Wetlands and the Water Framework Directive:

Key challenges for achieving good ecological status at the Anglesey and LLŷn Fens SACs.

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Abstract

The Water Framework Directive (WFD) requires assessment of water quality and quantity in groundwater bodies that are hydrologically linked to designated wetlands. The Anglesey and Llŷn Fens face chemical (e.g. nitrate) and quantitative (e.g. historic drainage) groundwater pressures. Hydrogeologists and ecologists have successfully worked together during the WFD classification process and impacts from diffuse nutrients have resulted in 'poor' chemical status for the surrounding Carboniferous Limestone groundwater body.

Long term hydrological and chemical monitoring programs allow the assessment of baseline conditions, identification of trends and extreme climatic events (floods and droughts) possibly associated with our changing climate.

Nutrient management plans, aimed at the reduction of inorganic fertilisers, must be

agreed, implemented and monitored to ensure the return of the Anglesey and Llŷn Fens to favorable ecological condition and good groundwater chemical status.

Key challenges include encouraging both ecologists and hydrogeologists to work together; continuing to work well with landowners and farmers; implementation of plans to reduce over application of inorganic fertilizers and to continue monitoring the Anglesey and Llŷn Fens as part of future climate change monitoring programs.

If nothing is done to address these key challenges or the 'after LIFE' work is not supported there is a real risk of failure of targets associated with both the Water Framework Directive and Habitats Directive.

Introduction

The European Commission's Anglesey and Llŷn Fens LIFE project is the largest wetland restoration project in Wales, aiming to improve 751 hectares of rare fen habitat in north west Wales (www.angleseyandllynfens.com). The Anglesey and Llŷn Fens are comprised of several separate sites that include Cors Bodeilio, Cors Erddreriniog and Cors Geirch. The LIFE project has seen a multidisciplinary approach to restoring and improving the condition of the Anglesey and Llŷn Fens, with hydrogeologists and ecologists working together to achieve shared goals. Wetlands face a range of pressures (see SNH, 2011) including poor management, historic drainage and under or over grazing. Many of these pressures have been identified and addressed by the LIFE project, for example programs of fencing and the introduction of grazing animals have yielded quantifiable improvements.

Diffuse pollution of nutrients (principally nitrogen and phosphate) may be one of the greatest challenges currently faced by both environment managers and also the Anglesey and Llŷn Fens. Fens, like many other wetlands, depend on a low nutrient input to maintain the diversity of species and to limit succession of species that thrive in higher nutrient systems. Nutrient input can have many sources but industry and agriculture are perhaps the most common in the UK. Pathways for nutrients can include atmospheric deposition such as precipitation, surface water and groundwater flow pathways.

This paper describes work undertaken by Environment Agency Wales and the Countryside Council for Wales (now Natural Resources Wales), to assess the chemical and quantitative status at the Anglesey and Llŷn Fens. The majority of the work was undertaken in response to the requirements of the Water Framework Directive (WFD 2000/60/EC), which shares key goals with the Habitats Directive (HD 94/43/EC) for achieving favorable status at designated sites. Many of the readers of these proceedings will have an ecological background and be aware of the Habitats Directive but perhaps less familiar with the Water Framework Directive. In recognition of this a short overview of the WFD is presented, describing how it has been instrumental for the collection of detailed baseline data and highlighting the plight of the Anglesey and Llyn fens.

Why the Water Framework Directive is good for Wetlands

The WFD is a key piece of European legislation that aims to facilitate the improvement of both surface and groundwater quality and quantity in all EU member states. The WFD requires an assessment of whether groundwater is causing ‘significant damage’ (see

Whiteman *et al.,* 2010) to terrestrial ecosystems that are directly dependent on that groundwater (WFD Annex V 2.3.2). In simple terms the WFD requires member states to undertake a classification and risk assessment of all groundwater bodies, assigning each body as being in either 'poor' or 'good' status. Groundwater bodies are management units delineated around aquifers, which are strongly influenced by the bedrock and superficial geology. Groundwater level and quality monitoring is routinely undertaken in each groundwater body by Natural Resources Wales. Using this evidence it has been possible to undertake assessments of water resources (EAW, 2007) and produce baselines for groundwater quality (EAW, 2008). For example, the data collected as part of the requirements of the WFD allows evidence based assessments of the status of groundwater bodies that support and supply water to the Anglesey and Llŷn Fens.

