Desmoulin's whorl snail. (Should be undertaken by Natural England).
- Monitor near-surface water-levels, via dipwells, in the most sensitive communities (M9?, M13, S2 and S25).
- Vegetation monitoring of plots located adjacent to the dipwells.
- Topographic survey.
- Investigations to understand the localised lithologies and structure of the geomorphological features that characterise the site.
- Water quality sampling of the depression ponds to establish the source of the water. This information would also feed into the condition monitoring for the sensitive fen features on site.
- Determine the datum of the existing gaugeboard (TF91/119).

Part 3. Installation of monitoring equipment

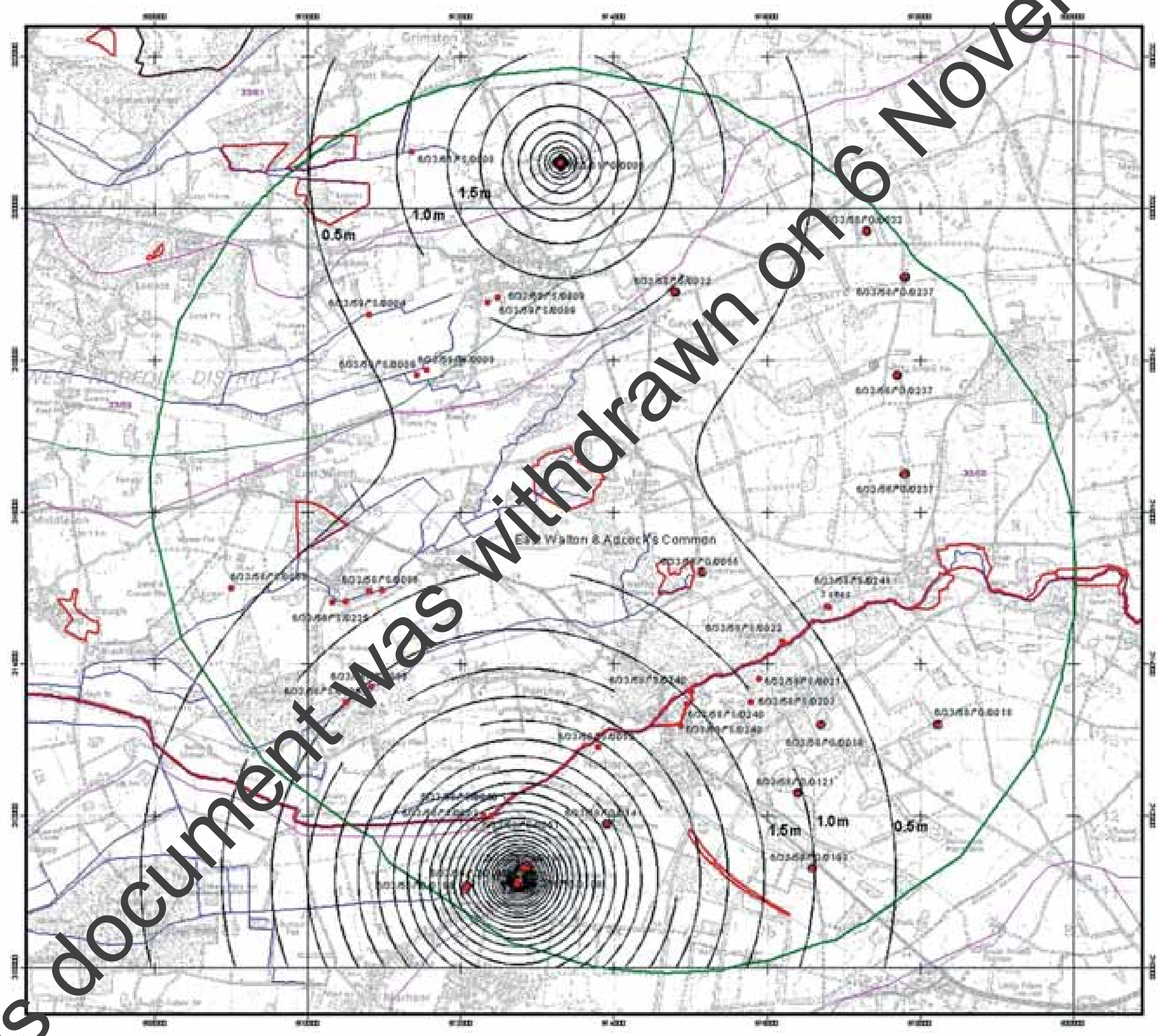
- Installation of 2 piezometers (with loggers) into the Chalk and gravels strata at Adcock's Common.
- Adaptation of existing structure to a flow gauge on East Walton.
- Installation of data loggers at existing piezometers (TF71/116 and TF71/117) and gaugeboard (TF71/118).
- Installation of gaugeboards in ground depressions at different levels

The risk assessment will be revisited and refined as new data are obtained and decisions made about the most appropriate course of action:

- i.e. whether there are sufficient data to complete Stage 3 (appropriate assessment) and Stage 4 (decision to affirm, amend or revoke licences)

All of the recommendations for fieldwork and further studies may be subject to review and modification as further work is progressed and reviewed.

Figure 1 Drawdown analysis of ground water abstractions within 5km of the East Walton and Adcock's common site



SSSI Boundary

Main river

Hydrometric Catchment Boundary

Other rivers

34/7 Hydrometric area number

osm Drawdown Contour

Abstraction point

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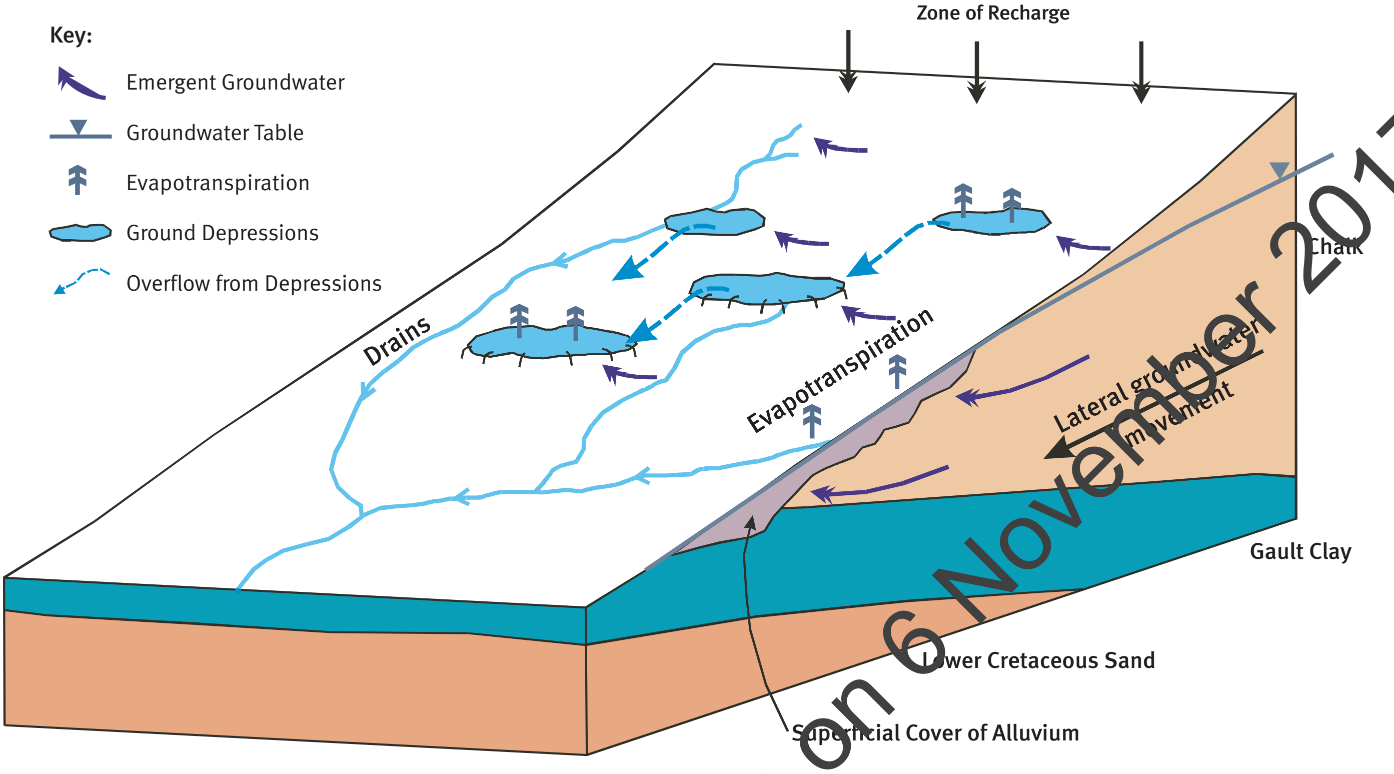
Figure 2 Schematic of the key hydrological systems at East Walton



This document was withdrawn on 6 November 2017

Great Cressingham Fen

Stage 2 Ongoing (planned Stage 3 Assessments)

This document was withdrawn on 6 November 2017

Ecology

Site type
Valley Fen

Area of SSSI
13.7 ha

SAC features
Norfolk Valley Fens cSAC:

- Alkaline Fens (M13);
- Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae* (S25c); and
- Molinia meadows on calcareous, peaty or clayey-silt laden soils (M24).

SPA features
N/A

Water resources

See schematic figures overleaf

Geology/hydrogeology
Peat and Clay (central and eastern part of site)

Source(s) of water supply
The site is ground water fed by springs/seepage from the Chalk aquifer via granular alluvial deposits. Surface inputs are from rainfall and limited rainfall generated runoff.

The eastern part of the site floods at times of high water level although it is not known whether this is due to inundation from the River Wissey or backing up of water draining from the fen.

Level of confidence in the conceptual understanding site
Medium

Relationship between ecology and water resources

Relationship between european features and water supply
M13 requires permanently high water levels. Other SAC features (represented by S25c and M24) prefer generally lower levels and are able to tolerate greater fluctuation.

Do any european features have a specific requirement for ground water
Yes – M13 critically dependent upon water from the Chalk aquifer

Are any of the features supported by ground water inputs
Yes – S25c and M24 both supported by ground water levels although not specifically dependent on it.

What are the potential effects on the site

Ground water
Great Cressingham Fen is fed by Chalk ground water that emerges into the north part of the fen as springs and seepages at the site margins or where ponds and drains intersect the Chalk/Drift water table. There is a potential hydrological effect at the site due to the effects on spring discharge of surrounding licensed ground water abstractions associated with both public water supply and spray irrigation. In this instance, predicted drawdown has been assessed in Stage 3 using the AQUIFER WIN32 program, the Hantush application, a Radial-MODFLOW 2D model as well fully distributed 2 and 4 layer ground water MODFLOW models to represent the 'leaky/semi-confined' conditions. These assessments supersede Stage 2 evaluations based on a Theis methodology assuming uniform flow through a homogeneous porous medium, and which does not allow for recharge, layering or other local geological or hydrological variants.

Surface water
There are no inflows to the fen directly via surface watercourses and rainfall generated runoff to the site is likely to be limited. However at times of high water levels, the southeastern corner of the fen may be susceptible to difficulties regarding drainage out from the fen and possible flooding. The fen drains the to River Wissey, but the effect of near-by river stage elevation on the degree of fen flooding has not been ascertained.

The fen is susceptible to changes in rainfall and evaporation as these become manifest as changes in direct precipitation on the wetland and as changes to ground water levels in the underlying Chalk aquifer. Consideration of available meteorological and ground water level data has shown that ground water levels in the fen fall significantly during time of low rainfall resulting in springs and seepages drying up several times since 1989. However, these problems may have been exacerbated by increased local ground water abstractions. The observed magnitude of change in ground water levels suggests that the fen may also be vulnerable to increased density of drains – i.e. which may lead to further draining of the shallow fen deposits and consequently to lower water levels within the central part of the fen.

Potential risk due to Environment Agency licensed abstractions as assessed at the end of stage 2

Hazard	Nature and magnitude of potential	Potential impact on the overall water supply	Likelihood of occurrence	Consequent risk to european features (preliminary assessment only)	Level of confidence
Licensed surface water abstractions	Reduction in flow to the wetland (F2) Minor change water quality (Q3)	Low	Low	Low	Very Low
Licensed ground -water abstractions	Major reduction (i.e. well above HST) in wetland ground water levels (L1, C1) Major interception of flow to the wetland (F1)	High	Medium	High	Low

Stage 3 Proposed/ongoing work (recommendations made at the end of stage 2)

Appropriate assessment is considered essential for the site but this should be undertaken in an integrated way as outlined below:

A. Baseline investigations

1) Further site characterisation by undertaking detailed on-site hydrological investigations under the AMP3 National Environmental Programme and by other interested parties (e.g. Natural England and local abstractors). These to include:

- Ecological Investigation and Monitoring – clarification on the possible loss of species, further vegetation monitoring including determining the mobility of the peat raft beneath the *Sphagnum* areas, defining existing water levels and fluctuations to determine sensitivity to additional change, undertaking a topographic 'spot height' survey to ascertain the relationship between ground surface, seepage/spring discharges and water levels and determining the role of the River Wissey in the support of fen water levels
- Hydrological Monitoring – increasing the number and distribution of existing monitoring locations (boreholes and gaugeboards), in particular to assess the hydrological impact of abstraction at the fen from the AWS North Pickenham and South Pickenham Estates sources.

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2) Further conceptual inderstanding by:

- Integrating hydrological data (including new data gathered since Stage 2) to support a hypothesised view of flow from the underlying Chalk aquifer to the ground surface through the unsaturated and saturated aquifer system within and across the boundaries of the hydrological domains. The dominant processes should be emphasised within each domain.
- Undertaking a 'natural' water budget, i.e. as the site would naturally be in the absence of any abstractions or discharges. The budget to be estimated based on both long term average and dry year conditions (e.g. 1976). Results to be used as part of the initial assessment of possible flow impacts.

