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Methodology for characterisation and classification of non-SSSI groundwater dependent wetlands

Report: SC120029

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Miranda Kavanagh

Director of Evidence

Executive summary

Introduction

The Water Framework Directive (WFD) requires the Environment Agency to classify each groundwater body as good or poor status. The Environment Agency must assess each groundwater body to see if it is causing significant damage to any groundwater dependent terrestrial ecosystem (GWDTE) (groundwater dependent wetlands). To do this, both quantitative and chemical pressures acting on the wetland must be considered. The method used to date to assess whether a site is at risk of significant damage has focused on Sites of Special Scientific Interest (SSSIs) and is summarised in Figure ES1.

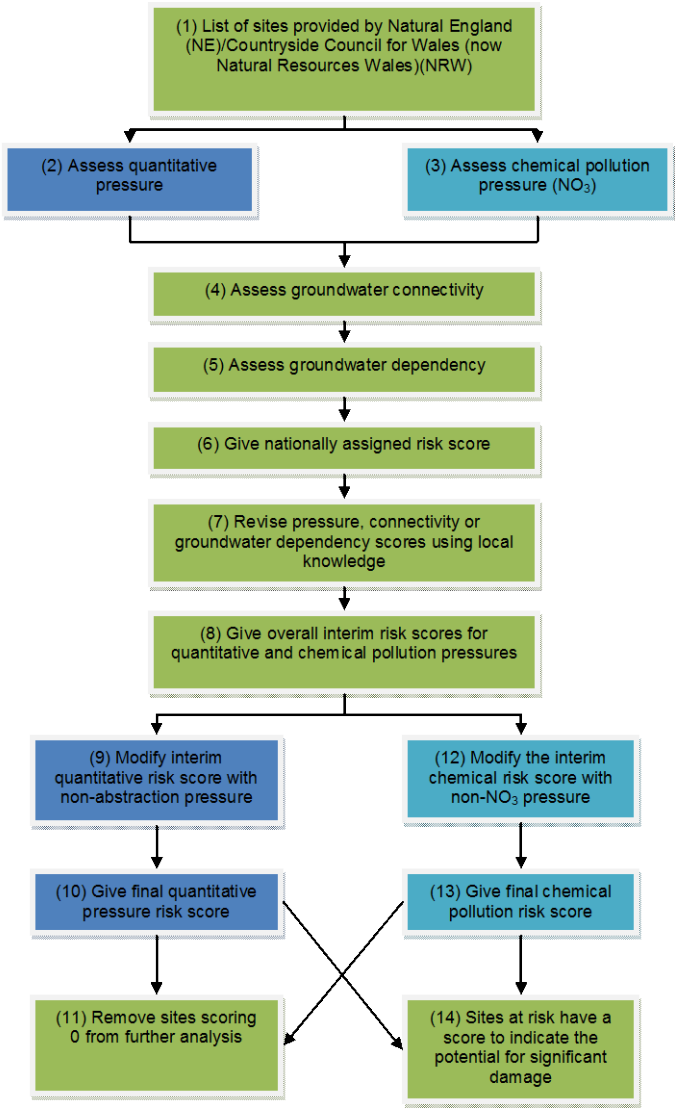

Figure ES1 Overview of the method for assessing the risk of significant damage

However, the WFD defines GWDTEs as 'wetlands identified as being directly dependent on groundwater bodies' (UKTAG 2005). There is no distinction made as to whether a site is designated or not, or how big it is. As a result, the Environment Agency, Natural England and Natural Resources Wales (NRW) have undertaken this study to develop the method used to date so that it can be applied to non-SSSI groundwater dependent wetland areas at an appropriate point in the future.

This project is a scoping exercise for England/Wales only and is not UK agreed. The work will inform a paper currently being drafted by the UKTAG Wetland Task Team on 'determining significant damage within and outside of Natura 2000 sites'. However, further development of the method may be required following production of the Wetland Task Team paper.

Review of existing method

A brief review of the steps was initially undertaken to assess which would be applicable if non-SSSI wetlands were to be addressed.

The result of this review is that the majority of steps could be undertaken irrespective of whether the assessed site is an SSSI or not. However, steps 1, 3 and 5 in Figure 1 need to be revisited to enable the method to account for non-SSSI wetlands. Additionally, site condition data are required for the determination of significant damage (UKTAG 2005). Consideration has been given to whether it is possible to assign a condition to non-SSSI groundwater dependent wetlands.

Results of the review

Step 1: List of sites provided by Natural England/NRW

It is suggested that the focus of future analyses of the risk of significant damage to groundwater dependent wetlands should be on Wildlife Sites and Local Nature Reserves.

Development of the list of non-SSSI groundwater dependent wetlands will require liaison between the Environment Agency/NRW and Natural England as appropriate and local authority ecologists, local Wildlife Trusts and Biological Records Centres.

Step 5: Assess groundwater dependency

The approach taken to assigning groundwater dependency to sites will depend upon the data available. Where available, National Vegetation Classification (NVC) data should be used, as currently. In the absence of NVC data, however, Phase 1 habitat survey data can be used. If no NVC or Phase 1 data are available, Biodiversity Action Plan (BAP) priority habitat inventories and species inventories can be used to identify wetland areas. These wetlands should be assigned a low groundwater dependency only. However, sites that are assessed as being exposed to high pressure with a high connectivity following application of the other steps should be investigated.

Step 3: Assessment of chemical pollution pressure (NO_3)

The approach taken to assigning the threshold against which an exceedance is assessed is based on the botanical community or habitat present. The suggested approach to assigning a nitrate threshold to non-SSSI sites is based on the percentage of arable and improved grassland within a 2 km buffer of a site, although the highest pressure score can only be achieved based on groundwater quality data, as currently.

Site condition

Site condition data are required in the determination of whether a site is significantly damaged. However, it is not generally possible, at this time, to assign a condition to non-SSSI groundwater dependent sites. As a result it is suggested that if sites are assessed as being exposed to high pressure with a high connectivity they should be targeted for site-specific assessment to determine their condition.

Project recommendations

Recommendations have been made in respect of further data development/ interpretation and also method development.

Conclusions

A revised method has been proposed following review of available datasets. There are a number of data gaps and anticipated difficulties with data access.

It is strongly recommended that the method is trialled. This will require the Environment Agency/NRW as appropriate and/or Natural England to liaise with a Wildlife Trust or Biological Records Centre to arrange this.

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1 Introduction

1.1 Background

The Water Framework Directive (WFD) requires the Environment Agency to classify each groundwater body as good or poor status. The Environment Agency must assess each groundwater body to see if it is causing significant damage to any groundwater dependent terrestrial ecosystem (GWDTE) (groundwater dependent wetlands). To do this, both quantitative and chemical pressures acting on the wetland must be considered. The method used to date to assess whether a site is at risk of significant damage is described in Environment Agency Operational Instruction D08_254: 'Water Framework Directive: risk screening for significant damage to groundwater-dependent terrestrial ecosystems' and presented in Figure 1.1. This report should be read in conjunction with the Environment Agency Operational Instruction.