The WFD classification process comprises a series of tests (UKTAG, 2012a) that are undertaken using the best available evidence to assign either poor or good status to a groundwater body. Tests are included to asses for saline or other intrusions, surface water, drinking water protected areas, a general quality assessment and a water balance, factors which effect many groundwater bodies (Fig. 1). Importantly, where designated sites (such as the Anglesey and Llŷn Fens) rely upon groundwater as a hydrological supporting condition then an additional test called the 'Groundwater Dependent Terrestrial Ecosystems' test is undertaken. This test identifies where unfavorable ecological conditions are a direct result of groundwater mediated pressures, such as elevated nutrients (see Schutten *et al.,* 2011). The importance of this test cannot be underestimated. If the test is failed, for example due to elevated nitrate from the groundwater body causing unfavorable condition at a fen, then the entire groundwater body will be placed at 'poor' chemical status. As a direct result of the failure a program of measures will need to be identified to return the wetland to favorable ecological condition and ultimately during the next classification return the groundwater body status to 'good'.

The WFD is a very powerful piece of legislation that can be used to highlight wetlands that are unfavorable due to poor groundwater chemical or quantitative status, and subsequently to drive actions that can return groundwater bodies to good status and the wetlands to favorable condition.

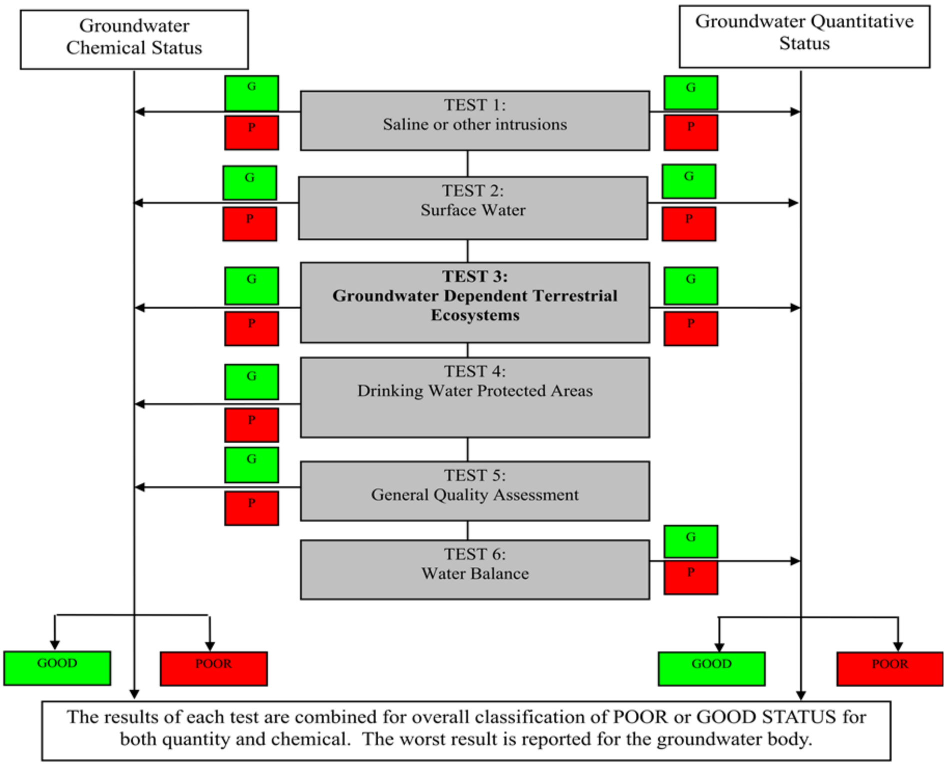

Figure 1. Water Framework Directive classification tests for chemical and quantitative assessment of a groundwater body. The Groundwater Dependent Terrestrial Ecosystems test is a useful tool for identifying where designated wetlands can be at risk from groundwater mediated pressures.

