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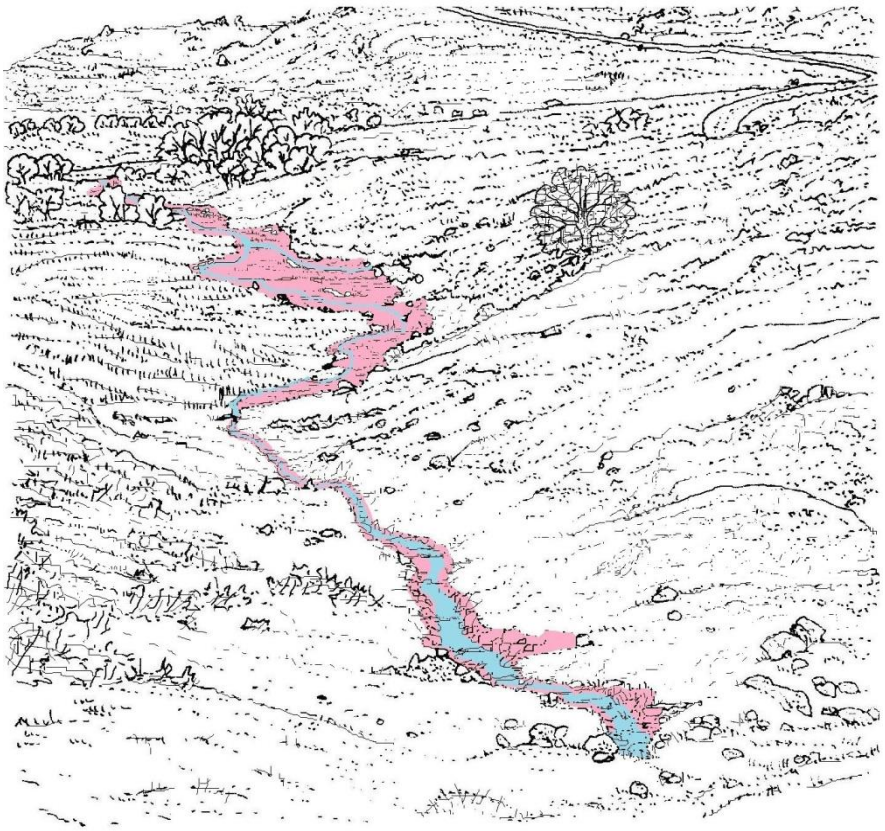
# Survey, characterisation and condition assessment of *Palustriella* dominated springs 'H7220 Petrifying springs with tufa formation (*Cratoneurion*)' in Wales



NATURAL RESOURCES WALES EVIDENCE REPORT NO.136

CEH REPORT REFERENCE WL/NEC03832/13_14/T6

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G Farr, J Graham and C Stratford.



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## About Natural Resources Wales

Natural Resources Wales is the organisation responsible for the work carried out by the three former organisations, the Countryside Council for Wales, Environment Agency Wales and Forestry Commission Wales. It is also responsible for some functions previously undertaken by Welsh Government.

Our purpose is to ensure that the natural resources of Wales are sustainably maintained, used and enhanced, now and in the future.

We work for the communities of Wales to protect people and their homes as much as possible from environmental incidents like flooding and pollution. We provide opportunities for people to learn, use and benefit from Wales' natural resources.

We work to support Wales' economy by enabling the sustainable use of natural resources to support jobs and enterprise. We help businesses and developers to understand and consider environmental limits when they make important decisions.

We work to maintain and improve the quality of the environment for everyone and we work towards making the environment and our natural resources more resilient to climate change and other pressures.

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- Maintaining and developing the technical specialist skills of our staff;
- Securing our data and information;
- Having a well resourced proactive programme of evidence work;
- Continuing to review and add to our evidence to ensure it is fit for the challenges facing us; and
- Communicating our evidence in an open and transparent way.

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# Foreword

This report is the product of a Natural Resources Wales (NRW) contract to survey, characterise and assess the Annex 1 habitat; *Palustriella* dominated springs H7220 Petrifiying springs with tufa formation (*Cratoneurion*) in Wales. This is the first comprehensive baseline survey of this habitat in Wales and includes a selection of 15 sites in both North and South Wales.

Article 17 of the Habitats and Species Directive requires member states to submit reports concerning the conservation status of habitats listed under Annex I of the Directive at six yearly intervals. This report combines new information on habitat condition, water quality and pressures at a selection of sites across Wales.

The data contained within this report aims to provide a baseline resource for this understudied terrestrial Annex 1 habitat in Wales.

# Acknowledgements

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# Contents

# Figures

# Tables

# Summary

This report contains baseline information for Article 17 reporting in Wales for the Annex 1 habitat H7220 Petrifying springs with tufa formation (*Cratoneurion*). Natural Resources Wales selected a total of 14 sites, across Wales for inclusion within the study. Only one site, Nant Peris, is part of a designated SAC (Eryri SAC) where petrifying springs are a notifiable feature and as such they had benefited from prior study (see Creer, 2012). The remaining sites included within this survey were associated with a mixture of designated and undesignated sites for which there was little to no baseline information on the petrifying spring habitats.

A methodology was devised and applied where possible at each site, involving an ecologist (Jonathan Graham) and a hydrogeologist (Gareth Farr) working together. It was important that both the hydrological and ecological surveys were undertaken simultaneously in order to make important linkages between hydrological supporting condition, the occurrence of species and condition of the site.

Each survey started with a 'site walkover' to allow familiarisation with the site and to help form initial conceptual ideas. Following this a vegetation survey and collection of species for detailed identification for both bryophytes, lichens and flowering plants was undertaken, using the DAFOR scale. A total of 130 species were recorded including 77 flowering plants, 46 bryophytes, one club moss, two ferns, 3 horsetails, 2 blue green algae and one charophyte. Detailed maps were drawn for key sites within this study. Elevation data shows that *Palustriella falcata* occurs over a smaller range within an upland setting and *Palustriella commutata* occurs over a wider range in a primarily (but not exclusively) lowland setting. In situ water quality readings and lab analysed samples were collected proving the sites were dominantly Calcium Bicarbonate type waters, however some sites such as Nant Peris were much less calcareous, with the majority of sites having very low levels of nutrients. Vegetation transects accompanied by field readings of water quality were undertaken whenever possible showing that there can be dramatic changes in pH over very small distances (<1m). An assessment was made of the immediate catchment, with the aim of identifying any hydrological threats or pressures to the habitats.

Two broad group are proposed for this habitat in Wales

**Group 1:** mainly upland or open hills and dominated by *Palustriella falcata,* it is species rich and has a greater number of associated flowering plant species.

**Group 2**: mainly lowland and dominated by *Palustriella commutata,* it is species poor and associated more with partially shaded (i.e not open) sites.

*Each group is further divided into two subgroups ' Group A and Group B'* .

*Palustriella* dominated springs occurred across a range of geologies (not all Carboniferous Limestone) and also associated with a mixture of bedrock, superficial and made ground. Importantly active or historic tufa deposition was not observed at all sites. Visual estimates of flow varied but were frequently low and diffuse. Condition assessments suggest that all of the sites included within this study should be considered as being in both favourable ecological and hydrogeological condition.

# 1 Introduction

## Aims and scope of project

The aim of this project is to provide a baseline information resource for one of the least well known of the Annex I terrestrial wetland habitats in Wales, namely H7220 *Petrifying Springs with Tufa Formation* (Cratoneurion), required for Article 17 reporting. H7220 Petrifying springs with tufa formation (*Cratoneurion*) are 1 of 9 terrestrial wetland habitats listed in Annex I of the Habitats & Species Directive which occur in Wales. Sam Bosanquet and Dr Peter Jones of Natural Resources Wales (NRW) provided a list of sites and surveys of vegetation, water chemistry and hydrogeological risk assessments were carried out at each site. Inverterbrate surveys were not included as this report is designed for Article 17 reporting only.

## Background

Reporting on the status and condition of habitats listed in Annex I of the Habitats & Species Directive is a statutory requirement for the UK under Article 17 of the Directive. Every six years, member states of the European Union report on implementation of the Habitats Directive.

The Habitats Directive (HD) report focuses on a first assessment of conservation status of all habitats and species of community interest. The reporting format set by the European Commission requires a separate analysis for each species and each habitat in each biogeographic region. In the UK the reporting is the responsibility of the devolved administrations and the amalgamated report is coordinated by the Joint Nature Conservation Committee (JNCC). In Wales the habitats and species reports were compiled for the Welsh Government by the Habitat and Species specialists of the Countryside Council for Wales and are now the responsibility of Natural Resources Wales.

## Review of work to date

The second article 17 reporting round (JNCC, 2007) concluded that the overall assessment for H7220 in the UK was unfavourable – bad but improving. The lack of reliable information caused difficulties estimating the area covered by the habitat. The potential for many sites to exist outside of the statutory sites series was also highlighted as a potential problem.

The third round of article 17 reporting (Jones et al, 2013) draws on an improved, but still limited knowledge base in Wales for H7220. The report includes updates and additional information above what is included in earlier article 17 reports (JNCC, 2007). It is currently estimated that there is 5.5 ha covered by H7220 in Wales, however it is also acknowledged that this is based on best available evidence at the time of writing, and that further survey is likely to identify new areas of H7220 (Jones et al., 2013). The range, long term trends in status and total area can only be estimated and a range of potential pressures and unknown condition of many of the sites resulted in an unfavourable status for the Article 17 assessment (Jones et al., 2013).

# 2 Definition of petrifying springs with tufa formation (*Cratoneurion*)

The Interpretation Manual of European Union Habitats (European Commission, 2013) defines the Annex 1 habitat H7220 Petrifying springs with tufa formation (*Cratoneurion*) as:

i) Hard water springs with active formation of tufa. These formations are found in such diverse environments as forests or open countryside. They are generally small (point or linear formations) and dominated by bryophytes (*Cratoneurion commutati*);

lists the following associated plant species:

ii) Flowering plants: *Arabis soyeri, Pinguicula vulgaris, Saxifraga aizoides; Cochlearia pyrenaica* (in sites with heavy metals); *Carex appropinquata, Epilobium davuricum, Juncus triglumis* (in the Boreal region). Mosses: *Catoscopium nigritum, Palustriella commutata, Palustriella falcata, Cratoneuron filicinum, Eucladium verticillatum, Hymenostylium recurvirostrum* and *Hamatocaulis vernicosus, Philonotis calcarea, Scorpidium revolvens, S. cossonii, Palustriella decipiens, Bryum pseudotriquetum* (in the Boreal region); and

iii) confirms that this vegetation type corresponds (in the UK) to the UK National Vegetation Classification (NVC) types "M37 *Cratoneuron commutatum-Festuca rubra* spring community" and "M38 *Cratoneuron commutatum-Carex nigra* spring community" as described by Rodwell (1998).

For the purposes of this report, the pleurocarpous moss *Cratoneuron commutatum* comprises the two species *Palustriella commutata* (Hedw.) Ochya, J.Hattori Bot., 1989 and *Palustriella falcata* (Brid.) Hedenas, Bryophyte. Biblioth., 1992 (as described by Smith, 2004). Together these two species will often be referred to as *Palustriella* species or as *Palustriella* dominated vegetation. The ecology of these two species has been described by Hedenäs and Kooijman (2004).

Both M37 and M38 can also generally be considered analogous with the *Cratoneurion commutati community*, Koch 1928, a community recorded by a number of ecologists in EU member states and typically described as "calcareous spring communities commonly dominated by mosses".

As the European Commission has defined the Annex I habitat *H7220 Petrifying springs with tufa formation (Cratoneurion)* as *"*springs with active formation of tufa", the classification of sites in Wales is more complex than for some other Annex 1 habitats as it requires both an assessment or characterisation of both the vegetation structure (NVC) and hydrogeology (determining active formation of tufa).

JNCC (2001) provide an interpretation and summary of the floristic details of the M37 *Cratoneuron commutatum-Festuca rubra* and M38 *Cratoneuron commutatum-Carex nigra* spring communities and these can be summarised as follows:

M37 - Springs overwhelmingly dominated by *Palustriella* species with *Philonotis fontana* rare to occasional. *Sphagnum* species absent or occurring rarely at the margins. Small sedges are scarce and the diversity of vascular plants quite poor, but usually including *Cardamine pratensis, Festuca rubra* and *Agrostis stolonifera.*

M38 – Springs dominated by *Palustriella* species that are species rich, have frequent although sparce *Carex* spp. (especially *C. nigra*, *C. panicea* and *C. demissa). Sphagnum* species absent or occurring rarely at the margins. Diverse herbs including *Cardamine pratensis, Scorzoneroides autumnalis, Trifolium repens* and *Polygonum viviparum. Philonotis fontana* can be frequent in the moss carpet.

JNCC (2001) highlight that springs dominated by *Palustriella* and *Cratoneuron filicinum* also occur widely, but locally, in the British lowlands, and further sampling of these is needed.

Invertebrate surveys of calcareous (although not all tufa depositing) seepages (e.g. Goodfrey, 2009) show that these sites have a potential to provide habitats for UK BAP species, *Vertigo geyeri* (at Craig y Cilau – Waun Ddu) and *Lipsothrix nervosa*.

# 3 Processes of tufa formation and tufa classification

### Tufa or travertine?

The term 'tufa' is common in English speaking countries and a range of other names for tufa deposits occur across the world, the other most common being travertine. Pentecost (1995) offers a discussion on the merits of both terms (tufa and travertine) and recognises the need, but also the inherent difficulty, in undertakeing any classification that would clearly define one from the other. Although Pentecost (1995) goes on to use 'travertine' rather than tufa, we will take the opposite approach and use the word 'tufa' in recognition of the habitat type and classification agreed upon by the EU and the JNCC.

Pentecost (1995) also offers the most up to date definition of travertine (tufa);

*'A chemically-precipitated continental limestone formed around seepages, springs and along streams and rivers, occasionally in lakes and consisting of calcite or aragonite, of low to moderate intercrysalline porosity and often high mouldic or framework porosity within a vadose or occasionally shallow phreatic environment. Precipitation results primarily though the transfer (evasion or invasion) of carbon dioxide from or to a groundwater source leading to calcium carbonate supersaturation, with nucleation/crystal growth occurring upon a submerged surface'*

### Hydrogeochemistry of tufa deposition

Tufa formation is derived from the dissolution of rocks rich in calcium carbonate and can also be a significant hydrogeological characteristic of karst environments (Banks & Jones, 2012). These rocks will principally be limestone or other carbonate rich strata and several of the sites in this study are also heavily influenced by dissolution of calcium carbonate from unconsolidated lime spoil associated with historic limestone quarrying operations. A basic understanding of the hydrochemical process of tufa formation and the carbonate system is provided as a background to understanding how to geology and hydrogeology influences where the sites occur.

Precipitation provides effective recharge to aquifers in the form of rainfall or snow and ice melt, precipitation is also acidic and undersaturated with respect to calcium carbonate. During the recharge process, via the soil layer, superficial deposits and bedrock, dissolved carbon dioxide in the water can dissolve ions (cations and anions) including Ca, $HCO_3$, Mg, Na, K, and $SO_4$, Na and Cl often originating from marine aerosols, an effect observed on many coastal areas (e.g. WMC, 2008) and Islands (Webb, 2000). It is during this process that the more acidic recharge can dissolve calcium carbonate and other ions in the soils and bedrock, the water often referred to as 'attacking' (see Pentecost, 2005). The groundwater ultimately becomes supersaturated with respect to calcium bicarbonate creating the perfect conditions for tufa deposition. Groundwater will need to leave the aquifer, or interact with the atmosphere, in order to deposit tufa and this occurs where the piezometric head of the water (i.e. the water table) intersects the topographical land surface, in simple terms this is where springs and seepages often occur. The residence time (age) of groundwater within the various aquifers in this study has not been defined, however CFC and $SF_6$ aerosol analysis could provide information on the residence time of water supplying tufa springs in future projects.

Once the groundwater emerges at the surface, via a spring or seepage or as river baseflow, interactions with the atmosphere cause the loss or evasion of $CO_2$ and the resultant precipitation of calcium carbonate, as tufa:

$Ca_2+ + 2\ HCO_3- \leftrightarrow CaCO_3 + CO2 + H_2O$

**Tufa Classification**

Three main criteria for tufa classification exist; i) Geochemical - precipitation process and carbon dioxide geochemistry ii) Fabric and iii) Morphology (Pentecost & Viles, 1994).

i) Tufa can occur in two broad geochemical categories, either associated with thermal waters (thermogene) or meteoric waters (meteogene). Meteogene tufas are the most widely distributed (Pentecost & Viles, 1994) and cover all the examples within this report. Meteogene tufas can be distingused from thermogene tufas as they have different stable carbon isotope values (Pentecost & Viles, 1994).

ii) Tufa fabric can be visible with the naked eye (mesofabric) or in more detail under the microscope (microfabric). There are many factors that influence tufa fabrics including; temperature, flow rate, $CO_2$ evasion rate, supersaturation with respect to calcite, ion transport mechanisms, plant growth and animal burrows (Pentecost, 2005). Fabrics have also been the basis of several classification schemes which emphasize the influence of plants (Pentecost & Viles, 1994) on the the formation of a variety of tufa fabrics. Bryophytes and algae can influence tufa fabrics through the trapping and binding of calcite (Pentecost, 1993).

iii) Tufa morphologies, unlike most erosional or destructive land surface processes are frequently constructive in nature (Pentecost, 2005). There have been many different attempts to classify tufa deposits from all around the world, however these are of limited use to this study. The most applicable work to this project is a paper titled 'British travertines: a review' (Pentecost, 1993).

| **Classification** | **Type** | **Description from Pentecost (1993)** |
|---|---|---|
| Deposits on gentle slopes (*c.* <10°) | Paludal | Surface coatings of tufa on vegetation, marshy locations or alluvial valley bottoms |
| Deposits on steep slopes (*c.* >10°) | Cascades | On waterfalls and steep ground |
| | Barages | Spanning streams or rivers (e.g. Nash Brook S Wales) |
| | Stream spring crusts | Irregular sometimes nodular deposits on river beds |
| | Laucustrine | Rare and no examples in Wales (see Malham Tarn) |
| | Cemented rudites | Infill between detrital rocks such as breccias and scree |
| | Perched springline | Dominated by bryophytes |
| Clastic Deposits | | Re-deposited material (Nash Brook, Caerwys and Ddol – Clwyd) |

**Table 1 Classification of autochthonous tufa depsoits in the UK after Pedley (1990) and Pentecost (1993)**

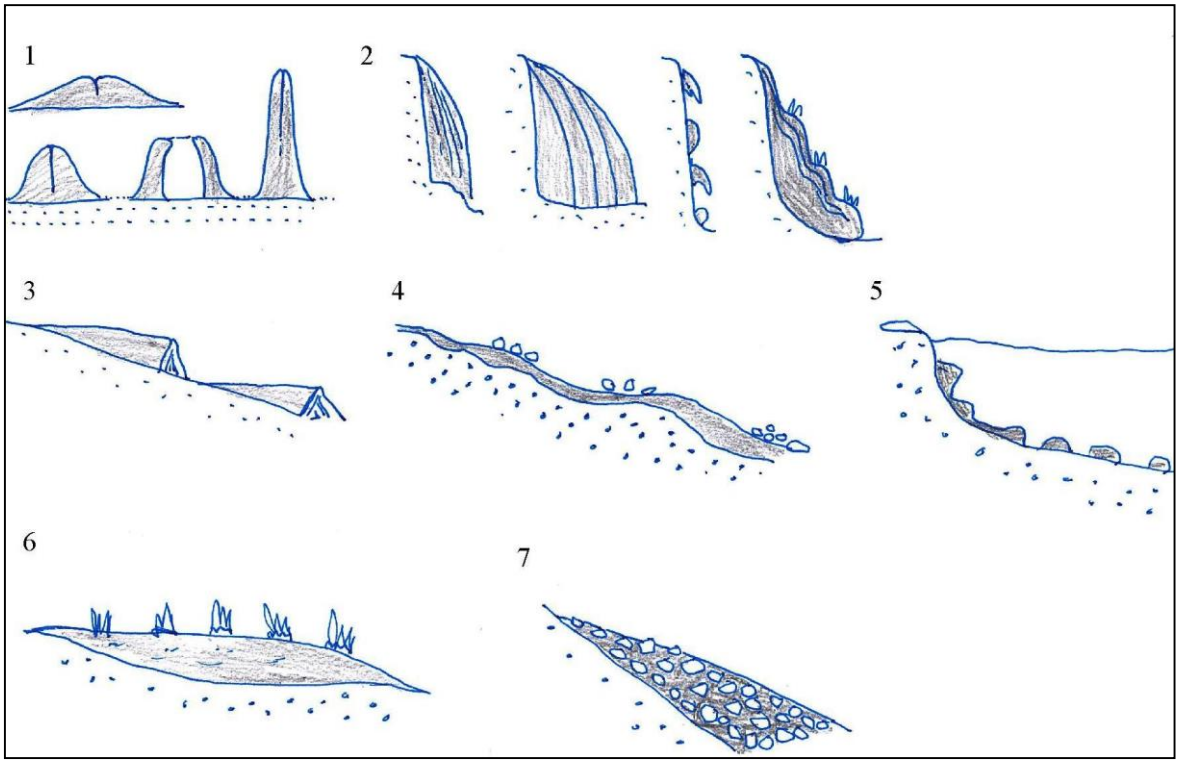



**Figure 1 Sectional drawings of autochthonous travertines (tufa) 1) Spring mounds, 2) cascades 3) barrages 4) fluvial crusts 5) laucstrine crusts 6) paludal deposits 7) surface cemented rudites after Pentecost & Viles (1994)**

# 4 Selection of H7220 Petrifying springs with tufa formation (*Cratoneurion*) by other EU member states

Since the recent publication of the Interpretation Manuel of European Union Habitats (European Commission, 2013), a number of recent and relevant ecological studies provide for the selection of H7220 Petrifying springs in a small number of EU member states. These studies are either existing (i.e. relevant to the selection of H7220 springs) or were undertaken very near to publication of the interpretation manual (i.e. pre-emptive to the duty to select H7220 springs).

These studies have all followed the European Commission's Interpretation Manuel in selection of H7220 springs in that all sites selected (or surveyed or characterised) were "springs with active formation of tufa"

The following two studies (in particular) highlight the difficulties in selecting H7220 springs within different EU member states when there are local differences in geology, types of site (such as Boreal mountain, wooded and stream side), occurrence and types of tufa deposition, natural occurrence of key plant species that characterise the vegetation type:

**Ireland** – all sites described had actively forming tufa accumulations associated with bryophytes (usually *Palustriella commutata)* with many sites in woodland and/or associated with streams. Most of the tufa formations (relating with certainty to Carboniferous Limestone glacial drift but perhaps also calcareous strata within the Old Red Sandstone) are described as 'cascades' (formed by water flowing or trickling down a slope) and associated formations (Heery, 2007).

**Netherlands** – "Tufa formation associated with hard-water springs is very rare in the Netherlands. The potential area of H7220 is naturally limited by specific geological and hydrological conditions and thus restricted to areas underlain by limestone or other calcareous rocks. Only in Limburg does groundwater rich in calcium carbonate come to the surface, allowing deposits of tufa to be formed.

The overall quality of the habitat varied considerably from one place to another, as well as within sites. Ninety-six of the investigated springs (34 percent) failed to qualify as H7220, and the quality of over 50% of the 187 springs that did qualify was poor, mostly as a result of desiccation or due to a tufa coverage far below the minimum of 10 m². Springs with extensive tufa banks and tufa cascades are restricted to the Bunder- en Elsloërbos wood and the Noorbeemden/Hoogbos wood, both Natura 2000 sites. The quality of habitat type H7220 in the Geuldal valley and several smaller sites is far lower, though some good examples of petrifying springs with tufa were observed near Vliek and Waterval.

Among the qualifying species, *Brachythecium rivulare* and *Cratoneuron filicinum* appeared to be very common. The very rare *Palustriella commutata* was only found in springs in the Bunder- en Elsloërbos and Noorbeemden/Hoogbos woods, where extensive stands of *Palustriella commutata* were identified as Cratoneurion, an underestimated and so far under described bryophyte syntaxon in the Netherlands". (K. van Dort *et al.,* 2012).

# 5 Survey methodology

### Site walkover

The first stage of every site visit involved a site walkover, by both the hydrogeologist (Gareth Farr) and the bryologist (Jonathan Graham). The ecological boundary of each site was then delimited by focusing on homogenous vegetation dominated by the pleurocarpous moss *Palustriella commutata* (incl. *P. falcata*). The conjectural hydrological boundary (surface water catchment and groundwater catchment) of each site was considered.

### Vegetation

A complete species list was obtained for each site and the occurrence of each species recorded using the DAFOR scale. Particular note was made of species occurring at very low frequency (less than 1% cover) including species such as Creeping Bent *Agrostis stolonifera*, Yorkshire Fog *Holcus lanatus* as such species are negative indicator species for the purposes of Common Standards condition assessment when occurring in M37/M38 flushes (JNCC 2009).

Flowering plants, bryophytes and lichens were identified (where possible) in the field but where there was uncertainty, specimens were collected and determined microscopically. All records of algae were determined microscopically.

The location of species of note **or** species occurring locally within a site **or** species occurring in discrete locally dominant patches were more precisely noted. This included prominent cushion-forming mosses such as *Hymenostylium recurvirostrum*, locally dominant stands of the large pleurocarpous moss *Scorpidium scorpioides* as well as various flowering plants (such as Fools Water-cress *Apium nodiflorum*, Marsh St John's-wort *Hypericum elodes*, Bog Pondweed *Potamogeton polygonifolius*) which were often confined to narrow surface water runnels.

A detailed map was drawn in the field for each site noting locations of individual spring heads, runnels and tufa, and particular effort was made to accurately delimit areas of *Palustriella* dominated vegetation.

**Topographical survey**

Using a portable real time Lecia 'Smart Rover' GPS unit, location (x,y) and elevation in maOD (z) were recorded for key features. Survey points focused upon key features of each site including, location and elevation of spring heads, transects and site transects to calculate slope, key areas of vegetation and other markers such as river water levels. The location and elevation data were then corrected using OS RINEX (Receiver Independent Exchange Format) base station data from South Wales stations that allows the post processing of survey data to produce a more accurate result. Sufficient elevation readings were taken at each site in order to be able to calculate slope.

**Figure 2 Surveying using the Leica Smart Rover** (Blaen Onnen nr SN157170)

**Hand auger, soil samples and HCI**

Using an Eijkelkamp™ soil auger with a 150mm head samples were taken at selected locations within each site in order to define if tufa was present and if so what was its thickness relationship to underlying deposits. The sensitive nature of these protected sites ensured that any hand auguring was undertaken with extreme care, to protect both the bryophytes and the geological conservation features. At Herberts Quarry - Foel Fawr (Mynydd Ddu SSSI) site we did not auger directly into the tufa formation as this is a key part of the Geological SSSI, and would have resulted in damage to the site. In many places at Herberts Quarry (Foel Fawr) there are opportunities to observe areas of tufa that have been eroded or downcut but water runoff, and these locations allow you to measure the depth of the tufa deposits, without damaging the site.

At some sites where the presence or absence of tufa needed to be confirmed (e.g Clydach Bridge) then hand auguring was undertaken, with descriptions of the soil being made, and photographs obtained. Where the sites were extremely sensitive (e.g Hen Allt Common, McWalters Dingle) or the tufa deposit was on a vertical face then no hand augering was undertaken. Using a small vile of HCI (hydrochloric acid) the superficial deposits and soil in the hand auger, were tested for any reaction representative of a high calcium carbonate content (represented by 'fizzing' of the HCI on the carbonate material).

## In-situ water quality readings

In-situ water quality field readings for temperature $^{o}$C, pH, specific electrical conductivity uS/cm, dissolved oxygen % and mg/l and ORP mV were collected using a YSI$^{TM}$ Professional Plus hand held meter. The YSI$^{TM}$ meter was successfully calibrated daily for dissolved oxygen and then using two pH solutions (pH 4.23 and pH 7.6), the calibration results are included within the Appendix.

| Parameter | **Range** | **Accuracy** | **Resolution** |
|---|---|---|---|
| pH | -2.60 to 16.60 | ±0.1 mV (0.01 pH units) | 0.1 mV (0.01 pH units) |
| ORP | -1999 to +1999 mV | ±0.5 mV | 0.1 mV |
| Conductivity | 0.0 to 200 mS/cm | ±0.1% FS ±1 digit for µS/cm to 0.1 mS/cm | 0.0001 mS/cm or 0.1 |
| Dissolved Oxygen | 0.00 to 90 mg/L; 0 to 550% | ±0.2% FS (550% air saturation) ±1 digit (with 1.25 PE membrane at 10°C) | 0.01 mg/L; 0.1% air saturation |
| Temperature | -10 to 100.00°C | ±0.2% FS ±1 digit | 0.1°C |

**Table 2YSI Professional Hand Held Meter, Range, Accuracy and Resolution**

Field water quality readings were obtained from the inflows, outflows, main runnels, and along small transects within each site, and ecological and general observations were made to complement each reading. To obtained defensible field readings the YSI$^{TM}$ meter was submerged, preferably within the area of flowing water, and left for at least 5 minutes until the readings stabilised. During this time the Leica GPS unit was used to obtain a 10 figure grid reference and elevation value. Care was taken to ensure the probes were completely submerged within the water to avoid erroneous readings.

**Figure 3 YSI Professional Series Fieldmeter in situ until the readings have stabilised. Foel Fawr Site 2 FF2.13 NGR SN7344419167.**

**Water Quality Samples & Flow estimates**

Water chemistry samples were collected at each site for analysis of a pre determined suite of analytes. Analysis was undertaken at the Natural Resources Wales Lab, accredited by UKAS to the current EN ISO 17025 standard. During the project the NRW labs suffered a malfunction of some key equipment and back up samples for nutrients and selected ions were sent and anylised by Alcontrol Laboratories (UKAS accredited). Samples were collected from spring inflows, runnels or outflows in conjunction with in situ water quality parameters and notes on the vegetation. It is important to note that water chemistry were NOT collected from pure stands of key species as this was outside of the scope of this project. Once the YSI™ meter had stabilised three bottles a General 1 l plastic, Metals 125ml and Dissolved Metals 125ml were filled, using great care to select only the desired water. A disposable plastic 50ml syringe and a 0.45micron filter were used to remove any metals not in solution. The samples were returned to the closest Natural Resources Wales office within 24 hours (often much sooner) to be refrigerated and transported to the Laboratory for analysis. The corresponding field readings, time, and NGR were recorded on the paperwork for each sample. Where possible a visual flow estimate in l/s was made. Alkalinity was not recorded in the field and was undertaken as a lab based analysis as per NRWs sampling regime, however future surveys may consider in situ field readings of alkalinity.

**Transects**

Where it was possible a transect was selected at a site, often perpendicular to a runnel, where the microtopography and vegetation showed obvious changes. Each transect was between 1-2m in length and was selected on the basis of having visible changes in vegetation as well as including some *Palustriella* dominated vegetation. Once the transect was identified a measuring tape was laid out across the area and 4-5 sample points were located.

The sample points each reflect a change in vegetation for instance from an elevated *Sphagnum* hummock to the transition zone near the runnel or the open runnel itself. Working from left to right water was collected from the bryophytes, by squeezing a small sample, and a 50ml 'calibration cup' was filled. This calibration cup screws directly onto the base of the YSI™ field meter, allowing readings to be obtained for temperature, pH, EC us/cm, DO% and mg/l and ORP mV. This method was repeated across the transect with the aim of showing how water quality (especially pH) could change across a very small transect. Where the site was vertical e.g. on a cliff face or there was not enough moss to squeeze a sample of water from or the site was too fragile a transect was not undertaken.

**Catchment assessment**

For each site an assessment of potential or actual pressures was undertaken within the conjectural catchment. An assessment of the following was made; vegetation condition, on site or other drainage, abstraction, poaching by wild or livestock animals, damage from direct human activity and fencing or lack of fencing. Potential sources of enrichment were assessed and the general surrounding land use was recorded with any point sources for nutrients identified (i.e septic tanks, slurry etc).