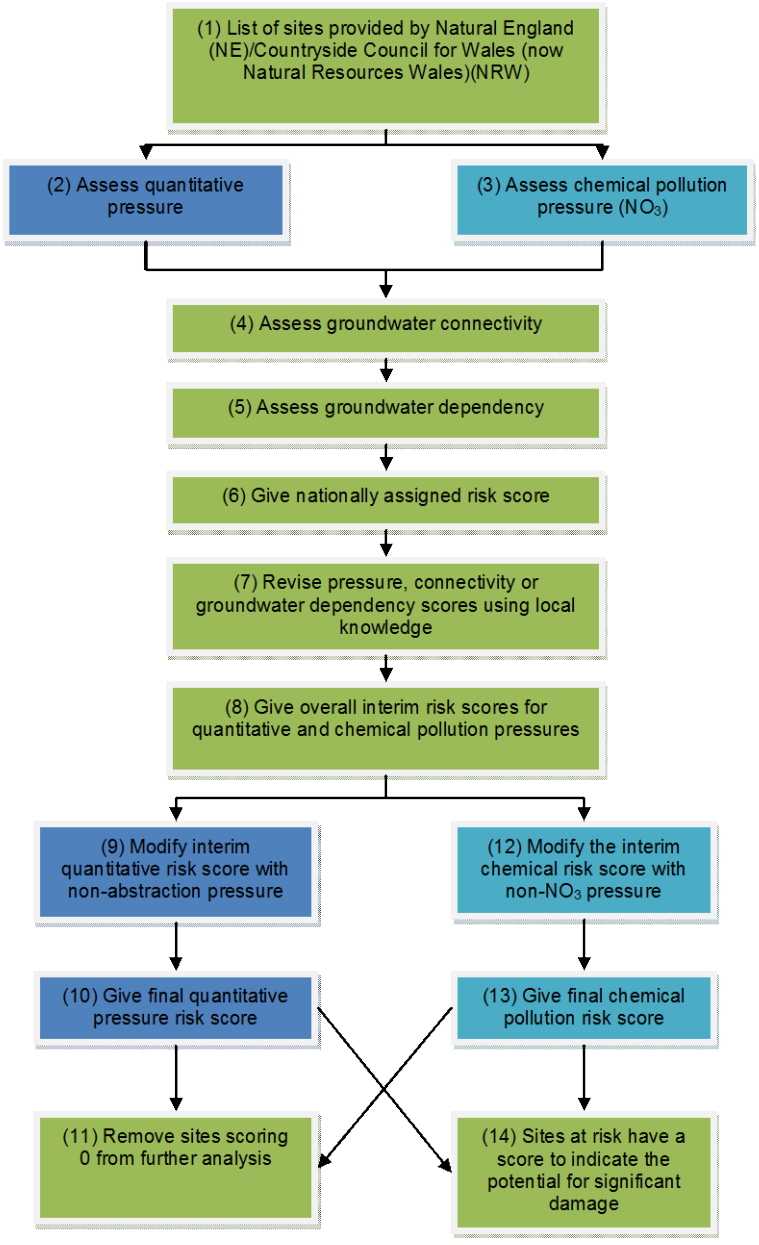

Figure 1.1 Overview of the method for assessing the risk of significant damage

The condition of wetlands at high risk of significant damage is then assessed to determine whether a site is recorded as being damaged by a pressure that could be acting through the groundwater body. Where this is the case, the wetland is taken through WFD Classification (Papers 11b(i) and (ii) on groundwater chemical and qualitative classification (respectively) for the purposes of the WFD and the Groundwater Directive (UKTAG 2012a, 2012b)), which ultimately determines whether a groundwater body is at good or poor status.

Common Implementation Strategy (2003) Guidance Document No. 12 on the role of wetlands in the WFD explains that the expression 'significant damage' is based upon:

- the magnitude of the damage;
- the ecological or socio-economic significance of the terrestrial ecosystem.

The magnitude of the damage needs to be related to whether the GWDTE continues to have the capacity to continue to fulfil its ecological or socio-economic function.

The focus of the assessment of risk to date has been on Sites of Special Scientific Interest (SSSIs) which are recognised to be of national importance, and may underpin the designation of Special Areas of Conservation (SACs), under the Conservation of Habitats and Species Regulations 2010, which are 'protected areas' under the WFD. Additionally, there is generally more data available for SSSIs than for sites of less than national importance.

The WFD defines GWDTEs as 'wetlands identified as being directly dependent on groundwater bodies' (UKTAG 2005). There is no distinction made as to whether a site is designated or not, or how big it is. This is important because not all groundwater dependent wetlands are designated, while the SSSI series is just a representative sample of some of the most important sites.

As a result, the Environment Agency, Natural England and Natural Resources Wales (NRW) have undertaken this study to develop the method used to date so that it can be applied to non-SSSI groundwater dependent wetland areas at an appropriate point in the future.

This project is a scoping exercise for England/Wales only and is not UK agreed. The work will inform a paper currently being drafted by the UKTAG Wetland Task Team on 'determining significant damage within and outside of Natura 2000 sites'. However, further development of the method may be required following production of the Wetland Task Team paper.

1.2 Project specification

The overall aim of the project is to develop the methodology for characterisation and classification of non-SSSI groundwater dependent wetlands. The main objectives are:

- Review of all available sources of information. This is essential to ensure that the methodology developed can be applied to other non-SSSI sites. The project should also propose how the data on non-SSSI sites might be collated and what information would need to be requested from whom.
- Develop a revised methodology, including a method of assessing site condition.
- Apply the revised methodology to a pilot dataset (proposed as the Natural England inventory of Alkaline Fens and Transition Mires and Quaking Bogs (hereafter 'AFTQB')).

Non-SSSI groundwater dependent wetland areas can include:

- **Local Nature Reserves (LNRs).** LNRs are declared by local authorities for the benefit of wildlife and people. They are typically on land owned and managed by local authorities, often in partnership with other bodies. Information on LNRs is held locally (i.e. at the county level).
- **Wildlife Sites.** Local authorities for any given area may designate certain areas as being of local conservation interest. The criteria for inclusion, and the level of protection provided, if any, varies between areas. Most individual counties have a similar scheme, although they do vary. These sites are given various titles such as Ecosites, Local Wildlife Sites (LWS), Local Nature Conservation Sites (LNCS), Sites of Importance for Nature Conservation (SINCs), or Sites of Nature Conservation Importance (SNCIs). A panel comprising the local Wildlife Trust, local council and Natural England (or NRW as appropriate) typically decides whether a site should be designated and the local Wildlife Trust liaises with the landowner. Information on Wildlife Sites is held locally (i.e. at the county level).
- **Non-designated areas.** There are areas of groundwater dependent habitat that lie outside the designated site series.

Some of these non-SSSI sites contain Habitats Directive Annex 1 habitats such as alkaline fens, transition mires, alluvial forests etc.

In the sections that follow a review of available sources of information and suggestions for a revised methodology are presented along with recommendations for further development of the datasets and approach.

The revised method has not been applied to a pilot dataset at this stage because the Natural England AFTQB inventory uses National Vegetation Classification (NVC) information and so this can be assessed against the existing methodology. Additionally, no alternative suitable dataset was available and there were time and budget constraints. It was therefore agreed early on in the project that this task would not be completed. However, a number of possible approaches have been trialled against available datasets to assess their value.

The approaches trialled and draft outputs from the project have been discussed and agreed with the project steering group throughout the project.

1.3 Review of existing method

An overview of the method for assessing the risk of significant damage was presented in Figure 1.1. A brief review of the steps was initially undertaken to assess which would be applicable if non-SSSI wetlands were to be addressed.

The result of this review is that the majority of steps could be undertaken irrespective of whether the assessed site is an SSSI or not. However, steps 1, 3 and 5 need to be revisited to enable the method to account for non-SSSI wetlands as discussed below.

Step 1 is currently described as ‘List of sites provided by Natural England (NE)/NRW’. However, while Natural England and NRW oversee SSSIs for England and Wales respectively, typically the local Wildlife Trust or local authority are involved in advising on, or managing Wildlife Sites and LNRs. There is therefore a need to revisit step 1 to identify how a list of non-SSSI groundwater dependent wetlands can be identified for assessment.

Step 3 is the assessment of chemical pollution pressure (NO_3). While the majority of this step can be completed based on data from groundwater monitoring boreholes, the

threshold against which an exceedance is assessed in this step is based on the botanical community or habitat present. Botanical information is therefore required to enable step 3 to be completed for non-SSSI areas.

Step 5 is the assessment of groundwater dependency of a wetland. Under the existing methodology this requires botanical information at NVC community level. This may not be available for many non-SSSI wetlands so an alternative approach is required where NVC information is not available.

Site condition data are required for the determination of significant damage (UKTAG 2005). Consideration has been given to whether it is possible to assign a condition to non-SSSI groundwater dependent wetlands.

1.4 Report structure

Section 2 describes the work undertaken in respect of steps 1 and 5 (which are related insofar as they both concern the identification of groundwater dependent sites/areas), while section 3 describes the work undertaken in respect of step 3 (assessment of chemical pollution present). A number of possible approaches have been trialled against available datasets in sections 2 and 3 to assess their value.

Possible approaches to assigning site condition are discussed in section 4.

Section 5 presents a revised method, makes recommendations for further data requirements and method development, and presents brief conclusions.

2 Steps 1 and 5: Identification of non-SSSI wetlands

2.1 The Issue

Natural England and NRW have responsibility for SSSIs in England and Wales. As these are sites of, at least, national importance there is always information available that has been used in the notification of the sites that can also be used to identify whether they are likely to be groundwater dependent.

To identify the list of SSSIs for assessment Natural England and NRW reviewed which sites supported communities assigned a groundwater dependency score in 'UKTAG list of NVC communities_210513.pdf'. In this list, NVC communities are assigned a groundwater dependency on a scale of low, medium or high. Communities not listed are assumed to be not groundwater dependent.

To extend the assessment to non-SSSI groundwater dependent wetlands, a list is required that would ideally include information on the habitats or communities present that can be used to assign a groundwater dependency.

Producing this list is not a straightforward task. As indicated in section 1.2, Wildlife Site and LNR information is typically held locally (i.e. there is no national inventory of sites and the habitats/communities present on each) by Wildlife Trusts or Biological Records Centres. The reason that steps 1 and 5 of the method are addressed together here is that to produce a list of groundwater dependent wetland sites/locations, analysis is required of where wetland habitats are located (i.e. within an SSSI, LNR, Wildlife Site or non-designated area) and whether the wetland habitats are groundwater dependent.

2.2 Review of available data

The tasks listed below were undertaken to assess how best to identify where wetland habitats are located and whether the wetland habitats are groundwater dependent:

- Review of available habitat inventories
- Review of available species inventories
- Review of data held for Wildlife Sites
- Review of other techniques for identifying groundwater dependent wetlands
- Review of other data
- Use of groundwater models to identify groundwater dependent wetlands.