UK Technical Advisory Group for Wetlands and threshold values for nitrate

The UK Technical Advisory Group (UKTAG) for Wetlands comprises representatives from the UK and Ireland, including Natural Resources Wales, Environment Agency, Scottish Environment Protection Agency and the British Geological Survey. The role of this group is to outline processes and methods by which the WFD can be implemented within the UK and includes people with both ecological and hydrogeological expertise. The identification of Groundwater Dependent Terrestrial Ecosystems (GWDTEs) (UKTAG, 2004) and methods for the determination of significant damage (UKTAG, 2005 and Whiteman *et al.,* 2010) are both direct outputs of this group.

Long term (>6 years) groundwater quality data was collated from environmental regulators across the UK and compared to that from GWDTE, such as fens that were in both favorable and unfavorable condition (UKTAG, 2012b). Using statistical analysis together with expert assessment 'threshold values' were derived for groundwater bodies that are hydrologically connected to a GWDTE. The threshold values for nitrate (Table 1) are used to identify risks to wetlands and to act as an early warning system to trigger measures to reduce nutrient loading.

GWDTE Category	Altitude <175maOD	Altitude >175maOD	Any altitude
Quaking bog	4	1	
Fen(mesotrophic) and fen meadow	5	2	

Fen (oligotrophic and wetlands at tufa forming springs)	**4.5**	**1**	
Wet grassland	**6**	**2**	
Peat bog and woodland on peat bog			**2**
Wetlands directly irrigated by spring or seepage			**2**
Swamp (mesotrophic) and reedbed			**5**
Swamp (oligotrophic)			**4**
Wet woodland	**5**	**2**	

Table 1. Nitrate threshold values (NO_3-N mg/l) for a range of groundwater dependent terrestrial ecosystems (UKTAG, 2012b)

Cors Bodeilo and Cors Erddreiniog (SWS, 2010a & SWS, 2010b) are important peat rich calcareous and alkaline fens that are both at risk of elevated (>2 mg/l N) nutrient input via groundwater pathways such as springs and diffuse seepages. Long term data collected at groundwater monitoring points was compared to the UKTAG threshold values and used as evidence to assign poor status to the surrounding groundwater body (Carboniferous Limestone) during the GWDTE test, part of the 2nd Cycle WFD classification process.

Hydrological extremes and the need for long term monitoring

The WFD requires properly designed long term monitoring programs to characterize baseline conditions, classify groundwater body status, monitor improvements in wetlands resulting from programs of measures and to ensure the return to good ecological status. Monitoring for the WFD may consist of both groundwater levels and groundwater quality and will also rely on the ecological maps and assessments undertaken by NRW staff for the Habitats Directive assessments.

It is important that the classification process for WFD is based on long term data sets. Individual water quality samples or water level readings are useful as part of one off investigations and can contribute to baseline datasets, but they do not allow us to recognize seasonal or long term variations and trends.

For example, if we collect one groundwater quality sample and the nitrate level exceeds that of the proposed threshold value this is not sufficient evidence to designate this site as poor status. Single water quality samples could be subject to sampling or analytical error, or be unrepresentative as they may be collected during periods of either high or low nutrient input in a systems that shows annual variations.

If however we collect several samples throughout the year, all of which have similar levels of nitrate then our level of confidence will increase. Trends and patterns in groundwater quality can occur throughout the year but these seasonal patterns can also be overlain by longer term trends. Long term trends in water quality are a reflection of the time it can take groundwater to reach the fens, and in some cases nitrate levels may represent the application of fertilizers several years or even decades previously. Working together hydrogeoloists and ecologists have been able to improve their conceptual understanding of the Anglesey and Llŷn fens. Defining and applying WETMECS or Wetland Water Supply Mechanisms (Wheeler *et al.,* 2009) to individual sites and delineating key recharge areas for nutrient enriched waters (e.g SWS, 2010) has helped to target land management actions.

Since the installation of a borehole and piezometer (Fig. 2) network at Cors Bodeilio, Cors Erdderiniog and Cors Gerich (WMC, 2008) hourly groundwater level data has been collected using pressure transducers, from several dipwells, piezometers and boreholes, within the peat and underlying Carboniferous Limestone aquifers (Fig. 3.).