# 6 Site Descriptions

A list of potential sites (see below) was provided by NRW based on the occurrence of *Palustriella* dominated vegetation, the presence of tufa or NVC M37 community, a vegetation type known to occur widely in Wales based on preliminary NRW surveys. Descriptions of the sites are provided in the following sub chapters.

| **Site** | **1:50K Geology** | **Tufa forming?** |
|---|---|---|
| Foel Fawr Site 1 | Carboniferous Limestone – Dowlais Limestone Formation | Yes |
| Foel Fawr Site 2 | Carboniferous Limestone – Dowlais Limestone Formation | Yes |
| Foel Fawr: Moel Gornach | Carboniferous Limestone – Dowlais Limestone Formation | v.small area |
| Foel Fawr: Brest Rhiw | Carboniferous Limestone – Dowlais Limestone Formation | Yes |
| Pont Clydach | Lower Devonian Old Red Sandstone – Brownstones Formation | No |
| Blaen Onnen | Carboniferous Limestone - Abercriban Oolite Subgroup | Yes |
| Llyn y Fan Fach | Lower Devonian Old Red Sandstone – Brownstones Formation underlain by the Lower Devonian Senni Formation | v.small on one plant |
| Cwm Clydach | Carboniferous Limestone – Castell Coch Limestone formation | Yes |
| Waun Ddu / Craig y Cilau | Carboniferous Limestone sequence (Pembroke and Avon Group) overlying Devonian Qtz conglomerate and brownstones | No |
| Tarren y Esgob | Lower Devonian Old Red Sandstone, Senni Formation calcrete horizon | Yes |
| Hen Allt Common | Devonian Raglan Mudstone Formation calcrete horizon | Yes |
| Cors Erdderiniog | Junction of Carboniferous Clwyd Limestone Group overlying the Lligwy Sandstone | Yes |
| Fedw Fawr Beach | Carboniferous Clwyd Limestone Group Loggerheads Limestone formation (includes sandstone in cliff section) | Yes |
| Ddol Uchaf | Quaternary Tufa Deposit underlain by Silurian Elwy formation | Yes |
| Mc Walters Dingle | Carboniferous Pennine Lower Coal Measures Formation | Yes |
| Nant Peris | Ordovician Snowdon Volcanic Group | No |

**Table 3 List of sites and geology**

## 7.1 FOEL FAWR SITES 1&2, BREST RHIW AND MOEL GORNACH

### 7.1.1 **Introduction**

Foel Fawr, including Herbert's Quarry, is located north of Brynamman (SN7313319125) on land owned by the Brecon Beacons National Park (BBNP). The area has been designated as a SSSI (Mynydd Ddu) for its geological interest and it is also located within the Fforest Fawr Geopark area. Herbert's quarry is a post industrial site that has been quarried extensively for lime and agricultural quick lime since pre-industrial times and increased in the 19$^{th}$ century to supply demand for lime flux in iron production (Andrews et al., 1997). The high pH waters (recorded up to pH 12.2 in this study) can be considered hyperalkaline and are the result of dissolution of lime spoil (Andrews et al., 1997). Foel Fawr sites 1 & 2 and Brest Rhiw are all located within close proximity of the lime spoil and have thus been included together, where as Moel Gornach acts as a natural comparison being located away from the historic mining area and spoil. There is significant tufa deposition at Foel Fawr Sites 1&2 and Brest Rhiw with limited more localised tufa deposition at Moel Gornach.

### 7.1.2 **Geological and hydrogeological data**

The main historic quarrying operations are concentrated within the Carboniferous Dowlais Limestone Formation with large areas of unconsolidated lime spoil deposited on the northern flank of Foel Fawr and elsewhere below the main quarries. Recharge occurs from precipitation on the topographically higher ground above the lime spoil. Springs and seepages occur at the base of the lime spoil and also at or near where the Carboniferous Limestone contacts with the Avon Group (lower limestone shales). It is below the area of lime spoil where the tufa deposits are more concentrated and they are strongly associated with the historic dumping of lime waste in the area. Surface water flows to the north via several small unnamed streams and the Cwm Nant-dywyll, all which cut down into the underlying Devonian Old Red Sandstone before joining the Afon Clydach.

**Foel Fawr Site 1:** two water quality samples were obtained, FF1.1'downstream' and FF1.6 'upstream'. Both samples are dominated by calcium and bicarbonate ions, however the ion balance for both samples was over the recommended 10% limit. Neither sample contained elevated nutrients in the form of nitrate and phosphate. The most notable changes, possibly related to the deposition of $CaCO_3$ and associated ions from solution as tufa between the upsteam sample (location 6) and the downstream sample (FF1.1) are the reduction in the following:

Hardness (as $CaCO_3$ mg/l) from 1490mg/l to 183mg/l

Calcium from 594 mg/l to 71.7mg/l

Magnesium from 360 to 32.9ug/l

Manganese from 360 -32.9ug/l and

Iron from 1910 to 32.9ug/l

pH readings in the field range from 11.42pH (location 8) at the top of the site near the inflow and become less alkaline as you walk down through the site to 8.22pH (location 9).

**Foel Fawr Site 2:** four water quality samples were obtained from sites FF2.1, FF2.2, FF2.3 and FF2.4. All samples were dominated by calcium and bicarbonate ions, however the ionic balance for sample FF2.4 was over the recommended 10% limit. All four samples contained very little evidence of nutrient enrichment, with most samples below the limit of detection for nitrate and phosphate. The waters at the base of the spoil (Sites FF2.1) had a pH value of 12.2.

**Brest Rhiw:** one complete sample and one nutrient only sample were collected at Brest Rhiw, like the samples at Foel Fawr Sites 1&2 calcium and bicarbonate are the dominant ions and there is only a small amount (1.64mg/l $NH_4$), with a more neutral pH value of 7.32.

**Moel Gornach:** two samples were obtained from sites MG1.3 (top of the site) and MG1.1 (towards the base of the site). Unlike Foel Fawr 1 & 2 and Brest Rhiw there is no lime spoil in the area of Moel Gornach and there is also less tufa deposition, with only a very small amount observed forming near the spring head. Both samples were dominated by calcium and bicarbonate ions and both have pH values > 8. The upland setting and low intensity land use is reflected by the low level of nutrients within both samples, many below or close to the lower limits of detection.

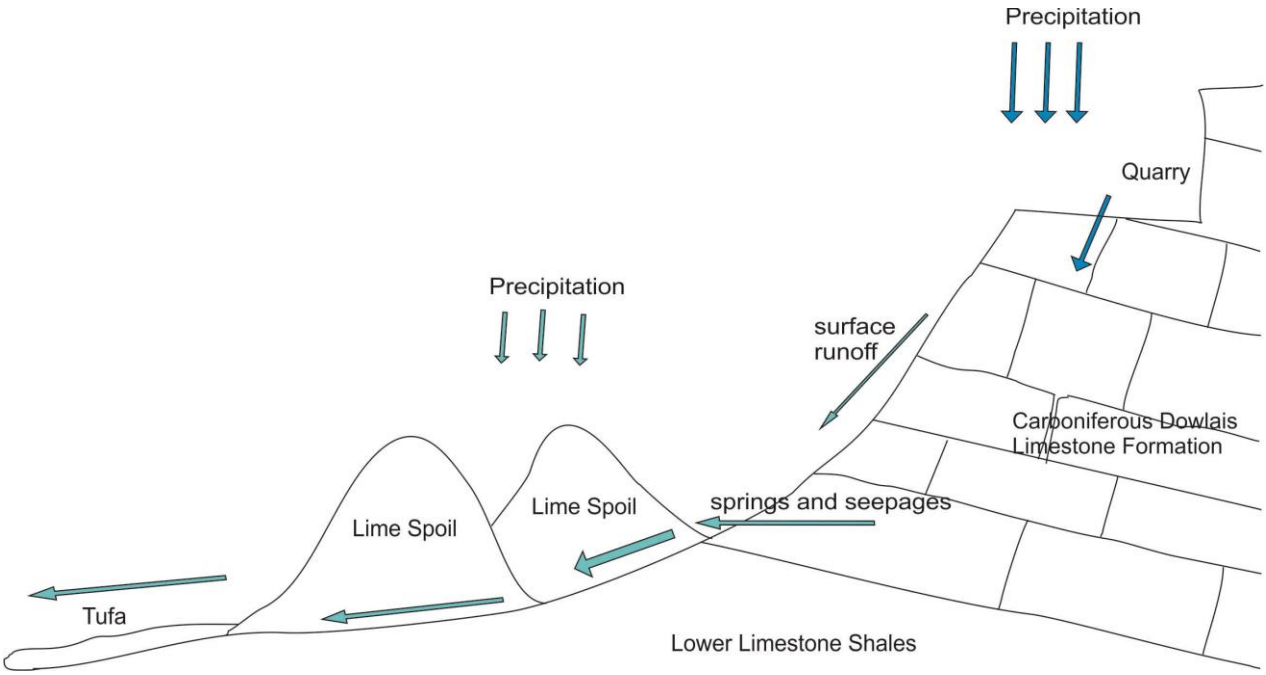



**Figure 4 Foel Fawr initial site conceptual model**

### 7.1.3 **Land use and pressures**

**Foel Fawr (sites 1 & 2)** are located near a car park, main road and footpath into Herberts Quarry, and as a result there was some localised littering but no evidence of damage from walking or disruption of the site. The land surrounding the site is sheep and horse grazed. There is no evidence of substantial poaching, burning or obvious signs of nutrient enrichment at any part of the site. It is unlikely that there are any groundwater or surface water abstractions in the immediate area. The site could receive runoff from the adjacent road and there is a possible road drain in the southwest corner of the site. Significant negative indicator species such as *Agrostis stolonifera* display <1% cover.

**Brest Rhiw** is located adjacent to the main road and has similar issues to Foel Fawr, in that the land is open for walkers and grazing animals although there was no sign of substantial poaching, burning or nutrient enrichment.

**Moel Gornach** is located further away from the main road and receives less footfall from walkers. The area is open for grazing although there was no sign of substantial poaching, burning or nutrient enrichment.

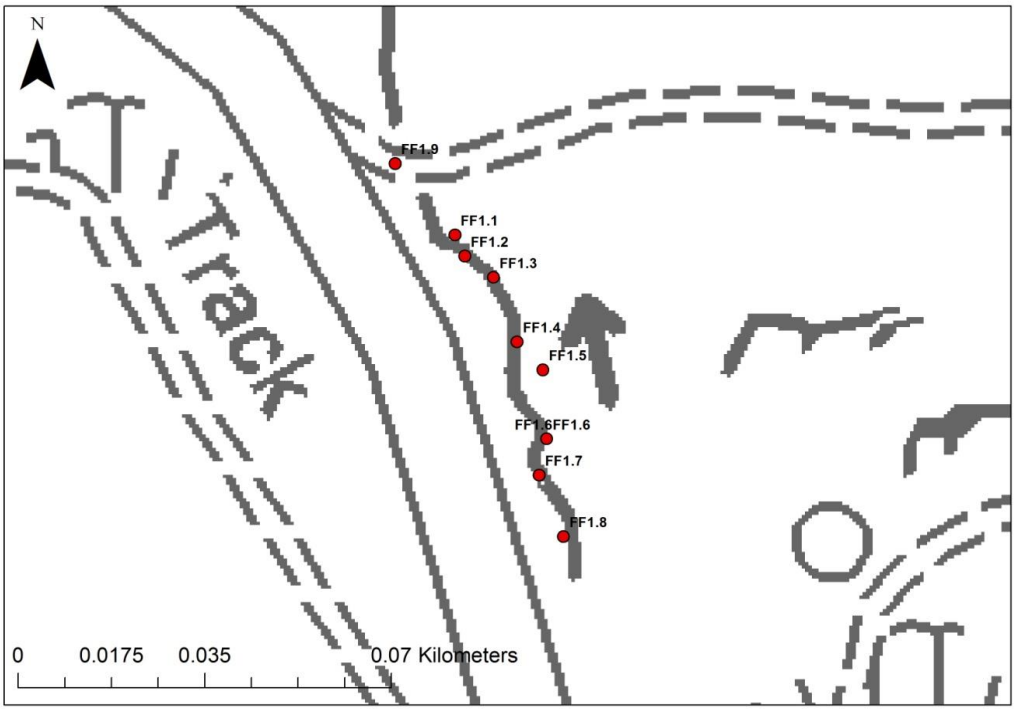



**Figure 5 Foel Fawr Site 1 Ordnance Survey map and GPS survey points. © Ordnance Survey.**

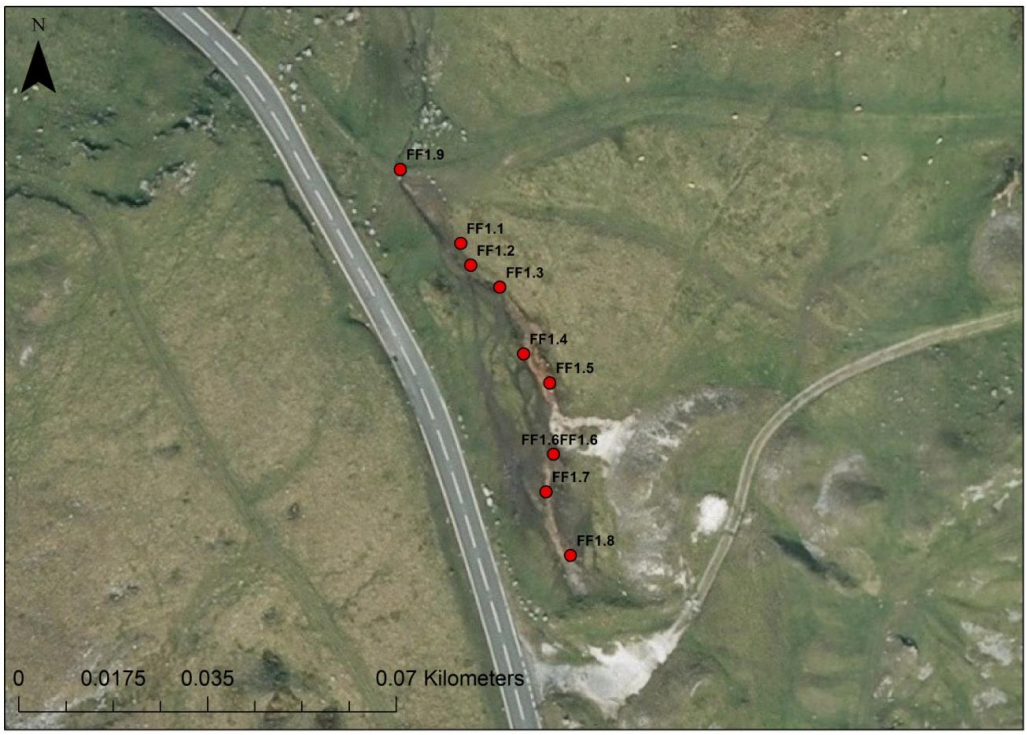



**Figure 6 Foel Fawr Site 1 Aerial photograph © UKP/Getmapping Licence No. UKP2006/01**

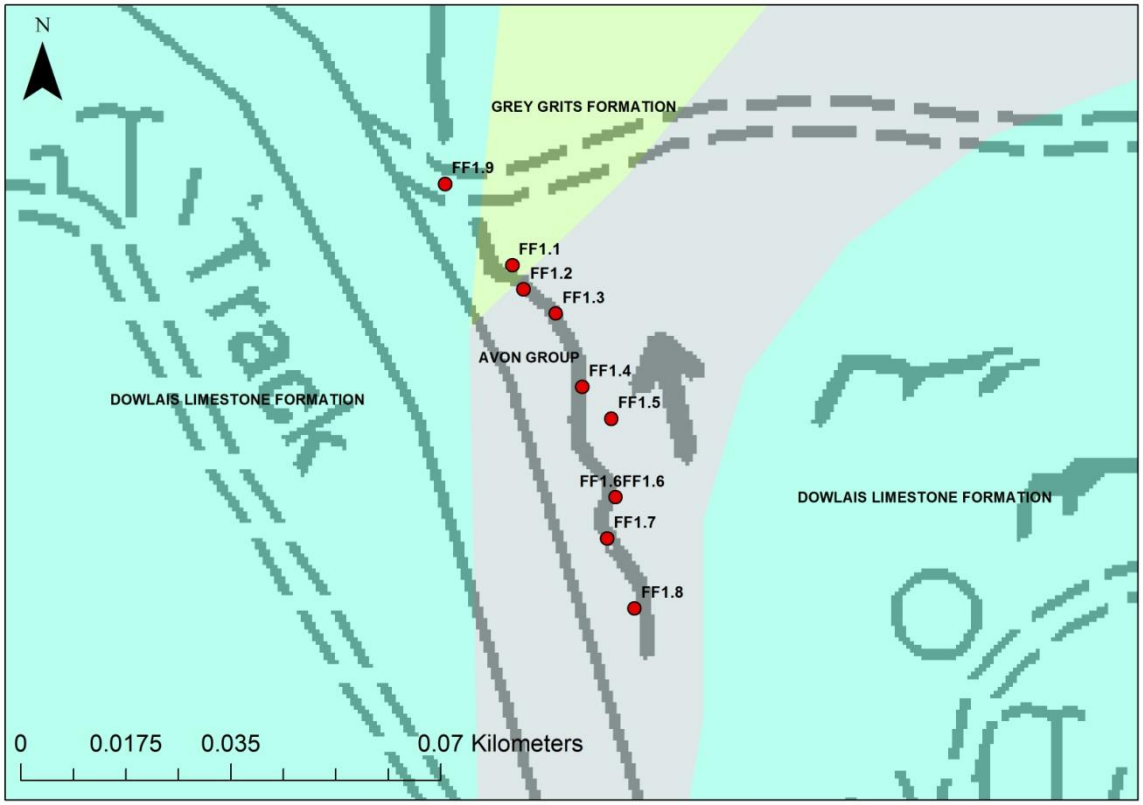
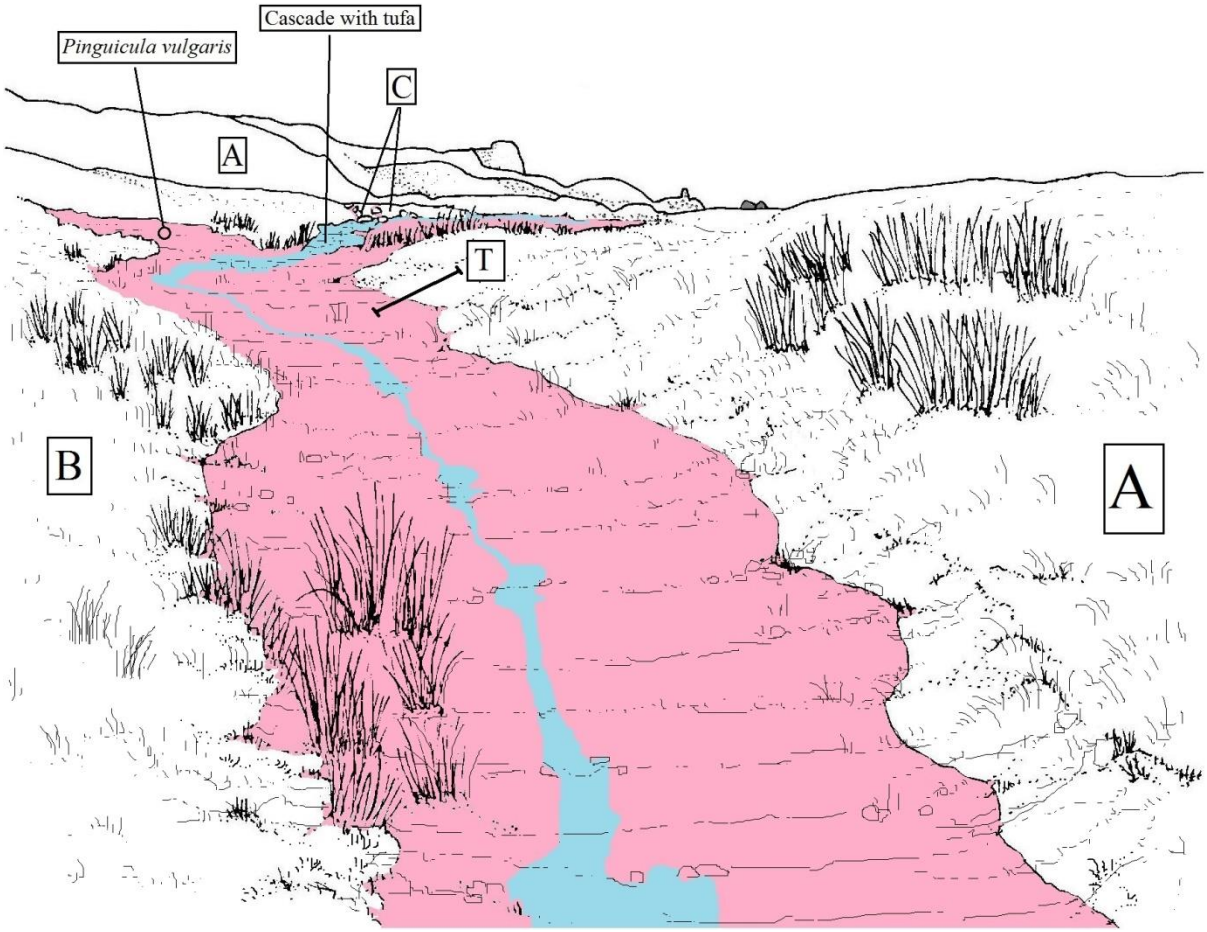



**Figure 7 Foel Fawr site 1, 1:50,000 Bedrock Geology. ©BGS © Ordnance Survey.**

| Survey Site | Survey Ref | Date | Temperature of Water | SEC | Ammoniacal Nitrogen as N | Nitrogen, Total Oxidised as N | Nitrate as NO3 | Nitrate as N | Nitrite as N | Hardness, Total as CaCO3 | Alkalinity to pH 4.5 as CaCO3 | Chloride | Orthophosphate, reactive as P | Orthophospahte as PO4 | Sulphate as SO4 | Phosphate :- {TIP} |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CEL | uS/Cm | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l |
| Foel Fawr Site 1 | FF1.1 | 24/11/2013 | 1.90 | 166.5 | <0.03 | 0.35 | | 0.35 | <0.004 | 182 | 73 | 6.4 | <0.02 | | <10 | <0.02 |
| Foel Fawr Site 1 | FF1.6 | 24/11/2013 | 2.30 | 199.3 | <0.03 | 0.25 | | 0.25 | <0.004 | 1490 | 62 | 6.0 | <0.02 | | <10 | 0.03 |

| Survey Site | Survey Ref | Date | Sodium | Potassium | Magnesium | Calcium | Redox Potential : In Situ | pH : In Situ | Manganese | Iron | Manganese, Dissolved | Iron, Dissolved | Ionic Balance | Bicarbonate as HCO3 | Oxygen, Dissolved, % Saturation | Oxygen, Dissolved as O2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/l | mg/l | ug/l | mg/l | mV | pH | ug/l | ug/l | ug/l | ug/l | % | mg/l | % | mg/l |
| Foel Fawr Site 1 | FF1.1 | 24/11/2013 | 3.7 | 0.56 | 0.84 | 71.7 | 51.2 | 8.22 | 32.90 | 248 | <10 | 38.90 | 34.20 | 89 | 116.8 | 16.2 |
| Foel Fawr Site 1 | FF1.6 | 24/11/2013 | 3.5 | 0.69 | 1.40 | 594.0 | 12.3 | 9.63 | 360.00 | 1910 | <10 | <30 | 89.60 | 76 | 102.9 | 14.1 |

**Figure 8 Foel Fawr Site 1 Water quality data. The red boxes indicate that an ionic balance >10% was reported for both samples.**




| | |
|---|---|
| | *Palustriella* dominated vegetation |
| | Tufa/ surface runnel |
|  | *Juncus effusus* beds |
| T | Transect |

| | |
|---|---|
| A | Acid grassland |
| B | Calcareous grassland (on limestone spoil) |
| C | Rocks & lumps of tufa (within area of flush/spring but above level of seepage water) |

**Figure 9 Foel Fawr Site 1 Vegetation map**

### 7.1.4 **Vegetation (spring)**

*Palustriella falcata* dominated short vegetation (between 1-3cm height) with *Scorpidium cossonii* locally dominating margins of runnels (or hollows where there is movement of water). Cushions of *Hymenostylium recurvirostrum* and locally *Eucladium verticillatum* are associated with exposed tufa. *Pinguicula vulgaris* occurs in one place.

| | | | |
|---|---|---|---|
| *Agrostis stolonifera* | R (<1%) | *Juncus acutiflorus* | F |
| *Aneura pinguis* | F | *Juncus effusus* | R (<1%) |
| *Bellis perennis* | O | *Jungermannia atrovirens* (per.) | A |
| *Bryum dichotomum* | R | *Leicolea badensis* | F |
| *Bryum pseudotriquetrum* | O | *Nostoc sp.* | R |
| *Calliergonella cuspidata* | R | *Palustriella commutata* | O |
| *Campylium protensum* | R | *Palustriella falcata* | A |
| *Campylium stellatum* | F | *Philonotis calcarea* | F |
| *Cardamine pratensis* | R | *Philonotis fontana* | R |
| *Carex demissa* | O | *Pinguicula vulgaris* | R |
| *Carex flacca* | F | *Plantago lanceolata* | R |
| *Carex nigra* | R (<1%) | *Pressia quadrata* | R |
| *Cirsium palustre* | R | *Prunella vulgaris* | R |
| *Climacium dendroides* | R (<1%) | *Ranunculus acris* | R (<1%) |
| *Cratoneuron filicinum* | O | *Ranunculus flammula* | R |
| *Ctenidium molluscum* | R (<1%) | *Riccardia multifida* | R (<1%) |
| *Didymodon fallax* | R (<1%) | *Sagina cf nodosa* | O |
| *Eucladium verticillatum* | O | *Scorpidium cossonii* | O |
| *Festuca ovina* | R (<1%) | *Scorzoneroides autumnalis* | R |
| filamentous algae (Chlorophyta) | R | *Taraxacum sp.* | R (<1%) |
| *Fissidens adianthoides* | O | | |
| *Hymenostylium recurvirostrum* | F | | |

**Table 4 Foel Fawr Site 1 Species list – *Palustriella* dominated vegetation**

Mainly calcareous rocks and older tufa deposits within the area of flush/spring but above the level of seepage water supporting a small number of acrocarpous calcareous bryophyte species.

| | |
|---|---|
| *Didymodon rigidulus* | O |
| *Ditrichum gracile* | R (<1%) |
| *Fissidens dubius* | R (<1%) |

**Table 5 Foel Fawr Site 1 Species list – Rocks and lumps of tufa (within area of flush/spring but above level of seepage water**

### 7.1.5 Vegetation (adjoining spring)

Upland acid grassland to 25cm height (*Nardus stricta, Hylocomium splendens, Dicranum scoparium, Galium saxatile, Potentilla erecta, Rhytidiadelphus squarrosus, occasional Vaccinium myrtillus*).

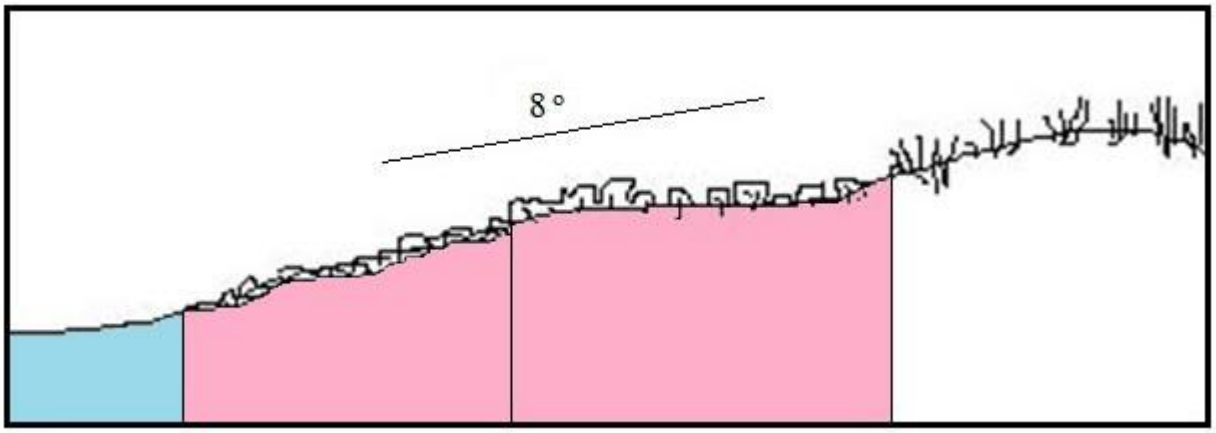
| | |
|---|---|
| *Hylocomium splendens* | F |
| *Dicranum scoparium* | O |
| *Nardus stricta* | A |
| *Galium saxatile* | O |
| *Potentilla erecta* | R |
| *Vaccinium myrtillus* | R |
| *Scleropodium purum* | R |
| *Juncus effusus* | R (<1%) |

**Table 6 Foel Fawr Site 1 Species list – Acid grassland**

Short sheep and horse grazed calcareous grassland (to 5 cm height) dominated by *Ctenidium molluscum* on old mining spoil.

| | |
|---|---|
| *Agrostis stolonifera* | O |
| *Bellis perennis* | R |
| *Ctenidium molluscum* | A |
| *Cynosurus cristatus* | O |
| *Plantago lanceolata* | O |
| *Rhytidiadelphus squarrosus* | R |
| *Thymus polytrichus* | R (<1%) |
| *Trifolium repens* | O |

**Table 7 Foel Fawr Site 1 Species list – Calcareous grassland (on mining spoil)**




| | | | |
|---|---|---|---|
| Open water<br>Tufa | *Palustriella falcata*<br>*Scorpidium cossonii*<br>Exposed tufa | *Anagallis tenella*<br>*Carex flacca*<br>*Palustriella falcata* | *Juncus squarrosus*<br>*Nardus stricta*<br>*Potentilla erecta*<br>*Sphagnum subnitens* |
| No field readings for pH or EC collected at first transect | | | |