2.3 Available habitat inventories

It was considered that potentially the most straightforward approach to identifying where wetland habitats are located would be to use existing habitat inventories. As the method of assessing the risk of significant damage to groundwater dependent wetlands is applied across England and Wales, nationally available habitat inventories were investigated first. Available national inventories comprise the following:

- Biodiversity Action Plan (BAP) priority habitats in England
- AFTQB inventory for England
- Phase 2 (NVC) surveys of lowland peatland, lowland grassland and lowland heathland in Wales
- Habitat survey (JNCC 2003a) of Wales (Phase 1 habitat survey).

2.3.1 BAP priority habitat inventories

BAP priority habitat inventories for England, which are also believed to cover all Habitats Directive Annex 1 habitats in England, are listed in Table 2.1.

Table 2.1 UK BAP priority habitat inventories available

BAP priority habitats
Blanket Bog
Coastal and Floodplain Grazing Marsh
Coastal Sand Dunes*
Coastal Vegetated Shingle
Deciduous Woodland*
Limestone Pavements
Lowland Calcareous Grassland*
Lowland Dry Acid Grassland
Lowland Fens
Lowland Heathland*
Lowland Meadows*
Lowland Raised Bog
Maritime Cliff and Slopes
Mudflats
Purple Moor Grass and Rush Pastures
Reedbeds
Saline Lagoons
Saltmarsh
Traditional Orchards
Upland Calcareous Grassland
Upland Hay Meadows
Upland Heathland
Wood-pasture and Parkland

Wetland habitats are emboldened.
*** Can contain wetland communities but mainly dry habitats.**

The potential for these inventories to be used to identify groundwater dependent wetlands has been reviewed. However, because a number of the BAP priority habitats can comprise a range of different NVC communities, which can range from having no groundwater dependency to being highly groundwater dependent (see Table 2.2 for example), the presence of the majority of BAP priority habitats in any one location cannot be taken as an indicator of the presence of a groundwater dependent wetland. It would not be possible to identify areas of Annex 1 habitat from the inventory for the same reasons that they cannot be used as an indicator of the presence of a groundwater dependent wetland.

Table 2.2 Example deciduous woodland NVC communities and their groundwater dependency

NVC community	Groundwater dependency*
W16 (*Quercus* spp. – *Betula* spp. – *Deschampsia flexuosa* woodland)	No
W6 (*Alnus glutinosa – Urtica dioica* woodland)	Low
W2 (*Salix cinerea – Betula pubescens – Phragmites australis* woodland)	Medium
W4 (*Betula pubescens – Molinia caerulea* woodland)	High

* Source: UKTAG list of NVC communities_210513.pdf

The exceptions to this are lowland fens and reedbeds. The majority of the communities included in the lowland fens habitat are assigned a groundwater dependency, although they range from low to high (see Table 2.3). Reedbeds comprise S4 (*Phragmites australis* swamp), which is assigned a low groundwater dependency.

Table 2.3 Example lowland fens NVC communities and their groundwater dependencies

NVC community	Groundwater dependency*
S3 (*Carex paniculata* swamp)	Low
M27 (*Filipendula ulmaria – Angelica sylvestris* mire)	Medium
M13 (*Schoenus nigricans – Juncus subnodulosus* mire)	High

* Source: UKTAG list of NVC communities_210513.pdf

It is worth noting that a number of studies (e.g. Entec 2009) have identified significant issues with the reliability of the existing BAP priority habitat inventories due to overlaps in inventories and mis-mapping of habitats. However, Natural England has been working to improve these and is about to release a single GIS layer indicating the distribution of all the BAP priority habitats that will, at least, remove the overlaps.

Recommendation for the methodology

On the basis of this review it is suggested that where lowland fens and reedbeds are identified in the BAP priority habitat inventories then these areas can be assumed to have at least a low groundwater dependency and could be used in the identification of non-SSSI groundwater dependent sites for further investigation.

2.3.2 Inventories of Alkaline Fens and Transition Mires and Quaking Bogs habitats for England

Alkaline fens and transition mires and quaking bogs (AFTQB) habitats are of international nature conservation importance. Natural England has produced inventories of the distribution of these two habitats (Tratt et al. 2013).

Alkaline fens typically comprise NVC communities that are highly groundwater dependent. The Joint Nature Conservation Committee (JNCC) defines the core NVC communities contributing to this habitat as:

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

The JNCC defines the core NVC communities contributing to the transition mires and quaking bogs habitat as:

- 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.

These communities are typically assigned a lower groundwater dependency compared to the alkaline fens habitat.

The AFTQB inventories present the distribution of these habitats as a combination of polygons and point locations. An NVC community is assigned to almost every polygon and point location. Therefore it is possible to assign a groundwater dependency to these locations, as defined in the existing methodology.

The inventory contains 3,828 records, of which the majority are from SSSIs, but over 600 come from non-SSSI locations. Of those non-SSSI locations around 90 intersect with Wildlife Sites. The remaining records, numbering around 525, appear to be from non-designated locations.

Recommendation for the methodology

The AFTQB inventories should be used to supplement notified feature information for SSSIs, and also to assign groundwater dependency scores to Wildlife Sites and non-designated locations.

2.3.3 Phase 2 (NVC) survey of lowland grassland, lowland peatland and lowland heathland sites in Wales

NRW has completed a Phase 2 (NVC) survey of lowland grassland, lowland peatland and lowland heathland sites in Wales. The lowland grassland survey covered 17,700 ha, the peatland survey has covered 5,681 ha and the extent of the heathland survey is not quoted. These surveys are expected to have covered the majority of sites supporting groundwater dependent lowland grassland, lowland peatland and lowland heathland habitats in Wales.

The lowland grassland and lowland peatland NVC survey data have been used to assign a groundwater dependency to SSSI and non-SSSI sites in Wales for the interim assessment of the risk of significant damage, recently completed. Lowland heathland data were not provided for the interim assessment but are available if requested. However, the National Biodiversity Network (NBN) indicates that problems have been encountered with the classification of humid heath (H4) and wet heath (M15 and M16). These communities require further analysis to fully understand the floristic differences so maps and land cover figures should be treated with caution. The paper maps in the reports are of better quality than the GIS layer and therefore should be referred to as a more accurate source of information (https://data.nbn.org.uk/Datasets/HL000010).

Recommendation for the methodology

Use these three Phase 2 (NVC) survey datasets to identify groundwater dependent habitats on SSSI and non-SSSI wetlands in Wales.

2.3.4 Habitat survey of Wales (Phase 1 habitat survey)

The habitat survey of Wales was carried out between 1979 and 1997 to gather information on the extent and location of all the different habitats in Wales. Trained surveyors went out into the field to record habitats onto large-scale Ordnance Survey maps. More than 99% of Wales was mapped. Habitat patches as small as either 0.1 ha or 0.25 ha were recorded, although smaller patches were frequently mapped (source: http://www.ccgc.gov.uk/landscape--wildlife/habitats--species/terrestrial/habitats/habitat-surveys.aspx). The habitats were mapped according to the Phase 1 habitat survey methodology.[1] This inventory was obtained for this project.

To be useful in respect of determining areas of groundwater dependent wetland, it was necessary to assess whether it is possible to assign a groundwater dependency to Phase 1 habitat categories.

Many of the Phase 1 habitat categories are fairly broad in respect of the NVC communities that they can include, and there are also many overlaps between Phase 1 habitat types and NVC communities, which introduces significant uncertainty when trying to assign a groundwater dependency to a Phase 1 habitat category. Nonetheless, following a review of the NVC communities representative of particular Phase 1 habitat categories, and subsequent discussion with Natural England (Iain Diack, personal communication), groundwater dependency categories were assigned to Phase 1 habitat types as indicated in Table 2.4. A trial of the first iteration against the groundwater dependency scores, based on NVC information, assigned to SSSIs in Wales suggested that amendments were required. This resulted in the second iteration presented in Table 2.4.

Table 2.4 Phase 1 habitat type and groundwater dependency score assigned

Phase 1 habitat type	Groundwater dependency 1st iteration	Groundwater dependency 2nd (final) iteration
Broadleaved woodland (wet – if target noted only) (A1.1.1)	Not groundwater dependent unless target noted, in which case low groundwater dependency	Not groundwater dependent unless target noted, in which case medium groundwater dependency
Marshy grassland (B5)	Low groundwater dependency (although acknowledged some stands will not be groundwater dependent)	High groundwater dependency. Amended because first trial suggested that some highly groundwater dependent NVC communities have been mapped as marshy grassland
Wet dwarf shrub heath (D2)	High groundwater dependency	High groundwater dependency
Flush and spring (E2.1) – acid/neutral	High groundwater dependency	High groundwater dependency
Flush and spring (E2.2) – basic	High groundwater dependency	High groundwater dependency
Fen – mire (E3)	Not separated in 1st trial	High groundwater dependency
Fen – basin mire/valley mire (E3.1)	High groundwater dependency	High groundwater dependency
Fen – basin mire/valley mire (E3.1.1)	Not separated in 1st trial	High groundwater dependency
Fen – basin mire (E3.2)	Medium groundwater dependency	Medium groundwater dependency
Swamp (F1)	Low groundwater dependency	Low groundwater dependency
Dune slack (H6.4)	High groundwater dependency	High groundwater dependency
All other habitats	Not groundwater dependent	Not groundwater dependent

In the first iteration the groundwater dependency of 488 out of 1,355 SSSIs (36%) matched exactly, with 757 assigned a lower groundwater dependency than the NVC data suggested and 110 assigned a higher dependency. The results of the second

[1] JNCC (2003). Phase 1 habitat survey – a technique for environmental audit.

iteration were that 868 out of 1,355 SSSIs (64%) matched exactly, with 333 assigned a lower groundwater dependency than the NVC data suggested and 154 assigned a higher dependency.