Figure 2. Piezometer 'BD2' showing artesian groundwater pressure (12th January 2011)

The hydrological monitoring has been complemented by a program of water quality sampling undertaken since 2006 by Natural Resources Wales (Fig. 4). During this period the UK has experienced some of its most extreme years on record. In Wales, the autumn and winter of 2011 were very dry, depriving aquifers of recharge they normally receive after the drier summer months. Following this very dry period came 2012 which provisional Met Office statistics suggest was the second wettest year since records began. During 2012 the provisional amount of rainfall recorded by the Met Office in Wales was 1716.2mm, or 118% of the average annual precipitation based on data from 1981-2010.(http://www.metoffice.gov.uk/news/releases/archive/2013/2012-weather-statistics). The water quality data appears to show a decreasing trend in nitrate since 2006,for which there is currently no explanation. One possible hypothesis is that the reduction in nitrate is a reflection of the economic downturn, with fertilizers being more sparingly applied and thus a reduction in nitrates in the younger component of groundwater.

Both the hydrographs (Fig. 3) and the water quality data (Fig. 4) provide very good examples of the benefit of longer term monitoring (>5 years) compared with shorter monitoring periods (<1year). Clarke, D and Sanitwong Na Ayuttaya (2010) provide an example of the use of long term groundwater level data sets (1972-2007) to underpin modeling, and understand longer term groundwater level trends and climate change. Characterizing hydrological extremes, establishing a baseline or populating a groundwater model is only really possible to any degree of accuracy with longer term datasets and these may need to be decades long.

For example, consider that there was an application for a quarry next to a wetland and the regulators / applicants only had one year in which to characterize the water quality or levels of the wetland. What if that year was 2011 or indeed 2012? Would the data really be suitable to establish a defensible baseline? What would happen if this data was used to set target water levels for site condition monitoring plans and would these targets be representative? It is hopefully obvious from both data sets (Fig. 3 & Fig. 4) that longer term data is required not just to understand the on site dynamics but also to be able to understand hydrological extremes which are becoming more common as we face a changing climate.

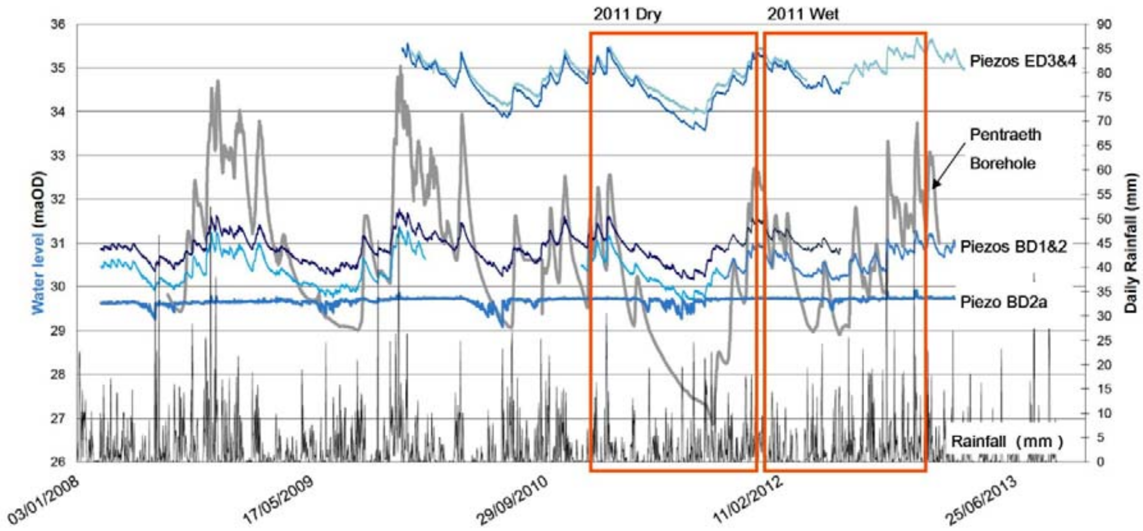

Figure 3. Hydrographs from groundwater monitoring network at Cors Bodeilio, Anglesey. The dry year of 2011 and very wet year of 2012 are indicated using red boxes (data source: Natural Resources Wales)