**Figure 10 Foel Fawr Site 1 Transect vegetation and chemistry data**

**Central channel - looking from lowest part of site up slope (south)**

**Upper part of site (looking up slope)**

**Spring heads at top of site looking north**

**Thick tufa deposit (cascade) - central part of site**

**Side flush - central part of site**

**Figure 11 Foel Fawr Site 1 Photographs**

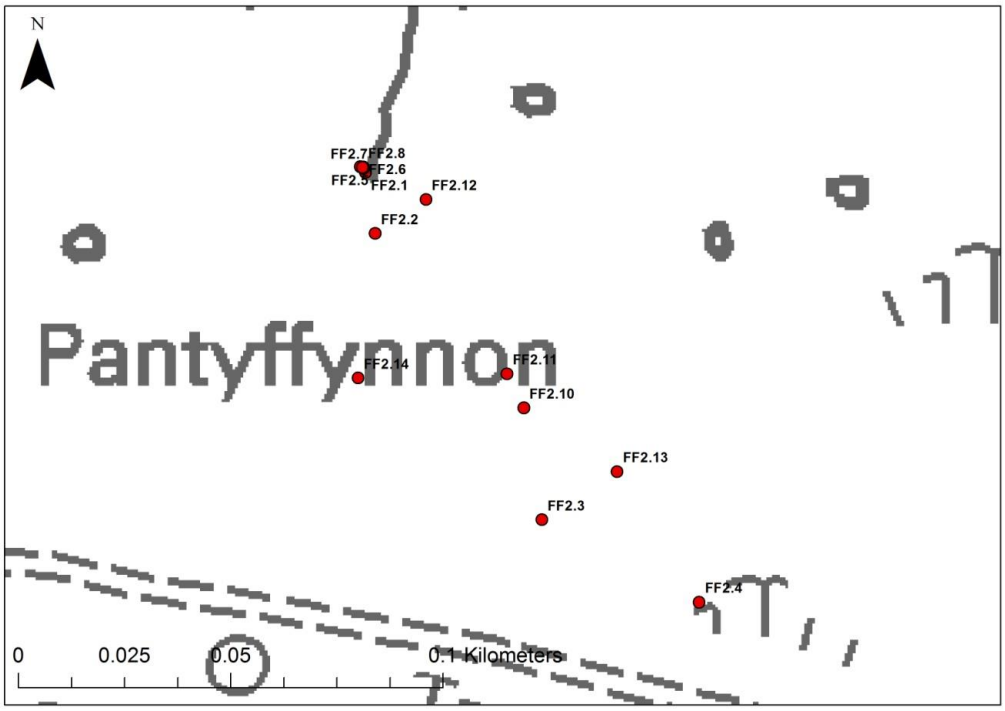



**Figure 12 Foel Fawr Site 2 OS Location Map and GPS survey points. © Ordnance Survey.**

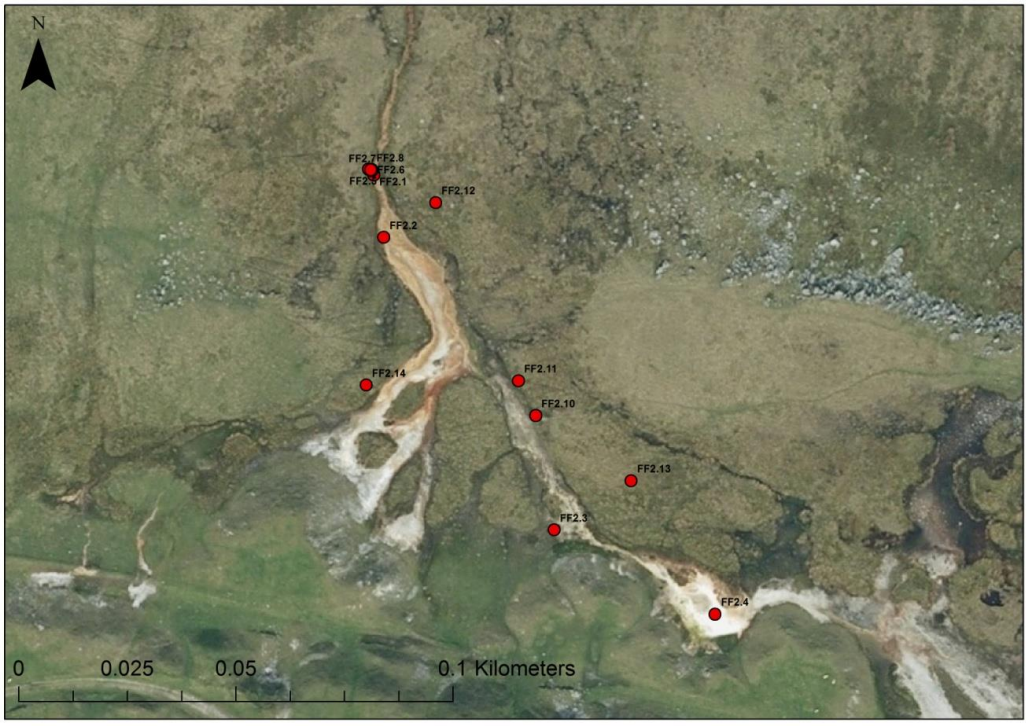



**Figure 13 Foel Fawr Site 2 aerial photograph and GPS survey pointsFoel Fawr Site 2**

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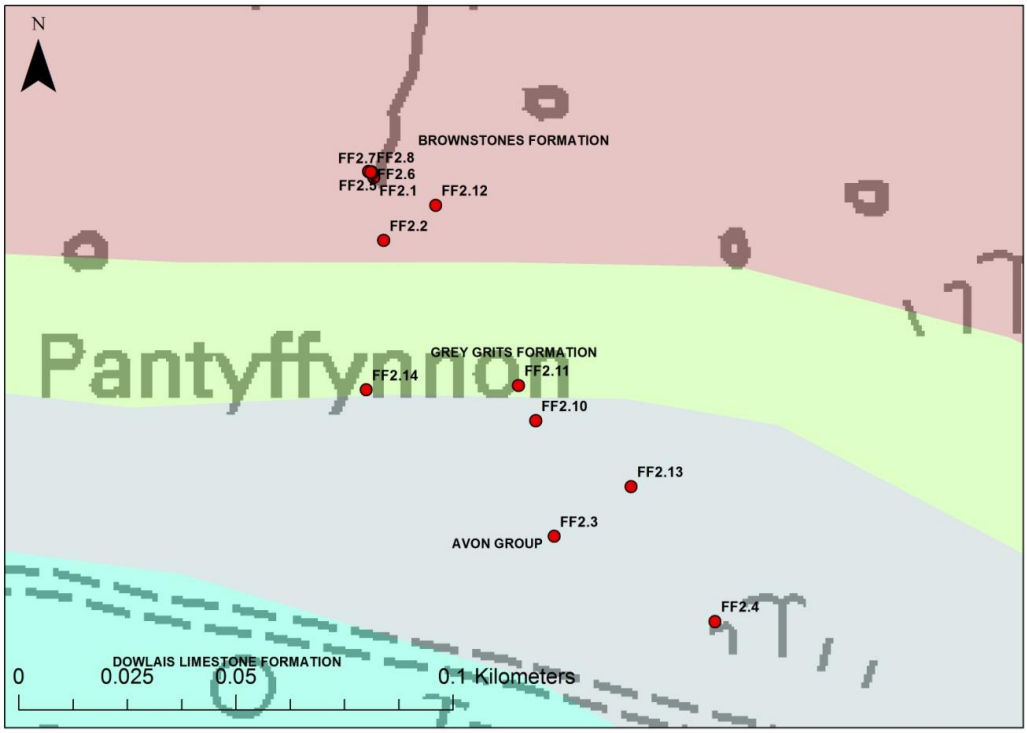
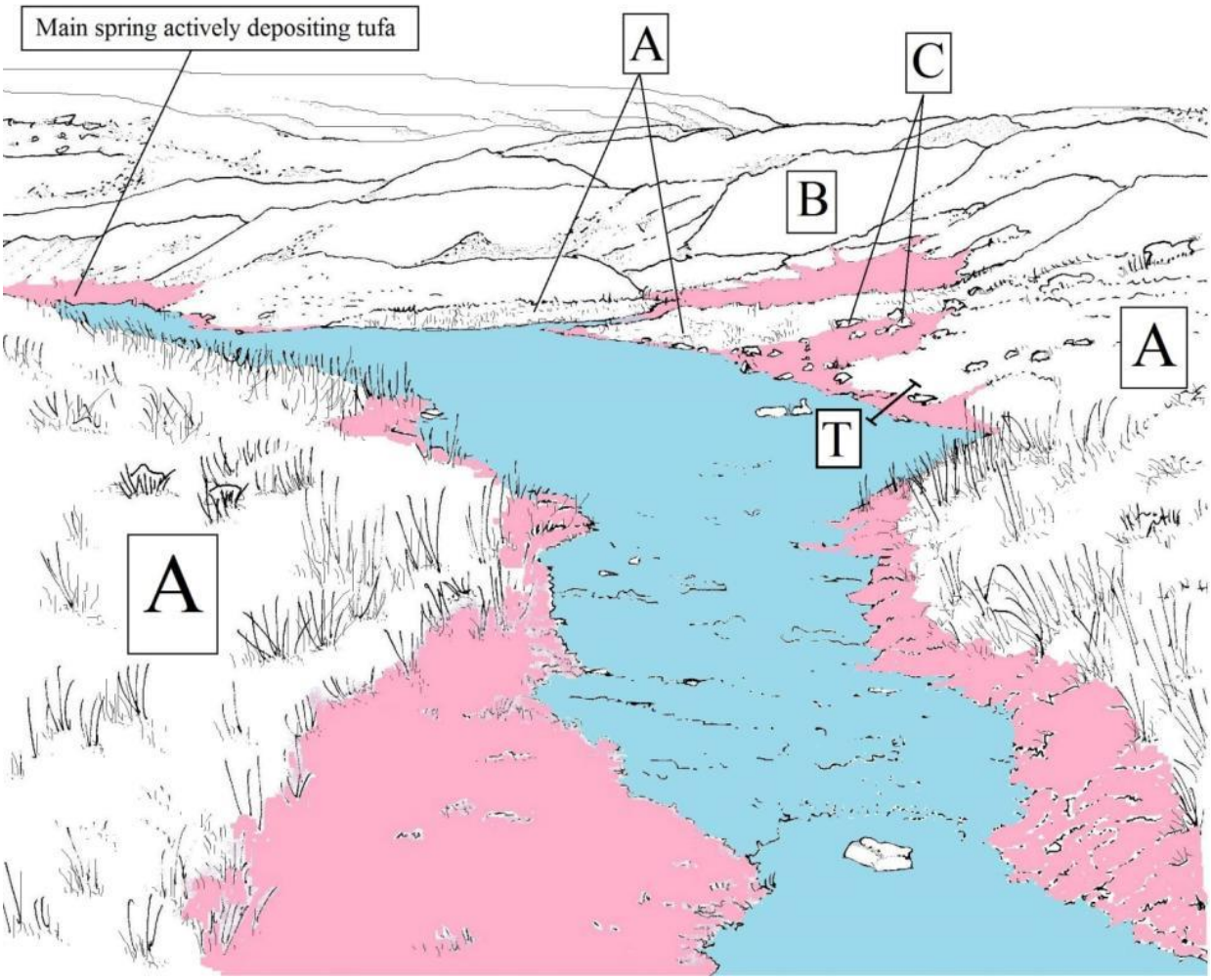



**Figure 14 Foel Fawr Site 2 1:50,000 Bedrock Geology Map. ©BGS. ©Ordnance Survey.**

| Survey Site | Survey Ref | Date | Temperature of Water CEL | SEC uS/Cm | Ammoniacal Nitrogen as N mg/l | Nitrogen, Total Oxidised as N mg/l | Nitrate as NO3 mg/l | Nitrate as N mg/l | Nitrite as N mg/l | Hardness, Total as CaCO3 mg/l | Alkalinity to pH 4.5 as CaCO3 mg/l | Chloride mg/l | Orthophosphate, reactive as P mg/l | Orthophospahte as PO4 mg/l | Sulphate as SO4 mg/l | Phosphate :- {TIP} mg/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Foel Fawr Site 2 | FF2.1 | 24/11/2013 | 5.30 | 860.0 | 0.31 | 0.25 | | 0.20 | 0.05 | 354 | 342 | 5.7 | <0.02 | | 13.20 | <0.02 |
| Foel Fawr Site 2 | FF2.2 | 24/11/2013 | 8.50 | 235.7 | <0.03 | 0.32 | | 0.32 | <0.004 | 107 | 116 | 5.9 | <0.02 | | <10 | <0.02 |
| Foel Fawr Site 2 | FF2.3 | 24/11/2013 | 4.20 | 197.4 | 0.04 | <0.2 | | <0.196 | <0.004 | 119 | 77 | 6.1 | <0.02 | | <10 | <0.02 |
| Foel Fawr Site 2 | FF2.4 | 24/11/2013 | 5.50 | 182.0 | <0.03 | 0.22 | | 0.22 | <0.004 | 147 | 78 | 5.8 | <0.02 | | <10 | <0.02 |

| Survey Site | Survey Ref | Date | Sodium mg/l | Potassium mg/l | Magnesium ug/l | Calcium mg/l | Redox Potential : In Situ mV | pH : In Situ pH | Manganese ug/l | Iron ug/l | Manganese, Dissolved ug/l | Iron, Dissolved ug/l | Ionic Balance % | Bicarbonate as HCO3 mg/l | Oxygen, Dissolved, % Saturation % | Oxygen, Dissolved as O2 mg/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Foel Fawr Site 2 | FF2.1 | 24/11/2013 | 2.5 | 1.02 | 0.39 | 141.0 | -44.6 | 12.20 | <10 | <30 | <10 | <30 | -0.64 | 417 | 72.3 | 9.2 |
| Foel Fawr Site 2 | FF2.2 | 24/11/2013 | 3.1 | 0.56 | 1.24 | 40.7 | 2.9 | 8.79 | 40.30 | 257 | <10 | <30 | -8.72 | 142 | 103.2 | 12.1 |
| Foel Fawr Site 2 | FF2.3 | 24/11/2013 | 3.2 | 0.49 | 0.83 | 46.3 | 7.3 | 9.45 | 45.50 | 124 | <10 | <30 | 13.30 | 94 | 102.1 | 13.3 |
| Foel Fawr Site 2 | FF2.4 | 24/11/2013 | 3.0 | 0.51 | 1.39 | 56.7 | 14.9 | 9.12 | <10 | 91 | <10 | <30 | 22.70 | 95 | 101.9 | 12.8 |

**Table 8 Foel Fawr Site 2 Water quality data**




| | |
|---|---|
| | *Palustriella* dominated vegetation |
| | Tufa/ surface runnel |
| | *Juncus effusus* beds |
| T | Transect |

| | |
|---|---|
| A | Acid grassland |
| B | Calcareous grassland (on limestone spoil) |
| C | Rocks & lumps of tufa (within area of flush/spring but above level of seepage water) |

**Figure 15 Foel Fawr Site 2 Vegetation map**

### 7.1.6 **Vegetation (spring) of Foel Fawr site 2**

*Palustriella falcata* dominated short vegetation between 1-3cm height with *Scorpidium cossonii* locally dominating margins of runnels (or hollows where there is movement of water). Cushions of *Hymenostylium recurvirostrum* and locally *Eucladium verticillatum*, *Gymnostomum aeruginosum* are associated with exposed tufa. *Scorpidium scorpioides* occurs locally.

| | | | |
|---|---|---|---|
| *Agrostis stolonifera* | R (<1%) | *Juncus effusus* | O |
| *Anagallis tenella* | R | *Jungermannia atrovirens* | A |
| *Aneura pinguis* | F | *Leicolea badensis* | O |
| *Bellis perennis* | R | *Leicolea bantriensis* | R |
| *Bryum dichotomum* | R | *Moerckia flotoviana* | R |
| *Bryum pseudotriquetrum* | O | *Nostoc sp.* | O |
| *Calliergonella cuspidata* | O | *Palustriella commutata* | O |
| *Campylium stellatum* | O | *Palustriella falcata* | D |
| *Cardamine pratensis* | O | *Pellia endiviifolia* | R |
| *Carex demissa* | F | *Philonotis calcarea* | F |
| *Carex flacca* | F | *Philonotis fontana* | O |
| *Carex nigra* | R (<1%) | *Pinguicula vulgaris* | R |
| *Cirsium palustre* | R | *Plagiomnium ellipticum* (non fertile) | R |
| *Climacium dendroides* | R (<1%) | *Plantago lanceolata* | R |
| *Cratoneuron filicinum* | F | *Pressia quadrata* | O |
| *Ctenidium molluscum* | R (<1%) | *Prunella vulgaris* | R |
| *Dicranella varia* (spor.) | O | *Ranunculus acris* | R (<1%) |
| *Equisetum cf variegatum* | R (<1%) | *Ranunculus flammula* | R |
| *Eucladium verticillatum* | R | *Riccardia multifida* | R |
| *Festuca ovina* | R | *Rivularia haematites* | R |
| *Ficaria verna* | O | *Scorpidium cossonii* | O |
| filamentous algae (Chlorophyta) | O | *Scorpidium scorpioides* | R |
| *Fissidens adianthoides* | O | *Scorzoneroides autumnalis* | R |
| *Galium palustre ssp. palustre* | O | *Taraxacum sp.* | R |
| *Gymnostomum aeruginosum* | O | *Trifolium repens* | R (<1%) |
| *Hymenostylium recurvirostrum* | F | *Tussilago farfara* | R (<1%) |
| *Juncus acutiflorus* | F | | |

**Table 9 Species list – Palustriella dominated vegetation**

Mainly calcareous rocks and older tufa deposits within the area of flush/spring but above the level of seepage water supporting a small number of acrocarpous calcareous bryophyte species.

| | |
|---|---|
| *Ditrichum gracile* | R (<1%) |
| *Fissidens dubius* | R (<1%) |
| *Schistidium sp.* | R |

**Table 10 Species list – Rocks and lumps of tufa (within area of flush/spring but above level of seepage water)**

### 7.1.7 **Vegetation (adjoining spring) of Foel Fawr site 2**

Upland acid grassland to 25cm height (*Nardus stricta, Hylocomium splendens, Dicranum scoparium, Galium saxatile, Potentilla erecta, occasional Vaccinium myrtillus*). Ocassional small hummocks occur comprised of *Aulocomnium palustre*, *Sphagnum subnitens* or *Polytrichum commune*.

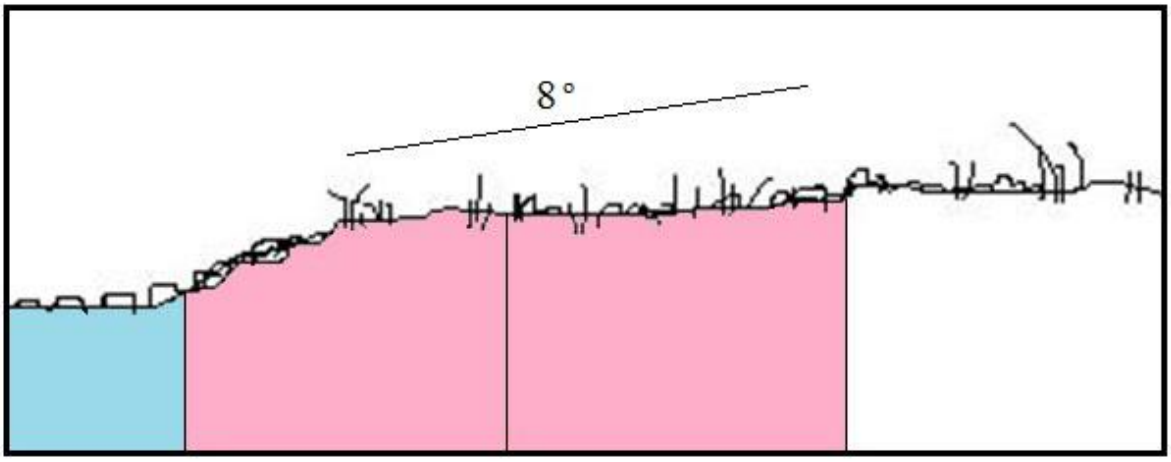
| | |
|---|---|
| *Aulocomnium palustre* | R |
| *Dicranum scoparium* | O |
| *Galium saxatile* | O |
| *Hylocomium splendens* | O |
| *Hypnum jutlandicum* | O |
| *Juncus effusus* | O |
| *Juncus squarrosus* | R |
| *Nardus stricta* | F |
| *Pleurozium schreberi* | R |
| *Polytrichum commune* | R |
| *Potentilla erecta* | R |
| *Sphagnum subnitens* | R |
| *Vaccinium myrtillus* | R |

**Table 11 Species list – Acid grassland**

Short sheep and horse grazed calcareous grassland (to 5cm height) dominated by *Ctenidium molluscum* with occasional *Thymus* on old mining spoil.

| | |
|---|---|
| *Agrostis stolonifera* | O |
| *Bellis perennis* | R |
| *Ctenidium molluscum* | A |
| *Cynosurus cristatus* | O |
| *Plantago lanceolata* | R |
| *Prunella vulgaris* | R |
| *Rhytidiadelphus squarrosus* | R |
| *Scorzoneroides autumnalis* | R |
| *Thymus polytrichus* | R (<1%) |
| *Trifolium repens* | R (<1%) |

**Table 12 Species list – Calcareous grassland (on mining spoil)**




| | | | |
|---|---|---|---|
| *Open water* | *Palustriella falcata*<br>*Scorpidium cossonii*<br>Exposed tufa | *Jungermannia atrovirens*<br>*Anagallis tenella*<br>*Carex flacca*<br>*Palustriella falcata* | *Juncus squarrosus*<br>*Nardus stricta*<br>*Potentilla erecta*<br>*Sphagnum subnitens* |
| *pH8.94*<br>EC188.3 | pH7.74<br>EC165.5 | pH6.93<br>EC182.7 | pH6.32<br>EC116 |

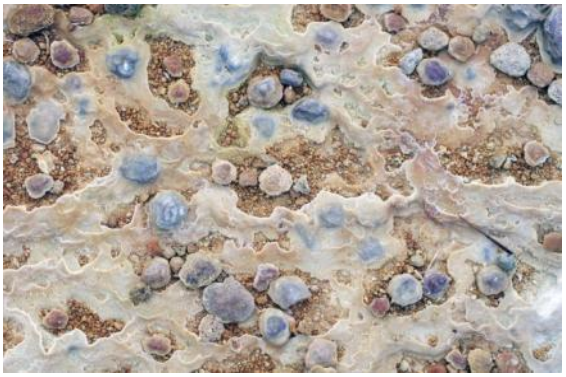
**Figure 16 Foel Fawr Site 2 Transect vegetation and chemistry**

Central channel - looking up slope (south)

Upper spring head with luxuriant growth of *Palustriella comutata*, *Cratoneuron filicinum*, *Philonotis fontana*.

Upper part of site with extensive tufa deposits

Main upper Spring feeding site (highly saturated with calcium carbonate and forming tufa)



Tufa deposits in upper part of site

**Figure 17 Foel Fawr Site 2 Photographs**

### 7.1.8 **Condition assessment**

The overall assessment is that Foel Fawr (sites 1 & 2) should be classified as as being in favourable ecological and hydrogeological condition.

## 7.2 BREST RHIW

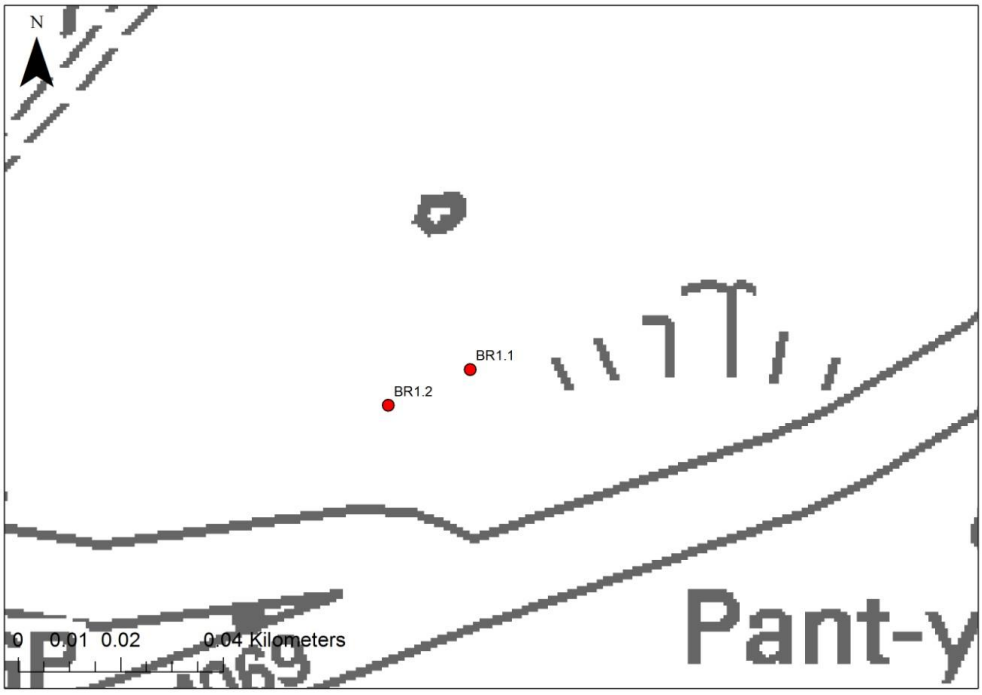



**Figure 18 Brest Rhiw Ordnance Survey map and GPS survey points ©Ordnance Survey.**


**Figure 19 Brest Rhiw Aerial photograph © UKP/Getmapping Licence No. UKP2006/01**


**Figure 20 Brest Rhiw Bedrock Geology 1:50,000. ©BGS. ©Ordnance Survey.**

| Survey Site | Survey Ref | Date | Temperature of Water | SEC | Ammoniacal Nitrogen as N | Nitrogen, Total Oxidised as N | Nitrate as NO3 | Nitrate as N | Nitrite as N | Hardness, Total as CaCO3 | Alkalinity to pH 4.5 as CaCO3 | Chloride | Orthophosphate, reactive as P | Orthophospahte as PO4 | Sulphate as SO4 | Phosphate :- {TIP} |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CEL | uS/Cm | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l |
| Brest Rhiw 1 | BR1.1 | 19/01/2014 | 9.7 | 633.8 | 1.64 | 0.11 | 0.48 | | <0.0152 | 337 | 115 | 29.1 | <0.02 | <0.05 | 25.1 | <.02 |
| Brest Rhiw 2 | BR1.2 | 19/01/2014 | | | <0.2 | 0.32 | 1.38 | | <0.0152 | | 130 | 83.1 | <0.02 | <0.05 | | |

| Survey Site | Survey Ref | Date | Sodium | Potassium | Magnesium | Calcium | Redox Potential : In Situ | pH : In Situ | Manganese | Iron | Manganese, Dissolved | Iron, Dissolved | Ionic Balance | Bicarbonate as HCO3 | Oxygen, Dissolved, % Saturation | Oxygen, Dissolved as O2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/l | mg/l | ug/l | mg/l | mV | pH | ug/l | ug/l | ug/l | ug/l | % | mg/l | % | mg/l |
| Brest Rhiw 1 | BR1.1 | 19/01/2014 | 13.0 | 1.05 | 4.85 | 127.0 | 22.6 | 7.23 | <10 | 153 | <10 | <30 | 1.66 | 312 | 80.7 | 9.2 |
| Brest Rhiw 2 | BR1.2 | 19/01/2014 | | | | | | | | | | | | | | |

**Table 13 Brest Rhiw water quality**

### 7.2.1 **Vegetation (spring) of Brest Rhiw**

*Palustriella falcata* dominated short vegetation between 1-3cm height. *Palustriella commutata* forms locally dominant patches around two rocky spring heads which are the source of the flushed vegetation. The lower part of the site has a wide band of old and eroded tufa which has frequent cushions of *Hymenostylium recurvirostrum* and locally dominant patches of *Jungermannia atrovirens, Preissia quadrata*.

| | | | |
|---|---|---|---|
| Agrostis stolonifera | R (<1%) | Juncus acutiflorus | F |
| Anagallis tenella | R | Juncus effusus | R (<1%) |
| Aneura pinguis | F | Jungermannia atrovirens | A |
| Bellis perennis | O | Leicolea badensis | O |
| Bryum pseudotriquetrum | R | Nostoc sp. | O |
| Calliergonella cuspidata | R | Palustriella commutata | O |
| Campylium stellatum | F | Palustriella falcata | A |
| Cardamine pratensis | O | Pellia endiviifolia | R |
| Carex demissa | O | Philonotis calcarea | O |
| Carex flacca | F | Philonotis fontana | O |
| Cerastium cf glomeratum | R (<1%) | Plantago lanceolata | R |
| Cirsium palustre | R | Pressia quadrata | F |
| Climacium dendroides | R (<1%) | Prunella vulgaris | R |
| Cratoneuron filicinum | O | Ranunculus acris | R |
| Ctenidium molluscum | R | Ranunculus repens | R (<1%) |
| Cynosurus cristatus | R (<1%) | Rhytidiadelphus squarrosus | R (<1%) |
| Festuca ovina | R | Scorpidium cossonii | F |
| filamentous algae (Chlorophyta) | A | Taraxacum sp. | R |
| Fissidens adianthoides | O | Trifolium repens | R (<1%) |
| Holcus lanatus | R (<1%) | Veronica beccabunga | R |
| Hymenostylium recurvirostrum | F | | |

**Table 14Species list – Palustriella dominated vegetation**

A mixture of calcareous rocks and tufa within the area of flush/spring but above the level of seepage water and supporting a small number of acrocarpous calcareous bryophyte species.

| | |
|---|---|
| *Ctenidium molluscum* | R (<1%) |
| *Ditrichum gracile* | R |
| *Schistidium sp.* | R |

**Table 15 Species list – Rocks and lumps of tufa (within area of flush/spring but above level of seepage water)**

### 7.2.2 **Vegetation (adjoining spring) of Brest Rhiw**

Upland acid grassland to 20cm height (*Nardus stricta, Agrostis capillaris)* with extensive rush pasture dominated by *Juncus effusus, Calliergonella cuspidata* with scattered *Juncus acutiflorus.*

| | |
|---|---|
| *Agrostis capillaris* | R |
| *Calliergonella cuspidata* | F |
| *Juncus acutiflorus* | R |
| *Juncus effusus* | A |
| *Nardus stricta* | R |

**Table 16 Species list – Acid grassland and rush pasture**

Short sheep grazed calcareous grassland (to 5 cm height) dominated by *Ctenidium molluscum* with occasional *Thymus* on old mining spoil.

| | |
|---|---|
| *Achillea millefolium* | O |
| *Agrostis stolonifera* | R |
| *Bellis perennis* | R |
| *Carex cf caryophyllea* | R |
| *Ctenidium molluscum* | A |
| *Cynosurus cristatus* | O |
| *Leontodon cf saxatilis* | R |
| *Plantago lanceolata* | O |
| *Thymus polytrichus* | O |
| *Trifolium repens* | O |

**Table 17 Species list – Calcareous grassland (on mining spoil)**

### 7.2.3 **Transect vegetation and chemistry data**

A transect was not undertaken at Brest Rhiw.

### 7.2.4 **Condition assessment**

The overall assessment is that Brest Rhiw should be classified as being in favourable ecological and hydrogeological condition.

Top spring head (left) - looking south (up slope)

Top spring head (right) - looking south (up slope)

Petrified *Palustriella falcata* (actively forming tufa), top spring head (right).

Middle section of site showing main runnel from spring head (right) - looking north (down slope)

downslope edge of limestone spoil heap

Lower part of site with wide band of deposited (and often eroded) tufa. Note main runnel (fed by both spring heads) to right hand side and dominant marginal stands of rush pasture.