Given the broad definitions of habitats included in the individual Phase 1 habitat categories, this result is considered reasonable but it must be recognised that wet woodland in particular is unlikely to be picked up using this approach and some wet grassland habitats are also likely to be missed because it is not possible to identify whether these habitats are groundwater dependent from the Phase 1 habitat categories.

Recommendation for the methodology

Phase 1 habitat survey data should be used in England and Wales, where available (see section 2.5), to assign a groundwater dependency to Wildlife Sites and non-designated wetlands although the uncertainties must be recognised.

Using this approach it is possible to determine which sites are likely to support habitats of high groundwater dependency, and at the very least this approach should be used to identify sites requiring further investigation.

2.4 Review of available species inventories

Many plant species (vascular plants and bryophytes) are most often found in groundwater-fed situations, although this does not necessarily mean that the species only occurs where groundwater is present. Nonetheless, the possibility of using plant species to identify potentially groundwater dependent locations has been considered.

Initially a list of potentially groundwater dependent species is required. A list of species often indicative of groundwater supply was developed in consultation with Iain Diack (Natural England, personal communication).

The list is presented in Table 2.5.

Table 2.5 Short list of higher and lower plants considered indicative of groundwater-fed situations

Vascular plants	No. of records on NBN	Bryophytes	No. of records on British Bryological Society
Anagallis tenella	12,298	*Aneura pinguis*	9,077
Carex dioica	6,369	*Bryum pseudotriquetrum*	8,133
Carex hostiana	12,181	*Campylium stellatum*	4,913
Carex lepidocarpa	7,322	*Climacium dendroides*	3,843
Carex pulicaris	17,451	*Cratoneuron filicinum*	8,961
Dactylorhiza incarnata	5,037	*Plagiomnium elatum*	1,290
Dactylorhiza praetermissa	10,496	*Plagiomniuim ellipticum*	797
Dactylorhiza traunsteineri	2	*Palustriella commutata*	4,829
Eriophorum latifolium	2,848	*Palustriella falcate*	1,893
Juncus subnodulosus	6,589	*Scorpidium cossonii*	No records
Liparis loeselii	579	*Scorpidium revolvens*	No records
Menyanthes trifoliata	22,013	*Scorpidium scorpioides*	2,344
Pedicularis palustris	10,709		
Pinguicula vulgaris	13,480		
Valeriana dioica	9,681		

Species data are held by a wide range of organisations in England and Wales, but the NBN Gateway (http://data.nbn.org.uk) holds collated datasets of vascular plants (in England, Wales, Scotland and Ireland) and the British Bryological Society holds collated records for bryophytes.

In respect of bryophytes the Environment Agency has access to the British Bryological Society dataset. The NBN has been interrogated to assess how many records are available for the bryophytes (see Table 2.5). These records are quoted as being available at 100 m resolution, but many of the records are quoted to the nearest tetrad (2 km × 2 km square) or hectad (10 km × 10 km square). It is considered likely that many of the records relate to SSSIs; however, it is expected that there will certainly also be records from non-SSSI wetlands. However at this resolution, many of the data points will not be useful. An example data download for *Bryum pseudotriquetrum* provided 46 data files and in one of these only around 30% of the records were presented at 100 m resolution. Therefore, only 30% of the records would be useful and use of this data will require a significant element of data translation and collation. However, it will still be possible to use those that are quoted to 100 m resolution, although there are likely to be reduced numbers of these, compared to the numbers quoted in Table 2.5.

In respect of vascular plants the Environment Agency only has access to NBN for protected species and therefore was not able to provide data for use as part of this project. However, as for the bryophytes, NBN has been interrogated to assess how many records are available for the vascular plant species (see Table 2.5). As for the bryophytes, these records are quoted as being available at 100 m resolution but it is likely there will be some variation as for the bryophytes and use of this data will likely require a significant element of data translation and collation.

Assuming full access can be obtained to the NBN data, it is considered that the bryophyte and vascular plant records could be used to identify locations that are probably subject to groundwater influence. It is not considered possible to assign a scale of groundwater dependency to a location taking this approach but, the more species recorded at any one location, the stronger the indication of the presence of groundwater. This approach could be used to target more local investigation.

One issue to be aware of with this approach, however, is that the number of people who could reliably and accurately identify a number of these species is probably limited, which may limit the availability of records but it is also possible that some records may be mis-identifications. As a result, it is suggested that greater confidence could be placed on the identification of a groundwater dependent site where a number of indicator species have been identified, rather than just a single record.

Recommendation for the methodology

It is suggested that the use of species records would be useful to the method and should be further developed. The following actions are recommended to take this forward:

- Full access to NBN data to be obtained by the Environment Agency/NRW and Natural England so that the species data can be obtained for the list of groundwater indicator species and resolution checked.
- Use the species records within the method to identify the locations of wetlands that support groundwater dependent communities. It is suggested that where records for more than one of the target species coincide then this could be considered indicative of potential groundwater influence on a site.
- Use of indicator species could contribute to a ‘weight of evidence’ approach to the identification of groundwater dependent sites for further investigation. Examples are where these records coincide with inventory data and/or mapped physical features such as springs.

2.5 Wildlife Site data

Local authorities are responsible for LNRs and Wildlife Sites. Polygons for LNRs and Wildlife Sites are available from Natural England, while polygons for Wildlife Sites are also available from the individual Biological Records Centres.

For the assessment of the risk of significant damage it is not sufficient just to know where the sites are located. Habitat data is also required to identify which sites support groundwater dependent habitats.

The focus of the work reported in this section has been on Wildlife Sites, but the comments regarding data availability that follow apply equally to LNRs.

2.5.1 Site polygons

Wildlife Site polygons were obtained from Natural England. The inventory contains 42,799 Wildlife Sites. For comparison Wildlife Site inventories were also obtained directly from Norfolk Biodiversity Records Centre and Shropshire Biodiversity Partnership. Comparison of these datasets revealed that:

- the Shropshire Wildlife Site dataset comprises 579 sites, of which only 414 appear to be captured on the Natural England supplied inventory;
- the Norfolk Wildlife Site dataset comprises 1,305 sites of which only around 900 appear to be captured in the Natural England supplied inventory.

Had a WFD assessment of the risk of significant damage been undertaken using the Natural England dataset, 35% of the sites in Norfolk and 28% of the sites in Shropshire could have been omitted.

Clearly, it is desirable to have the full Wildlife Site dataset when it is requested and this mis-match needs to be addressed by Natural England and the records centres.

2.5.2 Site survey data availability

Local Biological Records Centres and Wildlife Trusts were contacted to determine:

- whether Wildlife Sites have been surveyed;
- if surveyed, what type of survey has been undertaken;
- whether the survey data is available digitally.

A record of the consultation responses is provided as a separate addendum (spreadsheet) but the key points from the responses are summarised below:

- All the records centres have Wildlife Site polygons digitally available.
- Citations are available for the majority of sites. In some areas, such as Somerset, site information is only available via reference to the individual citations, which would need to be reviewed individually to identify wetland features. In other areas (e.g. Derbyshire), the key interest features (such as wet woodland, or individual species) are also stored in a database which could be searched to identify sites supporting wetland features.
- The majority of sites have had some form of habitat survey; however some areas are better than others. For example, around 10% of sites in north Wales have been surveyed while all have been surveyed in other areas (e.g. Sheffield and Northamptonshire).

- The level of survey is variable and includes BAP priority habitat level, Phase 1 habitat types and (limited) NVC data.
- BAP priority habitat data are available electronically for a number of areas (e.g. Derbyshire, Bedfordshire and Luton). It was reported that the BAP priority habitat inventories collated were typically supplied to Natural England for inclusion in wider national inventories but this did not apply to all BAP priority habitat data held. In other areas BAP priority habitat data is not mapped but is stored in a database and is available as an Excel™ spreadsheet (e.g. Norfolk).
- Phase 1 habitat data and NVC data are generally not available digitally although there is limited coverage in some areas, such as around Luton.
- The age of the survey data is variable and can date back to the 1990s or even the 1980s in the case of SNCIs in Lincolnshire. Many areas are in the process of updating the data for their sites. Frequency of site survey seems to be typically 10 yearly at best.
- There is no site condition data available for Wildlife Sites.