3) Assessment of possible flow reduction impacts by:

- Retaining simple conservative drawdown estimates at the fen, but by employing a more appropriate analytical approach than Theis, such as superposition of the Hantush analytical solution (i.e. for leaky aquifers).
- The further application of layered, radial flow model drawdown estimates to take account of the near-surface influences of ditch and/or river drainage boundaries which will tend to reduce the amplitude of both seasonal and abstraction related water level fluctuations.
- The application of simple transient two layer distributed ground water flow models to provide better details of changes in water level near the fen.
- Considering the use of a multi-layer or other conceptual model, given that the degree of aquifer property layering at Great Cressingham Fen is considered sufficiently complex.

To use this information to assess impact/mitigation of ground water abstractions on the site. These to include scenarios without abstraction, under recent and fully licensed abstraction conditions as well as individual assessments for those abstractions that have been identified as having a potentially significant hydrological impact (i.e. those that exceed the Hydrologically Effective Threshold (HST), either as a single abstraction or in combination with others).

4) Further clarification required of appropriate targets for the site, but primarily based on hydrological prescriptions for M13 and M24 ecological features.

Ongoing review of the Appropriate Assessment (and Risk Assessments) should be undertaken with progression of Baseline Investigations.

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Figure 2.3 Hydrogeological setting of Great Cressingham fen in the river wissey catchment

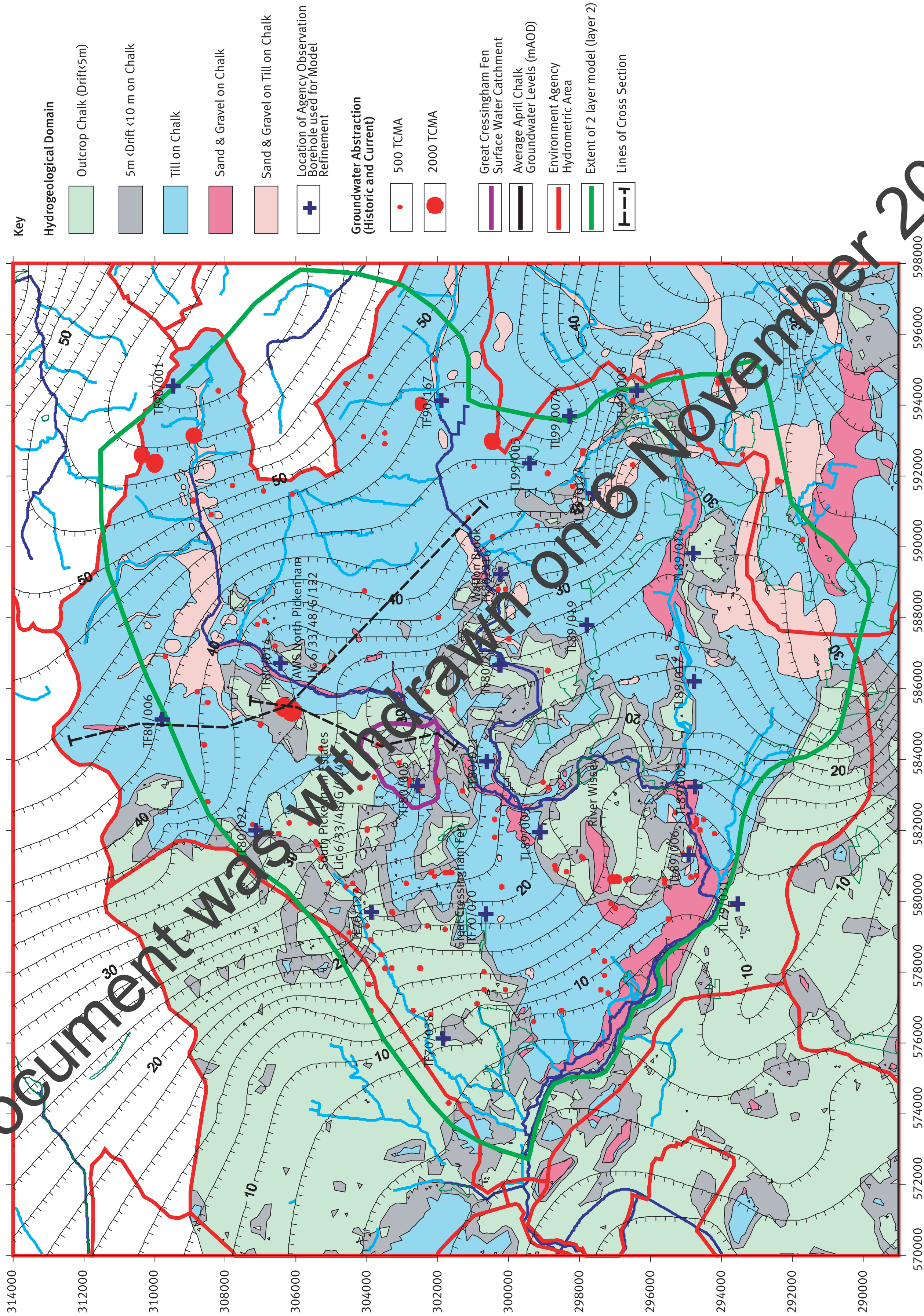

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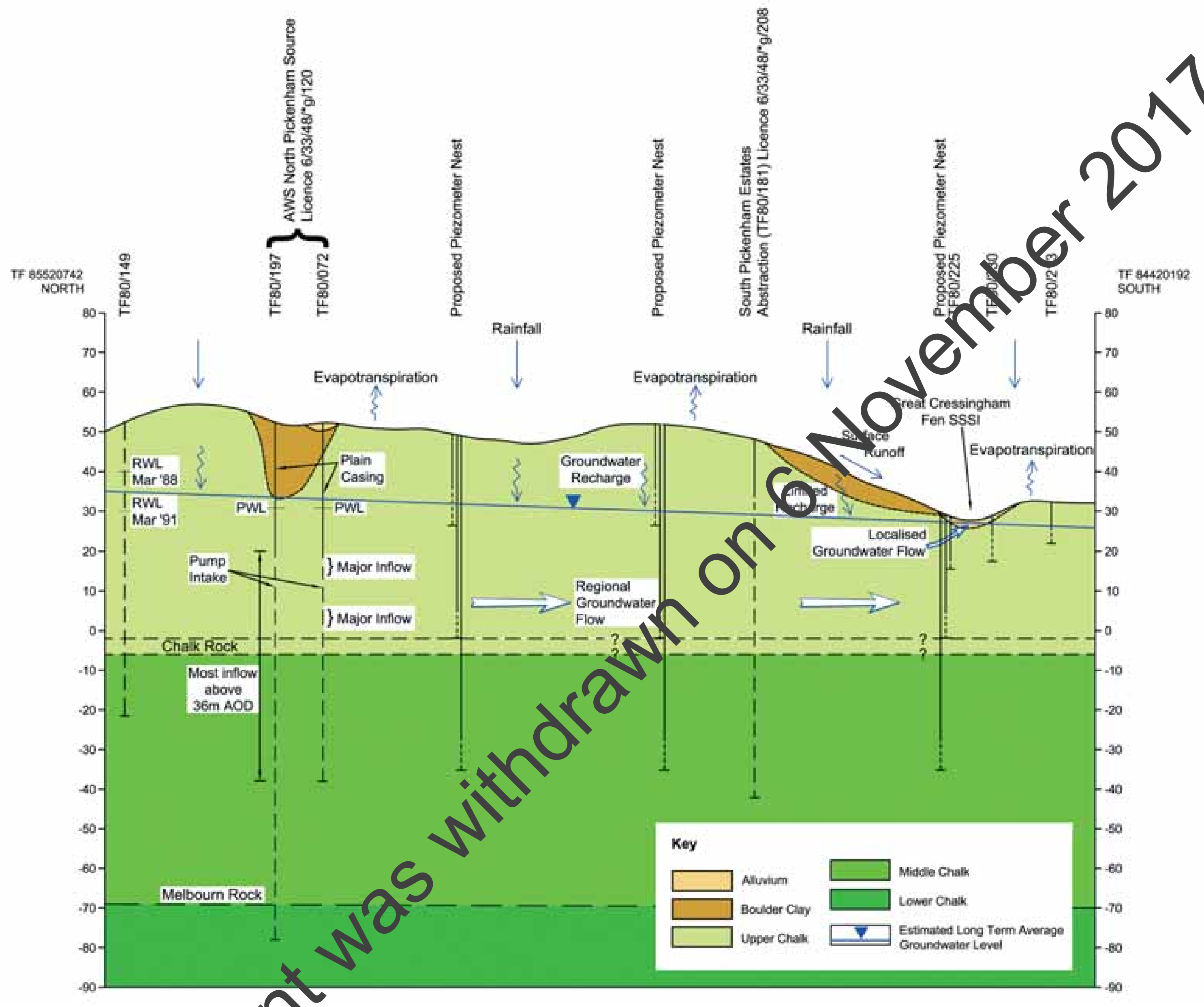
Figure 2 Cross section indicating locations of significant abstractions and proposed monitoring installations



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Portholme Meadow

Stage 2 Ongoing (& Stage 3 Assessments)

Ecology (section 3)

Site type
Lowland hay meadow

Area of SSSI
104 ha

SAC features
Portholme cSAC

Lowland hay meadow

SPA features
N/A

Existing ecological monitoring
Flora surveyed in 1997 and 1999. No other monitoring undertaken.

Water resources

See Schematic Figure overleaf.

Geology/hydrogeology
The hydrogeology of the site comprises a shallow gravel drift aquifer. This is believed to be recharged by surface water from the River Great Ouse upstream of Godmanchester Sluice, where levels are retained by the sluice as well as indigenous recharge from rainfall.

Source(s) of water supply
Surface water has a direct input to the system in times of flood. Water from the Alconbury Brook and River Great Ouse spills onto the site adjacent to the watercourses. Other inputs include ground water possibly enhanced by infiltration from the river.

Level of confidence in the conceptual understanding of the site
The general conceptualisation of the site is considered adequate to understand and rank the hydrologically related issues which detrimentally affect the site.

Relationship between ecology and water resources

Relationship between european features and water supply
SAC: An appropriate water level regime, developed through a DEFRA funded project and limited data from Portholme is presented below:

Winter – December to February; water tables oscillate between the soil surface and a depth of 40 cm with occasional inundations by floodwater (2 to 4 days in duration).

Spring – March to May; water levels fall gradually to about 60cm below mean field level by the end of May.

Summer – June to August; water tables often continue to fall to below 100 cm from the surface, where soil conductivity begins to limit evaporative losses. Although the water table is deep, the vegetation remains well supplied with water by virtue of the high available water content of the deep alluvial soils to which the community is restricted.

Autumn – September to November; water levels should rise back to within 40 cm of the surface.

SPA: N/A

What are the potential effects on the site

The hydrological system controlling the wetland regime at Portholme is shown schematically in the Figure overleaf. Spillage to the site can occur under flood conditions. Under normal or low flow conditions, surface water in the Bedford Ouse is held at a retained level upstream of Godmanchester Sluice. The surface water is then infiltrating the shallow gravel aquifer, and recharging ground water within site.

This document was withdrawn on 6 November 2017

Impacts from surface water abstractions

There is one major abstraction licence within 5 km and upstream of the Portholme site made by AWS at Offord used as the substantial source of input to Grafham Reservoir. Cessation clauses on licensed operations prevent any effect under low flow conditions but under high and average conditions there is the potential for appreciable flow reduction. However, the direct hydrological impact on the site is buffered, in river level terms, by the operation of various control structures around the site.

The Offord abstraction and those made from the Bedford Ouse further upstream may contribute to poor water quality but this is primarily influenced by point effluent and diffuse discharges to the river elevating sanitary and nutrient levels.

Impact from ground water abstractions

The impact from licensed ground water abstractions have been considered within a 5 km of the site using the model software AQUIFER WIN32. These analyses were conducted using both Neuman and Hantush methods and assuming no recharge over 200 days. The results suggest no discernable drawdown at the site.

Potential risk due to Environment Agency licensed abstractions and strategic water resources management

Hazard	Nature and magnitude of potential hydrological impacts	Potential hydro -ecological Effect	Likelihood of occurrence	Consequent risk to european features (preliminary assessment only)	Level of confidence
Surface water abstractions	River flows	Low	Low	Low	High
Surface water abstractions	River quality	Low-Medium	Unknown, possibly in range Low – Medium	Probably low	Low
Ground water abstractions	Ground water Levels	Negligible	Low	Negligible	High

Stage 3 Proposals

Appropriate assessment is considered essential for the site and Baseline investigations/assessments recommended are outlined below:

Hydrological monitoring

- Review of water quality in watercourses surrounding Portholme with respect to deposition of particulate nutrients during flood events. The impact of UWWTD implementation on eutrophication effects on the River Great Ouse should also be considered.
- Actual causes of RE3 failure to Alconbury Brook. And action taken to solve the issues.
- Further monitoring of dipwells for both level and water quality and extension of the dipwell network to characterise the whole site.

Ecological monitoring

- Update of the 1997 NVC survey.
- Annual monitoring of the fritillary and other criteria identified for definition of favourable condition.
- Collection of baseline data to allow a nutrient budget for the site to be undertaken.

The Risk assessment should be revisited and refined as new data are obtained and decisions made about the most appropriate course of action:

(i.e. proceed to Stage 3 (appropriate assessment) and Stage 4 where the decision is made to affirm, amend or revoke licences).

Nutrient analysis of soil and hay is required to determine the susceptibility of the site to nutrient deposition.