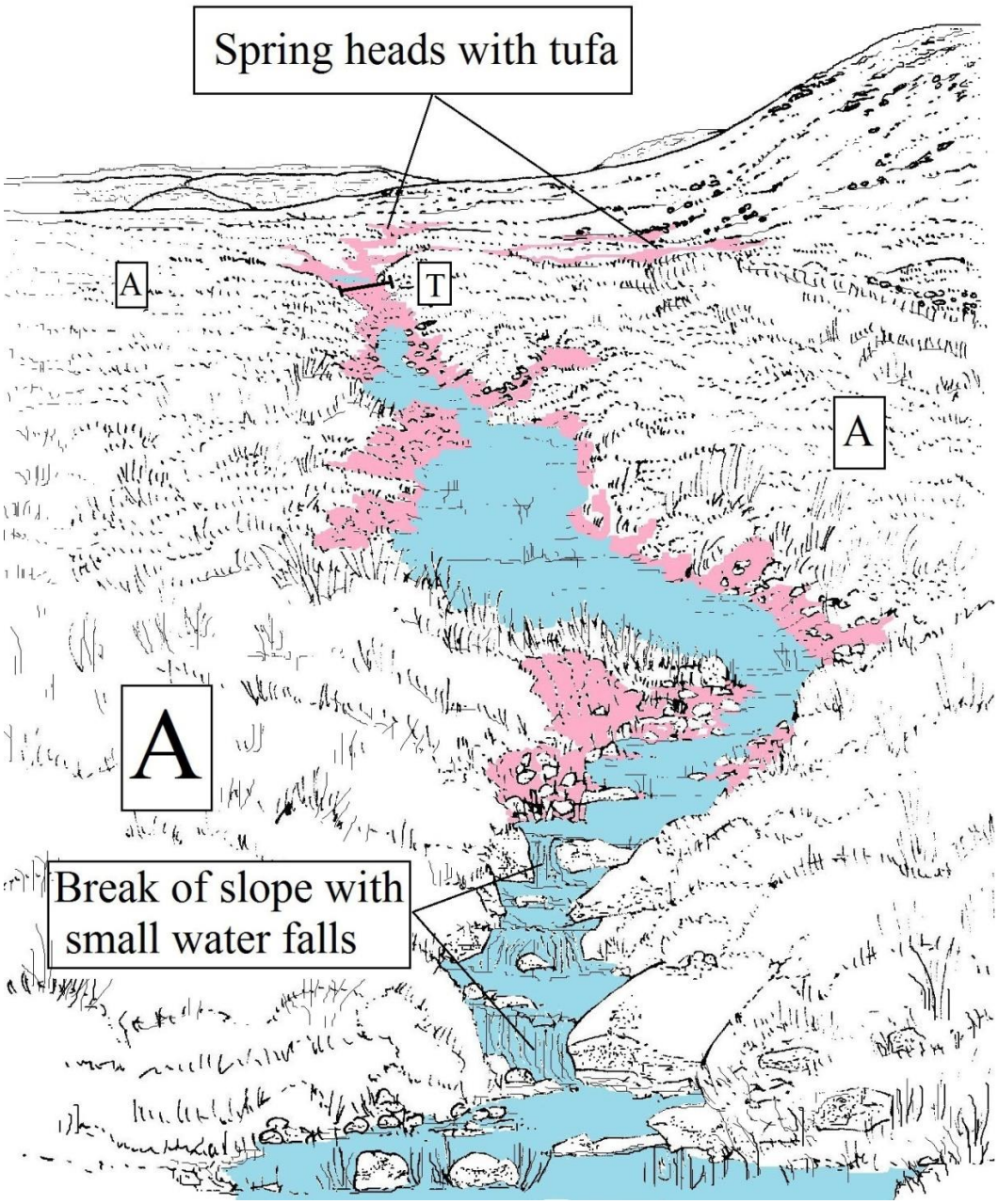
**Figure 21 Brest Rhiw photographs**

## 7.3 MOEL GORNACH

| Survey Site | Survey Ref | Date | Temperature of Water | SEC | Ammoniacal Nitrogen as N | Nitrogen, Total Oxidised as N | Nitrate as NO3 | Nitrate as N | Nitrite as N | Hardness, Total as CaCO3 | Alkalinity to pH 4.5 as CaCO3 | Chloride | Orthophosphate, reactive as P | Orthophospahte as PO4 | Sulphate as SO4 | Phosphate :- {TIP} |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CEL | uS/Cm | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l |
| Moel Garnach 1 (bottom of site) | MG1.1 | 19/01/2014 | 5.8 | 197.8 | <0.2 | 0.20 | 0.87 | | <0.0152 | 105 | 85 | 8.1 | <0.02 | <0.05 | <10 | <.02 |
| Moel Garnach 2 (top of site) | MG1.3 | 19/01/2014 | 5.2 | 307.8 | <0.2 | 0.28 | 1.23 | | <0.0152 | 131 | 90 | 10.4 | <0.02 | <0.05 | <10 | 0.059 |

| Survey Site | Survey Ref | Date | Sodium | Potassium | Magnesium | Calcium | Redox Potential : In Situ | pH : In Situ | Manganese | Iron | Manganese, Dissolved | Iron, Dissolved | Ionic Balance | Bicarbonate as HCO3 | Oxygen, Dissolved, % Saturation | Oxygen, Dissolved as O2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/l | mg/l | ug/l | mg/l | mV | pH | ug/l | ug/l | ug/l | ug/l | % | mg/l | % | mg/l |
| Moel Garnach 1 (bottom of site) | MG1.1 | 19/01/2014 | 3.0 | 0.13 | 0.77 | 40.6 | 20.5 | 8.18 | <10 | 95 | <10 | <30 | | 104 | 109.2 | 13.6 |
| Moel Garnach 2 (top of site) | MG1.3 | 19/01/2014 | 19.1 | 0.70 | 1.03 | 50.6 | 9.7 | 8.22 | 428 | 2250 | <10 | <30 | | 110 | 110.2 | 14.0 |

**Table 18 Moel Gornach water quality**




| | | | |
|---|---|---|---|
| | *Palustriella* dominated vegetation | A | Acid grassland |
| | Surface runnel | T | Transect |

**Figure 22 Moel Gornach Vegetation map (note central runnel with a high water level at the time of survey)**

### 7.3.1 **Vegetation (spring) of Moel Gornach**

*Palustriella falcata* dominated short vegetation between 1-3cm height. *Palustriella commutata* forms locally dominant patches around the upper rocky spring heads and *Scorpidium cossonii* locally dominates the margins of runnels (or hollows where there is movement of water) lower down the slope. *Hymenostylium recurvirostrum* forms occasional cushions associated with exposed tufa and *Leicolea bantriensis* occurs locally.

| | | | |
|---|---|---|---|
| *Agrostis stolonifera* | R (<1%) | *Hymenostylium recurvirostrum* | O |
| *Anagallis tenella* | R | *Juncus acutiflorus* | F |
| *Aneura pinguis* | F | *Juncus effusus* | O |
| *Bellis perennis* | R | *Leicolea badensis* | O |
| *Bryum pseudotriquetrum* | R | *Leicolea bantriensis* | R |
| *Calliergonella cuspidata* | R | *Nostoc sp.* | O |
| *Campylium stellatum* | O | *Palustriella commutata* | O |
| *Cardamine pratensis* | R | *Palustriella falcata* | A |
| *Carex demissa* | O | *Philonotis calcarea* | R |
| *Carex flacca* | O | *Philonotis fontana* | O |
| *Carex nigra* | R | *Plantago lanceolata* | R |
| *Cirsium palustre* | R | *Pressia quadrata* | O |
| *Cratoneuron filicinum* | O | *Prunella vulgaris* | R |
| *Ctenidium molluscum* | R | *Rhytidiadelphus squarrosus* | R (<1%) |
| *Dicranella varia* (spor.) | O | *Scorpidium cossonii* | F |
| *Eriophorum angustifolium* | O | *Scorzoneroides autumnalis* | R |
| *Festuca ovina* | F | *Trifolium repens* | R (<1%) |
| filamentous algae (Chlorophyta) | F | | |
| *Fissidens adianthoides* | O | | |

**Table 19 Moel Gornach Species list – Palustriella dominated vegetation**

A mixture of calcareous and acidic rocks within the area of flush/spring but above level of seepage water supporting a small number of acrocarpous calcareous and calcifuges bryophyte species.

| | |
|---|---|
| *Ptychomitrium polyphyllum* | O |
| *Schistidium sp.* | R |
| *Tortella tortuosa* | R |

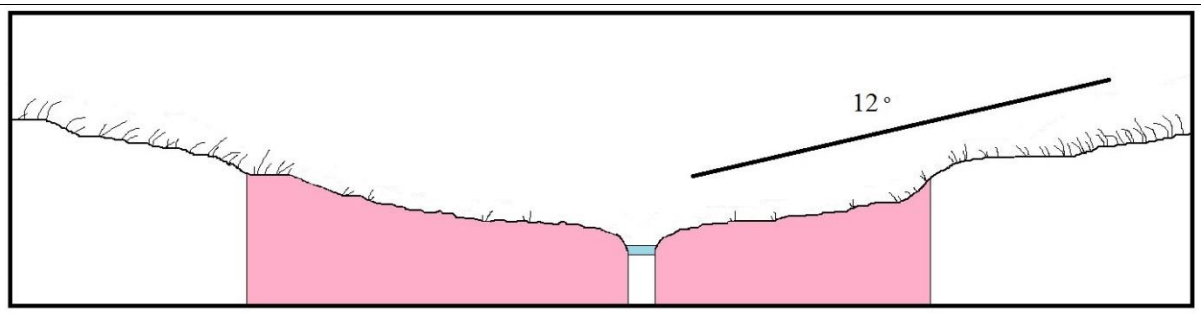
**Table 20 Moel Gornach Species list – Rocks within area of flush/spring but above level of seepage water**

### 7.3.2 Vegetation adjoining spring

Upland acid grassland to 30cm height (*Nardus stricta, Hylocomium splendens, Juncus squarrosos,* occasional *Vaccinium myrtillus*). There are ocassional small areas of rush pasture (*Juncus effusus*) as well as regular boggy areas with *Polytrichum commune, Eriophorum angustifolium* and *Sphagnum species.*

| | |
|---|---|
| *Eriophorum angustifolium* | O |
| *Hylocomium splendens* | O |
| *Juncus effusus* | O |
| *Juncus squarrosus* | R |
| *Nardus stricta* | F |
| *Polytrichum commune* | O |
| *Sphagnum fallax* | O |
| *Sphagnum inundatum* | O |
| *Vaccinium myrtillus* | R |

**Table 21 Moel Gornach Species list – Acid grassland and bog**




| | | | | | |
|---|---|---|---|---|---|
| *Hypnum jutlandicum*<br>*Juncus effusus*<br>*Juncus squarrosus*<br>*Nardus stricta*<br>*Polytrichum commune*<br>*Sphagnum subnitens* | | *Anagallis tenella*<br>*Campylium stellatum*<br>*Carex demissa*<br>*Carex flacca*<br>*Festuca ovina*<br>*Juncus acutiflorus*<br>*Scorpidium cossonii*<br>*Palustriella falcata* | Open water<br>*Juncus effusus* | *Campylium stellatum*<br>*Carex demissa*<br>*Carex flacca*<br>*Festuca ovina*<br>*Juncus acutiflorus*<br>*Scorpidium cossonii*<br>*Palustriella falcata* | *Dicranum scoparium*<br>*Festuca ovina*<br>*Hylocomium splendens*<br>*Juncus effusus*<br>*Pleurozium shreberi*<br>*Potentilla erecta*<br>*Sphagnum subnitens* |
| Length:<br>est 4.50m | pH4.74<br>no EC | pH6.3<br>EC 114.9 | pH6.82<br>EC 85.2 | pH6.66<br>EC 134 | pH5.27<br>EC 111.6 |

**Figure 23 Moel Gornach Transect vegetation and chemistry data**

Top spring of site - looking east

Rocky central part of site (main central channel looking down slope). Note close proximity of *Eriophorum* dominated bog (red colorartion) to the right distance

Only a very small area of tufa was located at Moel Gornach – the majority of the site was absent of tufa.

Hummock (spring swelling) dominated by *Crataneron filicinum, Philonotis fontana* (upper part of site)

Separate spring (side arm) sourced from a boggy area with frequent *Eriophorum* (looking north)

Bottom of site (lower limit of *Palustriella falcata* dominated vegetation), looking east (up slope).

**Figure 24 Moel Gornach photographs**

### 7.3.3 **Condition assessment**

The overall assessment is that Moel Gornach should be classified as being in favourable ecological and hydrogeological condition.

## 7.4 PONT CLYDACH (SITES 1, 2 & 3)

### 7.4.1 **Introduction**

Pont Clydach (Clydach Bridge) is the name given to the sites located along the Afon Clydach upstream and downstream of the road bridge, and less than 800m to the north of Foel Fawr / Herbert's Quarry. The streams that drain from Foel Fawr/ Herbert's Quarry also join the Afon Clydach along its course. Three sites were assessed along the 'Pont Clydach' section including one, upstream of Pont Clydach (SN7396519551) and two downstream (SN7338319189 and SN7364319860), all within a 500m stretch of the Afon Clydach.

### 7.4.2 **Geological and hydrogeological data**

The area is underlain by Lower Devonian Brownstones Formation and there are Devensian Glacial Till deposits mapped within the valley. Large boulders of conglomeratic Devonian Old Red Sandstone occur throughout this part of the Afon Clydach and form parts of all three sites. Hand auguring at Site 1 proved about 5cm of mineral ground underlain by unconsolidated sandy material with silicate material >1cm derived principally from the Devonian bedrock. The deposit was tested with HCI and there was no reaction, confirming that the shallow ground was dominantly silicate rich material. There was no evidence of tufa deposition at either Sites 1, 2 or 3.

All three sites are located on the eastern, or right hand bank of the Afon Clydach which flows to the north. Each of the three sites is fed by areas of diffuse seepage or by discrete springs or a combination of both. The water from the seepages and springs forms the runnels and shallow channels that flow towards and discharge into the Afon Clydach. It is not known if the Devonian bedrock or the unconsolidated superficial deposits provide the main source of water for the springs and flushes although a combination of both is possible.

A discrete spring near the base of Site 1 (SN7396519551) was estimated to be flowing at 0.5l/s however this water and the short runnel which it feds bypasses the main part of the site and did not support *Palustriella*. It can be very difficult to estimate flow from diffuse seepages in the field, however runnels fed by seepages do offer some potential to estimate the combined flow in certain areas. At Site 3 the flow in a runnel (downstream from several seepage areas) was estimated at 0.25l/s.

Four water quality samples were collected; two at Site 1 (SN7397319559 and SN7396519551) and one each at Sites 2 (SN7338319189) and 3 (SN7364319860). Nutrient levels are low or below the level of detection in all four samples with calcium and bicarbonate the dominant ions. pH values in the main parts of the sites range from 5.63-6.67 (Site 1), 6.74-7.3 (Site 2) and 7.07 – 7.5 (Site 3)

### 7.4.3 **Land use and pressures**

All three sites are located within a short distance from the road and there is open access for walkers and the public although there does not appear to be a heavy footfall in the area. Grazing from sheep and horses and associated poaching occurs but is not excessive. There is no evidence of burning or obvious signs of nutrient enrichment at any part of the site. There is nothing to suggest that there are any groundwater or surface water abstractions in the immediate area. Sites 2 and 3 (downstream from Pont Clydach) may both receive run off from the adjacent road and associated drainage.

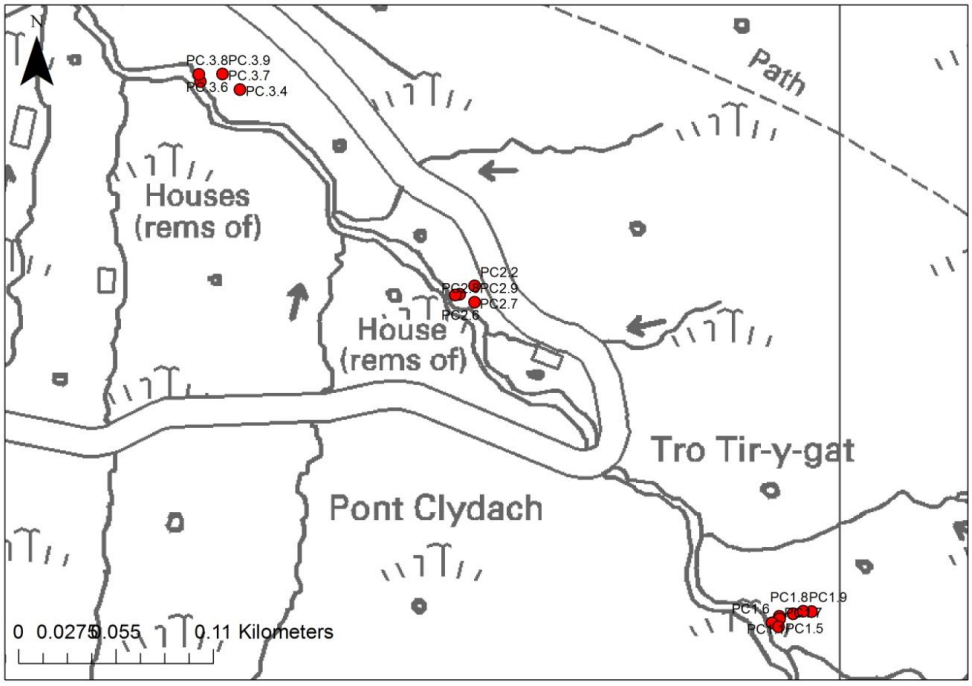



**Figure 25 Pont Clydach (Sites 1,2 & 3) Ordnance Survey map and GPS survey points. ©Ordnance Survey.**

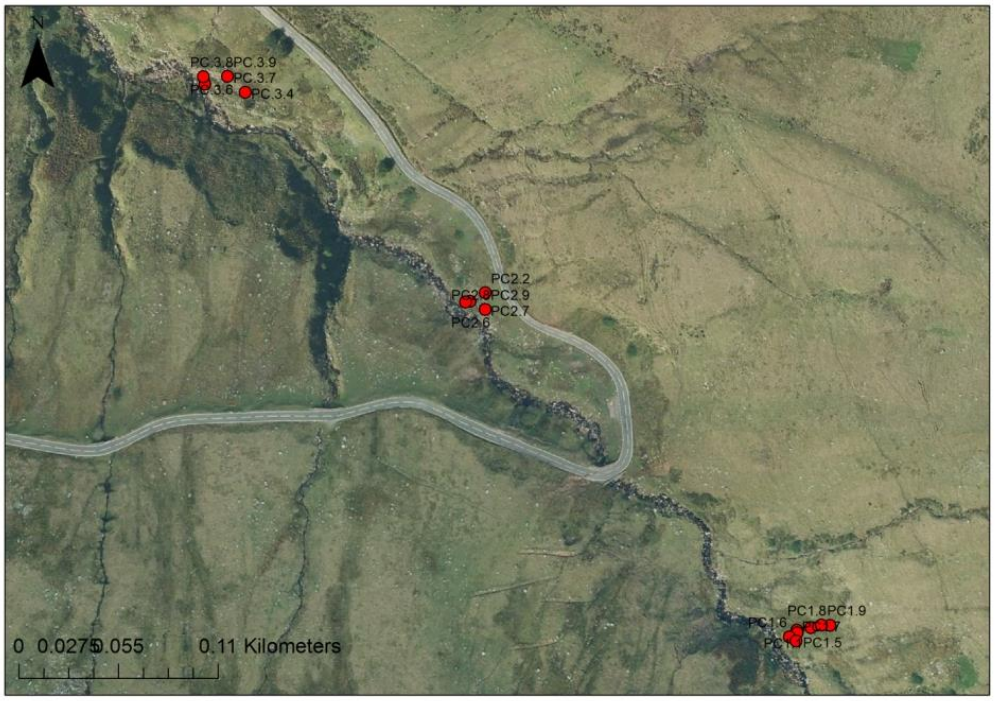



**Figure 26 Pont Clydach (Sites 1, 2 & 3) aerial photograph**

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**Figure 27 Pont Clydach Site 1 aerial photograph**

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**Figure 28 Pont Clydach Site 2 aerial photograph**

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**Figure 29 Pont Clydach Site 3 aerial photograph**

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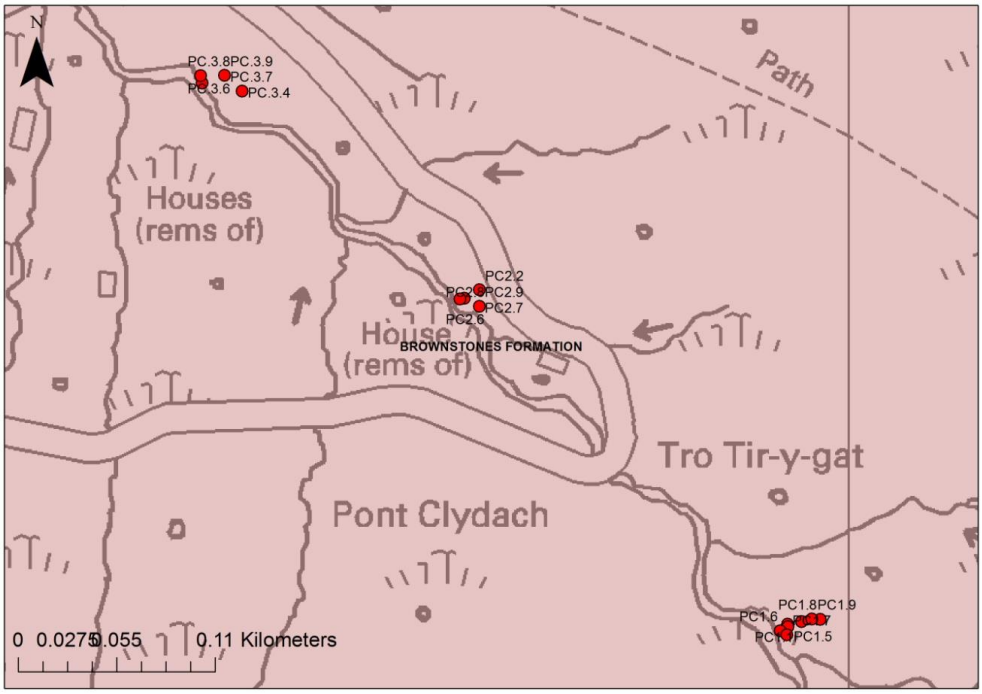
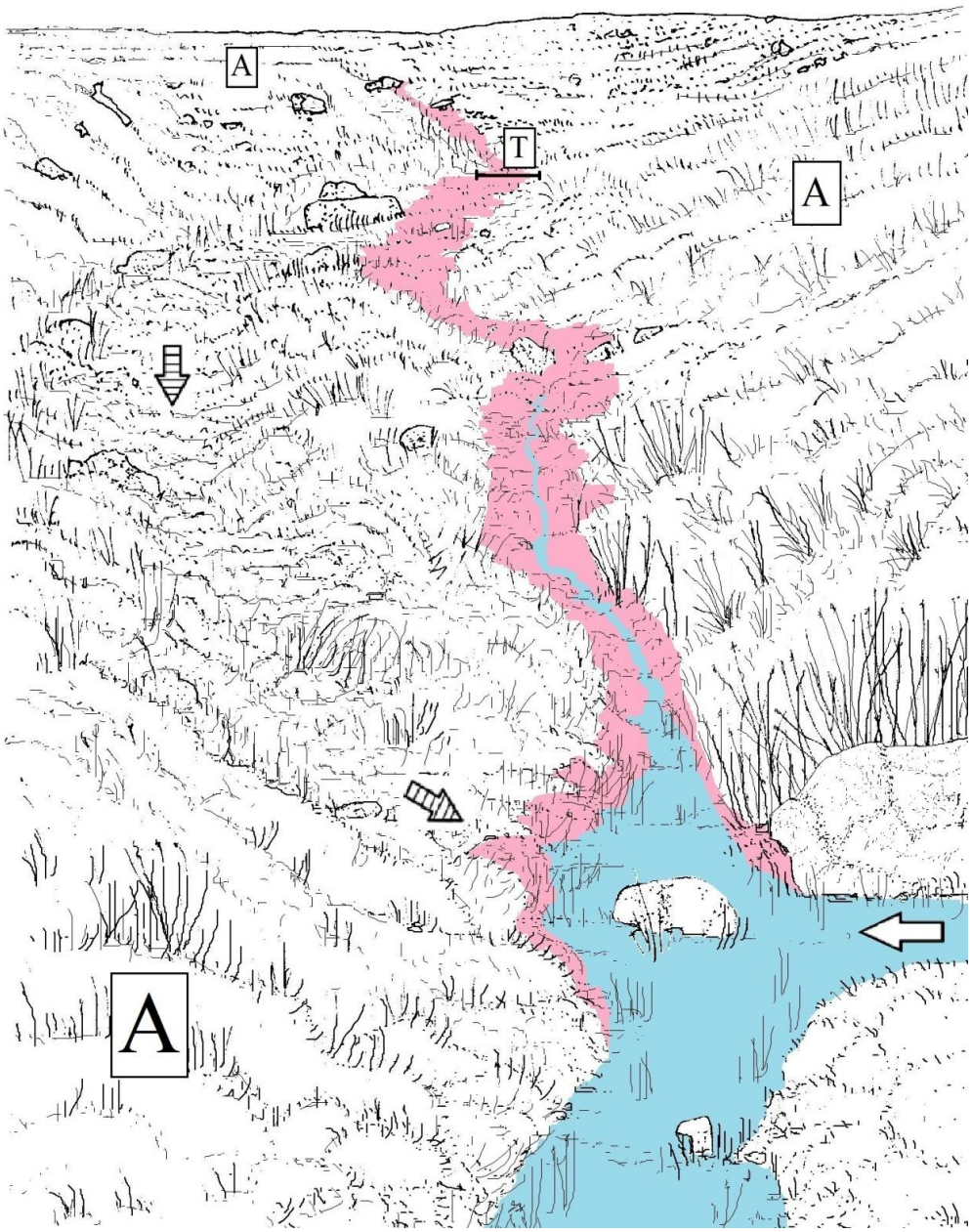



**Figure 30 Pont Clydach (Sites 1, 2 & 3) Bedrock Geology 1:50,000. ©BGS. ©Ordnance Survey.**

| Survey Site | Survey Ref | Date | Temperature of Water | SEC | Ammoniacal Nitrogen as N | Nitrogen, Total Oxidised as N | Nitrate as NO3 | Nitrate as N | Nitrite as N | Hardness, Total as CaCO3 | Alkalinity to pH 4.5 as CaCO3 | Chloride | Orthophosphate, reactive as P | Orthophospahte as PO4 | Sulphate as SO4 | Phosphate :- {TIP} |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CEL | uS/Cm | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l |
| Pont Clydach Site 1 (runnel at top of site) | PC1.4 | 25/11/2013 | 4.50 | 81.4 | <0.03 | <0.2 | | <0.196 | <0.004 | 35 | 30 | 5.7 | <0.02 | | <10 | 0.04 |
| Pont Clydach Site 1 (Spring head at base of site) | PC1.7 | 25/11/2013 | 9.20 | 125.2 | <0.03 | <0.2 | | <0.196 | <0.004 | 51 | 48 | 5.1 | <0.02 | | <10 | 0.02 |
| Pont Clydach Site 2 | PC2.4 | 25/11/2013 | 4.50 | 207.1 | <0.03 | <0.2 | | <0.196 | <0.004 | 78 | 77 | 13.7 | <0.02 | | <10 | 0.03 |
| Pont Clydach Site 3 | PC.3.1 | 25/11/2013 | 7.40 | 266.0 | <0.03 | <0.2 | | <0.196 | <0.004 | 111 | 116 | 11.0 | <0.02 | | <10 | <0.02 |

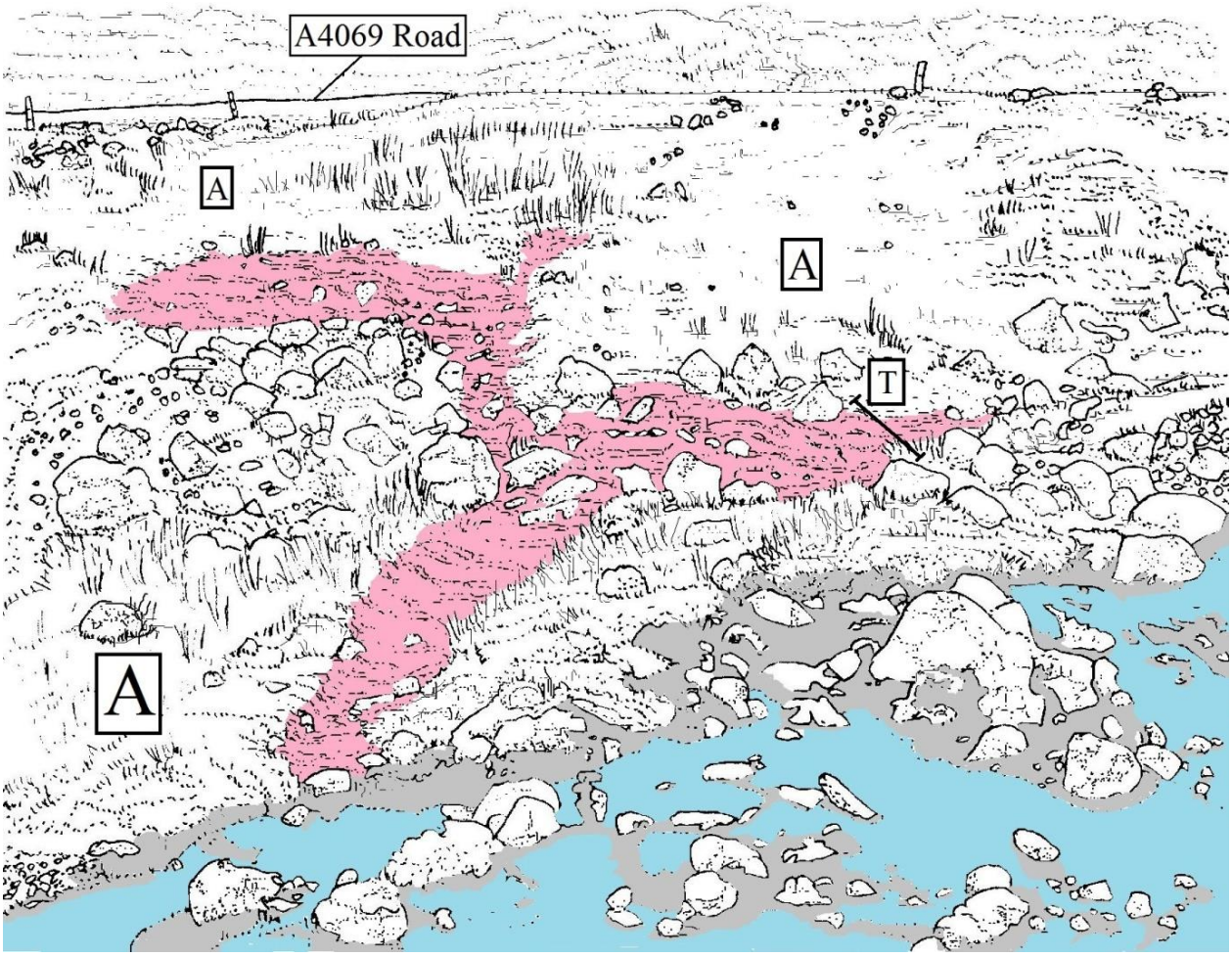
| Survey Site | Survey Ref | Date | Sodium | Potassium | Magnesium | Calcium | Redox Potential : In Situ | pH : In Situ | Manganese | Iron | Manganese, Dissolved | Iron, Dissolved | Ionic Balance | Bicarbonate as HCO3 | Oxygen, Dissolved, % Saturation | Oxygen, Dissolved as O2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/l | mg/l | ug/l | mg/l | mV | pH | ug/l | ug/l | ug/l | ug/l | % | mg/l | % | mg/l |
| Pont Clydach Site 1 (runnel at top of site) | PC1.4 | 25/11/2013 | 4.0 | 0.35 | 1.36 | 11.9 | 29.1 | 6.93 | 732.00 | 612 | <10 | <30 | -5.07 | 37 | 96.7 | 12.5 |
| Pont Clydach Site 1 (Spring head at base of site) | PC1.7 | 25/11/2013 | 4.1 | 0.40 | 1.95 | 17.1 | 29.7 | 6.37 | <10 | <30 | <10 | <30 | -4.82 | 59 | 85.4 | 9.8 |
| Pont Clydach Site 2 | PC2.4 | 25/11/2013 | 10.0 | 0.37 | 1.78 | 28.4 | 8.9 | 7.30 | 360.00 | 1200 | <10 | <30 | -3.43 | 94 | N | N |
| Pont Clydach Site 3 | PC.3.1 | 25/11/2013 | 7.9 | 0.76 | 4.15 | 37.7 | -11.2 | 7.23 | 37.00 | 446 | <10 | <30 | -4.90 | 142 | 87.8 | 10.5 |

**Table 22 Pont Clydach (Sites1 2 &3) water quality**



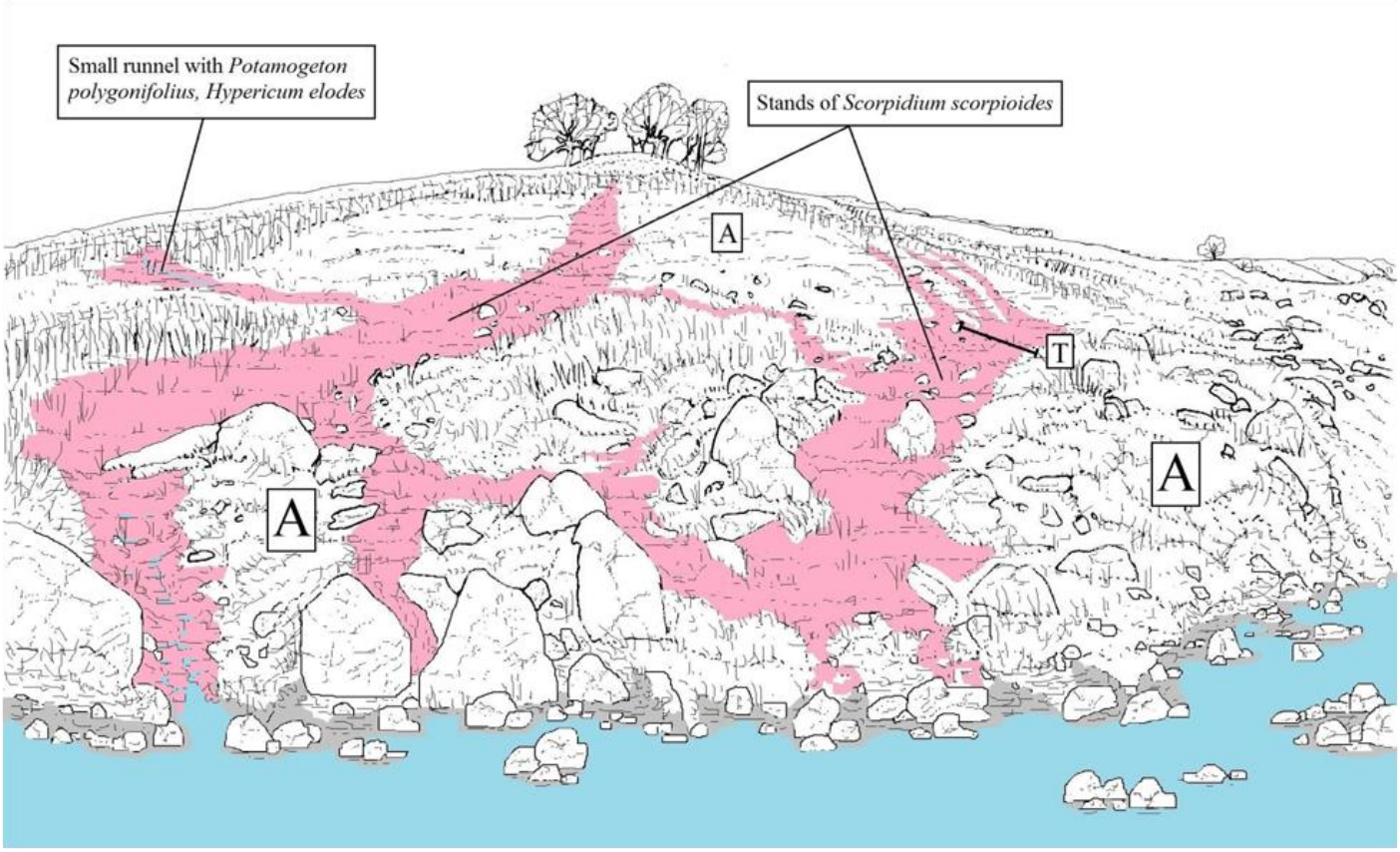

| | | | |
|---|---|---|---|
| | *Palustriella* dominated vegetation | A | Acid grassland |
| | *Juncus* dominated side spring with *Hamatocaulis* and no *Palustriella* | T | Transect |
| | Side spring (deeper ground water) with no *Palustriella* | | |