Recommendation for the methodology

As there is no national inventory of sites and the habitats that are supported, and the required information is held locally, it is recommended that the Environment Agency/NRW and Natural England as appropriate work with local authority ecologists, local Wildlife Trusts, conservation NGOs (e.g. RSPB) and Biological Records Centres to develop a list of non-SSSI groundwater dependent wetland sites.

The very limited availability of digital data will be problematic in respect of extending the method for assessing the risk of significant damage to non-SSSI areas in England. In section 2.3.1, it was suggested that where lowland fens and reedbeds are identified in the BAP priority habitat inventories then these areas can be assumed to have at least a low groundwater dependency and could be used in the identification of non-SSSI groundwater dependent sites, although this is limited in respect of the variety of potentially groundwater dependent wetland habitat types in the English landscape.

Ideally Phase 1 habitat survey or NVC data would be available digitally for Wildlife Sites (and non-designated areas). Natural England will need to work with the records centres to determine the scale of the task, in respect of both finance and manpower, in digitising data currently stored on paper and collating already available electronic data.

2.6 Other data

Data are constantly being collected for Wildlife Sites and BAP priority habitats. Ideally these data would be available and used within the method to identify non-SSSI wetland sites. For example, Norfolk Wildlife Trust produced a *Norfolk fens assessment* in 2006. This drew on data from the Wildlife Site system, Aerial Survey, Fen BASE, the Norfolk Grassland Survey and soils mapping to identify fen sites.

It will be a very large task to collate similar information from all the Biological Records Centres/Wildlife Trusts.

Recommendation for the methodology

Include county-specific investigations into specific habitat types where these are known about. Given sufficient time perhaps the Biological Records Centres/Wildlife Trusts etc. could be asked to provide a list of potentially relevant reports that could be reviewed and requested if considered useful to the method.

2.7 Review of published techniques for identifying groundwater dependent wetlands

A number of scientific papers and reports have been published that have sought to identify the nature and locations of wetlands. This section presents a summary of those considered in respect of this project.

WFD95: A Functional Wetland Typology for Scotland (SNIFFER 2009). A review of publications seeking to characterise wetlands was presented in this document. The Functional Wetland Typology for Scotland (which is not repeated here), however, built on the earlier publications and described a wetland typology comprising 11 main wetland types and the approach to be taken to identify the type of wetland present on the ground. This wetland typology is potentially useful and the habitat typology has been used as the basis for the recent technical report on GWDTE threshold values (UKTAG 2012c). Additionally, SNIFFER is currently working on a set of Ecohydrological Guidelines for the wetland types, which should be published in 2014. The drawback with the Functional Wetland Typology for Scotland in respect of the assessment of the risk of significant damage to groundwater dependent wetlands is that the location of a wetland needs to be known (i.e. it is not a predictive approach).

Wetland Inventory Phase 1 and Phase 2 (SEPA). The Scottish Environment Protection Agency (SEPA) is currently working on an approach to the identification of wetlands from aerial photography (Hans Schutten, SEPA, personal communication). This method will identify the presence of wetlands and will identify their character based on the Functional Wetland Typology for Scotland. However, it will not be possible to determine whether the wetland is groundwater dependent from this approach without subsequently applying local knowledge.

Airborne geophysics: a novel approach to assist hydrogeological investigations at groundwater-dependent wetlands (Beamish and Farr 2013). This approach identifies whether soil is wet but not whether the source is groundwater. Local information would be needed to assess whether a site was groundwater dependent and what communities or habitats were present. There would be additional practical difficulties in adopting this method in that aerial geophysics data would need to be collected; this is not widely available and specialist knowledge would be needed to interpret the data. This approach is not recommended for inclusion in the method without further research and development.

Groundwater-dependent biodiversity and associated threats: A statewide screening methodology and spatial assessment of Oregon (Brown *et al*. 2009, Brown *et al. 2010*). This approach drew on seven data sources to map wetlands in Oregon. The resources used included existing wetland mapping, soils, distribution of wetland communities (notably fens) drawn from various sources and LandSat imagery. The approach focused on fen habitats. Using this approach, or a variation of it, to identify groundwater dependent wetlands in England and Wales would be a significant piece of work and could not readily be incorporated into the existing method.

Atlas of groundwater dependent ecosystems (GDE atlas), Phase 2: Task 5 Report: Identifying and mapping GDEs (SKM 2012). This GIS-based approach used

a majority rules approach to rank the likelihood that a feature could be classified as a groundwater dependent ecosystem (GDE). In Australia these are not always wetlands but where the study covered wetlands the rules included consideration of persistence of water, wetland type, shallow water tables, presence of active vegetation during summer periods, substrate and losing landscapes. This is just a selection of the different rules used and different rules were used for each state in Australia. Analysis against these rules drew on numerous GIS datasets and has resulted in the production of maps of GDEs that rely on the subsurface presence of groundwater (vegetation), and maps of GDEs that rely on the surface expression of groundwater (rivers, wetlands and springs).

As for Brown et al. (2010) above, using this approach, or a variation of it, to identify groundwater dependent wetlands in England and Wales would be a significant piece of work and could not readily be incorporated into the existing method. Additionally, many of the data types used in the Australian study are not currently available for sites in England and Wales (e.g. depth to water table, vegetation type) but it may be possible to adopt some of the principles of the study in future method development.

Recommendation for the methodology

The wetland identification methods reviewed each have issues with respect to use in this project as they are either not predictive, do not indicate if the source of water is groundwater and/or do not indicate the nature of wetland plant communities. Only the methods described by Brown et al. (2010) and SKM (2012) are specifically aimed at identifying groundwater dependent systems, but the application of these, or variations of them, to identify groundwater dependent wetlands in England and Wales would be a significant piece of work, essentially creating a wetland inventory for England. While this would be desirable, it could not readily be included in the method without further development.

It is suggested that the Environment Agency and Natural England discuss these approaches further to decide whether to proceed. As the methods develop an inventory it may be useful for areas with few other data from which to identify non-SSSI groundwater dependent wetlands (although the SKM study may be less useful in these situations). As information for Wildlife Sites does exist, but not in a very accessible format in most cases, it is likely to be more productive, and potentially cost-effective, working with local Wildlife Trusts and local council ecologists to identify wetland sites.

2.8 Use of groundwater models to identify groundwater dependent wetland

Groundwater models are available for the principal aquifers in England although there are few principal aquifers in Wales covered by groundwater models. The distribution of groundwater investigation areas, which approximates to the areas covered by groundwater models, is indicated in Figure 2.1.

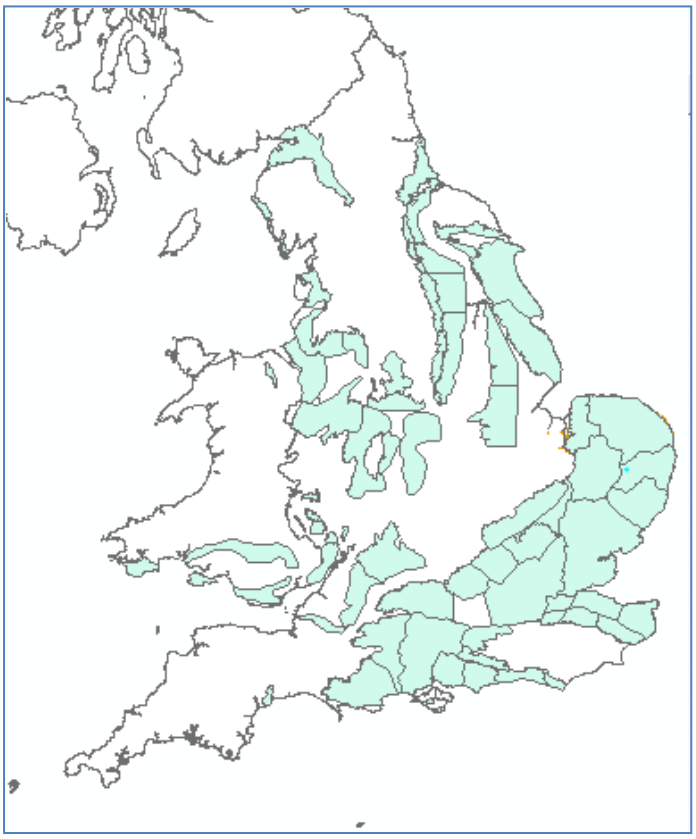

Figure 2.1 Groundwater investigation areas

Groundwater models can predict a number of hydrological parameters over the area covered and it was thought that depth to water table may be a useful predictor of whether a site would be wet and that groundwater was the likely source.

This hypothesis was tested in an area of north-east Norfolk using wetland BAP priority habitat data and Wildlife Site polygons provided by the Norfolk Biodiversity Information Service and ModelMap data for north-east Norfolk (sourced from the North East Anglian Chalk (NEAC) model) provided by the Environment Agency.

A simple analysis was undertaken of whether sites with a depth to water table of 1 m below ground level or less supported wetland vegetation, and the findings are summarised below.