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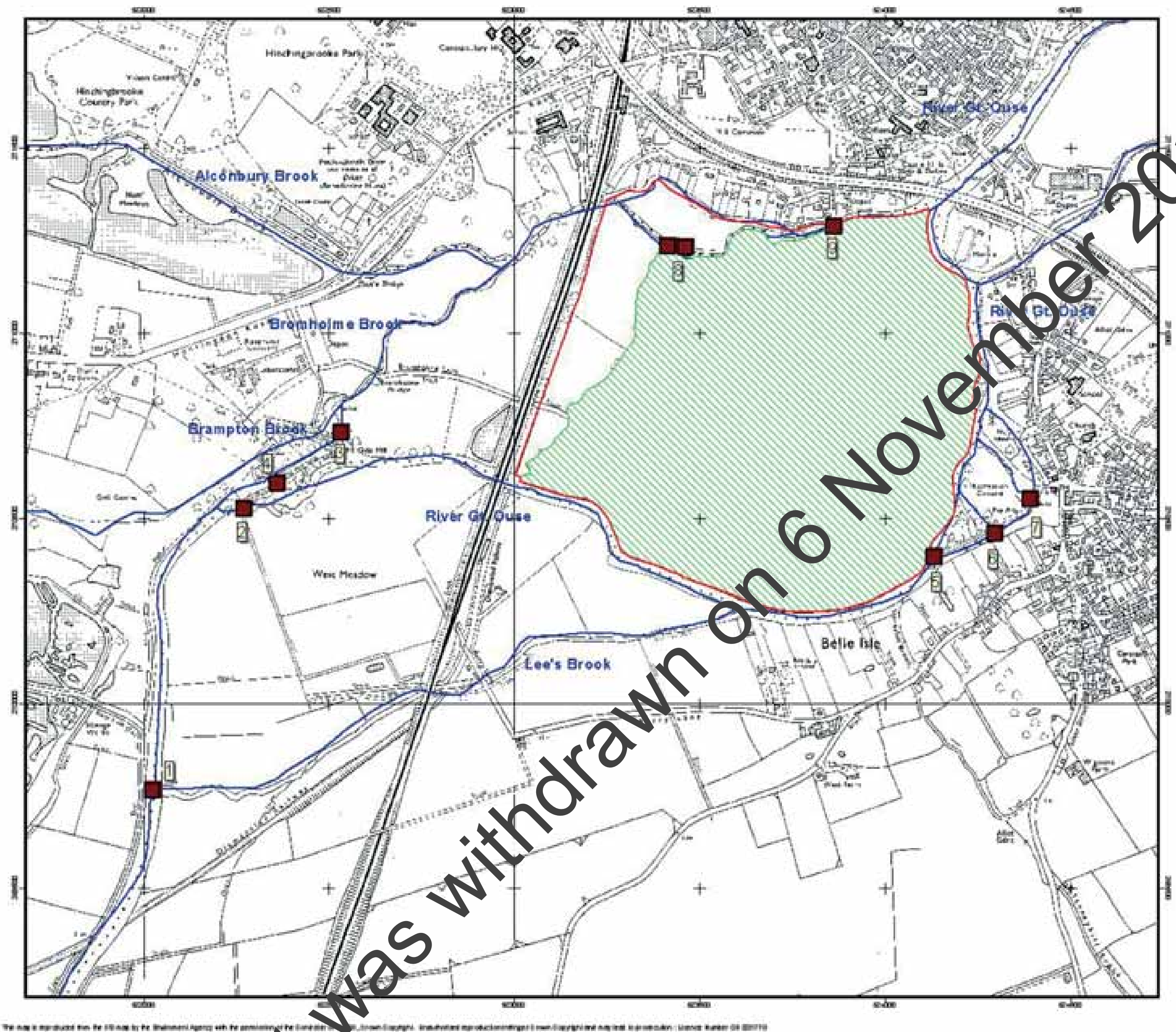
Figure 1 River structure around Portholme



Key:

SSSI Boundary

cSAC Area

Main rivers

1 Lee's Brook Weir – information not available
2 Brampton Lock – discharge at 20m³/sec . Lock opens at * discharge –65m³/sec
3 Brampton Mill House Sluice – open when Brampton Lock is open
4 Brampton Sluice – open when Brampton Lock is open
5 Godmanchester Lock – discharge at 20m³/sec. Lock opens at * discharge – 70m³/sec
6 Godmanchester Sluice – main and mill channel main sluice – retention level of 9.05m ODn opens at 9.08m ODN mill sluice open when main sluice is open.
7 Godmanchester side weirs information not available
8 Weirs information not available
9 Garkies Mill Sluices retention level 9.14m ODN
* Discharge corresponds to the discharge at Offord

This document was withdrawn on 6 November 2017

The Nene Washes

Stage 2 Ongoing (planned Stage 3 Assessments)

Ecology

Site type
Washland & Moreton's Leam

Area of SSSI
1310 ha

SAC features
Nene Washes cSAC

- Spined loach.

SPA features
Nene Washes SPA

- Wigeon
- Teal
- Garganey
- Gadwall
- Black-tailed godwit
- Shoveler
- Pintail
- Species contributing to the wintering assemblage.Internationally important waterfowl assemblage: greater than 20 000 waterfowl.

Water resources

See schematic figure overleaf.

Geology/hydrogeology
The geology of the site comprises variable drift overlying Jurassic clays. Ground water is thought to be of moderate significance to the western part of the sites generally associated with sand and gravel (River Terrace Gravel).

Source(s) of water supply
The site is supplied primarily from the River Nene via Moreton's Leam. Flood inflows are achieved when Stanground Sluice is opened and water spills into the Washes. Summer inflows are achieved via slacker inflows.

Moreton's Leam is also supplied by indigenous drainage from a small catchment, although supplies in summer are believed to be minimal.

Level of confidence in the conceptual understanding site
The general conceptualisation for the site is considered adequate to understand and rank the hydrologically related issues which detrimentally affect the site.

Relationship between ecology and water resources

Relationship between european features and water supply
SAC: Spined loach can tolerate poor water quality and may thrive in the absence of other species that cannot tolerate it. However the species requires macrophytes for cover and an abundant food supply which is more likely to be present in good quality water i.e. low phosphorus and sanitary determinands, high oxygen content. The species is poorly adapted to high flow rates.

SPA: The SPA species have varying water level requirements. The requirements of the food sources however also need to be met. Whilst the Wash grassland can tolerate winter flooding, spring flooding is not desirable and can lead to the loss of the fine-leaved grasses such as creeping bent *Agrostis stolonifera*. The ditch flora requires high levels of low nutrient status water, ideally with a P level <0.1mg/l. Spring flooding adversely affects the breeding success of the waders in particular, as the nests get flooded.

Do any european features have a specific requirement for ground water
SAC: No

SPA: No

Are any of the features supported by ground water inputs
No

What are the potential effects on the site

The western half of the Nene Washes are underlain by a Drift Gravels aquifer and there is potentially drawndown due to surrounding licensed ground water abstractions and dewatering operations associated with mineral extraction works. In this instance, predicted drawdown was assessed using the AQUIFER WIN32 program and the Neuman application to represent unconfined conditions.

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Surface water flows to the Nene Washes derived from the River Nene can be potentially compromised in:

- Winter; particularly by large scale abstractions for PWS, which can reduce the incidence (reliability and magnitude) of seasonal flooding to the site. This was considered by looking at potential effects to a marginal and specific flood event that may have given rise to limited flooding in the Washes without the effect of PWS abstractions.
- Summer; particularly by large scale non-licensed abstractions from the lower Nene. This threat is generally controlled by the Environment Agency through implementation of a Summer Operating Policy for the lower River Nene which aims to guarantee security of supply to the site and suppress usage by competing interests during periods of low flow when total demands exceed water availability. However, implementation of the Policy relies upon co-operation. This was considered by closely looking at the Summer Operating Policy and considering it's theoretical performance against various flow regimes for the Summer.

Another key issue for the site is the high nutrient status of the River Nene. The situation has recently improved through implementation of the UWWTD but improved levels are still likely to compromise the condition of the site. The present situation is influenced both by point discharges (mainly from STWs) and diffuse sources.

This document was withdrawn on 6 November 2017

Potential risk due to Environment Agency licensed abstractions and strategic water resources management

Hazard (Moreton's Leam and the Washes)	Nature and magnitude of potential effects on the water supply	Potential impact on the overall water supply	Likelihood of occurrence	Consequent risk to european features (preliminary assessment only)	Level of confidence
Licensed surface water abstractions	Flow (S)	Medium (S)	Low[1] (S)	Low[1] (S)	High
Non licensed surface water abstractions	Flow (S)	High (S)	Low[1] (S)	Medium[1] (S)	High (S)
Strategic catchment management	Flow (S)	Medium (S)	Low[2] (S)	Low[2] (S)	High (S)
Licensed ground-water abstractions	Level & Flow	Medium (Level) Low (Flow)	Low	Low	Medium

[1] Controlled by the Lower Nene summer operating policy
[2] The strategic Wansford MCF limits effects and overall abstraction/discharge effects contribute positively to the low-flow regime of the Nene at Orton.
(S) Summer effect controlled by operating policy
(W) Winter effect possibly attributed to AWS Wansford abstraction.

Stage 3 Proposed/ongoing work.

Appropriate assessment is considered essential for the site but this should be undertaken in an integrated way as outlined below:

A. Baseline investigations

- Further clarification required of appropriate targets for the site.
- Assess impact/mitigation of ground water abstractions (licensed and none licensed) on the site.
- Assess impact of AWS Wansford abstraction on Winter flooding regime/reliability of Washes.
- Investigate various flood defence issues (Rings End Sluice & siltation control on tidal Nene) and impact to site.
- Review significance of UWWTD implementation to phosphorus concentrations in the Nene.
- Investigate local catchment issues giving rise to RE3 failure in Moreton's Leam.
- Acquire available assessments and on-going monitoring from Bradley Fen extraction operation by Hanson to help inform future RoC assessments.
- Undertake detailed on-site hydrological investigations under the AMP3 National Environmental Programme.
- Undertake flow naturalisation studies for the Lower Nene.
- Investigate water balance for site.
- Investigate nutrient budget for site.

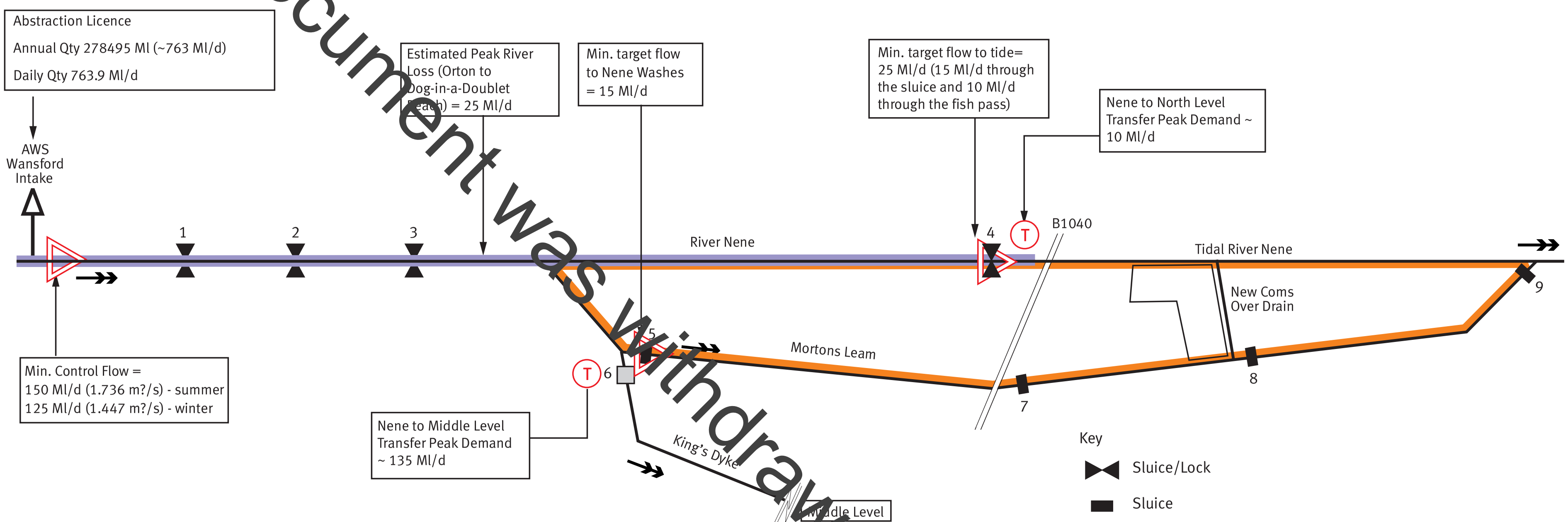
B. Assessment and development of revised Integrated management

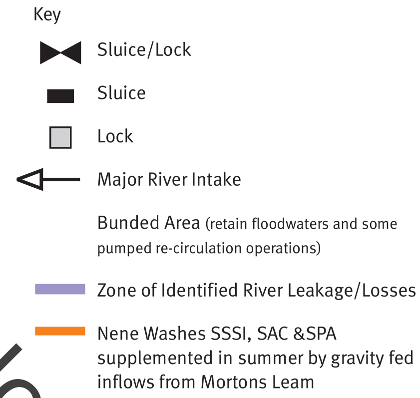
- Periodic Review of summer operating policy for the Lower River (and consideration toward positive use of discharge from Flag Fen (Peterborough) STW).
- Possible implementation of controlled winter flooding to the Washes.
- Implementation of channel maintenance practices sympathetic to spined loach.
- Possible schemes to further reduce phosphorus concentrations in the Nene (or on the site).

Ongoing review of the appropriate assessment (and risk assessments) should be undertaken with progression of baseline investigations and development of revised integrated management. It is anticipated that revisions of ongoing monitoring will be an integral requirement of revised management. Any introduction of controlled flooding must be considered in an integrated manor. The flood defence function and operation of the Washes must not be compromised.