**Figure 31 Pont Clydach Site 1 vegetation map**




| | | | |
|---|---|---|---|
| | *Palustriella* dominated vegetation | A | Acid grassland and quarry spoil |
| | Afon Clydach (open water) | T | Transect |
| | Bryophyte dominated riparian vegetation without *Palustriella* (Afon Clydach) | | |

**Figure 32 Pont Clydach site 2 vegetation map**




| | | | |
|---|---|---|---|
| | *Palustriella* dominated vegetation | A | Acid grassland and quarry spoil |
| | Runnels and Afon Clydach (open water) | T | Transect |
| | Bryophyte dominated riparian vegetation without *Palustriella* (Afon Clydach) | | |

**Figure 33 Pont Clydach site 3 vegetation map**

### 7.4.4 **Vegetation (spring) of Pont Clydach site 1**

*Palustriella falcata* dominated short vegetation between 1-3cm height following the margins of a central runnel. The immediate margins of the central runnel have locally dominant patches of *Campylium stellatum* with *Scorpidium revolvens* and occasional *Riccardia multifida*. *Palustriella commutata* occurs as scattered patches in the upper part of the site.

| | | | |
|---|---|---|---|
| *Anagallis tenella* | F | *Myosotis sp.* | R |
| *Aneura pinguis* | O | *Nostoc sp.* | R |
| *Bryum pseudotriquetrum* | R | *Palustriella commutata* | O |
| *Calliergonella cuspidata* | R | *Palustriella falcata* | A |
| *Campylium stellatum* | O | *Philonotis fontana* | O |
| *Cardamine pratensis* | R | *Plantago lanceolata* | R |
| *Carex demissa* | R | *Ranunculus flammula* | O |
| *Carex flacca* | O | *Rhytidiadelphus squarrosus* | O |
| *Cirsium palustre* | R | *Riccardia multifida* | R |
| *Cratoneuron filicinum* | R | *Rumex acetosa* | R |
| *Cynosurus cristatus* | R (<1%) | *Sagina cf nodosa* | R (<1%) |
| *Festuca rubra* | R (<1%) | *Scorpidium revolvens* | O |
| filamentous algae (Chlorophyta) | O | *Stellaria media* | R (<1%) |
| *Galium palustre ssp. palustre* | R | *Taraxacum sp.* | R |
| *Holcus lanatus* | R (<1%) | *Thuidium tamariscinum* | R |
| *Juncus acutiflorus* | O | *Trifolium repens* | R (<1%) |
| *Juncus effusus* | O | | |

**Table 23 Pont Clydach Site 1 Species list – *Palustriella* dominated vegetation (adjoining spring)**

A neutral rush dominated flush adjoining to the left of the main runnel with *Palustriella falcata* but with a different spring head source. Below the *Juncus* stems are abundant *Calliergonella cuspidate* and frequent *Hamataucalis vernicosus. Chrysosplenium oppositifolium* and *Warnstorfia sarmentosa* occur locally.

| | | | |
|---|---|---|---|
| *Aneura pinguis* | O | *Juncus effusus* | O |
| *Calliergonella cuspidata* | F | *Lotus pedunculatus* | R |
| *Cardamine pratensis* | R | *Myosotis sp.* | R |
| *Chrysosplenium oppositifolium* | O | *Philonotis fontana* | F |
| *Cynosurus cristatus* | R (<1%) | *Rhytidiadelphus squarrosus* | O |
| *Festuca rubra* | R | *Rumex acetosa* | O |
| *Galium palustre ssp. palustre* | R | *Scorzoneroides autumnalis* | R |
| *Hamatocaulis vernicosus* | F | *Trifolium repens* | R (<1%) |
| *Holcus lanatus* | R (<1%) | *Warnstorfia sarmentosa* | R (<1%) |
| *Juncus acutiflorus* | F | | |

**Table 24 Pont Clydach Site 1 Species list – Juncus spring to left of main *Palustiella* spring (without *Palustriella*)**

An acid rocky deep water spring which joins the main spring channel from the right low down and in close proximity to the Afon Clydach. It is dominated by *Brachythecium rivulare*, *Calliergonella cuspidata, Chrysosoplenium oppositifolium, Conocephalum conicum* and the central channel has patches of *Fontinalis antipyretica* attached to submerged stones.

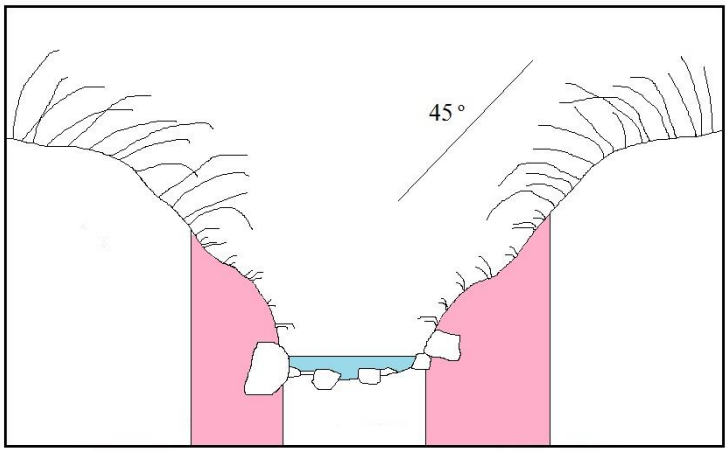
| | | | |
|---|---|---|---|
| *Brachythecium rivulare* | O | *Galium palustre ssp. palustre* | R |
| *Calliergonella cuspidata* | O | *Lophocolea bidentata* | R |
| *Chrysosplenium oppositifolium* | O | *Plagiomnium undulatum* | O |
| *Conocephalum conicum* | O | *Rhizomnium punctatum* | R |
| *Cratoneuron filicinum* | O | *Rumex acetosa* | O |
| *Dichodontium pellucidum* | R | *Scapania undulata* | R |
| *Fontinalis antipyretica* | O | *Thuidium tamariscinum* | R |

**Table 25 Pont Clydach Site 1 Species list – Juncus spring to right of main Palustiella spring (deeper spring without *Palustriella*)**

Upland acid grassland to 20cm height (*Nardus stricta, Galium saxatile)* with regular hummocks of *Aulocomnium palustre, Polytrichum commune* and *Sphagnum subnitens*.

| | |
|---|---|
| *Aulocomnium palustre* | R |
| *Dicranum scoparium* | O |
| *Galium saxatile* | O |
| *Hypnum jutlandicum* | R |
| *Juncus effusus* | R |
| *Nardus stricta* | A |
| *Polytrichum commune* | R |
| *Potentilla erecta* | R |
| *Rhytidiadelphus squarrosus* | O |
| *Sphagnum subnitens* | R |
| *Vaccinium myrtillus* | R |

**Table 26 Pont Clydach Site 1 Species list – Acid grassland**



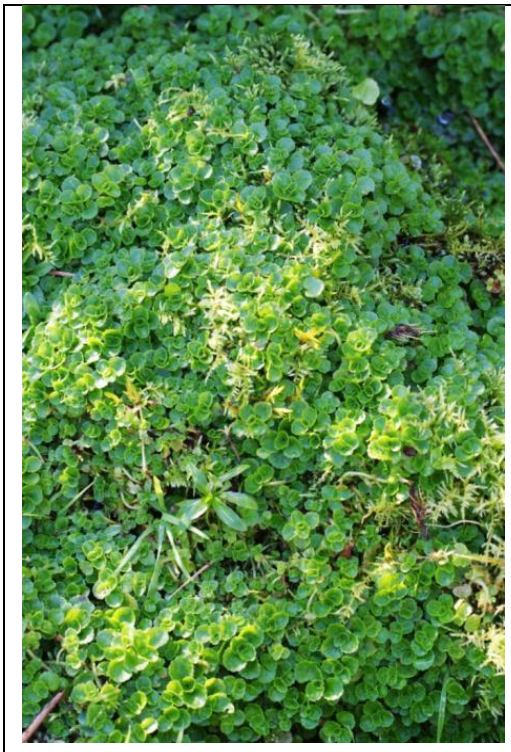

| | | | | |
|---|---|---|---|---|
| *Aulocomnium palustre*<br>*Dicranum scoparium*<br>*Hypnum jutlandicum*<br>*Juncus squarrosus*<br>*Nardus stricta*<br>*Sphagnum subnitens* | *Anagallis tenella*<br>*Campylium stellatum*<br>*Cirsium palustre*<br>*Carex demissa*<br>*Carex flacca*<br>*Juncus acutiflorus*<br>*Palustriella falcata* | *Anagallis tenella*<br>*Scorpidium revolvens* | *Anagallis tenella*<br>*Campylium stellatum*<br>*Carex demissa*<br>*Carex flacca*<br>*Juncus acutiflorus*<br>*Palustriella falcata* | *Aulocomnium palustre*<br>*Hypnum jutlandicum*<br>*Juncus squarrosus*<br>*Nardus stricta*<br>*Sphagnum inundatum*<br>*Sphagnum subnitens* |
| pH6.14<br>EC 111.2 | pH 6.56<br>EC83.1 | pH6.64<br>EC90.2 | pH6.67<br>EC 90.3 | pH5.63<br>EC 77.1 |

**Figure 34 Pont Clydach Site 1 Transect and chemistry**

Main spring head source of *Palustriella* flush – upper part of site looking north (up slope)

*Hamatocaulis,* rushy side spring (left arm)

Rushy neutral side spring (left arm) with abundant *Calliergonella, Hamatocaulis* - looking north (up slope)



Acid flush (right arm) dominated by *Chrysosplenium* (lower part of site adjoining Afon Clydach)

Hand auger: thin mineral ground with coarse silicate rich deposits – derived from Devonian bedrock. Tested with HCl and no reaction.

Main site runnel (lower part of site adjoining Afon Clydach) with frequent *Chrysosplenium*

Example of the unsorted material within the near surface, clasts are sourced from Devonian bedrock.

**Figure 35 Pont Clydach Site 1 photographs**

### 7.4.5 **Vegetation (spring) of Pont Clydach site 2**

*Palustriella falcata* dominated short vegetation between 1-3cm height following the margins of several runnels that converge into one. The immediate margins of the central runnel have locally dominant patches of *Campylium stellatum* with *Scorpidium cossonii, Scorpidium cossonii*, occasional *Philonotis calcarea* and *Jungermannia exertifolia ssp. cordifolia*. Larger central runnels support aquatic flowering plants including *Nasturtium officinale s.l, Mentha aquatica, Ranunculus flammula* while *Palustriella falcata* becomes less frequent towards the base of the flush (adjoining the Afon Clydach) being replaced by more frequent *Cratoneuron filicinum* and *Philonotis fontana*.

| | | | |
|---|---|---|---|
| *Agrostis stolonifera* | R (<1%) | *Jungermannia exsertifolia ssp. cordifolia* (non fertile) | O |
| *Anagallis tenella* | O | *Mentha aquatica* | R |
| *Aneura pinguis* | F | *Nasturtium officinale s.l.* | R |
| *Bryum pseudotriquetrum* | R | *Palustriella commutata* | O |
| *Calliergonella cuspidata* | R | *Palustriella falcata* | A |
| *Campylium stellatum* | O | *Philonotis calcarea* | O |
| *Cardamine pratensis* | O | *Philonotis fontana* | R |
| *Carex demissa* | R | *Plagiomnium undulatum* | R |
| *Carex flacca* | O | *Ranunculus flammula* | R |
| *Cirsium palustre* | R | *Scorpidium cossonii* | O |
| *Cratoneuron filicinum* | O | *Thuidium tamariscinum* | R |
| *Ctenidium molluscum* | R | *Trifolium repens* | R (<1%) |
| filamentous algae (Chlorophyta) | R | *Veronica beccabunga* | R |
| *Fissidens adianthoides* | R | | |
| *Hydrocotyle vulgaris* | R | | |
| *Juncus acutiflorus* | O | | |

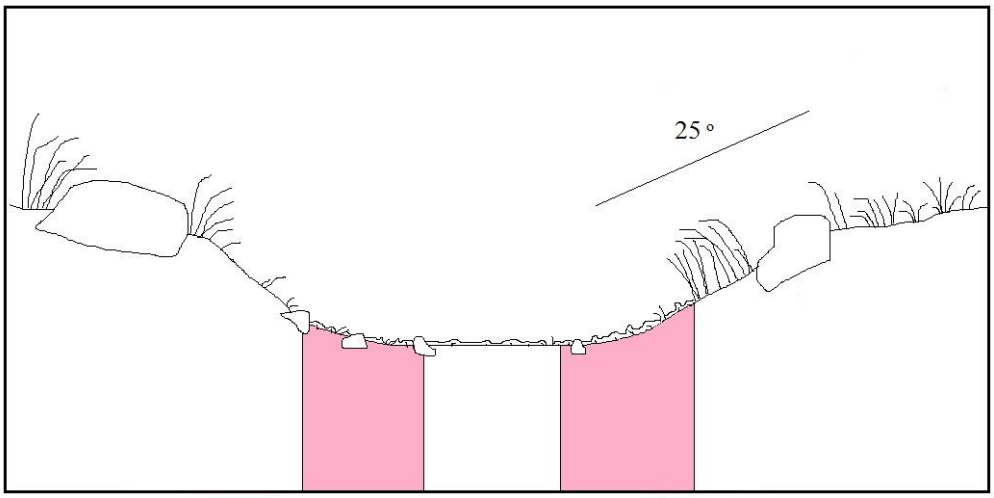
**Table 27 Pont Clydach Site 2 Species list – Palustriella dominated vegetation**

### 7.4.6 **Vegetation (adjoining spring) Pont Clydach site 2**

Upland acid grassland to 20cm height (*Nardus stricta, Agrostis capillaris)* with scattered extensive rush pasture dominated by *Juncus effusus, occasional Juncus acutiflorus.*

| | |
|---|---|
| *Agrostis capillaris* | R |
| *Calliergonella cuspidata* | F |
| *Juncus acutiflorus* | R |
| *Juncus effusus* | A |
| *Nardus stricta* | R |

**Table 28 Pont Clydach Site 2 Species list – Acid grassland and quarry spoil**




| | | | | |
|---|---|---|---|---|
| *Juncus effusus*<br>*Juncus squarrosus*<br>*Nardus stricta*<br>*Sphagnum subnitens* | *Campylium stellatum*<br>*Carex flacca*<br>*Juncus acutiflorus*<br>*Palustriella falcata* | *Carex flacca*<br>*Juncus acutiflorus*<br>*Scorpidium cossonii* | *Carex flacca*<br>*Cratoneuron filicinum*<br>*Juncus acutiflorus*<br>*Palustriella falcata*<br>*Philonotis fontana* | *Jucus effusus*<br>*Nardus stricta*<br>*Calliergonella cuspidata*<br>*Sphagnum subnitens* |
| pH 5.31<br>EC164.6 | pH6.70<br>EC 175.3 | pH 6.74<br>EC 194.8 | pH7.31<br>EC 265.2 | pH6.06<br>EC6.06 |

**Figure 36 Pont Clydach Site 2 Transect and vegetation chemistry**

Upper rocky spring head source of *Palustriella* flush – upper part of site looking east (up slope)

One of many acid bolders within but standing above the level of flushed water. The calcifuge moss *Racomitrium aciculare* can be seen growing on the top of the boulder where it receives primarily rain water (centre of site).

Main runnel with Palustriella (central part of site) Note close proximity of Afon Clydach to right.

Rocky side spring (left arm) – upper part of site looking east (up slope)

Main site runnel (lower part of site adjoining Afon Clydach) with frequent *Palustriella falcata, Cratoneuron filicinum, Philonotis fontana.*

Pont Clydach Site 2: view from acoss the Afon Clydach

**Figure 37 Pont Clydach Site 2 photographs**

### 7.4.7 **Vegetation (spring) of Pont Clydach site 3**

Particularly species-rich *Palustriella falcata* dominated short vegetation between 1-3cm height following the margins of a number of runnels eminating from several spring heads. The immediate margins of the central runnels have luxurious growth of *Campylium stellatum* with *Fissidens adianthoides, Bryum psedotriquetrum*, *Scorpidium cossonii, Philonotis calcarea* and notable stands of *Scorpidium scorpioides* occur in several places. Larger central runnels support aquatic flowering plants including *Nasturtium officinale s.l, Myosotis sp., Ranunculus flammula, Potamogeton polygonifolius* and locally *Hypericum elodes, Eriophorum cf latifolium.*

| | | | |
|---|---|---|---|
| *Agrostis stolonifera* | R (<1%) | *Juncus acutiflorus* | R |
| *Anagallis tenella* | O | *Juncus bulbosus* | R (<1%) |
| *Bellis perennis* | R | *Juncus effusus* | R |
| *Bryum pseudotriquetrum* | O | *Lotus pedunculatus* | R (<1%) |
| *Calliergonella cuspidata* | R | *Myosotis sp.* | R |
| *Campylium stellatum* | F | *Nasturtium officinale s.l.* | R |
| *Cardamine pratensis* | R | *Palustriella commutata* | O |
| *Carex demissa* | O | *Palustriella falcata* | A |
| *Carex flacca* | O | *Philonotis calcarea* | F |
| *Chrysosplenium oppositifolium* | R | *Philonotis fontana* | O |
| *Cirsium palustre* | R | *Potamogeton polygonifolius* | R |
| *Cratoneuron filicinum* | O | *Preissia quadrata* | R |
| *Ctenidium molluscum* | R | *Prunella vulgaris* | R |
| *Didymodon fallax* | R | *Ranunculus flammula* | R |
| *Equisetum palustre* | R | *Scorpidium cossonii* | O |
| *Eriophorum cf latifolium* | R (<1%) | *Scorpidium scorpioides* | R |
| *Festuca ovina* | R (<1%) | *Scorzoneroides autumnalis* | R |
| filamentous algae (Chlorophyta) | R | *Succisa pratensis* | R (<1%) |
| *Fissidens adianthoides* | R | *Taraxacum sp.* | R |
| *Hypericum elodes* | R | | |

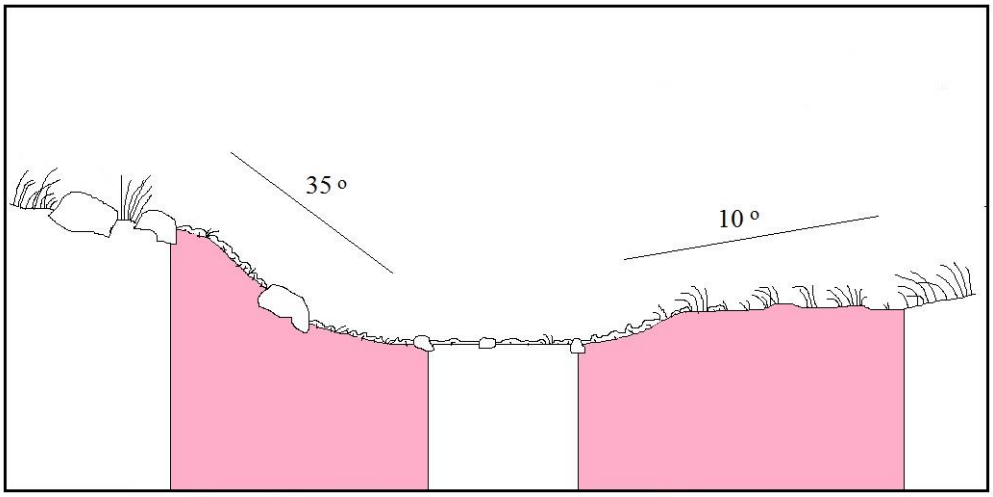
**Table 29 Pont Clydach Site 3 Species list – *Palustriella* dominated vegetation**

### 7.4.8 Vegetation (adjoining spring) Pont Clydach site 3

Heavily sheep grazed acid grassland to 20cm height (*Nardus stricta, Agrostis capillaris, Potentilla erecta)* often associated with quarry spoil and infill associated with repairs to the adjoining road (A4069). The sward has regular patches of *Hylocomium splendens, Rhytidiadelphus squarrosus .*

| | |
|---|---|
| *Agrostis capillaris* | R |
| *Hylocomium splendens* | O |
| *Hypnum cupressiforme* | O |
| *Juncus effusus* | O |
| *Nardus stricta* | F |
| *Pleurozium schreberi* | R |
| *Potentilla erecta* | R |
| *Rhytidiadelphus squarrosus* | R |
| *Sphagnum inundatum* | R |
| *Sphagnum subnitens* | R |

**Table 30 Pont Clydach Site 3 Species list – Acid grassland and quarry spoil**




| | | | | |
|---|---|---|---|---|
| *Hylocomium splendens*<br>*Juncus effusus*<br>*Nardus stricta*<br>*Sphagnum subnitens* | *Carex flacca*<br>*Cratoneuron filicinum*<br>*Myosotis sp.*<br>*Palustriella falcata*<br>*Philonotis fontana* | *Scorpidium cossonii*<br>*Juncus acutiflorus*<br>*Carex flacca*<br>*Campylium stellatum* | *Aneura*<br>*Carex flacca*<br>*Campylium stellatum*<br>*Juncus acutiflorus*<br>*Palustriella falcata*<br>*Scorpidium cossonii* | *Nardus stricta*<br>*Pleurozium schreberi*<br>*Sphagnum subnitens* |
| pH5.87<br>EC108.6 | pH7.24<br>EC252.2 | pH6.86<br>EC253.8 | pH6.51<br>EC 145.9 | pH 5.82<br>EC 86.6 |

**Figure 38 Pont Clydach Site 3 Transect and vegetation chemistry**

Upper rocky spring heads where *Palustriella* flush starts – upper part of site looking east (up slope)

Acid bolders within but standing above the level of flushed water. The calcifuge moss *Racomitrium aciculare* can be seen growing on the top of boulders where it receives primarily rain water (centre of site).

Central runnel with *Potamogeton polygonifolius, Camplylium stellatum, Hypericum elodes* – side spring (left)

Soil auger showing influence of Old Red Sandstone.

Section showing section of ORS derived superficial deposits and soils

Main runnel with *Palustriella falcata, Myosotis sp*. (lower part of site in close proximity to Afon Clydach).

**Figure 39 Pont Clydach Site 3 photographs**

### 7.4.9 **Condition assessment**

The overall assessment is that Pont Clydach (sites 1-3) should be classified as being in favourable ecological and hydrogeological condition. However, sites 2 & 3 shown some signs of over grazing and poaching by sheep. In addition, sites 2 & 3 are situated immediately below the A4069 and have related issues of soil creep, littering and trampling (close proximity of parking place).

## 7.5 BLAEN ONNEN

### 7.5.1 **Introduction**

Blaen Onnen is located midway between Mynydd Llangatwg and Mynydd Llangynidr, on the B4560 Beaufort to Llangynidr road (SN1574216878) at an elevation between 432 and 419maOD. The site is similar to Foel Fawr / Herbert's Quarry in that it is associated with past quarrying activities and is closely associated with lime spoil from the adjacent, and now mothballed Blaen Onnen Quarry.

### 7.5.2 **Geological and hydrogeological data**

The main area of tufa deposit is extensive enough to be mapped on the 1:50,000 geological map (Sheet 231 Merthyr Tydfil). It occurs in a small hollow that runs north-south parallel to the main road. The tufa has been deposited at the base of the hollow that has been cut down into the Carboniferous Abercriban Oolite Supgroup which is underlain by the Cwmyniscoy Mudstone Formation ('lower limestone shales'). The area is well known for its karst development and an extensive area of sink holes and shake holes occurs on Mynydd Llangatwg and Llangynidr. Extensive lime spoil and waste forms spoil mounds to either side of the main road. A hand auger hole made in a 'central island' of *Palustriella commutata* surrounded by runnels proved 5cm of mineral soil underlain by 20cm of carbonate rich gravel comprising eroded tufa clasts. At 30cm the material becomes very hard and the hole was terminated.

Blaen Onnen has several pathways for water to enter the site. At the top of the site near the road there is spring/seepage and this is also contributed to by a drain that takes runoff water from the entrance road to the quarry, under the main road and into the site. The drain was not flowing during the site visit (26/11/2013) however there was evidence that during rainfall the drain would be in operation. Inflows to the site could also include surface runoff from the adjacent main road. Seepages and springs occur along the base of the small valley from both the east and west. The contact of the Cwmyniscoy Mudstone and Abercriban Oolite formation in this area may influence the occurrence of springs and seepages. Diffuse seepages principally occur at the base of the historic spoil tips. Combined, the waters flow in runnels ultimately forming the headwaters of a tributary of the Nant Cwm Onnau.

Two samples were collected at Blaen Onnen. Sample BO1.1 was obtained from the spring head at the top of the site (SN1569816947) and sample BO1.4 from a *Palustriella* dominated runnel within the main area of the site (SN1574216878). Neither of the two samples showed elevated levels of nutrients and both nitrate and phosphate were close to their lower limits of detection. The dominant ions are calcium (77.4 – 82.8mg/l) and bicarbonate (228-268mg/l) although sodium (30.7 – 37.9mg/l) and chloride (60.4 – 73.8mg/l) are also present in significant amounts. Field readings of pH across the site ranged from 7.16 – 8.10.

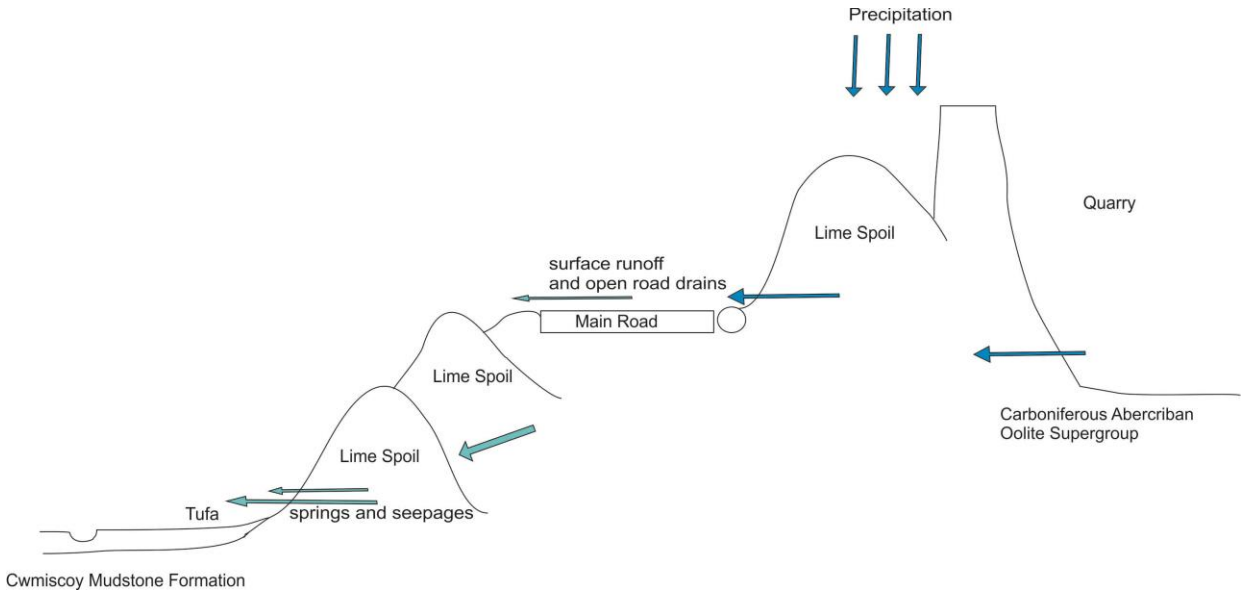



**Figure 40 Blaen Onnen initial site conceptual model**

### 7.5.3 **Land use and pressures**

The small gully in which the site is situated is located directly below the main road (B4560) that runs from Llangynidr to Beaufort /Rassau and is next to the mothballed 'Blaen Onnen Quarry'. Runoff from the road and the entrance into the quarry is diverted into open roadside drains and this runoff is channelled under the road and enters the top of the site via a plastic pipe. Direct surface runoff from the road is also possible. The land surrounding the site is sheep and horse grazed. There is substantial poaching across the area. There is no evidence for burning or obvious signs of nutrient enrichment at any part of the site. It is unlikely that there are any groundwater or surface water abstractions in the immediate area and there does not appear to be any dewatering taking place in the quarry.