- There are 1,305 Wildlife Sites in Norfolk.
- 360 of these have wetland vegetation as indicated by the presence of BAP priority habitats comprising lowland fens, wet woodland, reedbeds and coastal and floodplain grazing marsh. It must be recognised in this respect that there may be other sites with BAP priority habitats that are wet but that do not fall into one of the four clearly wet BAP priority habitat categories and hence it is not possible to include them in this analysis. An example of such a case would be lowland heathland which includes wet heath.
- Of the 360, 215 are within the boundary of the numerical groundwater model area and hence depth to water table can be calculated.
- Of the 215, 183 (85%) have a water table less than 1 m below ground level.
- However, of the 945 that are not recorded as supporting wetland BAP priority habitats, 624 are in the ModelMap area. Of these 292 (46%) have a water table less than 1 m below ground level.

- The permeability and thickness of the drift geology underlying the sites was also considered to assess whether this would improve the predictions but did not help reduce the number of sites that appear not to support wetland habitats but have a water table above 1 m below ground level.

Recommendation for the methodology

Based on these simple comparisons, it is not possible to use depth to water table to predict whether a site supports wetland vegetation. It is therefore recommended that this approach is not pursued further.

3 Step 3: Assessment of chemical pollution pressure (nitrate)

Step 3 is the assessment of chemical pollution pressure (nitrate). While the majority of this step can be completed based on data from groundwater monitoring boreholes, the threshold against which an exceedance is assessed in this step is based on the botanical community or habitat present. In the absence of groundwater monitoring data or botanical information, chemical loading data are used but this approach is less reliable since it is not linked to site condition. Botanical information is therefore advantageous to enable step 3 to be completed for non-SSSI areas and therefore the issues discussed in section 2 apply.

The UKTAG (2012c) report presented nitrate concentrations above which the affected habitat is likely to be damaged (see Figure 3.1, which reproduces Table 4 from the UKTAG report). The habitat classification used in the paper is based on the SNIFFER (2009) Functional Wetland Typology for Scotland. To apply this to the existing method, the habitat categories used in the UKTAG thresholds paper were cross-matched to NVC communities.

Table 4 Proposed nitrate trigger values (mg/l N)

GWDTE category	Low altitude (<175mAOD)	Medium altitude (>175mAOD)	Any altitude
Quaking bog	4	1	
Wet Dune_			3
Fen (mesotrophic) and fen Meadow)	5	2	
Fen (oligotrophic and wetlands at Tufa forming springs)	4.5	1	
Wet Grassland	6	2	
Wet Heath	3	2	
Peatbog and woodland on peatbog			2
Wetlands directly irrigated by spring or seepage			2
Swamp (mesotrophic) and reedbed			5
Swamp (oligotrophic)			4
Wet Woodland	5	2	

The above TVs are expressed as in N (in nitrate) in mg/l.

Figure 3.1 Copy of Table 4 from UKTAG (2012c)

3.1 Use of habitat data to define thresholds

It is apparent that, to use the existing methodology, habitat data (based on the Functional Wetland Typology for Scotland) or NVC data are required. It is clear from section 2 that:

- The Natural England AFTQB inventory for England presents NVC data for almost all recorded locations (section 2.3.2). Therefore the existing methodology could be applied to the locations recorded in this inventory.
- The GWDTE habitat categories used in the UKTAG (2012c) report are similar to (but not directly comparable with) some BAP priority habitats (see Table 3.1).

Table 3.1 Cross-mapping of GWDTE category with BAP priority habitats

GWDTE category	BAP priority habitat
Quaking bog	Lowland fens
Wet dune	Coastal sand dunes[+]
Fen (mesotrophic) and fen meadow	Lowland fens Upland flushes, fens and swamps*
Fen (oligotrophic and wetlands at tufa-forming springs)	Lowland fens Upland flushes, fens and swamps*
Wet grassland	Lowland meadowss[+]
Wet heath	Lowland heathland[+]
Peatbog and woodland on peatbog	Lowland fens Blanket bog Lowland raised bog Upland flushes, fens and swamps*
Wetland directly irrigated by spring or seepage	Lowland fens Upland flushes, fens and swamps*
Swamp (mesotrophic) and reedbed	Lowland fens Upland flushes, fens and swamps* Reedbeds
Swamp (oligotrophic)	Lowland fens Upland flushes, fens and swamps*
Wet woodland	Wet woodland[+]

* No inventory available for this BAP priority habitat.
[+] No inventory of wet forms of this habitat available.

The availability and potential use of BAP priority habitat inventories in the identification of groundwater dependent wetlands and the assignment of a groundwater dependency to a wetland was discussed in section 2.3.1. Lowland fens and reedbeds are both BAP priority habitats, and also habitats for which nitrate threshold values are presented, although two fen habitat types are used in the UKTAG paper. It is therefore suggested that, where BAP priority habitat data are used in the method, the reedbeds and oligotrophic fen (as a precautionary approach) threshold values (presented in Table 4 from UKTAG 2012c, see Figure 3.1) are adopted. This approach is not possible for other BAP priority habitats.

- Where Phase 1 habitat data are available (sections 2.3.4 and 2.5) it will be possible to apply a nitrate threshold based on cross-mapping of UKTAG habitat categories and Phase 1 habitat categories (Table 3.2). As there is some overlap in the cross-mapping, where this occurs the most precautionary thresholds should be adopted.

Table 3.2 Cross-mapping of wetland typology and Phase 1 habitat categories

GWDTE category	Phase 1 habitat category
Quaking bog	Flush and spring – acid/neutral (E2.1)
Wet dune	Dune slack (H6.4)
Fen (mesotrophic and fen meadows)	Fen – basin mire (E3.2) Fen (basin mire/valley mire (E3.1/E3.2)) Fen – floodplain mire (E3.3)
Fen (oligotrophic and wetlands at tufa-forming springs)	Flush and spring (bryophyte dominated spring (E2.3)) Flush and spring – basic (E2.2) Flush and spring – acid/neutral (E2.1)

Wet grassland	Marshy grassland (B5)
Wet heath	Wet dwarf shrub heath (D2) Wet heath/acid grassland (D6)
Peatbog and woodland on peatbog	Broadleaved woodland – semi-natural (A1.1.1) Bog (blanket, raised, modified (E1.6.1, E1.6.2, E1.7))
Wetlands directly irrigated by spring or seepage	No cross match possible
Swamp (mesotrophic) and reedbed	Swamp (F1)
Swamp (oligotrophic)	Swamp (F1)
Wet woodland	Broadleaved woodland – semi-natural (A1.1.1)

Note: Based on the cross-mapping presented in SNIFFER (2009).

- It is not currently possible to define nitrate thresholds on the basis of species records. This may be possible in future but would require specific analysis of the nitrate tolerance of individual species.

3.2 Use of land-use data

Where it is known that a site is a wetland, but there are no habitat data available, an approach has been developed to indicate whether nutrient pressure is likely. Based on experience, the key source of nutrient pressure on sites is the surrounding land use, and in particular the presence of arable and improved grassland in the vicinity. A pilot analysis has been undertaken to assess whether a relationship can be defined between the land use surrounding sites and the nitrate concentrations in monitoring boreholes deemed to be in good and moderate connection with the existing SSSI datasets for Norfolk and Cumbria. The percentage of arable and improved grassland within 2 km of each SSSI, defined using CEH Land Cover 2007 mapping (CEH, 2011), has been cross-mapped with the borehole groundwater average nitrate concentration. The results are presented in Figure 3.2.

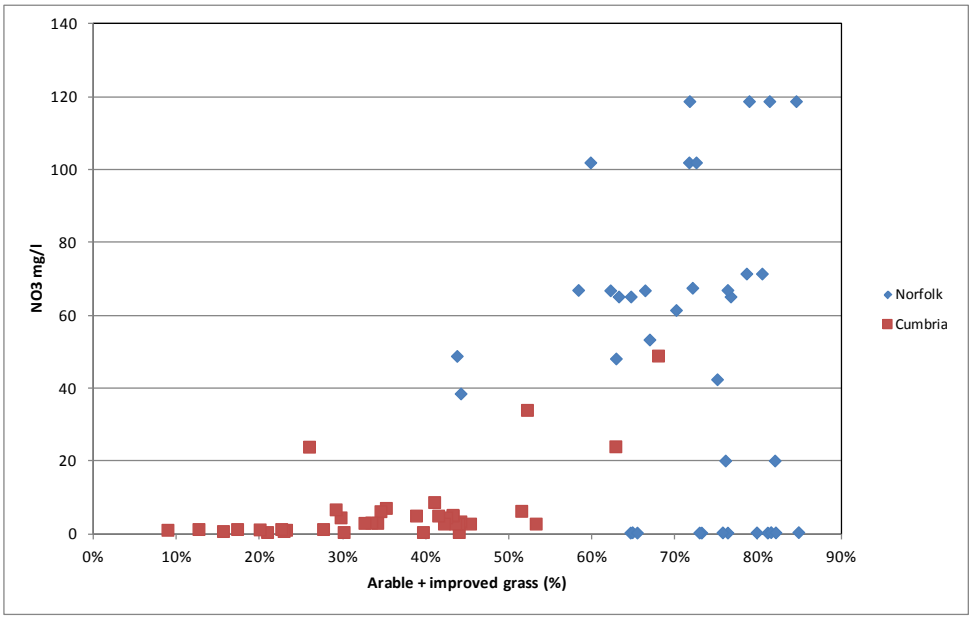

Figure 3.2 Nitrate concentration versus percentage of arable and improved grassland

Based on this pilot, there does seem to be a relationship between surrounding land use and nitrate concentrations although the uncertainties in this approach must be recognised in that only two counties have been trialled and these have very different

annual rainfall quantities which will influence the results. On the basis of the results of this limited trial, the approach seems potentially to be an improvement on the chemical loading data approach currently used for SSSIs. It is therefore suggested that this approach could be used with caution for non-SSSI sites (i.e. to target further investigation of pressures). It is also suggested that the approach should be tested further to determine whether it is an improvement on the method used for SSSIs currently. If the results are positive then the approach could be adopted for assessments of SSSI and non-SSSI sites.