This document was withdrawn on 6 November 2017

Figure 1 Lower Nene – Major summer water resource allocation





Map Ref	River Structure	Comment
1	Water Newton Sluice/Lock	Retention Level ~8.0 m AOD
2	Alwalton Sluice/Lock	Retention Level ~6.4 m AOD
3	Orton Sluice/Lock	Retention Level ~4.5 m AOD
4	Dog-in-a-Doublet Sluice/Lock	Retention Level ~2.9 m AOD (Nene Tidal Limit)
5	Stanground Sluice	Flood Inlet to Nene Washes (activated when Nene level › 3.7 m AOD)
6	Stanground Lock	Navigation Link between Nene and Middle Level
7	Little Bridge Sluice	Retention Level ~1.60 m AOD (summer), ~1.0 m AOD (winter)
8	Eldernell Sluice	Retention Level ~1.45 m AOD (summer), ~1.0 m AOD (winter)
9	Rings End Sluice	Retention Level ~1.10 m AOD (summer), ~1.0 m AOD (winter)

This document was withdrawn on 6 November 2017

The Stour Estuary

Stage 2 Assessments

Site description
A coastal plain estuary, i.e. a flooded pre-existing valley formed during the Holocene transgression.

Ecology

Area of SSSI
2150 ha

SAC features
Not applicable

SPA features
Annex 1 bird species of international importance:

- hen harrier; and
- golden plover (No longer qualifies).

Migratory bird species of international importance:
- dark-bellied brent geese (No longer qualifies)
- dunlin
- redshank
- ringed plover
- shelduck
- turnstone
- grey plover
- pintail
- black tailed godwit

Internationally important waterfowl assemblage

Existing ecological monitoring
No regular monitoring of habitats takes place. The Environment Agency carries out limited benthic invertebrate sampling within the estuary. Bird counts are carried out annually as part of the Wetland Bird Survey (WeBS) Core Counts.

Water resources

Geology
Glacial Sand and Gravel Drift underlain by Red Crag, with London Clay underlying the estuary.

Existing surface water and ground water monitoring
Some spot flow gauging on lower estuary inputs and the main channel

Source(s) of water supply
Freshwater inputs from small channel inputs and main river channel

Level of confidence in the conceptual understanding of the site
Medium

Relationship between ecology and water resources

Relationship between european features and water supply
SPA: The SPA qualifying bird species require the following habitats: saltmarsh communities; intertidal mudflats and sandflats; and shell, sand and gravel shores. The location and extent of these habitats is dictated mainly by coastal processes, i.e. sea level rise, land tilt, wave action, sediment deposition.

At the present time it is unclear whether or not birds use freshwater inflows within the estuary in preference to other habitats. It is possible that birds do prefer areas adjacent to freshwater inputs for a number of activities such as feeding, drinking, preening and loafing.

The distribution of saltmarsh plant species within the estuary appears to be primarily influenced by the height of sediments in relation to sea levels rather than changes in salinity.

Invertebrate abundance similarly appears to be independent of salinity, with the most productive areas of mudflat being located in those areas where the influence of freshwater is likely to be minimal.

Do any European features have a specific requirement for ground water.

SAC: Not applicable

SPA: No

Are any of the features supported by ground water inputs
No. Ground water seepages do occur along the shoreline of the estuary but these are small and do not appear to be supporting any of the European sub-features present. Ground water does provide base flow to the streams within the catchment which ultimately discharge into the estuary.

This document was withdrawn on 6 November 2017

Potential risk due to Environment Agency licensed abstractions

Hazard	Nature and magnitude of potential effects on the water supply	Potential impact on the overall water supply	Likelihood of occurrence	Consequent risk to interest features (preliminary assessment only)	Level of confidence
Surface water abstractions	Major interception of surface water and/or ground water flow to the wetland	High	High	Medium	Medium
Ground water abstractions	Major interception of surface water and/or ground water flow to the wetland	High	Medium	Medium	Medium

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Uncertainties

Two studies by Ravenscroft *et al* (1997) and Ravenscroft (1998) suggest that there is an association between some species of waterfowl and freshwater flows. Ravenscroft observed that some species tended to congregate around discrete channelled freshwater flows in larger numbers than expected when the small area involved was considered. One of the estuaries included within the 1998 study was the Stour, and shelduck, wigeon, pintail, grey plover, redshank, curlew and dark-bellied brent geese all showed statistically greater densities close to flows when compared with remaining areas of mudflat. However, this was not the case for black-tailed godwit, ringed plover and dunlin and no preference for freshwater seepage areas was demonstrated for any species. Ravenscroft proposed a number of hypotheses to explain why birds may be demonstrating a preference for areas with freshwater flows:

- Increased nutrient input to mudflats leading to increased biomass of prey species;
- Increased inputs of detritus providing a food source for invertebrates, thereby increasing their biomass;
- Improved feeding conditions (wetness of mudflats, prevention of mud freezing);
- Changes in salinity favouring euryhaline invertebrates;
- Shelter provided by channels.

Stage 3 Proposed/on-going work

Proposed ecological monitoring

The research of Ravenscroft et al (1997) and Ravenscroft (1998) have highlighted the need for further research into the importance of freshwater inputs to estuarine systems for waders and wildfowl. It is suggested that further research is carried out and bird surveys should:

- be carried out on a number of different estuaries and at a number of areas within each to increase the sample size from that in the research carried out by Ravenscroft;
- be carried out at different times of day, states of the tide and weather conditions to determine whether there is any relationship between these and usage of areas adjacent to freshwater flows;
- Record at the same time within freshwater flow areas and comparable areas of mudflat the number of each species and the activity of birds.

Assuming that birds do congregate around freshwater inflows in significant numbers, further research into why this happens is required. Investigations may include:

- invertebrate sampling to identify any differences in species assemblage and abundance between freshwater flow areas and surrounding mudflats;
- assessment of flora in the vicinity of freshwater inflows, in particular algae; and
- salinity measurements to identify extent of freshwater influence, possibly including interstitial salinity.

Proposed hydrological monitoring

Although the main River Stour is relatively well gauged, there is little data available to indicate what volume of freshwater enters the estuary directly. Limited flow gauging at all discrete discharge points to the estuary would provide a useful estimate of freshwater discharge volumes. Installation of piezometers in the Crag and Sands and Gravels and/or ground water modelling would improve understanding of ground water contribution to river flows and diffuse ground water contribution direct to the estuary. However, the collection of this data is only considered necessary if a clear link is established between bird assemblages and freshwater flows.

Figure 1 Schematic representation of the hydrological system of Stour estuary

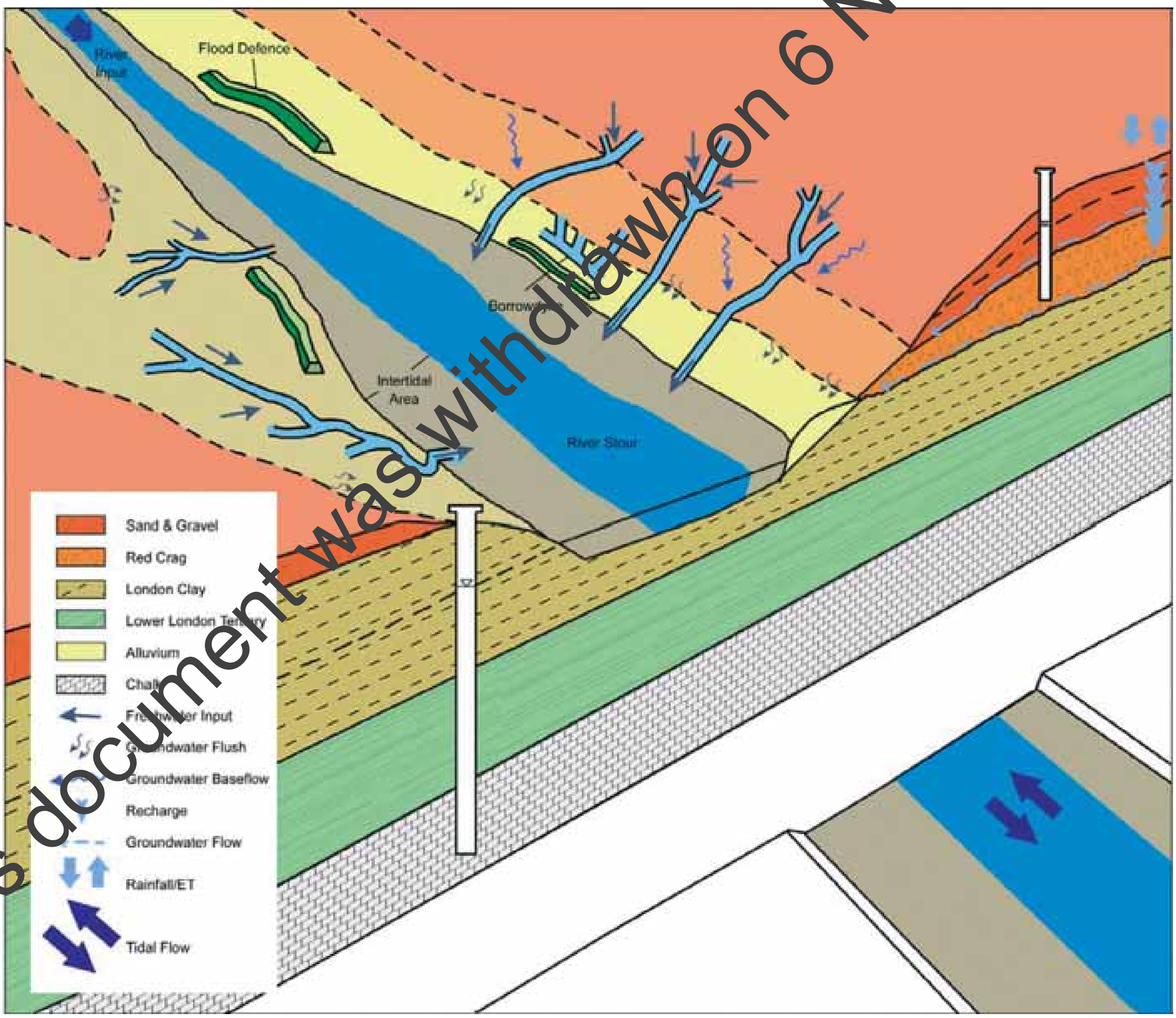

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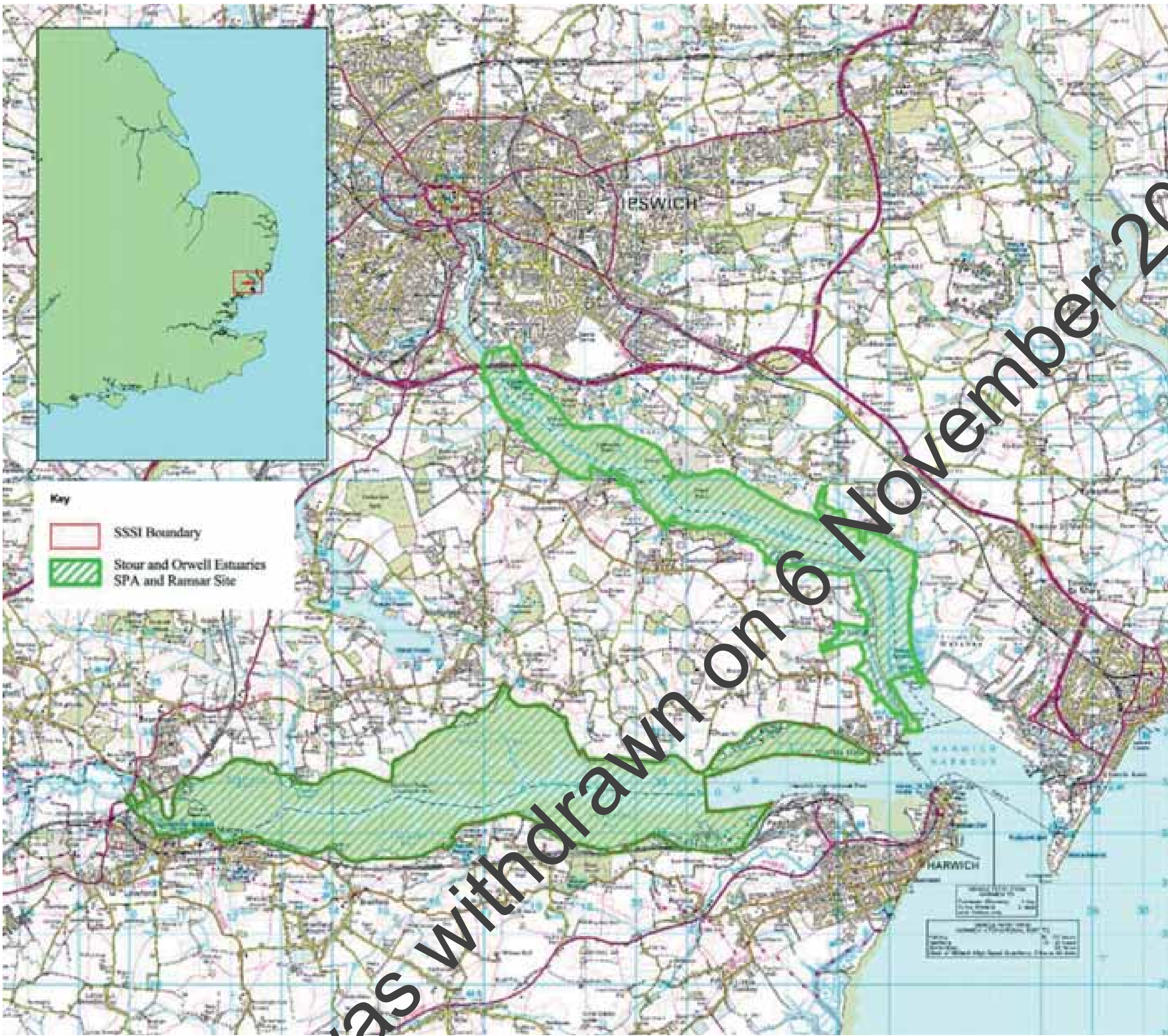
Figure 2 Stour estuary SSSI



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Gibraltar Point

Stage 2 Assessments (and Stage 3 Proposals)

Site description
Gibraltar Point SSSI supports a full transition of coastal habitats ranging from mudflats to mature sand dunes. Other habitats included within the site include saltmarsh, freshwater marsh and open pools, containing either fresh or brackish water. The site is principally valued for the range of coastal habitats supported, and the fauna associated with them, particularly wintering and passage waterfowl and breeding little tern.