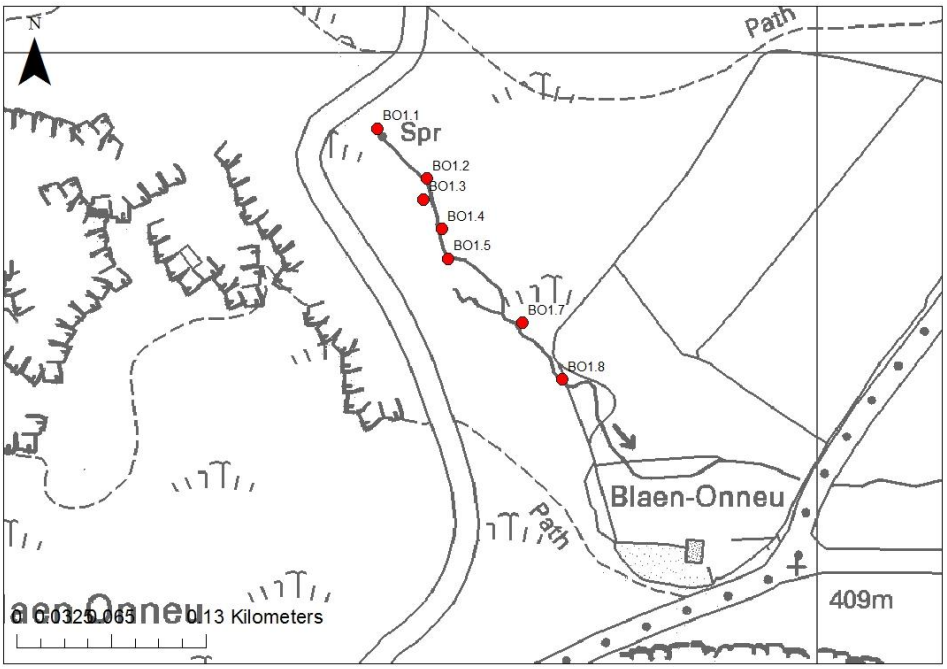



**Figure 41 Blaen Onnen Ordnance Survey map and GPS survey points. © Ordnance Survey.**


**Figure 42 Blaen Onnen Aerial photograph © UKP/Getmapping Licence No. UKP2006/01**

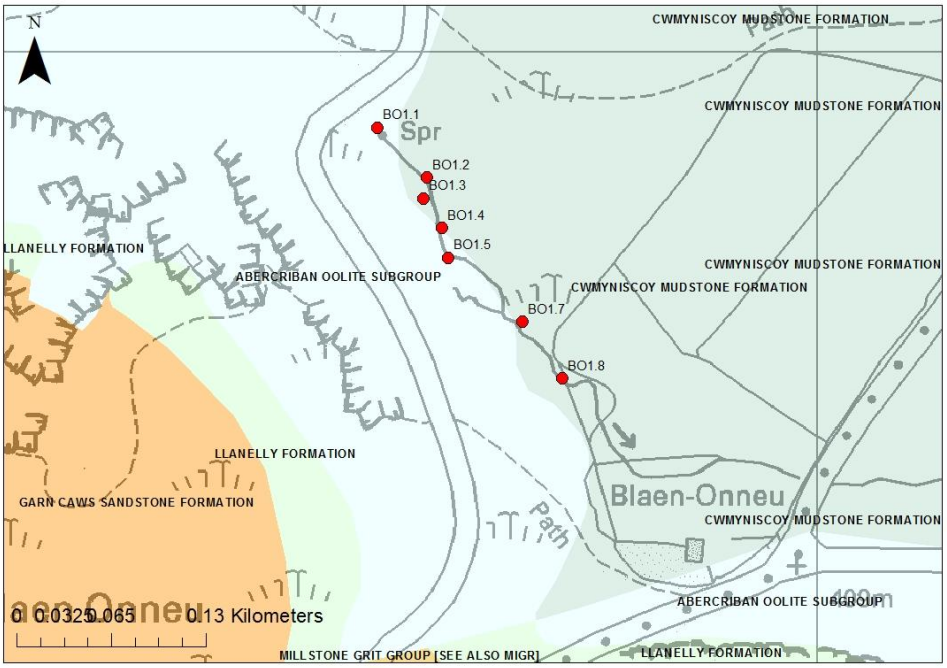
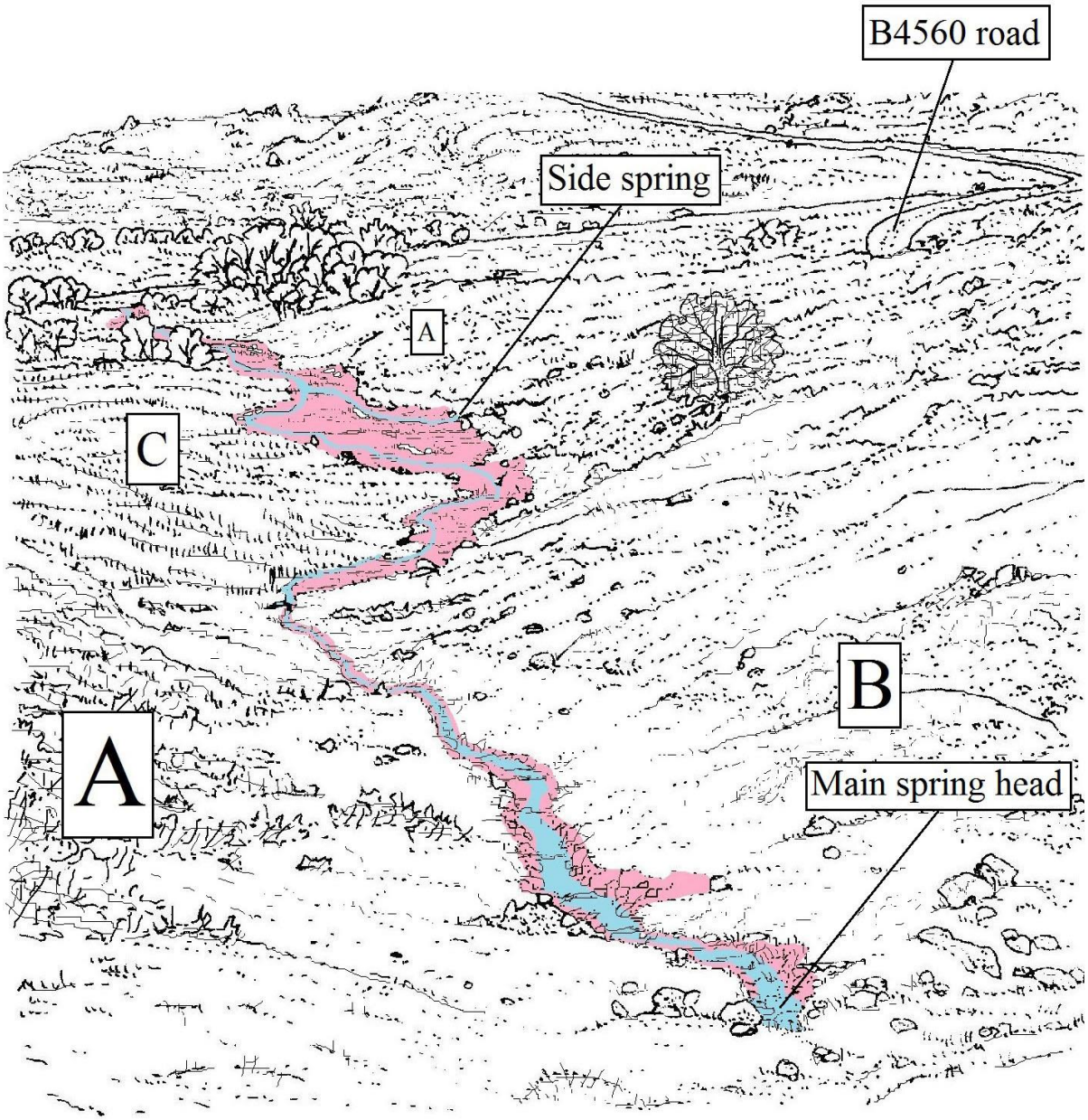



**Figure 43 Blaen Onned Bedrock Geology 1:50,000. ©BGS. ©Ordnance Survey.**

| Survey Site | Survey Ref | Date | Temperature of Water | SEC | Ammoniacal Nitrogen as N | Nitrogen, Total Oxidised as N | Nitrate as NO3 | Nitrate as N | Nitrite as N | Hardness, Total as CaCO3 | Alkalinity to pH 4.5 as CaCO3 | Chloride | Orthophosphate, reactive as P | Orthophospahte as PO4 | Sulphate as SO4 | Phosphate :-{TIP} |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CEL | uS/Cm | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l |
| Blaen Onnen (spring at head of site) | BO1.1 | 26/11/2013 | 9.20 | 665.5 | <0.03 | 0.54 | | 0.54 | <0.004 | 254 | 220 | 73.8 | <0.02 | | <10 | 0.06 |
| Blaen Onnen (runnel with Paulestriella) | BO1.4 | 26/11/2013 | 6.00 | 564.4 | <0.03 | 0.34 | | 0.34 | <0.004 | 231 | 187 | 60.4 | <0.02 | | 10.70 | 0.06 |

| Survey Site | Survey Ref | Date | Sodium | Potassium | Magnesium | Calcium | Redox Potential : In Situ | pH : In Situ | Manganese | Iron | Manganese, Dissolved | Iron, Dissolved | Ionic Balance | Bicarbonate as HCO3 | Oxygen, Dissolved, % Saturation | Oxygen, Dissolved as O2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/l | mg/l | ug/l | mg/l | mV | pH | ug/l | ug/l | ug/l | ug/l | % | mg/l | % | mg/l |
| Blaen Onnen (spring at head of site) | BO1.1 | 26/11/2013 | 37.9 | 0.87 | 11.40 | 82.8 | -38.4 | 7.24 | 27.50 | 419 | <10 | <30 | 0.10 | 268 | 87.3 | 10.0 |
| Blaen Onnen (runnel with Paulestriella) | BO1.4 | 26/11/2013 | 30.7 | 0.94 | 9.09 | 77.4 | -38.4 | 7.83 | 50.30 | 751 | <10 | <30 | 2.40 | 228 | 90.7 | 11.3 |

**Table 31 Blaen Onnen water quality**




| | | | |
|---|---|---|---|
| | *Palustriella* dominated vegetation | A | Bracken dominated vegetation |
| | Central runnel (open water) | B | Calcareous grassland (on quarry spoil) |
| | | C | Rush dominated pasture |

**Figure 44 Blaen Onnen Vegetation map**

### 7.5.4 **Vegetation (spring) of Blaen Onnen**

*Palustriella falcata* dominated short vegetation between 1-3cm height forming wide stands either side of a small winding runnel following the gentle dip of a small valley. The site has a single spring source and a number of small side springs but quickly forms a single central channel. The upper spring heads are notable for there absence of *Palustriella falcata* and dominance of *Cratoneuron filicinum, Apium nodiflorum Calliergonella cuspidata, Philonotis fontana* but quickly transform into rich *Palustriella falcata* flushed vegetation further down the slope. Locally, large

stands of *Campylium stellatum* occur with *Fissidens adianthoides*, S*corpidium cossonii, Philonotis calcarea*, occasional *Bryum pseudotriquetrum, Leicolea badensis* and with *Scorpidium cossonii* occurring as the dominant species along the sides of the main central channel. The main winding central channel is relatively deep lower down (to 15cm at the time of survey during a period of fine weather) with crystal clear water and a good assemledge of aquatic flowering plants including *Nasturtium officinale s.l., Apium nodiflorum, Myosotis sp., Mentha aquatica, Ranunculus flammula, Glyceria fluitans* and locally dominant stands of *Potamogeton polygoniferous*.

| | | | |
|---|---|---|---|
| *Agrostis stolonifera* | R (<1%) | *Jungermannia exsertifolia ssp. cordifolia* (non fertile) | R |
| *Anagallis tenella* | R | *Leicolea badensis* | R |
| *Aneura pinguis* | F | *Mentha aquatica* | R |
| *Apium nodiflorum* | R | *Myosotis sp.* | R |
| *Bellis perennis* | R | *Nasturtium officinale s.l.* | R |
| *Bryum pseudotriquetrum* | O | *Palustriella commutata* | O |
| *Calliergonella cuspidata* | R | *Palustriella falcata* | A |
| *Campylium stellatum* | A | *Pellia endiviifolia* | R (<1%) |
| *Cardamine pratensis* | R | *Philonotis calcarea* | R |
| *Carex demissa* | O | *Philonotis fontana* | O |
| *Carex flacca* | O | *Potamogeton polygonifolius* | R |
| *Cratoneuron filicinum* | O | *Preissia quadrata* | O |
| *Ctenidium molluscum* | R | *Ranunculus acris* | R |
| filamentous algae (Chlorophyta) | R | *Ranunculus flammula* | R |
| *Fissidens adianthoides* | R | *Riccardia multifida* | R (<1%) |
| *Galium plaustre ssp. plaustre* | R | *Rivularia haematites* | R |
| *Glyceria fluitans* | R | *Sagina cf nodosa* | R (<1%) |
| *Hydrocotyle vulgaris* | R | *Scorpidium cossonii* | A |
| *Juncus acutiflorus* | O | *Scorzoneroides autumnalis* | R |
| *Juncus effusus* | R | *Taraxacum sp.* | R |
| *Juncus inflexus* | R (<1%) | *Veronica beccabunga* | R |
| | | *Wahlendbergia hederacea* | R (<1%) |

**Table 32 Blaen Onnen Species list – Palustriella dominated vegetation**

Calcareous rocks within the area of flush/spring but above level of seepage water supporting occasional acrocarpous calcareous species.

| | |
|---|---|
| *Ditrichum gracile* | R |

**Table 33 Blaen Onnen Species list – Rocks within area of flush/spring but above level of seepage water**

### 7.5.5 **Vegetation adjoining spring**

Short sheep grazed calcareous grassland (to 5cm height) overlying old mining spoil and dominated by *Ctenidium molluscum*. A small number of other species are prominent including *Agrostis stolonifera, Bellis perennis, Calliergonella cuspidata, Plantago lanceolata* and *Prunella vulgaris.*

| | |
|---|---|
| *Achillea millefolium* | R |
| *Agrostis stolonifera* | O |
| *Bellis perennis* | O |
| *Calliergonella cuspidata* | O |
| *Cirsium arvense* | R (<1%) |
| *Craex flacca* | R |
| *Ctenidium molluscum* | A |
| *Cynosurus cristatus* | R |
| *Ditrichum gracile* | R |
| *Festuca ovina* | R (<1%) |
| *Fissidens dubius* | O |
| *Hypnum cupressiforme* | O |
| *Lotus corniculatus* | R |
| *Plantago lanceolata* | O |
| *Prunella vulgaris* | O |
| *Ranunculus repens* | R (<1%) |
| *Rhytidiadelphus squarrosus* | R |
| *Trifolium repens* | R (<1%) |

**Table 34 Blaen Onnen Species list – Calcareous grassland (on mining spoil)**

Main spring head with central channel dominated by *Apium nodiflorum* - upper part of site looking south (down slope)

Main rocky central channel borderered by wide stands of *Palustriella falcata* dominated vegetation – lower part of site looking south (down slope)

Road drain that likely contributes to spring flows during periods of high rainfall (upper part of site)

Main central channel borderered by wide stands of *Palustriella falcata* dominated vegetation – upper part of site looking south (down slope)

Small area of soil slip showing local soil profile and with short cover of sheep grazed calcareous grassland (north-west slope of site).

20cm soil auger showing soil profile from near centre of site

Main central channel dominated by *Potamogeton polygonifolius, Glyceria fluitans* - lower part of site

**Figure 45 Blaen Onnen photographs**

### 7.5.6 **Condition assessment**

The overall assessment is that Blaen Onnen should be classified as being in favourable ecological and hydrogeological condition.

## 7.6 LLYN Y FAN FACH SITE 1 & 2

### 7.6.1 Introduction

Llyn y Fan Fach is located in the western area of the BBNP in the Mynydd Du (Black Mountain) south east from Llanddeusant and south from the Usk Reservoir (SN8057123770). Llyn y Fan Fach is the name given to a glacial lake or cirque, currently dammed it forms the headwarters of the Wennalt Fawr. Several other tributaries including the Afon Sychlwch, Nant Coch, Nant Melyn and Sychnant also flow into the Wennalt Fawr in the area. The survey concentrated on two locations along the Nant Melyn which flows from the base of Fan Foel to join the Wennalt Fawr near the small bridge close to the car parking area. During the survey two sites were assessed being Site 1 (SN8057123770 at 330maOD) and Site 2 (SN8011623781 at 280maOD). Tufa desposition was not identified at either site, other than on a few small branches of a single bryophyte (*Palustriella commutata*) at site 1.

### 7.6.2 Geological and hydrogeological data

The catchment of the springs and also the Nant Melyn comprise rocks from the Lower Devonian Brownstones Formation underlain by the Lower Devonian Senni Formation. The Devonian bedrock is overlain by glacial till and the area is important for a range of glacial and periglacial features from the Devensian late Glacial period (Campbell & Bowen, 1989). The Nant Melyn cuts down into the bedrock but also through the superficial deposits. The site is interdispersed with boulders sourced from the Devonian bedrock.

Site 1 located slightly further upstream along the Nant Melyn comprises a series of diffuse seepages that combine into a series of runnels, flowing off the break in slope and across a small flat area of river alluvium before reaching the Nant Melyn. The flow in several runnels was estimated and ranged from <0.1 l/s to 0.2 l/s and at the main outflow there was about 0.2l/s entering the Nant Melyn. The seepages are strongly associated with the break in slope along the bank of the river.

Two water quality samples were obtained, one from the main outflow runnel at Site 1 (LyF1.1) at SN8057123770) and one from the base of Site 2 (LyF2.4 at SN8011823779), pH values within Site 1 ranged from 7.09 to 7.32, and Site 2 from pH 7.0 – 7.36. Nutrient levels are close to or below the level of detection in both sites, and calcium and bicarbonate are the dominant ions.

### 7.6.3 Land use and pressures

Llyn y Fan Fach is located within the Brecon Beacons National Park (BBNP). Although Sites 1 & 2 are close to the car parking area, they are off the main footpath it is thought that footfall in these areas is low. The land is sheep grazed and there are sheep tracks through the site, following the break in slope at Site 1 but this is not considered to be evidence of substantial poaching. There is no evidence of burning or obvious signs of nutrient enrichment at any part of the site. It is unlikely that there are any groundwater abstractions in the immediate area.

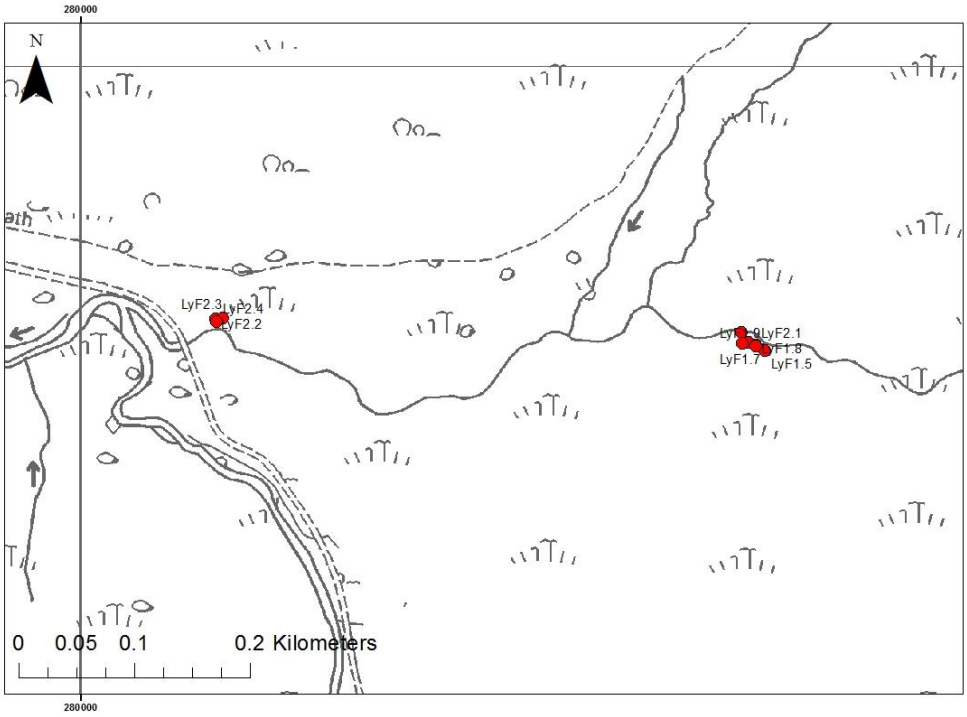



**Figure 46 Llyn y Fan Fach (1&2) Ordnance Survey map and GPS survey points. ©Ordnance Survey.**

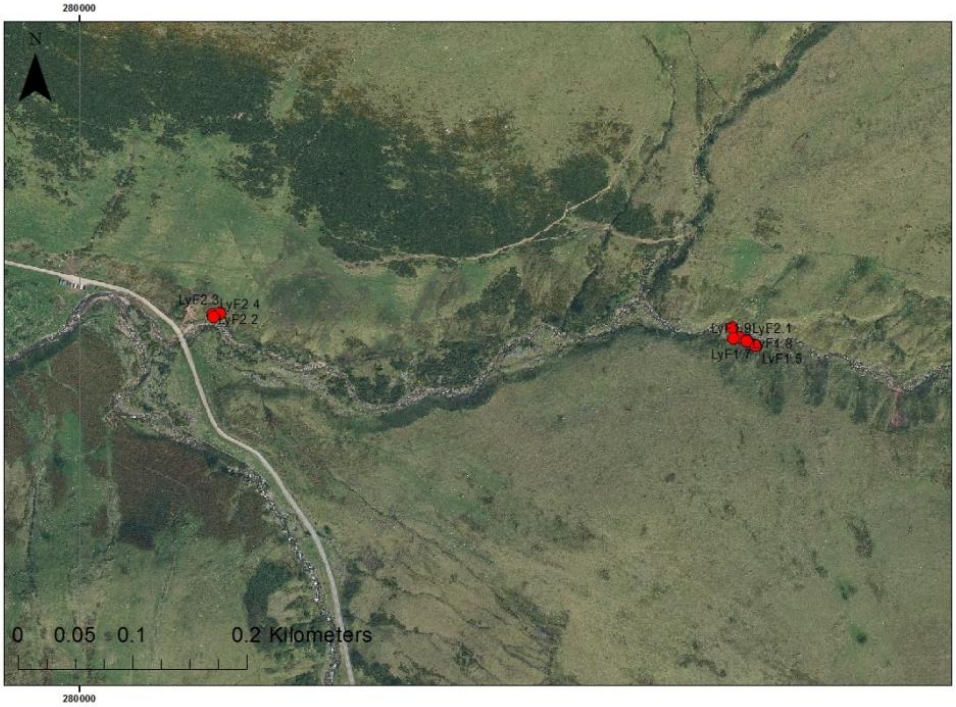



**Figure 47 Llyn y Fan Fach (1&2) aerial photograph**

© UKP/Getmapping Licence No. UKP2006/01

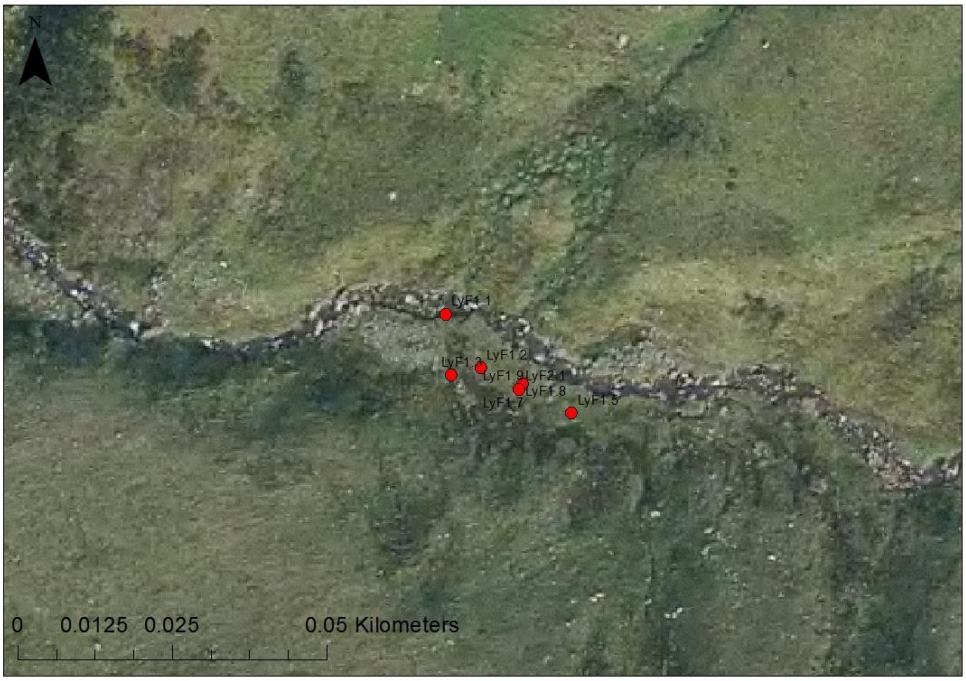



**Figure 48 Llyn y Fan Fach Site 1 aerial photograph**

© UKP/Getmapping Licence No. UKP2006/01


**Figure 49 Llyn y Fan Fach Site 2 aerial photograph**

© UKP/Getmapping Licence No. UKP2006/01

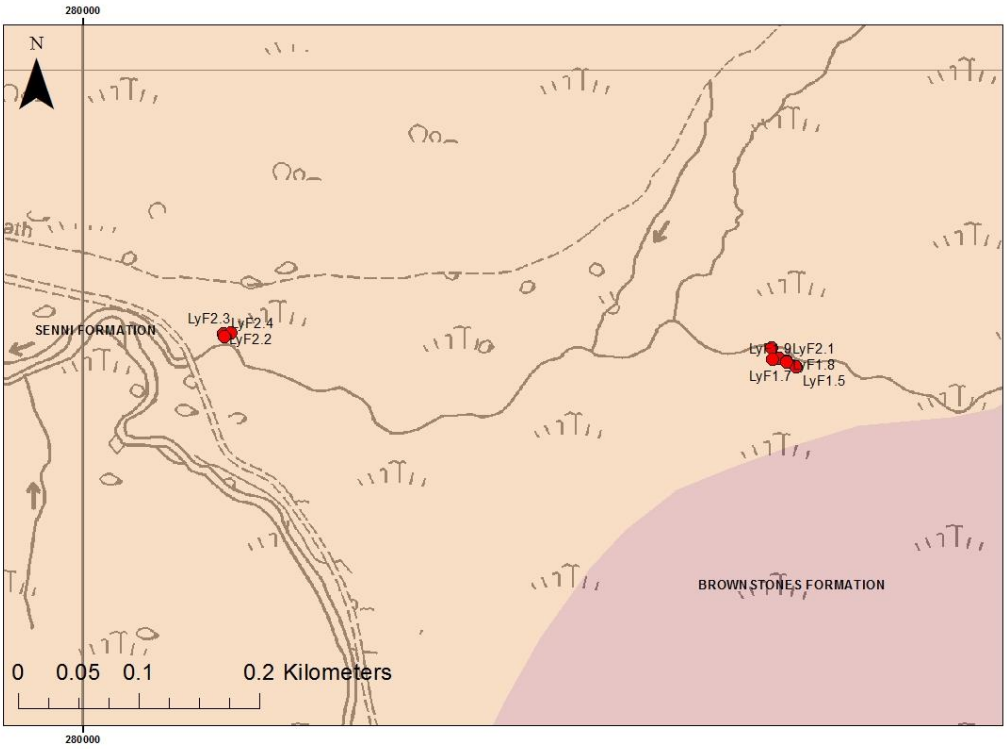
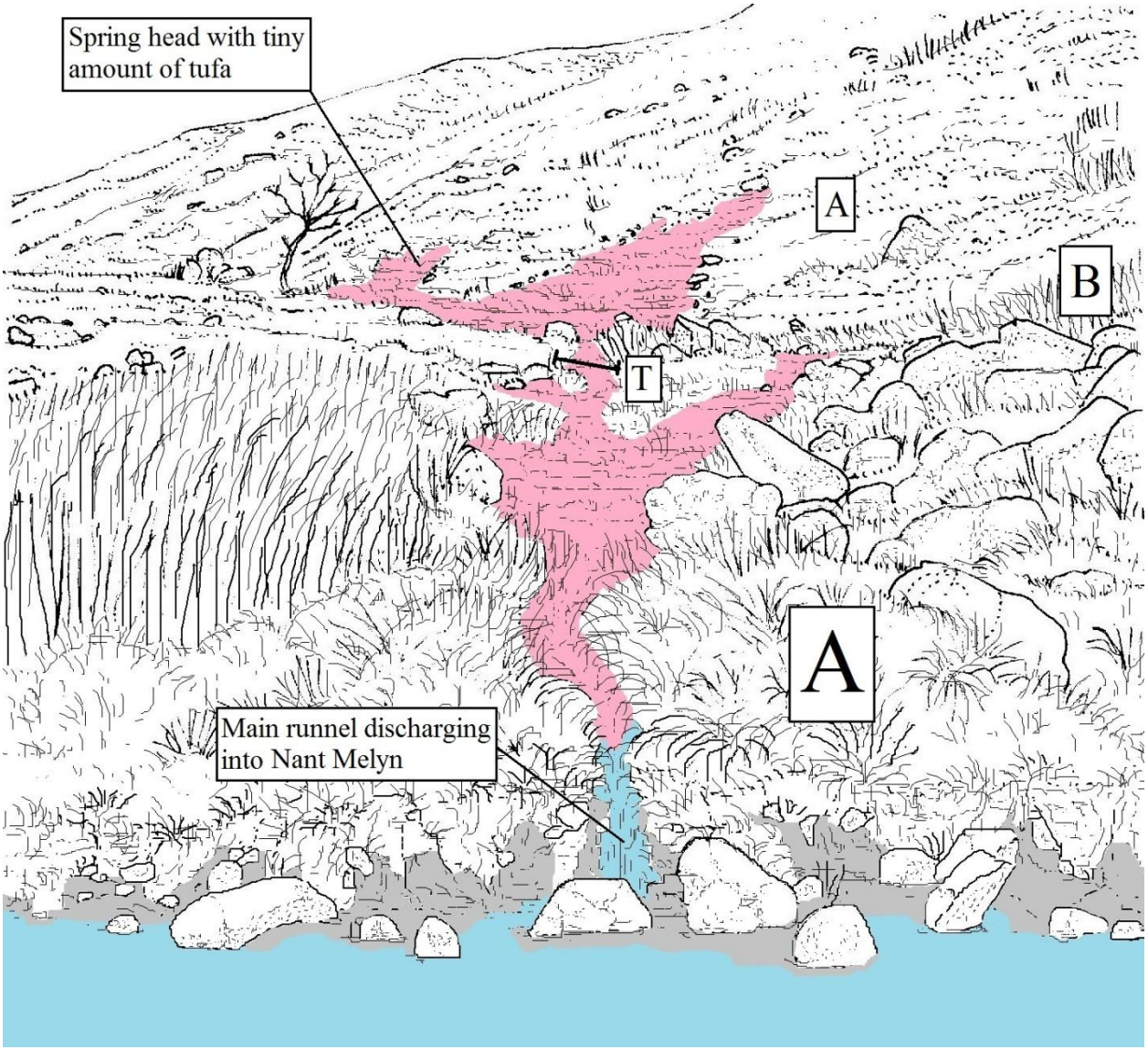



**Figure 50 Llyn y Fan Fach Bedrock Geology 1:50,000. ©BGS. ©Ordnance Survey.**

| Survey Site | Survey Ref | Date | Temperature of Water | SEC | Ammoniacal Nitrogen as N | Nitrogen, Total Oxidised as N | Nitrate as NO3 | Nitrate as N | Nitrite as N | Hardness, Total as CaCO3 | Alkalinity to pH 4.5 as CaCO3 | Chloride | Orthophosphate, reactive as P | Orthophospahte as PO4 | Sulphate as SO4 | Phosphate -{TIP} |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CEL | uS/Cm | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l |
| Llyn y Fan Fach Site 1 | LyF1.1 | 27/11/2013 | 7.3 | 222.6 | <.03 | 0.23 | | 0.23 | <.004 | 101 | 99 | 5.5 | <.02 | | <10 | <.02 |
| Llyn y Fan Fach Site 2 | LyF2.4 | 27/11/2013 | 9.50 | 202.3 | <0.03 | 0.29 | | 0.29 | <0.004 | 92 | 91 | 5.9 | <0.02 | | <10 | 0.07 |

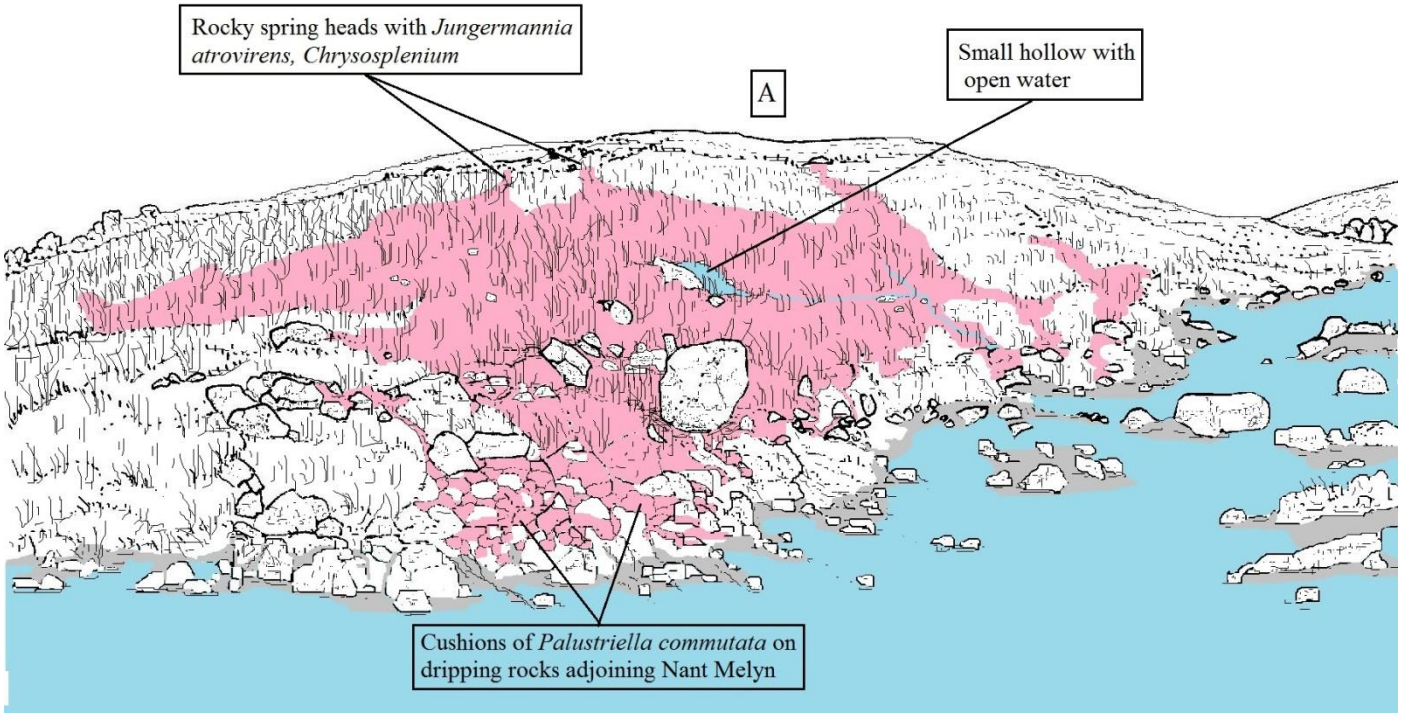
| Survey Site | Survey Ref | Date | Sodium | Potassium | Magnesium | Calcium | Redox Potential : In Situ | pH : In Situ | Manganese | Iron | Manganese, Dissolved | Iron, Dissolved | Ionic Balance | Bicarbonate as HCO3 | Oxygen, Dissolved, % Saturation | Oxygen, Dissolved as O2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/l | mg/l | ug/l | mg/l | mV | pH | ug/l | ug/l | ug/l | ug/l | % | mg/l | % | mg/l |
| Llyn y Fan Fach Site 1 | LyF1.1 | 27/11/2013 | 4.54 | 0.752 | 3.31 | 34.8 | 0.2 | 7.09 | 19.6 | 60.7 | <10 | <30 | 2.92 | 121 | 114 | 13.7 |
| Llyn y Fan Fach Site 2 | LyF2.4 | 27/11/2013 | 5.0 | 0.74 | 2.87 | 32.0 | -24.6 | 7.36 | 221.00 | 523 | <10 | <30 | -3.36 | 111 | 94.0 | 10.7 |