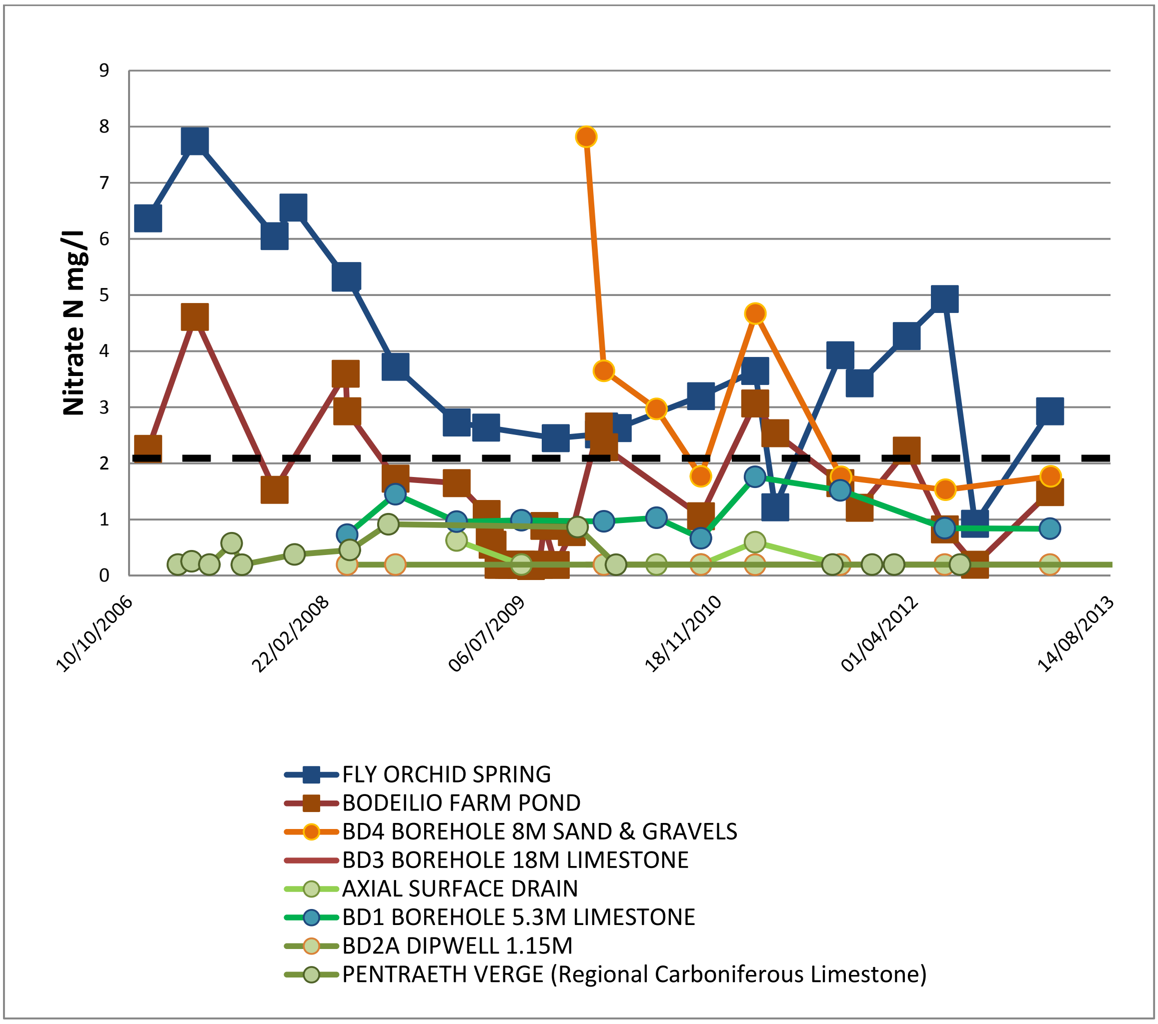

Figure 4. Water quality monitoring Cors Bodeilio, Anglesey (data source: Natural Resources Wales). The threshold value of 2mg/l NO_3-N for peatbogs is annotated with a horizontal dashed line.