Ecology

Site type
Coastal

Area of SSSI
581ha

cSAC interest features
The Wash and North Norfolk Coast cSAC:

- Atlantic salt meadows;
- Large shallow inlets and bays;
- Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*);
- Mudflats and sandflats not covered by seawater at low tide; and
- *Salicornia* and other annuals colonising mud and sand.

Saltfleetby-Theddlethorpe Dunes and Gibraltar Point cSAC:

- Embryonic shifting dunes;
Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes);
- Fixed Dunes with herbaceous vegetation (grey dunes);
- Humid dune slacks; and
- Dunes with *Hippophae rhamnoides*.

SPA interest features
Annex 1 species of international importance:

- wintering bar-tailed godwit;
- breeding little tern.

Migratory bird species of international importance:

- grey plover;
- knot.

Internationally important waterfowl assemblage, greater than 20 000 waterfowl.

Existing ecological monitoring
A number of ecological monitoring surveys are carried out and these include birds surveys as part of the Wetland Bird Survey (WeBS) and Common Bird Census (CBC), fixed quadrat vegetation surveys in Freshwater Marsh and natterjack toad surveys.

Water resources

Geology
- Thin blown sands deposits possibly overlying Terrington Beds;
- The above overlaying extensive fluvio-glacial sands and gravels;
- The above rest uncomfortably over Lower Cretaceous rocks.

Existing surface water and ground water monitoring
Operational monitoring of selected surface waters on-site by Lincolnshire Wildlife Trust (LWT).

The Golf Club to the north of the site undertake some water level and salinity monitoring associated with their ground water abstraction.

LWT also undertake further hydrometric monitoring associated with their plans to extend the reserve westward towards Jacksons/Croft Marsh.

- The Freshwater Marsh is served by indigenous, highly localised, surface drainage and ground water derived from rainfall runoff and recharge to (or very close to) the site.;
- Intertidal areas receive residual drainage from the Freshwater Marsh to the north and indigenous runoff but are primarily influenced by diurnal tidal inflow and occasionally, for very large tides, these inflows inundate the marshes

This document was withdrawn on 6 November 2017

Level of confidence in the conceptual understanding of the site

- The broad understanding of site hydrology is moderately understood but details are scarce, particularly for the Freshwater Marsh area, and therefore, the baseline ground water regime and interaction with pumped, IDB controlled, drainage to the west for this area are poorly understood

Relationship between ecology and water resources

Relationship between european features and water supply

The Wash and North Norfolk Coast cSAC:
The interest features are primarily influenced by coastal processes and largely independent of freshwater influences within the intertidal areas of Gibraltar Point SSSI.

Saltfleetby-Theddlethorpe Dunes and Gibraltar Point cSAC:
The interest features consist of a series of sand dune types and vegetation generally adapted to drought conditions and not dependent on freshwater flows. The exception to this are the humid dune slack areas of the site. Freshwater inputs to the sand dune system of Gibraltar Point are local and indigenous. Therefore, LWT carry out management aimed at retaining water through the summer months in an area known as the Freshwater Marsh. However, ground water abstraction carried out by Seacroft golf course to maintain their greens may give rise to sufficient drawdown in these areas to cause saline intrusion into some of the dune slack areas of Freshwater Marsh, with the possibility of affecting species composition and abundance within these areas.

Gibraltar Point SPA:
The interest features require a range of intertidal (and extreme tidal) habitats but these do not have significant freshwater dependence. Tenuous links for Interest Features have been postulated in estuarine outfalls and tidal creeks supplied by freshwater but these regimes in relation to the site are not considered to be significantly impacted.

What are the potential effects on the site

The principal area of the European designated site considered sensitive to the freshwater hydrological regime is the Freshwater Marsh zone. This zone is served by indigenous drainage which is managed by LWT to achieve a desired quantity and quality regime for the site. This zone is potentially vulnerable to saline intrusion by both surface and ground water conveyance. The former is controlled through a series of ponds and a lagoon by means of sluicing. The fresh ground water zone is believed to have very limited thickness and could be vulnerable to impacts under extreme drought or inappropriate operational regimes. Additional water level management by LWT, of water bodies immediately west of the site (including the Freshwater Marsh), is believed to buffer the site from potential hydrological impacts. Such impacts could potentially arise as a result of pump drained operations/management by the IDB for the Cow Bank Drain which may otherwise lower ground water levels at the site.

The intertidal areas of the site are primarily fed by tidal water, with limited freshwater input from Wainfleet Haven (the estuarine portion of the River Steeping) and one or two minor flows which drain from the sand dune system. Intertidal areas of the site are not considered vulnerable to any potential impacts to the freshwater component from the River Steeping. The only issues considered to be of potential concern to the site is whether water quality in Wainfleet Haven is detrimentally impacted by discharge, abstraction or any other operation affecting the River Steeping. This is not thought to be the case with the tidal river achieving a water quality compliant with a RE2 target.

The preliminary impact assessment indicates that there is a possible risk to ground water salinity regimes at the Freshwater Marsh from a local abstraction made by the Golf Club to the north of the site. The other possible effect considered worthy of further investigation is to check that IDB management/operations do not cause ground water level drawdown to the site. The precise effect on the Freshwater Marsh is difficult to quantify because the baseline hydrological regime for the site is not well known. Therefore further investigations of the site and adjacent operations are proposed to reduce uncertainty and enable a more robust assessment.

This document was withdrawn on 6 November 2017

Potential risk due to Environment Agency licensed abstractions and strategic water resources management

Hazard	Nature and magnitude of potential	Potential Hydro-ecological effect	Likelihood of occurrence	Consequent risk to European features (preliminary assessment only)	Level of confidence
Surface Water Abstractions	R. Steeping quality	Low	Very low (negligible)	Very low	High
Ground water Abstractions	Level regime	Very Low/ (negligible)	Low	Very low (negligible)	Medium
	Quality regime	Medium	Low (? But very uncertain)	Low (? Possibly medium)	Low (? Possibly very low)

Stage 3 Proposals

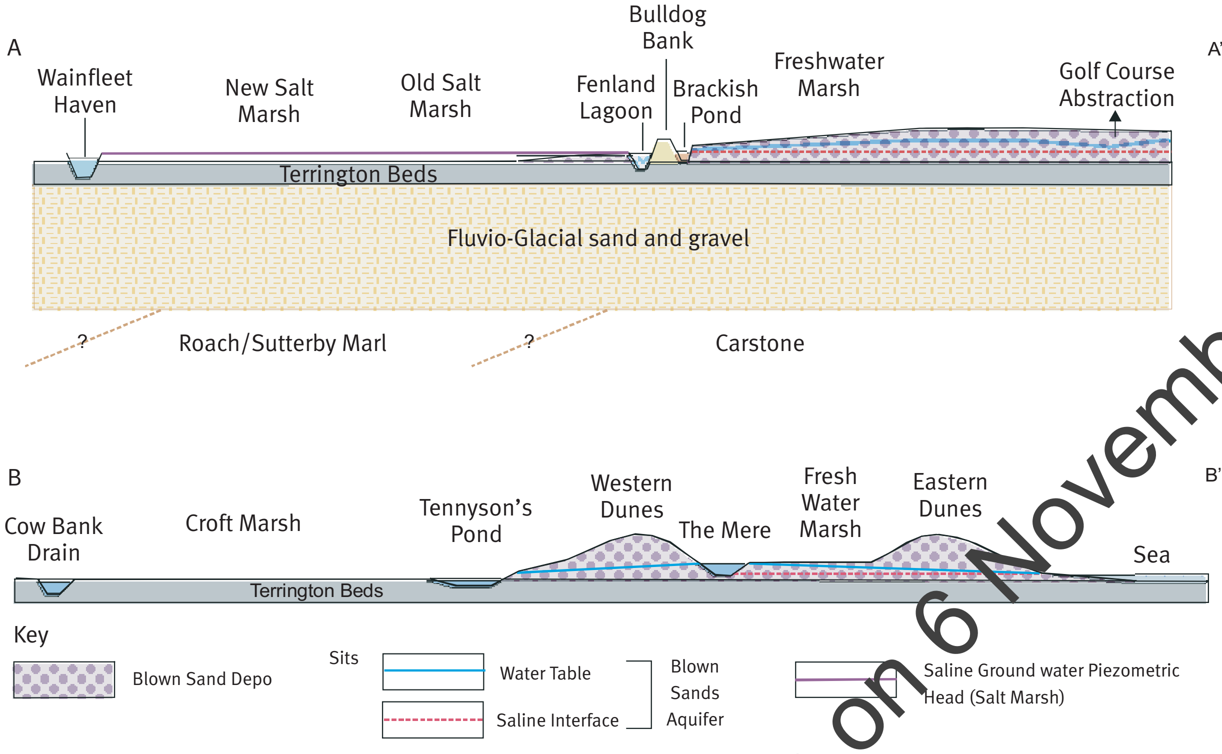
Appropriate Assessment is considered essential for the site and Baseline investigations/assessments recommended are outlined below:

- Further Baseline Hydrological Investigations of Freshwater Marsh component of site.
- Assess impact of Golf Club ground water abstractions on the site.
- Assess impact (if any) of IDB drainage on site.
- Site Specific Surveys
  – Detailed hydrological and water quality investigation of ground water and surface water regime across the Freshwater Marsh and extending beyond. This review would define more precisely the scope of specific SI including piezometer and data logger installations plus allied topographic levelling of key datums.
  – Signal testing of ground water abstraction effects on the Freshwater Marsh area of the site
  – Botanical monitoring to confirm the status of the flora of the humid dune slack areas may be necessary.

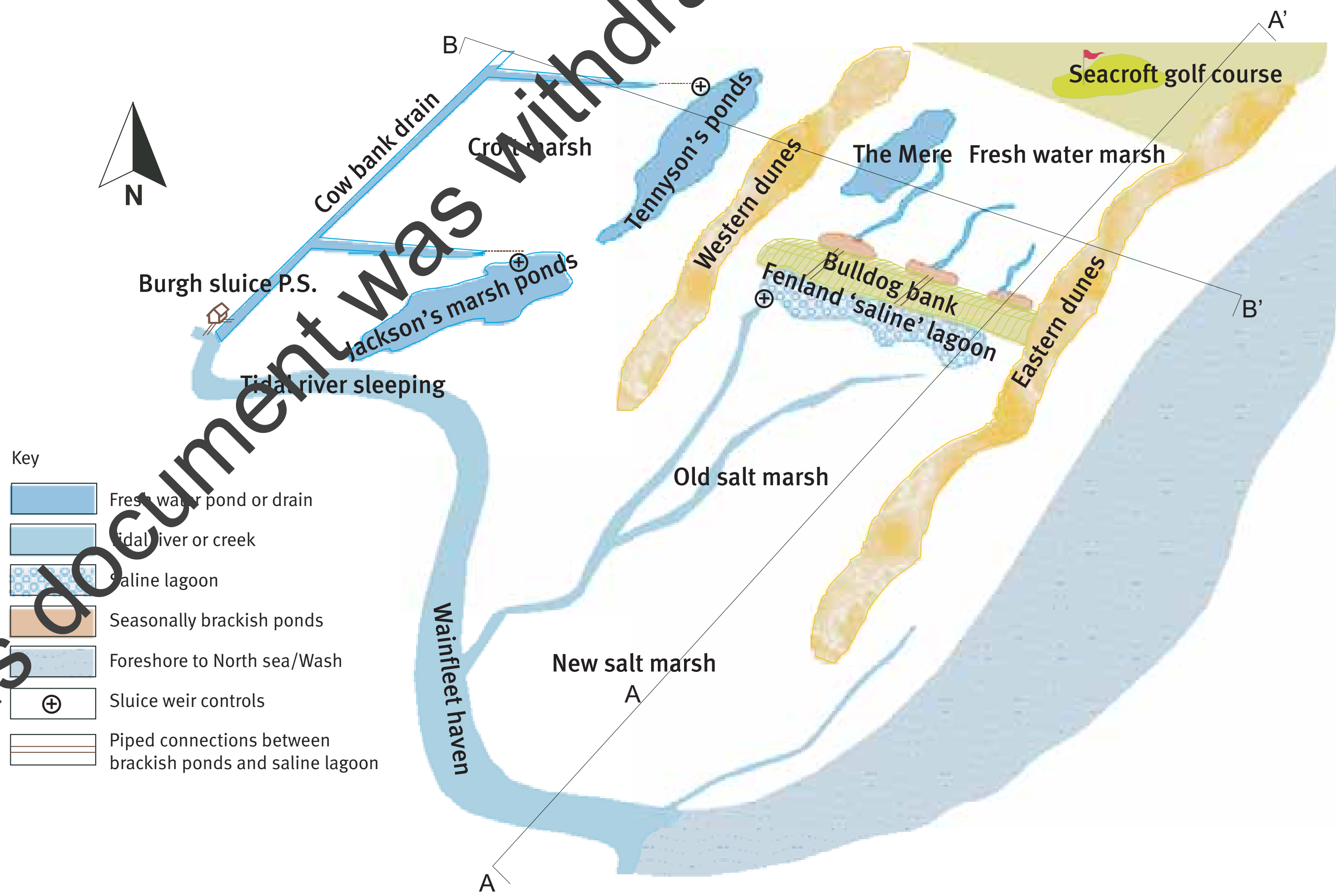
The Risk Assessment will be revisited and refined as new data are obtained and further assessments undertaken.