3.3 Recommendations for the methodology

It will be possible to assign a nitrate threshold to sites that have:

- NVC data (i.e. including the AFTQB inventory);
- BAP priority habitat data (lowland fens and reedbeds only);
- Phase 1 habitats, although the approach has limitations because there is some overlap in the cross-mapping, and where this occurs the most precautionary thresholds should be adopted.

Where there is no habitat information it will not be possible to assign a nitrate threshold, but it is suggested that the pressure on a groundwater dependent site could be scored using the following approach:

- Sites with <40% arable and improved grass in the surrounding 2 km are not likely to be under pressure and therefore would score 0.
- Sites with 40–60% arable and improved grass in the surrounding 2 km are likely to be under low pressure and would score 1.
- Sites with >60% arable and improved grass in the surrounding 2 km are likely to be under moderate pressure and would score 2.
- A score of 3 would only be achieved where monitoring data indicate a breach in threshold. It should be noted, however, that a score of 3 could not be achieved by a wetland unless the habitats have been clearly identified and a threshold assigned.

The thresholds and subsequent scores could be amended based on local knowledge as in the current methodology.

It is also suggested that the approach should be tested further to determine whether it is an improvement on the method currently used for SSSIs. It the results are positive then the approach could be adopted for assessments for SSSI and non-SSSI sites.

4 Site condition

Site condition is required in the determination of whether a site is significantly damaged (UKTAG 2005).

Site condition is assessed by Natural England and NRW for SSSIs, using the Common Standards Monitoring approach, which uses habitat-specific criteria to assess whether the habitats on a site are meeting the set targets. There are criteria for all the habitats for which sites are notified as SSSIs.

To assess the condition of any site, the habitats present must be assessed against a standard set of criteria, otherwise the assessment would be essentially meaningless and could not be compared with that of any other site.

With respect to Wildlife Sites, these should have been assessed against a standard set of criteria (Defra 2006) to determine that they meet the required standard for designation. However, each county has its own criteria and so they may not all be the same standard.[2] Additionally, achieving the criteria for designation as a Wildlife Site does not necessarily mean a site is in favourable condition. There is no site condition data available for Wildlife Sites because most organisations lack the resource to undertake such an exercise.

Local councils declare and manage LNRs but there are no site condition data for these either.

Given the limited habitat and species data available for the majority of non-SSSI wetlands (as discussed in section 2), and the absence of any measure of site condition, it is not considered possible to assign a condition to non-SSSI wetlands at this time.

4.1 Recommendations for the methodology

The absence of condition data means that it is not possible at this time to determine whether or why a non-SSSI groundwater dependent wetland has experienced significant damage. However, it is suggested that if sites are assessed as being at high risk of damage they should be targeted for on-site assessment to determine their condition.

The Common Standards Monitoring approach is probably too stringent; however, it is suggested that during a site visit you should look for direct evidence of chemical or quantitative pressures as follows:

Chemical pressure: Presence of effluent discharges or high livestock densities. Other indicators of chemical pressures include the presence of livestock dung, nettles, willowherb or intensely green vegetation suggesting nutrient enrichment. Additionally there may be murky water, abundant algal growth and a green tinge to water in any water bodies on site. Further information on the indicators of nutrient enrichment can be found in the *Fen management handbook* (McBride et al. 2011) and negative indicators for wetland habitat types are reported in JNCC's Common Standards Monitoring guidance (JNCC, 2003b)

(http://jncc.defra.gov.uk/page-2199)

[2] Comparing designation criteria is, however, beyond the scope of this project.

Quantitative pressure: This is more difficult to identify visually. It is typically indicated by the absence of species characteristic of particular habitats, or an unexpected abundance of species indicative of drier conditions within wetland habitats. This will require professional judgement from the surveyor to inform the assessment. Negative indicators for wetland habitat types are reported in JNCC's Common Standards Monitoring guidance

(http://jncc.defra.gov.uk/page-2199)

5 Suggested revised methodology

5.1 Revised methodology

An overview of the method for assessing the risk of significant damage for SSSI wetland sites was presented in Figure 1.1. As indicated in section 1.3, steps 1, 3 and 5 need to be revisited to enable the method to account for non-SSSI wetlands. The remaining steps are unchanged and are not discussed here.

Following the reviews in sections 2 to 4 the approaches for non-SSSI wetlands are presented depending on the data available. Limitations were also described in sections 2 to 4.

5.1.1 Step 1: List of sites provided by Natural England (NE)/NRW

It is suggested that the focus of future analyses of the risk of significant damage to groundwater dependent wetlands should be on Wildlife Sites and LNRs. This is because collation of data for the non-SSSI designated sites (of which there are over 44,000 in England alone – although only a small proportion of these are likely to be wetlands) will be a significant task. Non-designated wetlands should only be considered where the data are readily available (such as in the AFTQB inventory).

As there is no national inventory of the habitats that are supported by non-SSSI sites, and the required habitat information is typically held locally, development of the list of non-SSSI groundwater dependent wetlands will require liaison between the Environment Agency/NRW and Natural England (as appropriate) and local authority ecologists, local Wildlife Trusts and Biological Records Centres.

The observations below provide an initial indication of what is thought to be possible in this respect in England and Wales.

Welsh sites

Significant areas of peatland, grassland and lowland heathland in Wales have been surveyed to NVC level. It will be possible, using these data, to identify the majority of the non-SSSI areas that should be included within the list, although it should be recognised that this will not include all wetland types (notably woodland and coastal habitats).

The approach for Wales should be a straightforward exercise, using a GIS intersect approach to cross-map groundwater dependent NVC communities to Wildlife Sites. The Wildlife Site boundaries, however, would need to be obtained. During this project it became apparent that there is no central source of these and so they would need to be obtained from the individual Wildlife Trusts or Biological Records Centres in Wales.

English sites

There are significantly fewer data available for non-SSSI areas in England. Given current availability of data it is not considered possible to define a list of Wildlife Sites supporting groundwater dependent habitats. For England the process of identifying sites will need to form part of step 5. The site boundaries could be provided by Natural

England but these would need to be checked following the identification of differences between the Natural England and the Shropshire and Norfolk datasets (see section 2.5.1).

Definition of sites

Wildlife Sites and LNRs all have designated boundaries.

However, the Natural England AFTQB inventory has a number of locations supporting the habitats presented as a point. Where a wetland is identified as a data point it is suggested that there are three options that the Environment Agency could adopt. These are:

- Delimit the wetland on the basis of the relevant field margins. This may be problematic in upland situations.
- Delimit the wetland as a 1 ha area around the point.
- Note the location, but do nothing until the extent is identified through study/local knowledge.

BAP priority habitat inventories cover areas within and outside designated sites (although the majority will be from within designated sites because there has been more recording effort in designated sites). Areas outside of designated sites are most likely to be defined based on field boundaries and so if a BAP priority habitat inventory was used in the definition of the extent of a groundwater dependent wetland, the relevant field boundaries should be used to limit the extent. This principle may not hold for upland situations where local knowledge would be required to further refine boundaries.

5.1.2 Step 5: Assess groundwater dependency

The approach taken to assigning groundwater dependency to sites will depend upon the data available and is described below:

- If NVC data available, use existing method to assign a groundwater dependency to a site. This will include the Natural England AFTQB inventory.
- If no NVC, but Phase 1 data available, use the groundwater dependencies assigned in section 2.3.4 to assign a groundwater dependency to a site. Sites that are assessed as being at high risk following application of the other steps should be investigated to confirm the presence of groundwater dependent habitats or communities.
- If no NVC or Phase 1 data available, use BAP priority habitat inventories (lowland fens and reedbeds only) and species inventories (requiring more than one of the target species records to coincide on a site) to identify wetland areas. These wetlands should be assigned a low groundwater dependency only. However, sites that are assessed as being exposed to high pressure with a high connectivity following application of the other steps should be investigated to determine the presence of groundwater dependent habitats or communities. Investigation should initially comprise liaison with local organisations to determine how much information is already available for a site. It may then need to be visited.

It is worth noting that scores derived using these approaches could be amended based on local knowledge as in the current methodology.

None of the other possible approaches to the assignment of groundwater dependency to a site considered in section 2 of this report are considered viable at this time.