Risks and challenges in the 'after LIFE'

Although the LIFE project has come to an end there is still a lot of work to be done to get the Anglesey and Llŷn Fens to good chemical status. Put simply, failure to address these issues will lead to failure of both WFD and HD targets. We must still work hard to put into place land management changes to reduce the level of nutrients entering the fens and to maintain favorable hydrological conditions. The following is a list of the key recommendations which will help towards achieving both WFD and HD targets.

1. Hydrogeologists and ecologists should continue to work together to address pressures at wetlands including the Anglesey and Llŷn Fens SACs.
2. Where investigations have shown that nutrient enrichment from surrounding agricultural land is causing unfavorable status, targeted catchment actions (.e.g. soil nutrient plans) should be agreed and successfully implemented. Routine monitoring at the receptor (wetland) should be undertaken in order to assess the success of any land management changes.
3. Good working relationships with landowners and farmers are the key to success. Every effort should be made to show how nutrient management plans and soil assessments can provide financial savings for farmers and reduce nutrient input into the fens. Ongoing monitoring before, during and after these plans are implemented will provide evidence for both Natural Resources Wales and the farming community.

Where valuable long term water level and quality monitoring records have been established (e.g. Cors Bodeilio, Cors Erddreriniog and Cors Geirch SACs) consideration should be given for their continuation and inclusion as part of a Wales-wide wetlands and climate change monitoring program. This would provide valuable information not only for Wales but for the rest of the UK.

Conclusions

This paper illustrates how ecologists and hydrogeologists working together can use European legislation including the WFD and HD in conjunction with UKTAG guidance to provide evidence for the status of a wetland. The WFD is good for wetlands as it provides the drivers required to undertake data collection and assessment of status at designated sites. The WFD requires the improvement of groundwater bodies and designated wetlands in poor status, thus helping to support the implementation of land management actions aimed at reducing pressures such as diffuse pollution. Discussion of the benefits of longer term data collection for the successful characterization of wetlands and for the identification of trends within the data set is highlighted.

The risks and challenges in the project 'After LIFE' period are clearly outlined, supporting continued collaboration between hydrogeologist and ecologists; targeted catchment actions complemented with routine monitoring and the importance of maintaining good working relationships with landowners and farmers. NRWs groundwater monitoring programs at the Anglesey and Llŷn Fens will provide vital information for assessment against longer term trends, such as those experienced with our changing climate and should be maintained into the future.

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References

Clarke, D and Sanitwong Na Ayuttaya, S (2010). *Predicted effects of climate change, vegetation and tree cover on dune slack habitats at Ainsdale on the Sefton Coast. UK*.Journal of Coastal Conservation, 14, (2), 115-125.

EAW (2007). *The Ynys Môn Catchment Abstraction Management Strategy*. Environment Agency Wales. http://www.environmentagency.gov.uk/business/topics/water/119933.aspx

EAW (2008). *Groundwater quality and supply survey: The Carboniferous Limestone, Anglesey*. Water Management Consultants (WMC) commissioned report for Environment Agency Wales.

Habitats and Birds Directive (94/43/EEC). Council directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora, 21st May 1992. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1992L0043:20070101:EN:PDF

JNCC (2004). *Common Standards Monitoring Guidance for Lowland Wetland*. Version August 2004. ISSN 1743-8160. http://jncc.defra.gov.uk/pdf/CSM_lowland_wetland.pdf

Schutten, J, Verweij, W, Hall, A. & Scheidleder, A. (2011). *Common Implementation Strategy for the Water Framework Directive (2000/60/EC)*. Technical Report No.6 Technical Report on Groundwater Dependent Ecosystems. European Commission Technical Report – 2011- 056, December 2011. ISBN 978-92-79-21692-3.