This document was withdrawn on 6 November 2017

Schemative of key hydrological systems at Gibraltar Point



Schematic of assumed hydrogeological controls at Gibraltar Point



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The North Norfolk Coast

Stage 2 Ongoing (planned Stage 3 Assessments)

Ecology

Site type
Coastal

Area of SSSI
7700 ha

SAC features
The Wash and North Norfolk Coast cSAC:

- Atlantic salt meadows (which includes tidal reedbeds);
- Large shallow inlets and bays;
- Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*);
- Mudflats and sandflats not covered by seawater at low tide;
- Common seal;
- *Salicornia* and other annuals colonising mud and sand; and
- Sandbanks which are slightly covered by seawater all of the time.

Additional proposed interest:

- Coastal Lagoons

The North Norfolk Coast cSAC:

- Coastal lagoons;
- Fixed Dunes with herbaceous vegetation (grey dunes);
- Embryonic shifting dunes;
- Humid dune slacks;
- Mediterranean and thermo-Atlantic halophilous scrubs (Sarcocornetea fruticosi);
- Perennial vegetation of stony banks; and
- Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes).

Additional proposed interest:

- Otter
- Petalwort

SPA features
Annex 1 species of international importance:

- wintering and breeding avocet;
- wintering and breeding bittern;
- breeding common tern;
- breeding little tern;
- breeding roseate tern;
- breeding sandwich tern;
- breeding Mediterranean gull;
- breeding marsh harrier;
- wintering bar-tailed godwit;
- wintering golden plover;
- wintering ruff;
- wintering hen harrier; and
- breeding little tern.

Migratory bird species of international importance:

- wintering pink-footed goose;
- wintering pintail; and
- wintering wigeon.

Internationally important waterfowl assemblage:

- greater than 20 000 waterfowl.

Water resources

Geology/hydrogeology
The geology of the site comprises variable marsh drift overlying sands & gravels on a Chalk platform with the landward margin of the marshes generally demarked by a palaeo cliff-line cut into the Chalk. The Marsh deposits generally comprise variable accretional Holocene deposits typically made up of salt marsh silts and clays but also including variable quantities of peat and sands and gravels. Seaward of the marshes sand dune deposits and sand/shingle beach and ridge deposits are significant. Beyond areas of inter-tidal salt marsh mud and sand banks are widespread. Ground water enters much of the coastal marshes, particularly to the west of the site, directly from the Chalk aquifer. Further west, Chalk confinement by boulder clay together with increased drift sands and gravels means that drift aquifers have more significance.

Source(s) of water supply
In addition to direct ground water supply of the coastal marshes estuarine components of the site are supplied by rivers draining to the North Norfolk Coastal site and from west to east include;.R. Hun; R. Burn; Wells Harbour Stream (a very minor system); R. Stiffkey; and, R. Glaven. Essentially these rivers have Chalk baseflow dominated regimes but in the case of the Stiffkey and Glaven drift sands and gravels have hydrological significance too.

This document was withdrawn on 6 November 2017

Hydrological division of site

The site has been divided into 10 discrete zones to help with the characterisation and assessment (see Figure 1 enclosed).

Level of confidence in the conceptual understanding site

The general conceptualisation for the site is considered adequate to understand and rank the hydrologically related issues which detrimentally affect the site but local detail along the coast is quite variable.

Relationship between ecology and water resources

Relationship between european features and water supply

See Table 1 for the distribution of interest features across the zone receptors.

The hydrology of the North Norfolk Coast needs to be considered in a Regional context. In summary, the following can be concluded:

- The principal rivers include the Hun, Burn, Stiffkey and Glaven (Zones 1, 3, 7 and 9 respectively) all of which are baseflow dominated rivers principally influenced by the Chalk aquifer. The Hun and Burn have minor surface water abstraction/discharge influences in terms of quantity but the equivalent influences for the Stiffkey and Glaven are relatively greater. Investigations have revealed that for the Stiffkey and Glaven groundwater abstractions have a more significant impact on flow regimes. This is due in part to large abstractions for public water supply. Water quality is good in the Burn and Stiffkey (and thought also to be so in the Hun but no data are readily available here) but poor in the Glaven, and all rivers are enriched with high nutrient levels.
- The small river system of Wells Harbour Stream (Zone 5) is also believed to exhibit a Chalk ground water dominated flow regime albeit of relatively minor proportions. There are virtually no data on quantity of quality for this minor river system. The small size of the inflow suggests that this inflow is of no hydrodynamic significance to the tidal Wells Harbour Channel. It should also be noted that the quantity effluent input to Wells Harbour Channel from the local sewage treatment works is likely to be far greater than the minor stream inflow.
- Extensive ground water capture zones, essentially defined for the Chalk aquifer, are thought to exist supplying freshwater to coastal areas. Inflows to Zone 2 (Thornham to Deepdale Marshes) may also be enhanced by deeper ground water outflow from the Burn catchment (Zone 3). The principal areas of ground water outflow believed to supply freshwater to habitats in reclaimed marshes and freshwater influenced salt marshes include:
  - Part of Zone 1 to Holme NNR.
  - Zone 2 (Thornham to Deepdale) supplying freshened salt marsh (supporting tidal reed) and freshwater grazing marshes.
  - Zone 4 (Wells West Bank) freshwater grazing marshes.
- With current knowledge it is not possible to distinguish those parts of Zone 3 (Burn) which supply freshwater to the reclaimed grazing marsh areas of both Burnham Norton and Burnham Overy but some relatively small portion of discharge is believed to flow to these areas.
- Relatively minor ground water discharges are believed to flow and supply freshwater to both Zone 8 (Morston Salt Marsh and Blakeney Freshes) and Zone 10 Cley/Salthouse Marshes. The relatively minor ground water outflows to these Zones are made up by discharges from both Chalk and gravel aquifers. The significance of the inferred outflows to Morston Salt Marsh is not currently known (or indeed corroborated by any field evidence). The ground water inputs to Blakeney Freshes (reclaimed grazing marsh) are thought to be of some significance although the major inflow, in quantity terms, comes in as a diversion from the River Glaven at Cley.
- There is believed to be no freshwater discharge to Zone 7 (Warham to Stiffkey Salt Marshes) and this is inferred from both hydrogeological conceptualisation and field evidence which indicates no freshening of marine waters in this Zone.

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Impact assessment

based on hydrological impact assessment using RAM aquifer response function and consideration of theoretical drought yields (see Table 2). Figure 1 shows extent of capture zones and licensed abstractions.

Surface water abstraction licences

Is the site hydraulically connected to:

River Estuaries
Yes (Hun, Burn, Wells Harbour Stream, Stiffkey and Glaven)

Local marsh drainage systems
Yes (the Freshwater (reclaimed) Grazing Marshes are intersected by IDB controlled drains some of which are spring fed by the Chalk)

Are there existing licensed abstractions within the contributory surface water catchments to the site?
Yes

River Estuaries
Yes (but none on the R. Burn)

Local marsh drainage systems
Yes

If Yes, to what extent does this affect water supply to the site (at the current licensed quantity)
Risk is considered to range from negligible to medium.

Ground water abstraction licences

Is the site hydraulically connected to underlying aquifers?
Yes

Do ground waters significantly contribute to river flow input to estuaries?
Yes

How important is the ground water component in the overall supply of water to European features?
Coastal Marsh Zones
Varies from very low (Zone 6) to medium (Zone 2).

Estuarine Zones
In the range low to medium although the dependence on freshwater for the interest features is not presently well understood

Is the ground water water supply to the site likely to be affected by existing ground water abstractions (at the current licensed quantity)
Yes

If yes, what is the likely impact on the overall water supply to the site
Coastal Marsh Zones
Varies from negligible (Zone 6) to Medium (Zone 2).

Estuarine Zones
Varies from Negligible (Hun and Burn to Medium (Stiffkey and Glaven)

To what extent could this affect european features?
Coastal Marsh Zones
Varies from negligible (Zone 6) to Medium (Zone 2).

Estuarine Zones
Varies from Low (Hun and Burn) to Medium (Stiffkey and Glaven)

This document was withdrawn on 6 November 2017

Potential risks and level of confidence in the assessment

Environment Agency water resources consents

Zone	Source of risk	Potential risk to european features	Level of confidence
Zone 1	**Hun (including Holme NNR)**		
	GW abstractions	Low	Low
	SW abstractions	Negligible	Medium
	All abstractions	Low	Low
Zone 2	**Thornham to Deepdale Marshes**		
	GW abstractions	Medium	Low
	SW abstractions	Very Low	Medium
	All abstractions	Medium	Low
Zone 3	**Burn (including Burnham Norton & Overy)**		
	GW abstractions	Low	Medium
	SW abstractions	Negligible	High
	All abstractions	Low	Medium
Zone 4	**Wells West Bank**		
	GW abstractions	Negligible	Low
	SW abstractions	Negligible	Low
	All abstractions	Very low	Low
Zone 5	**Wells Harbour & Salt Marsh**		
	GW abstractions	Low	Low
	SW abstractions	Medium	Low
	All abstractions	Medium	Low
Zone 6	**Warham to Stiffkey Salt Marshes**		
	GW abstractions	Negligible	Medium
	SW abstractions	Negligible	High
	All abstractions	Negligible	Medium
Zone 7	**Stiffkey Estuary**		
	GW abstractions	Low – Medium	Low
	SW abstractions	Low	Low
	All abstractions	High	Low
Zone 8	**Morston Salt Marsh & Blakeney Freshes**		
	GW abstractions	Low	Medium
	SW abstractions	Low	Low – Medium
	All abstractions	Low – Medium	Medium
Zone 9	**Glaven Estuary**		
	GW abstractions	Medium	Low
	SW abstractions	Low	Low
	All abstractions	High	Low
Zone 10	**Cley/Salthouse Marshes**		
	GW abstractions	Low – Medium	Low – Medium
	SW abstractions	Very Low	High
	All abstractions	Low – Medium	Low – Medium

This document was withdrawn on 6 November 2017

Further investigations required under review of consents

Are further hydrological and/or ecological investigations required to define the impact of Environment Agency consents?
Yes

Water resources abstraction licences?
Yes

Water quality discharge consents?
Yes

Waste management licences?
Possibly

Flood defence management?
Yes

IDB drainage
Probably not! Natural England aim to seek new land use/ management agreements in areas of arable land which conflict with favourable regimes in freshwater grazing marshes

Natural England
Yes – Investigation/guidance on management of Marsh Drains and on the unlicensed transfer onto the SSSI from the Glaven into Blakeney Freshes.

If yes, what?

Part 1. Appropriate assessment

- Appropriate assessment of selected abstractions is recommended. The 1st step suggested in the next stage of appropriate assessment involves refining; the spatial distribution of interest features and defining their freshwater requirements (where possible) and getting a more definitive assessment of actual freshwater feeds to certain salt marshes and better quantifying freshwater inflows to the site more generally. If these assessments continue to indicate a significant risk to the site more targeted investigation may be required to better define the hydrogeological regime of coastal marsh systems and their precise interaction with chalk ground water. Assessments should be co-ordinated with requirements under flood defence and water quality possibly co-ordinated through the SMP.

Part 2. Further investigations

Ecological Investigation:

- The significance of an increase in salinity of the water entering those saline lagoons which have a significant freshwater input;
- Water balance relationships within humid dune slacks to define the water level requirements of the feature;
- The relationship between salinity and vegetation community of grazing marshes, as well as the relationship between grazing marsh invertebrate community composition and salinity;
- The relationship between freshwater flows across intertidal areas (mudflats and also in tidal creeks) and the distribution of benthic invertebrates and wintering birds.

Hydrological and Hydrochemical Investigation:

- Water quality monitoring for the River Hun.
- Hydrological Desk Studies bringing together findings from; abstraction licence application impact assessments and monitoring; ongoing Regional studies (Entec); ongoing UEA research (Green); SMP related studies; and monitoring /assessments associated with the ongoing Cley-Salthouse sea defence scheme. These studies will define if further monitoring and/or modelling are required.
- Estuarine desk studies reviewing availability of hydrodynamic and ecological data.

Part 3. Installations and specialist surveys

Initial recommendations include;

- Quantity and quality monitoring of the Hun and Wells Harbour Stream;
- Flow accretion surveys of the Burn (below Burnham gauge) and the Catchwater Drain (Zone 10);
- Reconnaissance and gauging of significant springs in Zones 1,2, 3 and 8;
- Salinity monitoring and gauging of freshened tidal creeks in Zone 2;
- Salinity monitoring to identify if any freshening occurs to tidal creeks in Zones 3, 5, and 8;
- Gauging of the Glaven diversion into Blakeney Freshes;
- Down hole logging of selected boreholes in and around Zone 2 to ascertain if deep ground water flow occurs in the chalk and may be associated with possible direct flow to sea;
- Reconnaissance and surveying of boreholes installed on Cley/Salthouse Marshes for investigations associated with the tidal flood defence scheme to include:
  - Ground water level monitoring
  - Depth/salinity profiling to characterise the ground water salinity regime for the site.

This document was withdrawn on 6 November 2017

Table 1 Distribution of european features in relation to ground water capture/outflow zones

North Norfolk Coast cSAC	Zone 1	2	3	4	5	6	7	8	9	10
Coastal lagoons	✓			✓						✓
Humid dune slacks	✓			✓						
Otter (probably associated predominantly with river channels and drains)	✓?	?	✓?	✓?	?	?	✓?	✓?	✓?	✓?
Petalwort	?			✓?						