The approaches to defining the extent of sites indicated in section 5.1.1 should be adopted where necessary.

5.1.3 Step 3: Assessment of chemical pollution pressure (nitrate)

The approach taken to assigning the threshold against which an exceedance is assessed is based on the botanical community or habitat present. The suggested approach to assigning a nitrate threshold to non-SSSI sites is detailed below:

- If NVC data available, use existing method to assign a threshold.
- If no NVC, but Phase 1 data available, apply the cross-mapping approach described in section 3.
- If no NVC or Phase 1 data are available, but BAP priority habitat data are available indicating the presence of lowland fens or reedbeds, use the thresholds for these habitat types. It will not be possible to assign a threshold for any other BAP priority habitats.
- Where there is no habitat information it will not be possible to assign a nitrate threshold, but the potential pressure on a site could be scored using the following approach:
  - sites with <40% arable and improved grass in the surrounding 2 km are not likely to be under pressure and therefore would score 0;
  - sites with 40–60% arable and improved grass in the surrounding 2 km are likely to be under low pressure and would score 1;
  - sites with >60% arable and improved grass in the surrounding 2 km are likely to be under moderate pressure and would score 2;
  - a score of 3 would only be achieved where monitoring data indicate a breach in a threshold. It should be noted, however, that a score of 3 could not be achieved where the wetland habitats present have not been clearly identified.

The shortcoming of the last point in the list above is that, where there is no habitat information and hence no groundwater dependency score, the site would score 0 in the risk assessment. However, this approach could be used to screen sites that then require input of local knowledge.

It is also suggested that the Environment Agency give consideration to the application of this approach as a replacement, in the assessment of risk to SSSIs, for the use of National Environment and Agricultural Pollution Nitrate (NEAP-N) model (Lord & Anthony, 2000) data because no relationship was found between the NEAP-N and groundwater nitrate concentrations. This may reflect the scale for determining NEAP-N loadings.

It is not considered possible at this time to adapt any of the other approaches to the assignment of groundwater dependency (e.g. use of species indicators) to indicate a nitrate threshold.

5.1.4 Site condition

Site condition data are required in the determination of whether a site is significantly damaged. However, it is not generally possible, at this time, to assign a condition to non-SSSI groundwater dependent sites and hence determine whether a wetland has experienced significant damage. It is suggested that if sites are assessed as being exposed to high pressure with a high connectivity they should be targeted for site-specific assessment to determine their condition.

The Common Standards Monitoring approach is probably too stringent; however, it is suggested that during a site visit you should look for direct evidence of chemical or quantitative pressures as follows:

Chemical pressure: Presence of effluent discharges or high livestock densities. Other indicators of chemical pressures include the presence of livestock dung, nettles, willowherb or intensely green vegetation suggesting nutrient enrichment. Additionally, there may be murky water, abundant algal growth and a green tinge to water in any water bodies on site. Further information on the indicators of nutrient enrichment can be found in the *Fen management handbook* (McBride et al. 2011) and negative indicators for wetland habitat types are reported in JNCC's Common Standards Monitoring guidance

(http://jncc.defra.gov.uk/page-2199)

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Quantitative pressure: This is more difficult to identify visually. It is typically indicated by the absence of species characteristic of particular habitats, or an unexpected abundance of species indicative of drier conditions within wetland habitats. This will require professional judgement from the surveyor to inform the assessment. Negative indicators for wetland habitat types are reported in JNCC's Common Standards Monitoring guidance

(http://jncc.defra.gov.uk/page-2199)

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5.2 Project recommendations

A revised method has been described in section 5.1, but it is clear that the identification and assessment of non-SSSI groundwater dependent wetlands will be more straightforward in some areas than others (i.e. easier in Wales than England).

As indicated in section 1.2, the method was not trialled during this project. It is recommended that this is undertaken for a single county as it is likely that application to a full dataset will result in further issues being identified and recommendations being made. To achieve this, the relevant local Wildlife Trust or Biological Records Centre is likely to need funding, which should be included/accounted for within any project funding bid.

Following the review and method development undertaken in this report, a number of recommendations can be made.

5.2.1 Data development/interpretation

- The Environment Agency/NRW and Natural England (as appropriate) should work with local authority ecologists, conservation NGOs, local Wildlife Trusts and Biological Records Centres to develop a list of non-SSSI

groundwater dependent wetland sites (Wildlife Sites, LNRs and non-designated areas). Ideally the required data for inclusion in the assessment, which would include an agreed set of site polygons and required habitat data, would be delivered through this process. Taking this approach should enable access to the other possible datasets contained in species reports, as discussed in section 2.6. This process will require a significant amount of time and effort and so should be programmed accordingly, with specific funding allocated, otherwise it is unlikely to be undertaken .

- In recent years Wildlife Trusts and Biological Records Centres have been asked by Natural England to produce inventories of BAP priority habitats. However, there are limitations on the use of BAP priority habitat data in the method because, although a number of BAP priority habitats contain potentially groundwater dependent elements (e.g. broad leaved woodland, lowland heathland), these are not separated in the BAP priority habitat inventories. Consideration should be given by Natural England to the separation of the wetland elements of these habitats from the non-wetland elements. Using the existing data may result in potentially valuable areas of wetland habitat being overlooked. If the data were separated, it would be possible to assign a groundwater dependency to more of the BAP priority habitat types.
- Wales has a national Phase 1 habitat survey, and Phase 2 (NVC) survey data for many thousands of hectares of lowland grassland, peatland and heathland. Pursuing a similar approach for England is probably unrealistic in the current climate. However, Wildlife Trusts and Biological Records Centres are constantly collecting data for sites in their areas. Natural England should encourage them to collect NVC data ideally, but Phase 1 data if NVC is not possible. These data could be translated to BAP priority habitats if there is a need to report at this level and the data would also be available to be pulled into an appropriate inventory for use in studies such as this.
- The data collected should be stored digitally, which would make the NVC and Phase1 data more accessible for informing the development of lists of groundwater dependent wetlands and also in assigning a groundwater dependency and a nitrate threshold to a site.
- Data available through the NBN is reported at a range of resolutions. A hectad or tetrad resolution is not useful for this project. NBN needs to be encouraged by Natural England to request all data to be supplied at 100 m resolution.

5.2.2 Method development

- Consideration should be given by the Environment Agency/NRW and Natural England to the development of a national inventory of wetlands, using the methods, or variations of those, described by Brown et al. (2009 and 2010) and SKM (2012). Whether this is required will, however, depend on whether local authority ecologists, local Wildlife Trusts and Biological Records Centres are able to engage in the process to develop a list of non-SSSI groundwater dependent wetland sites.
- It is suggested that the Environment Agency/NRW undertake further testing of the land-use approach to assigning chemical pressure to wetlands and, if

the results are positive, consider adopting this for SSSI and non-SSSI sites, replacing the NEAP-N approach currently used for SSSIs.

- Further development of the method in respect of determining whether damage to a GWDTE resulting from pressure acting through a groundwater body is considered significant may be required following production of the UKTAG Wetland Task Team paper on 'determining significant damage within and outside of Natura 2000 sites'.

5.3 Conclusions

A revised method has been proposed following review of available datasets. There are a number of data gaps and anticipated difficulties with data access. The key gaps are:

- The data currently collected does not always meet the requirements of this method (i.e. focused on BAP priority habitat type rather than NVC or Phase 1), but this could be addressed by the above recommendations.
- The need to transfer the majority of data held by Biological Records Centres and Wildlife Trusts to digital storage.
- Absence of site condition data for non-SSSI wetlands.

It is strongly recommended that the method is trialled if an example dataset can be made available, as this will probably lead to the identification of additional data issues and subsequent recommendations. This will require the Environment Agency/NRW (as appropriate) and/or Natural England to liaise with a Wildlife Trust or Biological Records Centre to arrange this.

Given current data availability it is likely to be easier to apply the method to Wales than England, as for the latter significant additional work will be required before risk characterisation/classification of non-SSSI groundwater dependent sites can be undertaken.

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List of abbreviations

AFTQB	Alkaline Fens and Transition Mires and Quaking Bogs
BAP	Biodiversity Action Plan
GDE	groundwater dependent ecosystem
GWDTE	groundwater dependent terrestrial ecosystem
JNCC	Joint Nature Conservation Committee
LNC	Local Nature Conservation Site
LNR	Local Nature Reserve
LWS	Local Wildlife Site
NBN	National Biodiversity Network
NE	Natural England
NEAC	Northern East Anglia Chalk groundwater model
NEAP-N	National Environment and Agricultural Pollution Nitrate model
NGO	non-governmental organisation
NO_3	nitrate
NRW	Natural Resources Wales
NVC	National Vegetation Classification
SAC	Special Area of Conservation
SEPA	Scottish Environment Protection Agency
SINC	Site of Importance for Nature Conservation
SNCI	Site of Nature Conservation Importance
SSSI	Site of Special Scientific Interest
UKTAG	United Kingdom Technical Advisory Group (for the Water Framework Directive)
WFD	Water Framework Directive

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