**Table 35 Llyn y Fan Fach water quality**




| | | | |
|---|---|---|---|
| | *Palustriella* dominated vegetation | A | Acid grassland |
| | Central runnel and Nant Melyn (open water) | B | *Juncus* dominated side spring (without *Palustriella*) |
| | Bryophyte dominated riparian vegetation without *Palustriella* (Nant Melyn) | | |

**Figure 51 Llyn y Fan Fach site 1 Vegetation map**




| | | | |
|---|---|---|---|
| | *Palustriella* dominated vegetation | A | Calcareous grassland (heavily sheep grazed with scattered *Nardus, Juncus squarrosus*) |
|  | *Juncus effusus* | | Runnels and Nant Melyn (open water) |
| | Bryophyte dominated riparian vegetation without *Palustriella* (Nant Melyn) | | |

**Figure 52 Llyn y Fan Fach site 2 Vegetation map**

### 7.6.4 **Vegetation (spring) of Lyn y Fan Fach site 1**

*Palustriella falcata* dominated short vegetation between 1-3cm height in patches around a number of small springs in a small area that ultimately discharges into the Nant Melyn. In places the flushed vegetation is species rich with abundant *Campylium stellatum, Fissidens adianthoides*, S*corpidium cossonii, Philonotis calcarea*, *Philonotis fontana*, *Bryum pseudotriquetrum* and locally marginal stands of *Breutelia chrysoscoma.* Several runnels have dominant patches of *Scorpidium cossonii* and *Leicolea bantriensis, Riccardia mutifida, Wahlenbergia hederacea* occur locally.

| | | | |
|---|---|---|---|
| *Agrostis stolonifera* | R (<1%) | *Juncus acutiflorus* | O |
| *Anagallis tenella* | R | *Leicolea bantriensis* | O |
| *Aneura pinguis* | F | *Molinia caerulea* | R (<1%) |
| *Breutelia chrysoscoma* | R (<1%) | *Palustriella commutata* | F |
| *Briza media* | R (<1%) | *Palustriella falcata* | D |
| *Bryum pseudotriquetrum* | O | *Pellia endiviifolia* | R (<1%) |
| *Calliergonella cuspidata* | R | *Philonotis calcarea* | F |
| *Campylium stellatum* | F | *Philonotis fontana* | R |
| *Carex demissa* | O | *Plantago lanceolata* | R (<1%) |
| *Carex flacca* | O | *Preissia quadrata* | R |
| *Cerastium fontanum* | R (<1%) | *Prunella vulgaris* | R |
| *Cirsium palustre* | R | *Rhytidiadelphus squarrosus* | R (<1%) |
| *Cratoneuron filicinum* | R (<1%) | *Riccardia multifida* | R |
| *Ctenidium molluscum* | R (<1%) | *Scorpidium cossonii* | F |
| *Cynosurus cristatus* | R (<1%) | *Thuidium tamariscinum* | R (<1%) |
| filamentous algae (Chlorophyta) | R | *Trifolium repens* | R (<1%) |
| *Fissidens adianthoides* | O | *Wahlendbergia hederacea* | R (<1%) |
| *Galium palustre ssp. palustre* | R | | |
| *Holcus lanatus* | R (<1%) | | |

**Table 36 Llyn y Fan Fach Site 1 Species list – Palustriella dominated vegetation**

Acidic rocks within the area of flush/spring but above level of seepage water supporting occasional acrocarpous calcifuge species.

| | |
|---|---|
| *Racomitrium aciculare* | O |
| *Ptychomitrium polyphyllum* | R |

**Table 37 Llyn y Fan Fach Site 1 Species list – Rocks within area of flush/spring but above level of seepage water**

### 7.6.5 **Vegetation adjoining spring**

Acidic *Juncus effusus* dominated rush pasture (to 30m height) occurring to the right of the main *Palustriella* springs with frequent patches of *Aulocomnium palustre, Polytrichum commune, Sphagnum* species within.

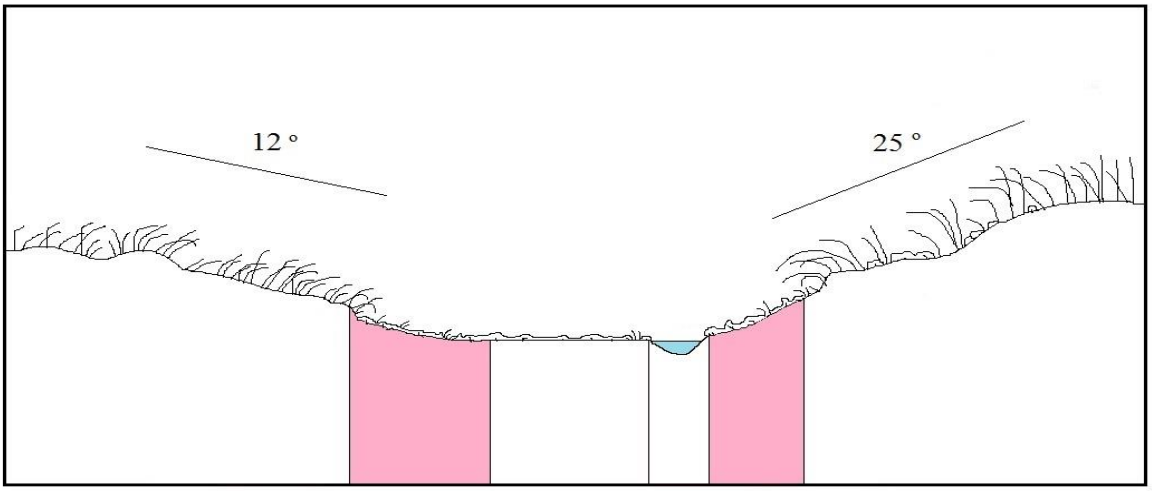
| | |
|---|---|
| *Aulocomnium palustre* | O |
| *Calliergonella cuspidata* | R |
| *Juncus effusus* | A |
| *Polytrichum commune* | O |
| *Sphagnum inundatum* | R |
| *Sphagnum subnitens* | O |

**Table 38 Llyn y Fan Fach Site 1 Species list – Juncus dominated flush (spring to right of central Palustriella dominated spring)**

Acid sheep grazed grassland (to 10cm height) dominated by *Nardus stricta, Galium saxatile* with scatterd patches of *Molinia* and *Sphagnum*.

| | |
|---|---|
| *Sphagnum inundatum* | R |
| *Hylocomium splendens* | R |
| *Juncus effusus* | O |
| *Juncus squarrosus* | O |
| *Molinia caerulea* | R (<1%) |
| *Nardus stricta* | F |
| *Potentilla erecta* | O |
| *Scleropodium purum* | R |
| *Sphagnum subnitens* | R |

**Table 39 Llyn y Fan Fach Site 1 Species list – Juncus dominated flush (spring to right of central Palustriella dominated spring)**




| | | | | |
|---|---|---|---|---|
| *Hylocomium splendens*<br>*Juncus effuses*<br>*Molinia caerulea*<br>*Nardus stricta*<br>*Pleurozium schreberi*<br>*Scleropodium purum* | *Carex flacca*<br>*Cirsium palustre*<br>*Juncus acutiflorus*<br>*Palustriella falcata*<br>*Scorpidium cossonii* | Open water<br>*Scorpidium cossonii* | *Anagallis tenella*<br>*Carex flacca*<br>*Juncus acutiflorus*<br>*Palustriella falcata* | *Hylocomium splendens*<br>*Nardus stricta*<br>*Pleurozium schreberi*<br>*Potentilla erecta*<br>*Sphagnum subnitens* |
| pH5.04<br>EC147 | pH7.29<br>EC229 | pH7.31<br>EC 187.0 | pH7.05<br>EC165.8 | pH5.56<br>EC124.7 |

**Figure 53 Llyn y Fan Fach Site 1 Transect and vegetation chemistry**

| | |
|---|---|
|  <br>Main spring head and start of *Palustriella* flush – upper part of site looking east (up slope) |  <br>Side spring (right) with acid rush pasture and occasional *Sphagnum* – upper part of site looking south (up slope |
|  <br>Main central runnel with narrow marginal stands of *Palustriella* dominated vegetation and surrounded by boulders and acid grassland. |  <br>Marginal stand of *Breutelia chrsoscoma* with *Carex flacca, Juncus acutiflorus, Anagallis tenella* |
|  <br>Main central runnel discharging into the Nant Melyn (lower end of site). | |

**Table 40 Llyn y Fan Fach Site 1 photographs**

### 7.6.6 **Vegetation (spring) of Lyn y Fan Fach site 2**

A series of springs fall onto an area of slipped soil allowing development of a mosaic of *Palustriella* dominated vegetation and rush pasture. *Palustriella* dominated vegetation is best developed around rocky runnels where *Fissidens adianthoides*, S*corpidium cossonii, Philonotis calcarea*,

*Philonotis fontana* and locally *Scorpidium cossonii* occur. Much of the flushed vegetation is more "neutral" in character with abundant *Juncus effusus, Cratanueron filicinum, Philonotis fontana, Calliergonella cuspidata* and occasional *Chrysosplenium oppositifolium*. Emergent flowering plants are well developed including *Nasturtium officinale s.l., Galium palustre ssp. palustre, Hydrocotyle vulgaris, Mentha aquatic* and *Epilobium sp*. The small leafy liverwort *Jungermania atrovirens* occurs locally on rocks at the immediate spring heads.

| | | | |
|---|---|---|---|
| *Agrostis stolonifera* | R (<1%) | *Juncus acutiflorus* | O |
| *Anagallis tenella* | F | *Juncus effusus* | F |
| *Aneura pinguis* | O | *Jungermannia atrovirens* (per.) | R |
| *Bellis perennis* | R | *Mentha aquatica* | O |
| *Briza media* | R | *Nasturtium officinale s.l.* | R |
| *Calliergonella cuspidata* | O | *Palustriella commutata* | O |
| *Cardamine pratensis* | O | *Palustriella falcata* | A |
| *Carex demissa* | R | *Pellia endiviifolia* | R |
| *Carex flacca* | O | *Philonotis calcarea* | O |
| *Chrysosplenium oppositifolium* | O | *Philonotis fontana* | F |
| *Cirsium palustre* | O | *Plantago lanceolata* | R |
| *Cratoneuron filicinum* | F | *Prunella vulgaris* | O |
| *Ctenidium molluscum* | R (<1%) | *Ranunculus acris* | R |
| *Epilobium sp.* | R | *Rumex acetosa* | O |
| *Equisetum plaustre* | R | *Scorpidium cossonii* | O |
| *Festuca rubra* | R | *Scorzoneroides autumnalis* | O |
| filamentous algae (Chlorophyta) | R | *Stellaria media* | R (<1%) |
| *Fissidens adianthoides* | R | *Taraxacum sp.* | R |
| *Galium palustre ssp. palustre* | R | *Trifolium repens* | R (<1%) |
| *Hydrocotyle vulgaris* | R | | |

**Table 41 Llyn y Fan Fach Site 2 Species list – Palustriella dominated vegetation**

Rocks within the area of flush/spring but above level of seepage water supporting occasional acrocarpous calcareous and calcifuge species.

| | |
|---|---|
| *Tortella tortuosa* | R |
| *Ptychomitrium polyphyllum* | O |

**Table 42 Llyn y Fan Fach Site 2 Species list – Rocks within area of flush/spring but above level of seepage water**

### 7.6.7 **Vegetation adjoining spring**

Heavily sheep grazed calcareous grassland (to 10cm height) dominated *Cynosurus cristatus, Bellis, Trifolium repens* and *Rhytidiadelphus squarrosus.*

| | |
|---|---|
| Agrostis capillaris | R |
| Bellis perennis | O |
| Cynosurus cristatus | O |
| Juncus squarrosus | R (<1%) |
| Nardus stricta | R (<1%) |
| Plantago lanceolata | O |
| Rhytidiadelphus squarrosus | O |
| Rumex acetosa | R |
| Scorzoneroides autumnalis | R |
| Taraxacum sp. | R |
| Trifolium repens | O |

**Table 43 Llyn y Fan Fach Site 2 Species list – Calcareous grassland (heavily sheep grazed with scattered Nardus, Juncus squarrosus)**

### 7.6.8 **Transect vegetation and chemistry data**

No transect was undertaken at Llyn y Fan Fach site 2.

Several springs converge below an area of land slip to produce a mosaic of rush pasture and *Palustriella* flush – upper part of site looking north (up slope)

Lower paty of site in close proximity to the Nant Melyn – looking south (up slope)

One of several runnels with narrow marginal stands of *Palustriella commutata, Chrysosplenium* – central part of site.

Small cental hollow with *Cratoneuron filicinum, Calliergonella cuspidata, Pellia endiviifolia*.

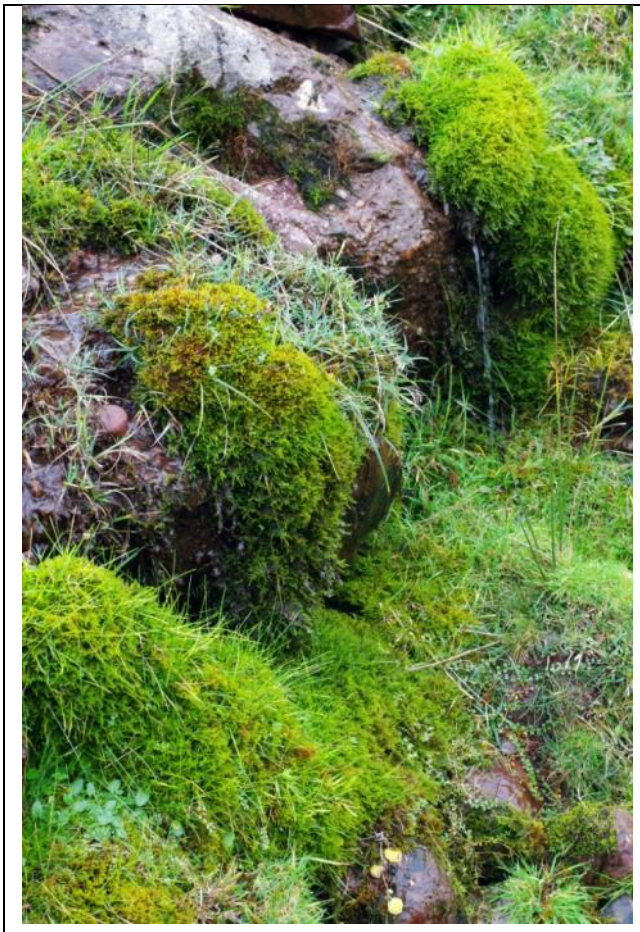
| | |
|---|---|
|  <br>Lower party of site where spring water discharges into the Nant Melyn – looking south (up slope). Note well developed dripping cushions of *Palustriella commutata*. | |

**Figure 54 Llyn y Fan Fach Site 2 photographs**

### 7.6.9 **Condition assessment**

The overall assessment is that Llyn-yr-Fan fach (sites 1 & 2) should be classified as being in favourable ecological and hydrogeological condition.

## 7.7 CRAIG Y CILAU / WAUN DDU

### 7.7.1 Introduction

Craig y Cilau is a Natural Nature Reserve (NNR) located within the Brecon Beacons National Park west of Crickhowell at SO1861016416. Craig y Cilau is part of the wider Mynydd Llangatwg SSSI and Waun Ddu, a raised bog, is located at the base of the escarpment within the NNR. The site has a peripheral stream that flows south between the raised bog (Waun Ddu) to the east and the large escarpment to the west. During the site visit no tufa deposits were identified.

### 7.7.2 Geological and hydrogeological data

The highest ground at Craig y Cilau comprises Carboniferous Twrch Sandstone Formation that overlies the Dowlias Limestone Formation, part of the Pembroke Limestone Group. Moving down the cliff face the Carboniferous Llanelly Formation, Cwmyniscoy Mudstone Formation and Abercriban Oolite are underlain by the Devonian Quartz Conglomerate Group. There is a large scree slope formed against the ridge and comprises a mixture of boulders from the Carboniferous strata in the area. Waun Ddu represents the principal superficial deposit (peat) in the study area.

The site comprises the margins of the southwards flowing stream that flows between Waun Ddu raised bog to the east and the large scree slope to the west. There are several possible and potentially complex water supply mechanisms to this site, the following description is based upon a single site visit and should not be considered a definitive account of the hydrology/hydrogeology of the site. The stream and its tributaries follow the periphery of the raised bog and diffuse seepage from the base of the bog, and even surface runoff will contribute to the stream water. Raised bogs are rainfall dominated (ombrotrophic) and also peat based, these are two factors that will influence the quality of the water flowing into the stream from its western banks. Some of the farm land to the east is located on the Devonian Brownstones and also drains into these ditches and streams and again it is reasonable to include these areas in the possible catchment. Moving to the west large parts of the karstic upland of Craig y Cilau could potentially be within the catchment for this site as tracer tests in other areas have proven long connections with sinkholes and spring sources. The junction between the limestone and Cwmyinscoy Mudstone Formations somewhere near the scree slope could also provide ideal locations for seepages and springs to occur and the series of springs across the base of the scree slope may support this idea. The scree slope itself will also act as a potential pathway allowing rainwater and seepage from the Carboniferous strata to reach the western banks of the stream.

One sample was collected from CyC1.5 a spring on the western side of the stream. The water was pH7.73 and had a small amount of nitrate 1.78mg/l as $NO_3$. Field water quality measurements either side of the stream show that there are distinct differences between water entering from Waun Ddu compared to water from springs and seepages at the base of the scree slope. Water on the surface of Waun Ddu is acidic pH 4.14 -4.38 and has a low specific electrical conductivity 38.1-54.9us/cm, similar to many other upland areas and peat bogs. The springs and seepages from the western side of the stream have pH values ranging from 7.49-7.84 and specific electrical conductivities of 125-299 us/cm.

### 7.7.3 Land use and pressures

Craig y Cilau / Waun Ddu is part of a NNR and there is some, but limited footfall across the site. The general area is sheep grazed and there is evidence of both heavy sheep grazing and some poaching on the raised surface of Waun Ddu bog. There is no evidence of burning or obvious signs of nutrient enrichment at any part of the site. It is unlikely that there are any groundwater or surface water abstractions in the immediate area.

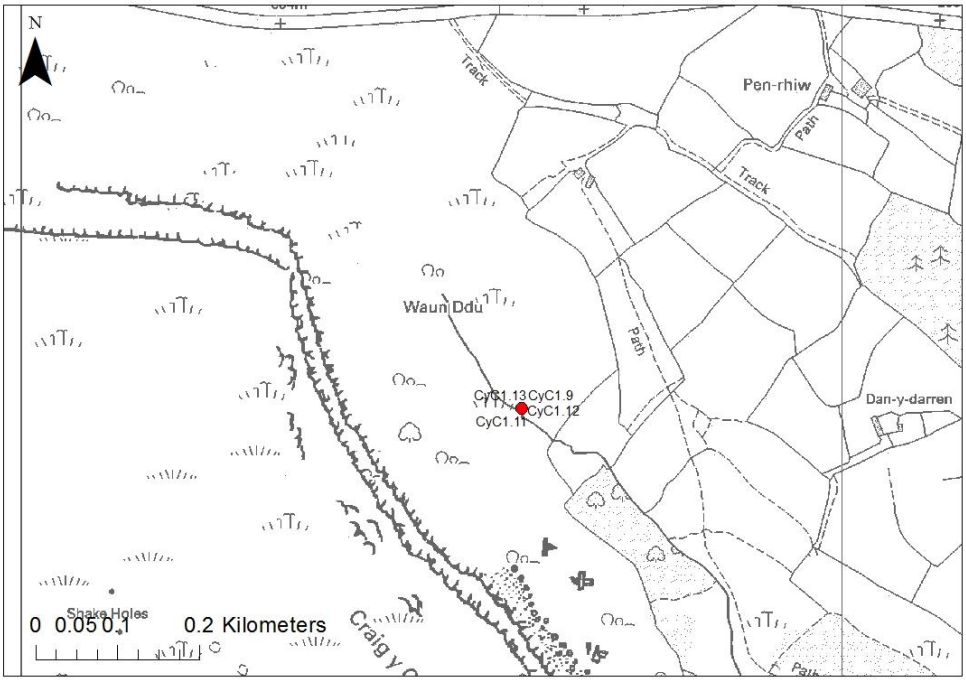



**Figure 55 Craig y Cilau/Waun Ddu Ordnance Survey map and GPS survey points. ©Ordnance Survey.**


**Figure 56 Craig y Cilau/Waun Ddu Aerial photograph**

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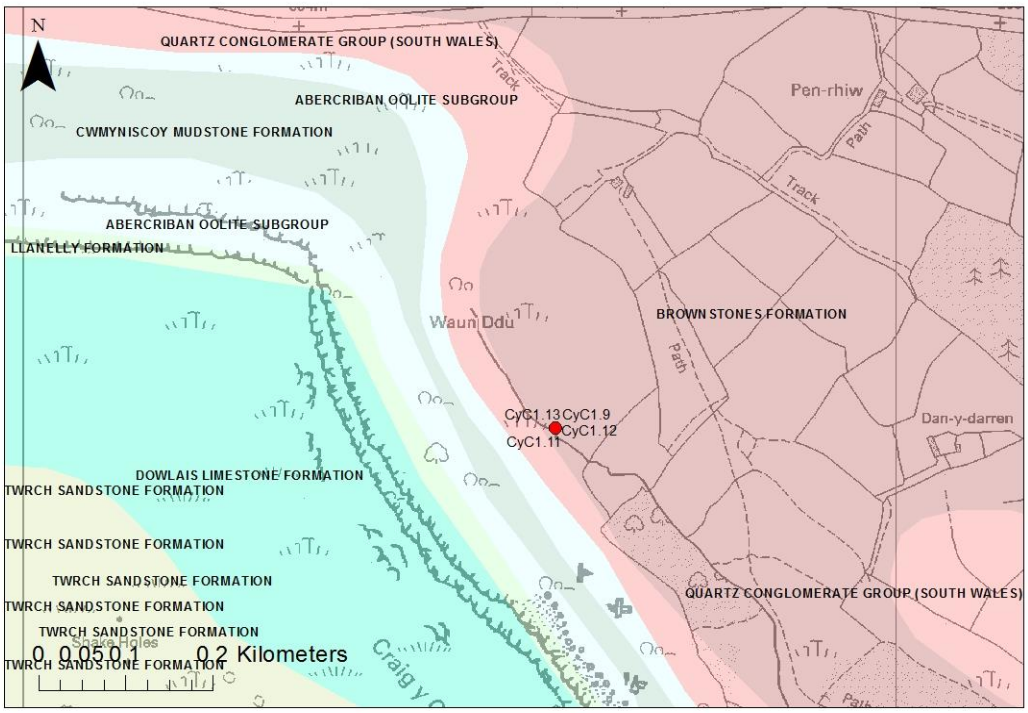
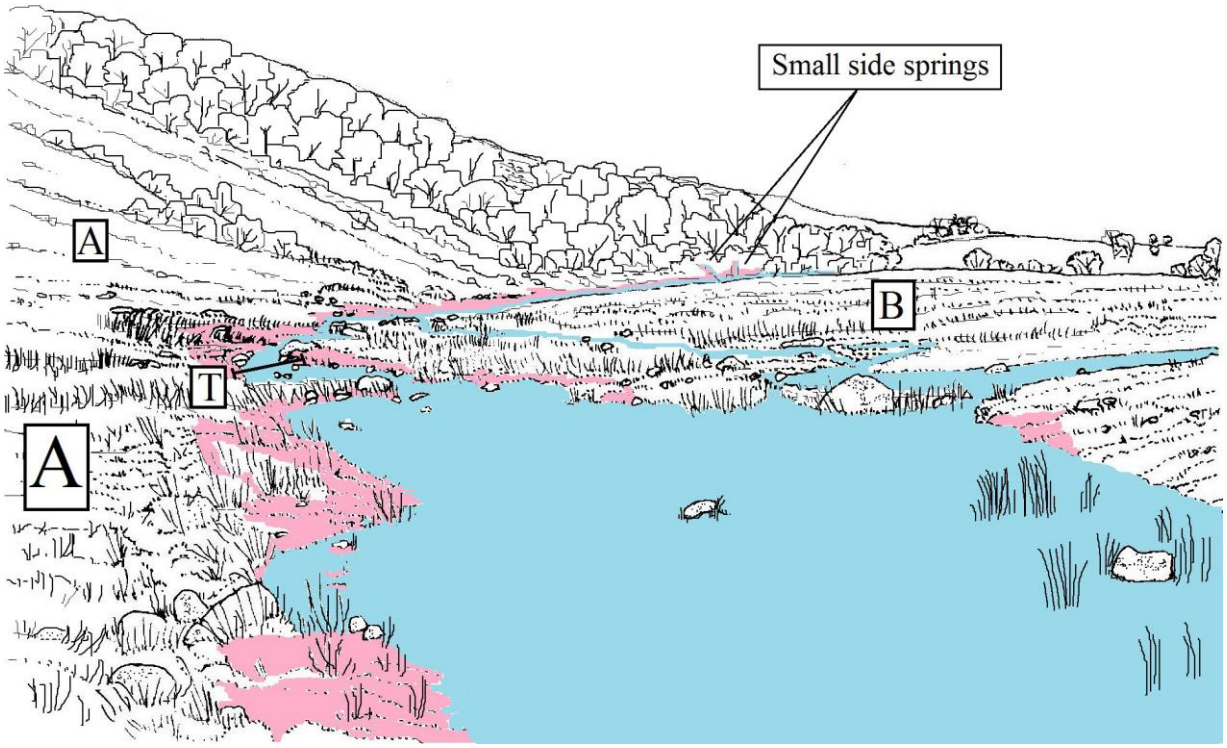



**Figure 57 Craig y Cilau/Waun Ddu Bedrock Geology 1:50,000. ©BGS. ©Ordnance Survey.**

| Survey Site | Survey Ref | Date | Temperature of Water | SEC | Ammoniacal Nitrogen as N | Nitrogen, Total Oxidised as N | Nitrate as NO3 | Nitrate as N | Nitrite as N | Hardness, Total as CaCO3 | Alkalinity to pH 4.5 as CaCO3 | Chloride | Orthophosphate, reactive as P | Orthophospahte as PO4 | Sulphate as SO4 | Phosphate :-{TIP} |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CEL | uS/Cm | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l |
| Criag y Cilau | CyC1.5 | 17/01/2014 | 7 | 259.5 | <0.2 | 0.41 | 1.78 | | <0.0152 | 133 | 120 | 7.1 | <0.02 | <0.05 | <10 | <.02 |

| Survey Site | Survey Ref | Date | Sodium | Potassium | Magnesium | Calcium | Redox Potential : In Situ | pH : In Situ | Manganese | Iron | Manganese, Dissolved | Iron, Dissolved | Ionic Balance | Bicarbonate as HCO3 | Oxygen, Dissolved, % Saturation | Oxygen, Dissolved as O2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/l | mg/l | ug/l | mg/l | mV | pH | ug/l | ug/l | ug/l | ug/l | % | mg/l | % | mg/l |
| Criag y Cilau | CyC1.5 | 17/01/2014 | 3.19 | 0.42 | 5.91 | 43.6 | 59.3 | 7.73 | <10 | 52 | <10 | <30 | | 146.3 | 88.0 | 10.7 |

**Table 44 Craig y Cilau/ Waun Ddu water quality**




| | | | |
|---|---|---|---|
| | *Palustriella* dominated vegetation | A | Acid grassland with bracken |
| | Surface runnel | B | Bog |
| | | T | Transect |

**Figure 58 Craig-y-cilau/Waun Ddu Vegetation map (note vast majority of Palustriella dominated vegetation on left (west) side of stream (stream with a high water level at the time of survey)**

### 7.7.4 **Vegetation (spring) for Craig-y-Cilau/Waun ddu**

Marginal stands of *Palustriella falcata* (up to 5m wide) occur along the west side of a spring run and central channel. To the east side of this central runnel is a bog with *Sphagnum cuspidatum* hollows and patches of *Sphagnum cuspidatum* frequently directly adjoin the east side of this channel. Very locally small patches of *Palustriella* dominated vegetation occur on the east side of the central channel (i.e. the bog side). Along the west side of the central channel (i.e. away from the bog) species-rich *Palustriella* dominated vegetation has developed with frequent *Fissidens adianthoides, Scorpidium cossonii, Philonotis fontana, Philonotis calcarea*, occasional *Bryum pseudotriquetrum.* Locally, extensive stands of *Campylium stellatum* occur mixed with *Scorpidium cossonii,* occasional *Plagiomnium ellipticum* and occasional small hummocks of a non fertile *Chiloscyphus* species. The main winding central channel is relatively deep lower down (to

15cm at the time of survey during a period with heavy rain) with crystal clear water and a good assemledge of emergent flowering plants including *Apium nodiflorum, Veronica beccabunga, Ranunculus flammula, Glyceria fluitans* and locally dominant stands of *Potamogeton polygoniferous.* The upper spring heads are notable for a greater dominance of *Crataneron filicinum.*

| | |
|---|---|
| *Agrostis stolonifera* | R (<1%) |
| *Anagallis tenella* | O |
| *Aneura pinguis* | F |
| *Apium nodiflorum* | O |
| *Bellis perennis* | O |
| *Bryum pseudotriquetrum* | R |
| *Calliergonella cuspidata* | R |
| *Campylium stellatum* | F |
| *Cardamine pratensis* | O |
| *Carex demissa* | O |
| *Carex flacca* | O |
| *Chiloscyphus sp.* (non fertile) | O |
| *Cirsium palustre* | R |
| *Cratoneuron filicinum* | O |
| *Ctenidium molluscum* | O |
| *Cynosurus cristatus* | R (<1%) |
| *Festuca ovina* | F |
| filamentous algae (Chlorophyta) | O |
| *Fissidens adianthoides* | O |
| *Glyceria fluitans* | R |
| *Hydrocotyle vulgaris* | R |
| *Juncus acutiflorus* | F |
| *Juncus effusus* | O |
| *Jungermania atrovirens* (per.) | R |
| *Palustriella commutata* | R |
| *Palustriella falcata* | A |
| *Philonotis calcarea* | O |
| *Philonotis fontana* | R |
| *Plagiomnium ellipticum* (non fertile) | R |
| *Plantago lanceolata* | R |
| *Potamogeton polygonifolius* | O |
| *Pressia quadrata* | R |
| *Prunella vulgaris* | R |
| *Ranunculus flammula* | O |
| *Sagina cf nodosa* | R |
| *Scorpidium cossonii* | F |
| *Scorzoneroides autumnalis* | R |
| *Succisa pratensis* | R |
| *Taraxacum sp.* | R |
| *Veronica beccabunga* | O |

**Table 45 Craig y Cilau/Waun Ddu Species list – *Palustriella* dominated vegetation**

Rocks within the area of flush/spring but above level of seepage water supporting occasional mixtures of calcareous as well as calcifuges bryophytes and lichens.

| | |
|---|---|
| *Parmelia saxatilis* | O |
| *Ptychomitrium polyphyllum* | O |
| *Scapania undulata* | R |
| *Schistidium sp.* | O |

**Table 46 Craig y Cilau/Waun Ddu Species list – Rocks (within area of flush/spring but above level of seepage water)**

### 7.7.5 Vegetation (adjoining spring) for Craig-y-Cilau/Waun ddu

Heavily sheep grazed and poached acid grassland (to 15cm height) dominated by *Agrostis capillaris, Nardus stricta* with scattered *Pteridium.*

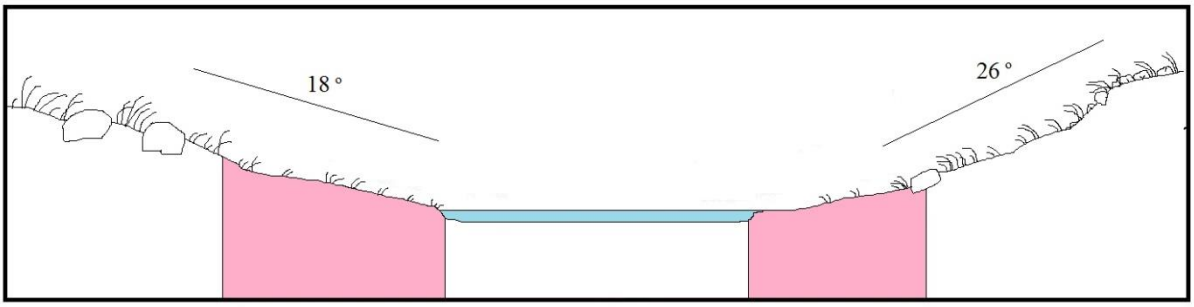
| | |
|---|---|
| *Agrostis capillaris* | O |
| *Dicranum scoparium* | O |
| *Galium saxatile* | O |
| *Hypnum jutlandicum* | O |
| *Nardus stricta* | O |
| *Potentilla erecta* | R |
| *Pteridium aquilinum* | F |
| *Rhytidiadelphus squarrosus* | R (<1%) |
| *Scleropodium purum* | O |
| *Thuidium tamariscinum* | R |

**Table 47 Craig y Cilau/Waun Ddu Species list – Acid grassland and bracken**

Heavily sheep grazed and partly degraded bog dominated by *Aulocomnium palustre, Polytrichum commune* and with regular *Sphagnum cuspidatum* in hollows.

| | |
|---|---|
| *Aulocomnium palustre* | F |
| *Campylopus intoflexus* | O |
| *Dicranum scoparium* | R |
| *Erica tetralix* | R |
| *Hypnum jutlandicum* | R |
| *Juncus effusus* | R |
| *Juncus squarrosus* | O |
| *Polytrichum commune* | F |
| *Sphagnum cuspidatum* | F |
| *Sphagnum subnitens* | O |
| *Thuidium tamariscinum* | R |

**Table 48 Craig y Cilau/Waun Ddu Species list – Bog**




| | | | | |
|---|---|---|---|---|
| *Agrostis capillaris*<br>*Galium saxatile*<br>*Hypnum jutlandicum*<br>*Nardus stricta*<br>*Potentilla erecta*<br>*Scleropodium purum* | *Anagallis tenella*<br>*Campylium stellatum*<br>*Carex flacca*<br>*Juncus acutiflorus*<br>*Palustriella falcata* | Open water | *Carex flacca*<br>*Juncus acutiflorus*<br>*Palustriella falcata* | *Aulocomnium palustre*<br>*Campylopus introflexus*<br>*Dicranum scoparium*<br>*Sphagnum cuspidatum* |
| *pH5.06*<br>*EC 49.3* | pH 6.8<br>EC 269.3 | No reading | pH7.42<br>EC 272 | pH4.93<br>EC 51.2 |

**Figure 59 Craig y Cilau/Waun Ddu Transect vegetation and chemistry**

### 7.7.6 **Condition assessment**

The overall assessment is that Craig-y-Cilau/Waun Ddu should be classified as being in favourable ecological and hydrogeological condition.