SNH (2011). *The Fen Management Handbook*, (2011), Editors A. McBride, I. Diack, N Droy, B. Hamill, P.Jones, J. Schutten, A. Skinner, and M. Street. Scottish Natural Heritage, Perth. http://www.snh.gov.uk/about-scotlands-nature/habitats-and-ecosystems/lochs-rivers-and-wetlands/fen/

SWS (2010a). *River basin planning through targeted investigations on selected Welsh Groundwater Dependent Terrestrial Ecosystems - Cors Bodeilio and Merthyr Mawr*. Schlumburger Water Services Report 1-274/R3 for Environment Agency.

SWS (2010b). *Desk study Cors Erddreiniog Investigations on selected Welsh Groundwater Dependent Terrestrial Ecosystems (GWDTEs)*. Schlumberger Water Services. Report 1-274/R3 for Environment Agency.

UKTAG (2004). *Guidance on the identification and risk assessment of groundwater dependent terrestrial ecosystems*. Version 5 (21/01/2004) http://www.wfduk.org/sites/default/files/Media/Characterisation%20of%20the%20water%20environment/Risk%20assessment%20of%20terrestrial%20ecosystems%20groundwater_Draft_210104.pdf

UKTAG (2005). *Draft Protocol for determining 'Significant Damage' to a 'Groundwater Dependent Terrestrial Ecosystem'*. Version 9.6. 04/10/2005 http://www.wfduk.org/sites/default/files/Media/Characterisation%20of%20the%20water%20environment/Determining%20significant%20damage%20to%20a%20groundwater%20dependent%20terrestrial%20ecosystem_Draft_011205.pdf

UKTAG (2011). *Characterisation of risks to groundwaters for the 2nd river basin cycle*. Version 7 March 2011. http://www.wfduk.org/resources%20/characterisation-risks-groundwaters-2nd-river-basin-cycle

UKTAG (2012a). Paper 11b(i) Groundwater Chemical Classification for the purpose of the Water Framework Directive and the Groundwater Directive. Version Feb 2012. http://www.wfduk.org/sites/default/files/Media/Assessing%20the%20status%20of%20the%20water%20environment/GWChemical%20Classification_FINAL_2802121.pdf

UKTAG (2012b). *Technical report on groundwater dependent terrestrial ecosystem (GWDTE) threshold values*. Version 8 March 2012. http://www.wfduk.org/resources%20/groundwater-dependent-terrestrial-ecosystem-threshold-values

Water Framework Directive (2000/60/EC). Directive 200/60/EC of the European parliament and of the council of 23rd October 2000 establishing a framework for community action in the field of water policy. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:327:0001:0072:EN:PDF

Wheeler, B.D., Shaw, S. & Tanner, K. (2009). *A wetland framework for impact assessment at statutory sites in England and Wales*. Environment Agency Science report: SC030232. http://a0768b4a8a31e106d8b050dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/scho0309bpoe-e-e.pdf

Wheeler, B.D., Shaw, S. & Tanner, K. (2009). *A wetland framework for impact assessment at statutory sites in England and Wales*. Environment Agency Science report: SC030232. http://a0768b4a8a31e106d8b050dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/scho0309bpoe-e-e.pdf

Wheeler, B.D., Shaw, S.C., Brooks, A, & Whiteman, M. (2010). *Ecohydrological guidelines for lowland wetland plant communities* - fens and mires update March 2010. Environment Agency.

Whiteman, M., Brooks, A., Skinner, A. & Hulme, P. (2010). *Determining significant damage to groundwater-dependent terrestrial ecosystems in England and Wales for use in implementation of the Water Framework Directive*. *Ecological Engineering,* **36**, 1118-1125.

Whiteman, M., Wheeler, B., Shaw, S., Lewis, T., Grout, G. & Tanner, K. (2009). *The use of WETMECs typology to aid understanding of groundwater-dependent terrestrial ecosystems in England and Wales. Groundwater Monitoring.* 2009. (eds Quevauviller, P., Fouillac, A.M., Grath, J. & Ward, R), pp. 259-272. John Wiley & Sons Ltd.

WMC (2008). *Groundwater Dependent Wetlands: investigation and instrumentation of six Welsh wetland sites of special scientific interest*. Water Management Consultants Report 1-234/R1 for Environment Agency Wales.