Wash and North Norfolk Coast cSAC	Zone 1	2	3	4	5	6	7	8	9	10
Atlantic salt meadows (refers in this table to tidal reedbed)		✓	✓						✓	
Mudflats and sandflats not covered by seawater at low tide (of relevance because of the possible interaction between freshwater and the benthic invertebrate fauna consumed by birds)	?	?	?	?	?	?	?	✓	✓	

Other habitats	Zone 1	2	3	4	5	6	7	8	9	10
Creeks carrying freshwater through saltmarsh	✓	✓	✓?						✓	
Freshwater reedbed	✓	✓								✓
Freshwater/brackish grazing marshes and associated ditches	✓	✓	✓	✓				✓		✓

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Table 2 Zonal licensed totals and comparisons with 'natural' drought minimum outflows

Licensed ground water abstractions only

Zone/catchment & receptor		Tallied license quantities				Estimated rechange & drought outflow quantities						Exceed criteria?		Exceed Criteria (>100%)	
GW cap zone	Outflow receptor	(FAQ) Full annual qty (Ml/d)	(FDQ) Full daily qty (Ml/d)	Selected annual qty (Ml/d)	Selected daily qty (Ml/d)	Average recharge (Ml/d)	Aquifer response function (Ml/d)	(DM_{BAR}) Mean annual (Ml/d)	(DM_5) 5yr drought minimum (Ml/d)	(DM_5) 10yr drought minimum (Ml/d)	(DM_5) 20yr drought minimum (Ml/d)	Full annual qty > 20yr drought minimum	Full daily qty > 5yr drought minimum	100* (FAQ/DM_{20}) (%)	100* (FAQ/DM_5) (%)
1	R. Hun (& Holme NNR)	4.87	11.01	4.87	11.01	36.54	21.68	17.06	11.86	8.29	5.14	N	N	94.6	92.8
2	Thornham to Deepdale Marsh	2.87	15.99	2.69	14.39	27.88	15.70	11.21	7.28	4.90	2.54	Y	Y	112.8	219.7
3	R. Burn (& Burnham Norton/Overy)	2.64	13.32	1.16	7.55	53.65	32.81	24.49	16.40	11.09	6.21	N	N	42.5	81.2
4	Wells West Bank	0.11	1.79	0.00	0.00	12.31	8.30	6.56	4.59	3.22	2.02	N	N	5.6	38.9
5	Wells (Harbour & Salt Marsh)	0.01	0.02	0.00	0.00	[illegible].28	1.05	0.54	0.36	0.24	0.14	N	N	6.1	6.4
6	Warham to Stiffkey (Salt Marsh)	0.00	0.00	0.00	0.00	1.2[illegible]	0.01	0.00	0.00	0.00	0.00	N	N	0.0	0.0
7	R. Stiffkey	10.30	29.44	10.05	27.91	45.41	10.08	8.85	6.28	3.90	2.16	Y	Y	477.5	468.9
8	Morston Marshes & Blakeney Freshes	0.65	4.86	0.44	1.68	6.27	2.85	1.85	1.27	0.81	0.43	Y	Y	150.3	381.7
9	R. Glaven	6.67	19.79	4.98	7.91	31.06	16.72	12.[illegible]	9.23	6.50	4.31	Y	Y	154.7	214.4
10	Cley/Salthouse Marshes	0.15	1.32	0.14	1.31	7.36	3.15	1.36	0.97	0.69	0.46	N	Y	32.9	135.8

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Table 2 Zonal licensed totals and comparisons with 'natural' drought minimum outflows

Licensed surface water abstractions only

Zone/catchment & receptor		Tallied License Quantities				Estimated rechange & drought outflow quantities						Exceed criteria?		Exceed criteria (›100%)	
GW cap zone	Outflow receptor	(FAQ) Full annual qty (Ml/d)	(FDQ) Full daily qty (Ml/d)	Selected annual qty (Ml/d)	Selected daily qty (Ml/d)	Average Recharge (Ml/d)	Aquifer response function (Ml/d)	(DM_{BAR}) Mean annual (Ml/d)	(DM_5) 5yr drought minimum (Ml/d)	(DM_5) 10yr drought minimum (Ml/d)	(DM_5) 20yr drought minimum (Ml/d)	Full annual qty › 20yr drought minimum	Full daily qty › 5yr drought minimum	100* (FAQ/DM_{20}) (%)	100* (FAQ/DM_5) (%)
1	R. Hun (& Holme NNR)	0.16	1.76	0.14	1.59	36.54	21.68	17.08	11.86	8.29	5.14	N	N	3.1	14.8
2	Thornham to Deepdale Marsh	0.31	4.83	0.20	1.14	27.88	15.70	11.21	7.28	4.90	2.54	N	N	12.2	66.4
3	R. Burn (& Burnham Norton/Overy)	0.00	0.00	0.00	0.00	53.65	32.81	24.49	16.40	11.09	6.21	N	N	0.0	0.0
4	Wells West Bank	0.11	1.30	0.00	0.00	12.31	8.30	6.58	4.59	3.22	2.02	N	N	5.3	28.3
5	Wells (Harbour & Salt Marsh)	0.33	3.48	0.16	1.23	[illegible].28	1.05	0.54	0.36	0.24	0.14	Y	Y	233.7	962.1
6	Warham to Stiffkey (Salt Marsh)	0.00	0.00	0.00	0.00	1.2[illegible]	0.01	0.00	0.00	0.00	0.00	N	N	0.0	0.0
7	R. Stiffkey	1.02	5.13	0.38	1.33	45.41	15.08	8.85	6.28	3.90	2.16	N	N	47.1	81.7
8	Morston Marshes & Blakeney Freshes	0.00	0.00	0.00	0.00	6.27	2.8[illegible]	1.85	1.27	0.81	0.43	N	N	0.0	0.0
9	R. Glaven	1.84	14.11	1.01	4.84	31.06	16.72	12.[illegible]3	9.23	6.50	4.31	N	Y	42.7	152.8
10	Cley/Salthouse Marshes	0.03	0.87	0.00	0.00	7.36	3.15	1.36	0.97	0.69	0.46	N	N	6.0	89.6

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Table 2 Zonal licensed totals and comparisons with 'natural' drought minimum outflows

Licensed surface & groundwater abstractions combined

Zone/catchment & receptor		Tallied license quantities				Estimated rechange & drought outflow quantities						Exceed criteria?		Exceed criteria (›100%)	
GW cap zone	Outflow receptor	(FAQ) Full annual qty (Ml/d)	(FDQ) Full daily qty (Ml/d)	Selected annual qty (Ml/d)	Selected daily qty (Ml/d)	Average recharge (Ml/d)	Aquifer response function (Ml/d)	(DM_{BAR}) Mean annual (Ml/d)	(DM_5) 5yr drought minimum (Ml/d)	(DM_5) 10yr drought minimum (Ml/d)	(DM_5) 20yr drought minimum (Ml/d)	Full annual qty › 20yr drought minimum	Full daily qty › 5yr drought minimum	100* (FAQ/DM_{20}) (%)	100* (FAQ/DM_5) (%)
1	R. Hun (& Holme NNR)	5.02	12.77	5.00	12.60	36.54	21.68	17.08	11.86	8.29	5.14	N	Y	97.7	107.7
2	Thornham to Deepdale Marsh	3.18	20.82	2.89	15.52	27.88	15.70	11.21	7.28	4.90	2.54	Y	Y	125.0	286.0
3	R. Burn (& Burnham Norton/Overy)	2.64	13.32	1.16	7.55	53.65	32.81	24.49	16.40	11.09	6.21	N	N	42.5	81.2
4	Wells West Bank	0.22	3.09	0.00	0.00	12.31	8.30	6.58	4.59	3.22	2.02	N	N	10.9	67.2
5	Wells (Harbour & Salt Marsh)	0.33	3.50	0.16	1.23	4.28	1.05	0.54	0.36	0.24	0.14	Y	Y	239.8	968.5
6	Warham to Stiffkey (Salt Marsh)	0.00	0.00	0.00	0.00	1.24	0.01	0.00	0.00	0.00	0.00	N	N	0.0	0.0
7	R. Stiffkey	11.32	34.57	10.44	29.24	45.41	15.08	8.85	6.28	3.90	2.16	Y	Y	524.6	550.6
8	Morston Marshes & Blakeney Freshes	0.65	4.86	0.44	1.68	6.27	2.85	1.85	1.27	0.81	0.43	Y	Y	150.3	381.7
9	R. Glaven	8.51	33.90	5.99	12.75	31.06	16.72	12.65	9.23	6.50	4.31	Y	Y	197.4	367.2
10	Cley/Salthouse Marshes	0.18	2.20	0.14	1.31	7.36	3.15	1.36	0.97	0.69	0.46	N	Y	38.9	225.4

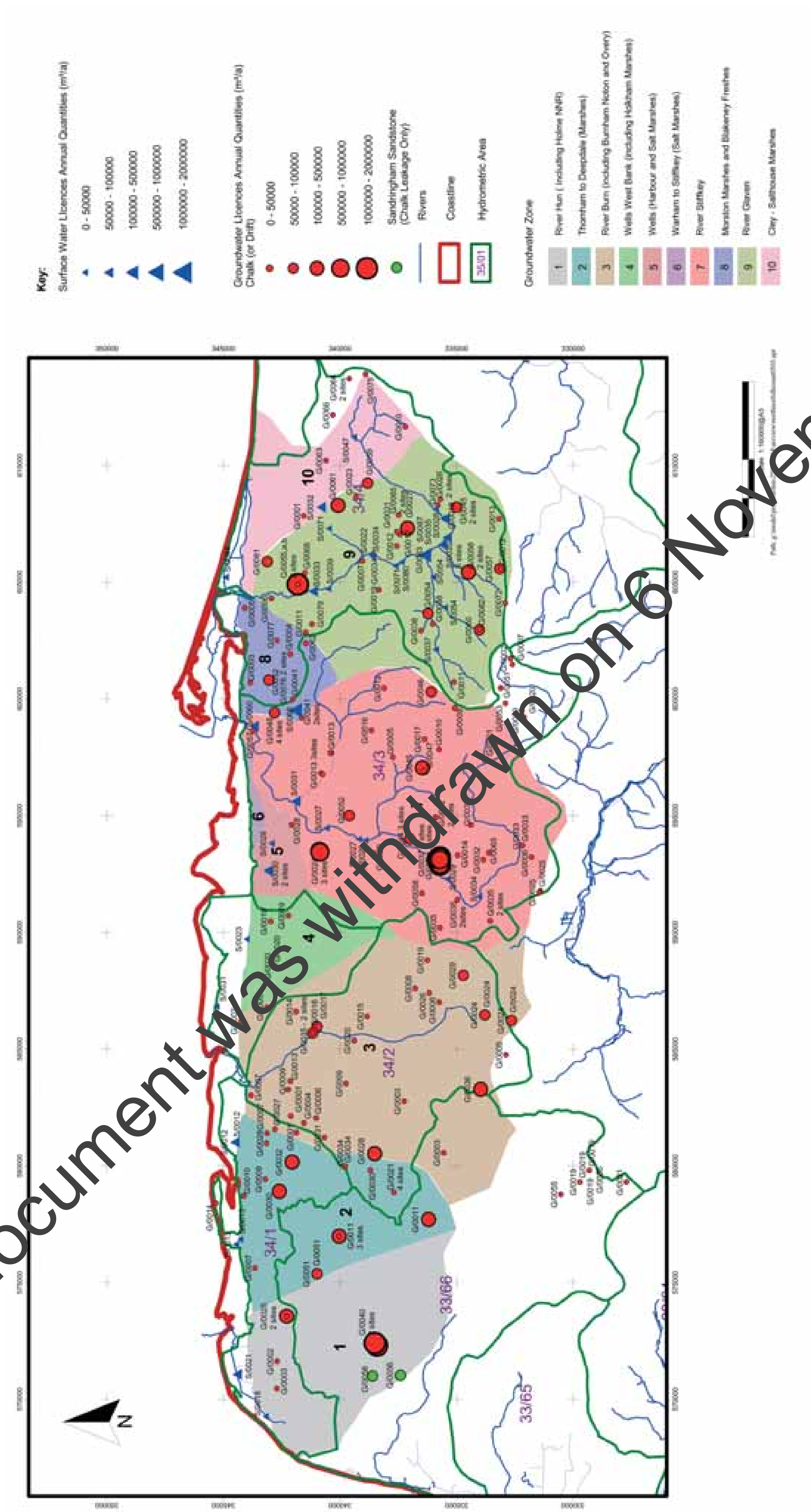

Figure 1 Licensed surface & groundwater abstractions within surface catchments or groundwater capture zones

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The Wash

Undertaken/planned investigations

Ecology

Site type
Coastal

Area of SSSI
63,135 ha

SAC features
The Wash and North Norfolk Coast cSAC:

- Atlantic salt meadows;
- Large shallow inlets and bays;
- Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*);
- Mudflats and sandflats not covered by seawater at low tide;
- Common seal (*Phoca vitulina*);
- Salicornia and other annuals colonising mud and sand; and
- Sandbanks which are slightly covered by seawater all the time.

Additional proposed interest includes; Coastal lagoons *Lutra Lutra* (otter); and, Biogenic reefs

SPA features
This site qualifies under **Article 4.1** of the Directive for the following species listed on Annex I:

- During the breeding season; Common Tern *Sterna hirundo*; Little Tern *Sterna albifrons*; and Marsh Harrier *Circus aeruginosus*.
- Over winter; Avocet *Recurvirostra avosetta*; Bar-tailed Godwit *Limosa lapponica*; Golden Plover *Pluvialis apricaria* and Whooper Swan *Cygnus cygnus*.

This site also qualifies under **Article 4.2** of the Directive for migratory species: On passage – Ringed Plover *Charadrius hiaticula*; Sanderling *Calidris alba*.

Water resources

See Figure overleaf.

Geology/geopmorpholgy
The solid geology of the Wash comprises Jurassic Clays to the south and Cretaceous deposits to the north. In general, the solid geology is hidden beneath the seabed sediments and does not outcrop in the Wash. The drift sediments distribution is complex, being made up of tidally redistributed Holocene deposits comprising intertidal and sub-tidal muds, sands and gravels. The seafloor is relatively flat throughout much of the area, generally less than 20m below Chart Datum. However, there is an elongated, steep sided depression that extends from the Lynn Deeps of the Wash to Skate Hole to the north east of the Wash.

Existing surface water and ground water monitoring
There is no ground water monitoring that is directly relevant to the Wash.
Tidal levels across the Wash are monitored at several locations by the Environment Agency, ports and other organisations. Special investigations have also been undertaken of tidal currents and offshore wave characteristics.
In general, river flows to the Wash are not gauged at the tidal limits and flow estimates need to be scaled using appropriate available data and adjusted to allow for key influences and contributions downstream of gauges.

Source(s) of water supply
Intertidal areas are primarily influenced by diurnal tidal inflow and occasionally, for very large tides, these inflows inundate the marshes.

Principal riverine inputs- Witham, Welland, Nene and Ouse. The latter being the largest. Other relatively minor inputs include those from smaller rivers (Steeping, Wolferton/Ingol and Heacham) and several minor inputs from IDB controlled drainage areas.

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Level of confidence in the conceptual understanding of the site

The broad hydro-dynamics of the Wash and the relative significance of marine/tidal v fluvial processes are adequately understood. Fluvial effects on salinity distributions are reasonably understood but the links between fluvially influenced sediment distribution and river flows are poorly understood.

Relationship between ecology and water resources

Relationship between european features and water supply

The Wash and North Norfolk Coast cSAC: The interest features are primarily influenced by coastal processes which affect a variety of environmental conditions such as the height of sediments in relation to sea levels and salinity. However, all of the vegetation communities are dominated by halophytic species and though freshwater influences salinity, any effects are likely to be very localised due to the small size of the inputs and the incised nature of the channels. Common seals haul-out on sandy beaches to rest, pup and suckle and have no specific requirement for freshwater flows in intertidal areas. It is considered that freshwater inputs have very little effect on the cSAC interest features that occur within intertidal areas of The Wash, and limited effect on subtidal features. Recent research has suggested that a number of species of waterfowl may preferentially use areas around freshwater flows. Within the Wash freshwater inputs arise from the Nene, the Ouse, the Welland and the Witham. Bird distribution in the Wash does not appear to be correlated to these areas; the detailed studies to demonstrate this are lacking.

The value of freshwater flows on this site to birds is likely to be negligible and is not considered to be a major factor in determining the abundance of distribution of SPA qualifying species. Breeding terns nest on shingle ridges and feed on small fish in shallow coastal waters and therefore have no specific requirement for freshwater. The main influence on the use of the intertidal areas by most SPA qualifying birds is likely to be the availability of invertebrate food. Invertebrate abundance appears to be largely independent of freshwater input, with the most productive areas of mudflat being located in areas where the influence of freshwater is likely to be minimal.

What are the potential effects on the site

There is considered to be no direct connection of significance between ground water and the Wash. Ground water and related abstractions are indirectly of importance because of baseflow contributions to riverflows and related impacts from ground water development.

Riverflows are the primary freshwater input to the Wash (particularly from the Ouse, Nene, Welland and Witham). The significance of these inflows to the ecology (Interest Features) of the site is not precisely known with tenuous links suggested between these inputs and the SPA Interest Features both in terms of providing drinking/preening habitats and through influences on the invertebrate food source. Freshwater related influences on the habitat are also likely to be more significantly controlled by impacts on salinity regime and riverine influences on sedimentation in the Wash. Identification and adequate understanding of the Source-Pathway-Receptor mechanism is further complicated because the freshwater regime may be of secondary (or tertiary) importance as controlling factors on the associations to these Interest Features. Tidal regimes, climatic variability, flood defence (tidal and riverine) and water pollution loading potentially having more significance than direct quantity related impacts from abstractions on riverflow. On this basis, total riverflows to the Wash have been estimated for both actual and 'naturalised' flow conditions and the main abstraction operations (both licensed and non-licensed) identified which contribute to flow impacts which could potentially affect the site (see figure showing flows expressed as a percentile exceedence graph).

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Potential risk due to Environment Agency licensed abstractions and strategic water resources management

Hazard (Moreton's Leam and the Washes)	Nature and magnitude of potential effects on the water supply	Potential impact on the overall water supply	Likelihood of occurrence	Consequent risk to European features (preliminary assessment only)	Level of confidence
Licensed Water Abstractions	Flow & Sediment (med.) & Quality (low)	Medium	Low-medium	Low-medium	Low
Non Licensed Surface Water Abstractions	Flow & Sediment (low)	Low	Low	Low	Low

Recommendations

Further investigations required under review of consents

Are further hydrological and/or ecological investigations required to define the impact of Environment Agency consents?

Water resources abstraction licences?

- Preening/drinking link for birdlife
- Desk study to re-examine possible link between invertebrates and flow using impacts on salinity and sediment as a surrogate indicator.

Water quality discharge consents?

- Nutrient Budget assessments
- Eco-toxicological (including in combination) assessments

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Figure 1. Rivers draining to the Wash

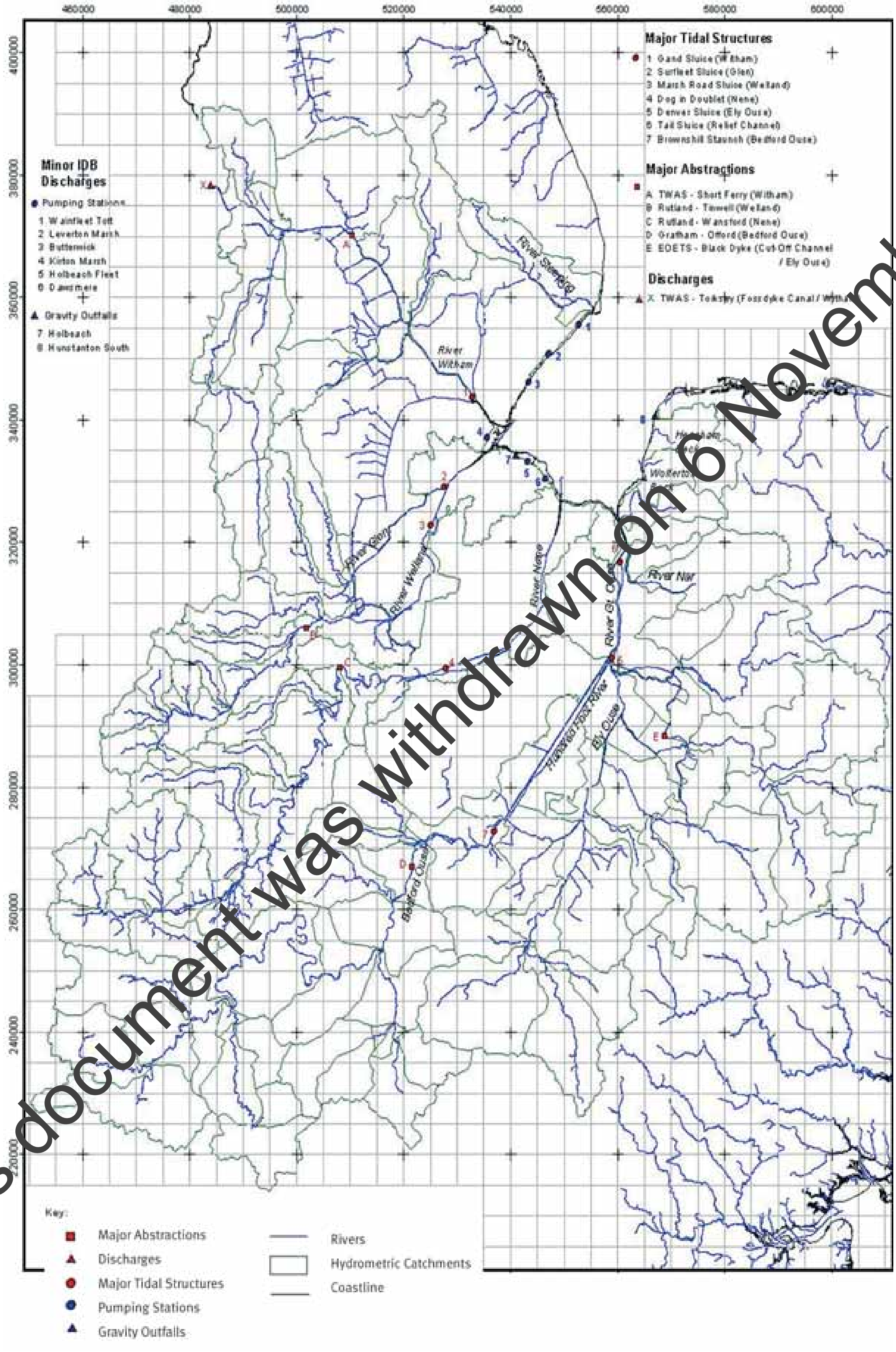

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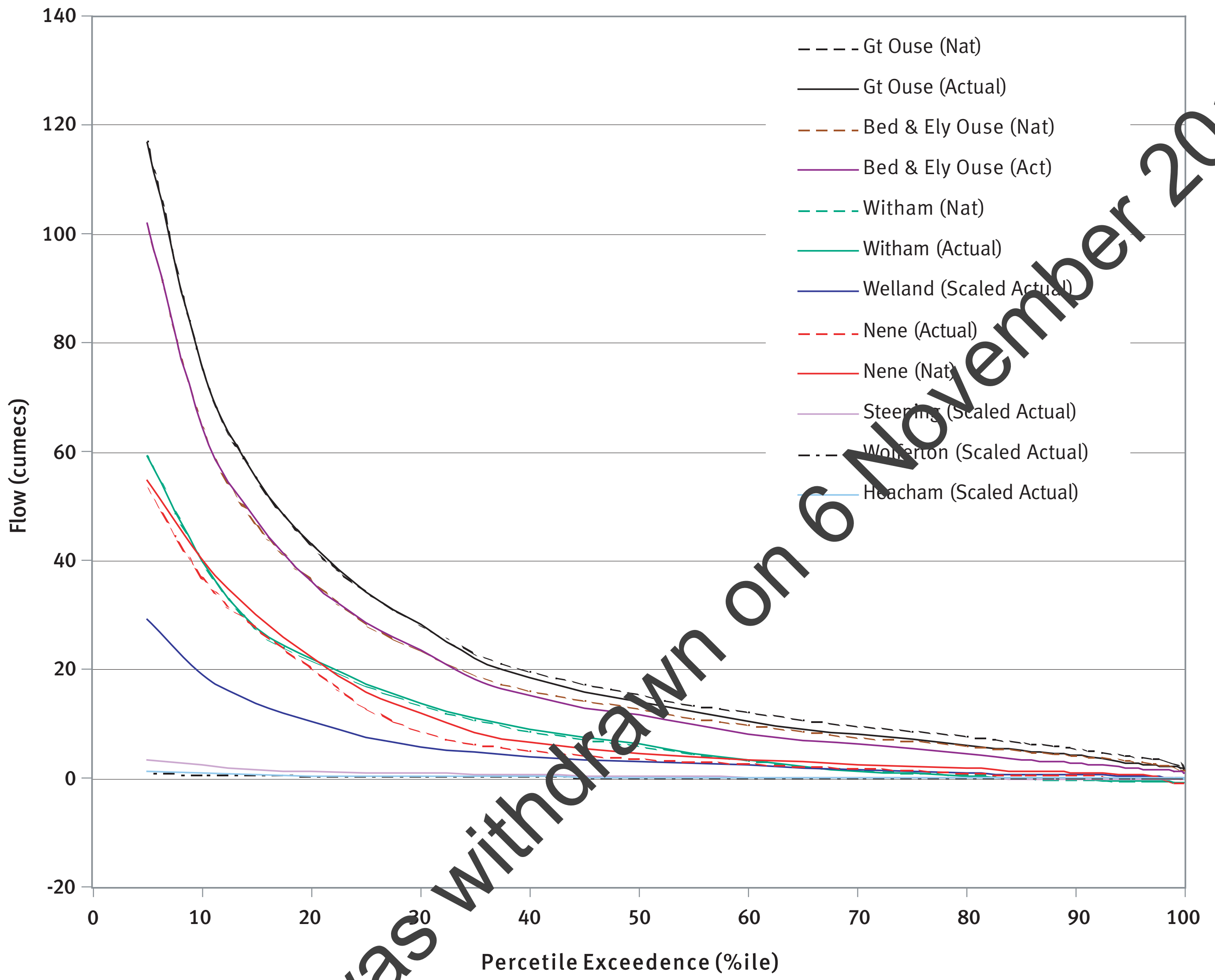
Figure 2. Percentile exceedence for freshwater river flows (standard) into the Wash (1991 – 1997)



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6 References

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Environment Agency

NATURAL ENGLAND

Cygnor Cefn Gwlad Cymru
Countryside Council for Wales

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6. References

The references listed below are referred to within this guideline document but do not repeat those references separately listed within the summaries given in Sections 2.2, 2.3 and 4.5 of this document.

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7 Glossary of abbreviations

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7. Glossary of abbreviations

CCW	Countryside Council for Wales
CEH	Centre for Ecology and Hydrology
cSAC	Candidate for Special Area of Conservation under the Habitats Directive
SAC	Special Area of Conservation under the Habitats Directive
Interest features	**(also referred to as European interest features or European features)**: is the common term for the range of qualifying habitats and species under the Habitats Directive (or Habitats Regulations in England and Wales)
JNCC	Joint Nature Conservation Committee (serving the individual nature conservation Regulatory Authorities for England, Wales, Scotland and Northern Ireland)
LIFE projects	Constitute a series of EU funded projects aimed at establishing the conservation requirements for interest features at UK cSACs
R&D	Research and development
source – pathway – receptor mechanism/concept	(See Section 3.4 for description)
SPA	Special Protection Area under the Wild Birds Directive
SSSI	Site of Special Scientific Interest
RSA	Restoring Sustainable Abstraction
BAP	Biodiversity Action Plan
PSA	Public Service Agreement

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Partner contact details

Natural England Northminster House, Peterborough PE1 1UA

Countryside Council for Wales Maes-y-Ffynnon, Penrhosgarnedd, Bangor, Gwynedd LL57 2DW

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