## 7.8 TARREN YR ESGOB

### 7.8.1 **Introduction**

Tarren yr Esgob is located on and accessed via privately owned land, north of Abergavenny near SO2392631499 and is part of the Black Mountains SSSI. The site comprises of a spring head / diffuse seepage area and resultant runnel that flows down a steep scree slope forming a small tributary to the Nant Bwch. There is a large area of tufa deposited along the runnel from the source down to the break in slope. The GPS could not pick up reception and detailed elevations were not obtained.

### 7.8.2 **Geological and hydrogeological data**

The high land surrounding Tarren yr Esgob comprises rocks from the Senni Formation of the Devonian Old Red Sandstone underlain by a silicate – conglomerate but importantly a calcite cemented unit, also known as a 'calcrete'. This calcrete forms part of the upper catchment of Tarren yr Esgob and is underlain by the St Maughns Formation. It is the calcrete that is the most likely source of $CaCO_3$. Mole hills on the slope adjacent to the site produced a typical red-brown looking soil often associated with the Old Red Sandstone, however the soil was rich with calcareous fragments, possibly reworked tufa deposits.

Groundwater in the Devonian rocks will primarily flow along bedding planes, between fractures and fissures (secondary permeability) but also within the rock matrix (primary permeability). During this process, and whilst in contact with the calcrete, the groundwater has an opportunity to become supersaturated with $CaCO_3$ providing the ideal chemical conditions for tufa deposition. At the top of the site, close to the main cliff, water can be seen seeping along bedding planes and fractures within the bedrock and some of the vertical rock faces are forming tufa deposits.

Three water quality samples were collected that represent the upper (TyE1.1 seepage direct from bedrock at SO2392631499), middle (TyE1.3 at 30-40 meters from the top SO239323149) and lower part of the site (TyE1.6 at SO2399731591). The previous night (17/01/2014) had seen heavy rainfall in this part of Wales and the flow and level within the runnel was elevated. Field readings of the water quality show that pH was 8.16 at the top of the site and gradually changed towards the base of the site where it was recorded at pH8.3. The electrical conductivity of the water also fell from 244us/cm at the top of the site to 204us/cm at the base. Nutrient levels are low with readings close to or below limits of detection for phosphate/orthophosphate and nitrate.

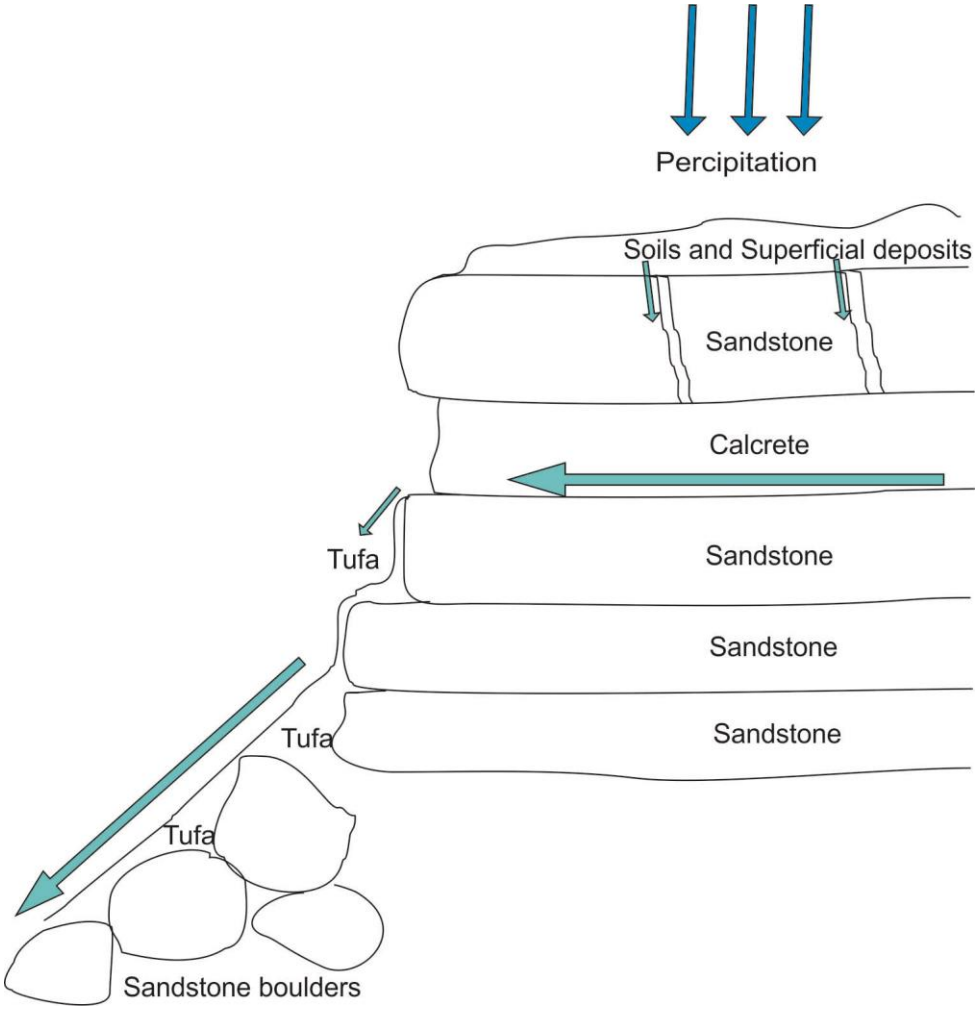



**Figure 60 Tarren yr Esgob initial site conceptual model**

### 7.8.3 **Land use and pressures**

Tarren yr Esgob is located on privately owned land and access to the site is away from the main footpaths, so footfall is expected to be limited. The area is horse and sheep grazed and there are no obvious signs of poaching. There is no evidence of burning or obvious signs of nutrient enrichment at any part of the site. It is unlikely that there are any groundwater or surface water abstractions in the immediate area.

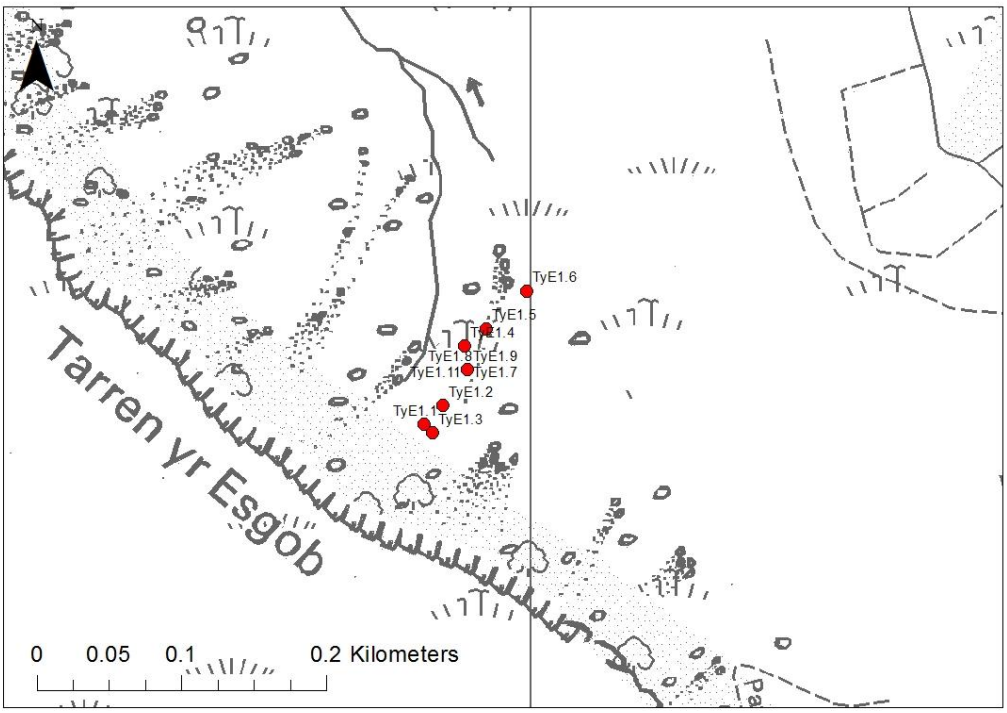



**Figure 61 Taren yr Esgob Ordnance Survey map and GPS survey points. ©Ordnance Survey.**


**Figure 62 Tarren yr Esgob aerial photograph**

© UKP/Getmapping Licence No. UKP2006/01

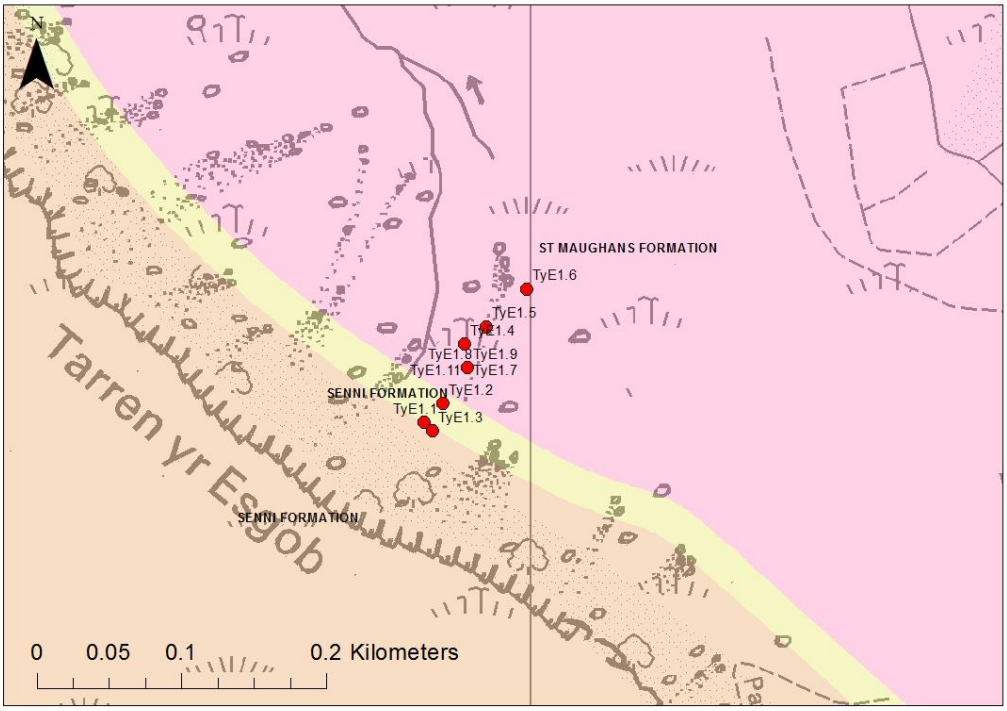
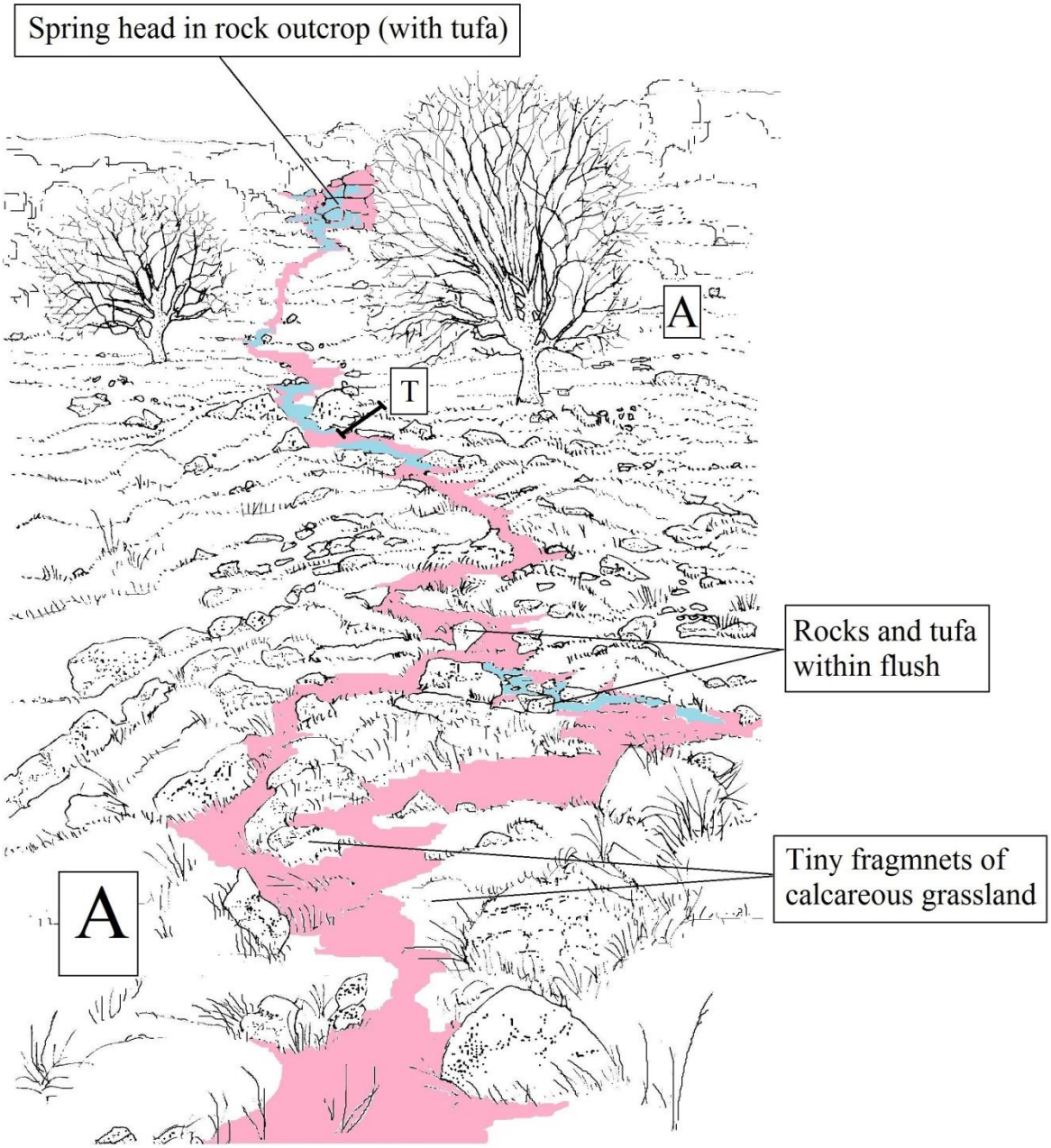



**Figure 63 Tarren yr Esgob Bedrock Geology 1:50,000. ©BGS. ©Ordnance Survey.**

| Survey Site | Survey Ref | Date | Temperature of Water | SEC | Ammoniacal Nitrogen as N | Nitrogen, Total Oxidised as N | Nitrate as NO3 | Nitrate as N | Nitrite as N | Hardness, Total as CaCO3 | Alkalinity to pH 4.5 as CaCO3 | Chloride | Orthophosphate, reactive as P | Orthophospahte as PO4 | Sulphate as SO4 | Phosphate : - {TIP} |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CEL | uS/Cm | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l |
| Tarren y Esgob 1 (top of site) | TyE1.1 | 18/01/2014 | 6.3 | 244.6 | <0.2 | 0.61 | 2.68 | | <0.0152 | 125 | 125 | 4.6 | <0.02 | <0.05 | <10 | <.02 |
| Tarren y Esgob 2 (30-40m down) | TyE1.3 | 18/01/2014 | 5.8 | 199.2 | <0.2 | 0.51 | 2.24 | | <0.0152 | | 100 | 4.8 | <0.02 | <0.05 | | <.02 |
| Tarren y Esgob 3 (bottom of site) | TyE1.6 | 18/01/2014 | 5.1 | 204.1 | <0.2 | 0.53 | 2.31 | | <0.0152 | 113 | 100 | 5.0 | <0.02 | <0.05 | <10 | 0.027 |

| Survey Site | Survey Ref | Date | Sodium | Potassium | Magnesium | Calcium | Redox Potential : In Situ | pH : In Situ | Manganese | Iron | Manganese, Dissolved | Iron, Dissolved | Ionic Balance | Bicarbonate as HCO3 | Oxygen, Dissolved, % Saturation | Oxygen, Dissolved as O2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/l | mg/l | ug/l | mg/l | mV | pH | ug/l | ug/l | ug/l | ug/l | % | mg/l | % | mg/l |
| Tarren y Esgob 1 (top of site) | TyE1.1 | 18/01/2014 | 4.2 | 0.56 | 6.70 | 39.1 | 12.4 | 8.16 | <10 | <30 | <10 | <30 | | 152.4 | 90.5 | 11.2 |
| Tarren y Esgob 2 (30-40m down) | TyE1.3 | 18/01/2014 | 3.7 | <1 | 5.49 | 31.8 | 3.0 | 8.29 | <10 | <20 | <10 | <30 | | 121.9 | 102.1 | 12.8 |
| Tarren y Esgob 3 (bottom of site) | TyE1.6 | 18/01/2014 | 3.8 | 0.60 | 5.32 | 36.6 | 2.1 | 8.3 | 22 | 155 | <10 | <30 | | 121.9 | 104.7 | 13.3 |

**Table 49 Tarren yr Esgob water quality**




| | | | | |
|---|---|---|---|---|
| | *Palustriella* dominated vegetation | | A | Acid grassland with bracken |
| | Surface runnel with tufa | | T | Transect |

**Figure 64 Tarren-yr-Esgob Vegetation map**

### 7.8.4 **Vegetation (spring) for Tarren-yr-Esgob**

An upland edge rocky spring with marginal *Palustriella commutata* dominated vegetation and frequent tufa dominated by *Hymenostylium recurvirostrum, Jungermannis atrovirens*, *Preissia quadrata, the algae Rivularia haematites* and occasional cushions of *Gymnostomum*

*aeruginosum*. The spring head appears at the base of a rocky ledge with extensive and well developed dripping matts of *Palustriella commutata* with *Festuca rubra.* Along the margins of the main steep central runnel *Palustriella commutata* dominated vegetation supports a number of other bryophytes including *Fissidens adianthoides, Philonotis calcarea, Ctenidium molluscum, Bryum psedutriquetrum*, occasional *Riccardia multifida, Jungermannas exertifolia ssp. cordifolia* but lacks the *Scorpidium* species and *Campylium stellatum* characteristic of similar looking upland flushes sampled. Parts of the site are shaded both by large bolders and small trees (*Salix* & *Crataegus monogyna*) and *Deschapsia cespitosa* is locally frequent along the margins of runnels.

| | |
|---|---|
| *Agrostis stolonifera* | R (<1%) |
| *Aneura pinguis* | F |
| *Bryum pseudotriquetrum* (spor.) | R |
| *Calliergonella cuspidata* | R |
| *Cardamine pratensis* | R |
| *Carex flacca* | F |
| *Cirsium palustre* | R |
| *Ctenidium molluscum* | R |
| *Deschampsia cespitosa* | O |
| *Festuca ovina* | R (<1%) |
| *Festuca rubra* | R |
| filamentous algae (Chlorophyta) | O |
| *Fissidens adianthoides* | O |
| *Gymnostomum aeruginosum* | R |
| *Hymenostylium recurvirostrum* | F |
| *Juncus acutiflorus* | F |
| *Jungermannia atrovirens* (per.) | A |
| *Jungermannia exsertifolia ssp. cordifolia* (non fertile) | R |
| *Nostoc sp.* | O |
| *Palustriella commutata* | A |
| *Pellia endiviifolia* | R |
| *Philonotis calcarea* | R |
| *Plantago lanceolata* | R |
| *Pressia quadrata* | R |
| *Primula sp.* | R |
| *Prunella vulgaris* | R |
| *Ranunculus repens* | R (<1%) |
| *Riccardia multifida* | R |
| *Rivularia haematites* | F |
| *Trifolium repens* | R (<1%) |

**Table 50 Tarren-yr-Esgob Species list – Palustriella dominated vegetation**

Rocks (including large boulders) within the area of flush/spring but above level of seepage water supporting occasional mixtures of calcareous as well as calcifuges bryophytes, lichens and ferns.

| | |
|---|---|
| *Asplenium adiantum-nigrum* | R |
| *Asplenium viride* | R |
| *Bryum capillare* | R |
| *Cladonia pyxidata* | R |
| *Frullania tamarisci* | R |
| *Grimmia trichophylla* | R |
| *Hypnum cupressiforme* | O |
| *Pressia quadrata* | O |
| *Racomitrium fasiculare* | O |
| *Racomitrium lanuginosum* | R |
| *Tortella tortuosa* | F |

**Table 51 Tarren-yr-Esgob Species list – Rocks (within area of flush/spring but above level of seepage water)**

### 7.8.5 Vegetation (adjoining spring) for Tarren-yr-Esgob

Tiny fragments of upland calcareous grassland on drier rocky areas ajoining the central channel. These small areas of grassland are dominated by *Cynosurus, Festuca ovina* and lightly horse grazed. Locally, species rich patches occur with *Linum catharticum, Pilosella* and *Thymus.*

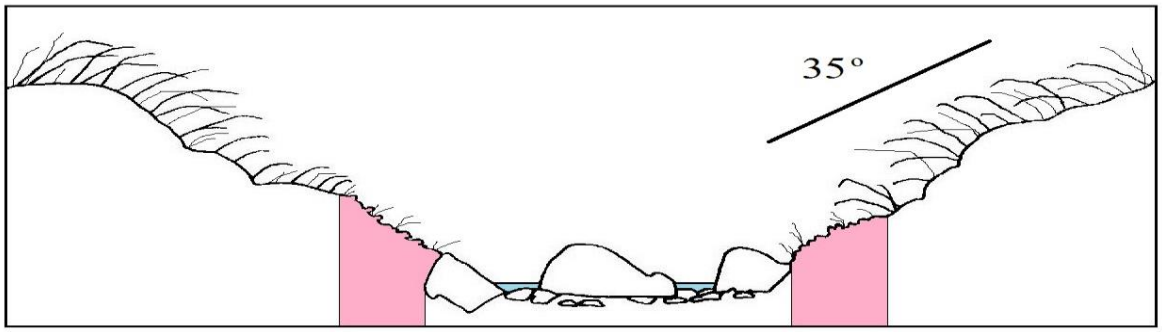
| | |
|---|---|
| *Agrostis stolonifera* | R |
| *Bellis perennis* | R |
| *Ctenidium molluscum* | A |
| *Cynosurus cristatus* | F |
| *Festuca ovina* | O |
| *Linum catharticum* | R |
| *Pilosella officinarium* | R |
| *Polygala serpyllifolia* | R (<1%) |
| *Prunella vulgaris* | R |
| *Rhytidiadelphus triquetrus* | O |
| *Thymus polytrichus* | O |
| *Viola cf hirsuta* | R |

**Table 52 Tarren-yr-Esgob Species list – Calcareous grassland**

Acid grassland (*Molinia, Dicranum scoparium, Hylocomium splendens*) with scattererd *Pteridium.* On steeper rocky slopes where grazing is limited, occasional stands of *Vaccinium myrtillus* and *Empetrum nigrum* occur.

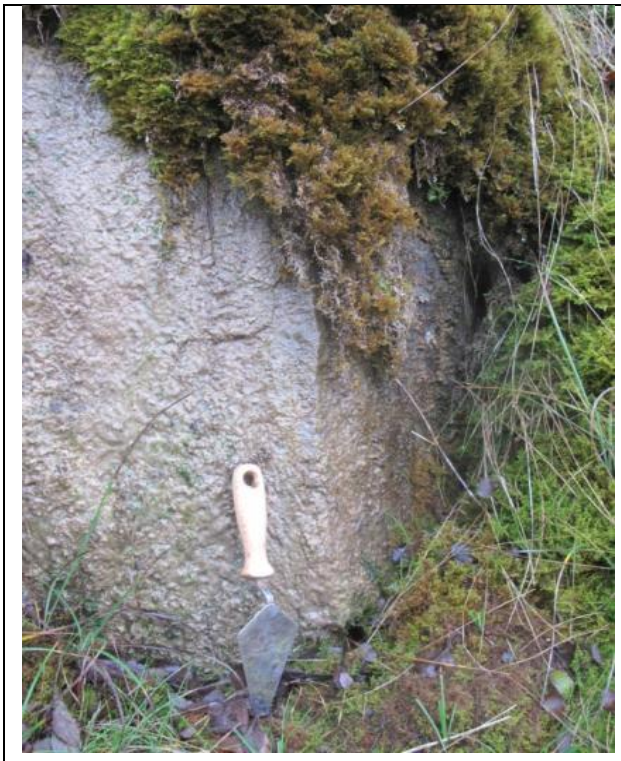
| | |
|---|---|
| *Betula pubescens* (seedling) | R |
| *Dicranum scoparium* | O |
| *Empetrum nigrum* | R (<1%) |
| *Galium saxatile* | R |
| *Hylocomium splendens* | O |
| *Mnium hornum* | R |
| *Molinia caerulea* | O |
| *Pleurozium schreberi* | O |
| *Polytrichum formosum* | R |
| *Potentilla erecta* | R |
| *Pteridium aquilinum* | F |
| *Rhytidiadelphus loreus* | O |
| *Salix sp.* (seedling) | R (<1%) |
| *Scleropdium purum* | R |
| *Thuidium tamariscinum* | R |
| *Vaccinium myrtillus* | R |

**Table 53 Tarren-yr-Esgob Species list – Acid grassland with bracken**




| | | | | | |
|---|---|---|---|---|---|
| *Dicarum scoparium*<br>*Galium saxatile*<br>*Plagiochila asplenioides*<br>*Plerozium shreberi*<br>*Polytrichum formosum* | | *Carex flacca*<br>*Palustriella commutata* | *Juncus acutiflorus*<br>*Jungermannia atrovirens*<br>*Rivularia haematites* | *Carex flacca*<br>*Juncus acutiflorus*<br>*Palustriella commutata* | *Dicarum scoparium*<br>*Molinia caerulea*<br>*Pteridium aquilinum*<br>*Scleropdium purum*<br>*Thuidium tamarascinum* |
| Length:<br>2.10m | pH 5.83EC 141.6 | pH 8.02<br>EC 179.9 | pH 8.31<br>EC 194.2 | pH 8.28<br>EC 184.4 | pH 6.95<br>EC 62.9 |

**Figure 65 Tarren-yr-Esgob Transect vegetation and chemistry**



Carboniferous Sandstone unit at the top of Tarren-yr-Esgob – note seeping water across rock face

Collection of a water quality sample and field readings from seepage at the top of the site

The alga *Rivularia haematites*, frequent on stones in running water of central runnel

Mole hill near the base of the site that contains a large amount of tufa fragments.

Rocky runnel with frequent patches of *Palustriella commutata* (lower part of site)

Steep rocky runnel with tufa (upper part of site)

**Table 54 Tarren-yr-Esgob photographs**

### 7.8.6 **Condition assessment**

The overall assessment is that Tarren-yr-Esgob should be classified as being in favourable ecological and hydrogeological condition.

## 7.9 HEN-ALLT COMMON

### 7.9.1 **Introduction**

Hen-Allt common is situated on land managed by the BBNP at SO2354039946. The area comprises a woodland and common land that is designated as a SSSI and its special features include unimproved grassland, Flat-sedge *Blysmus compressus* and Meadow Saffron *Colchium autumnal.* There is also significant localised tufa deposition.

### 7.9.2 **Geological and hydrogeological data**

Hen-Allt Common is located upon the Devonian Old Red Sandstone, Raglan Mudstone Formation and the St Maughans Formation and although not mapped on the site the Bishops Frome Limestone Member occurs in the area. During the site visit an eroded section of bedrock was identified below a more competent sandstone unit visible along the footpath between Penhenallt Farm and the site. It is possible that this eroded bed is in fact a calcrete horizon within the Devonian that has not been mapped on the 1:50K Geological Map and it could be related to the nearby Bishops Frome Limestone Member which has known calcrete horizons. This calcrete unit may also be located above the main site and can be proposed as a suitable source for the site.

The area of tufa formation is on the face of a small bedrock outcrop and in resulting mounds and runnels, the site occupying the side of a small gully. The tufa morphologies displayed at this site are very fragile and great care was taken whilst undertaking the survey. For this reason no auger holes were undertaken.

Two water quality samples were obtained from the site one from the seepage and drips direct from the tufa block (HaC1.1 at SO2354039946) and the other from below the site in a small runnel (HaC1.2 at SO2351339962). pH values ranged from 8.09 – 8.17 and dominant ions are calcium and bicarbonate. Neither sample showed elevated nutrients with results for nitrate and phosphate close to or below the lower limit of detection.

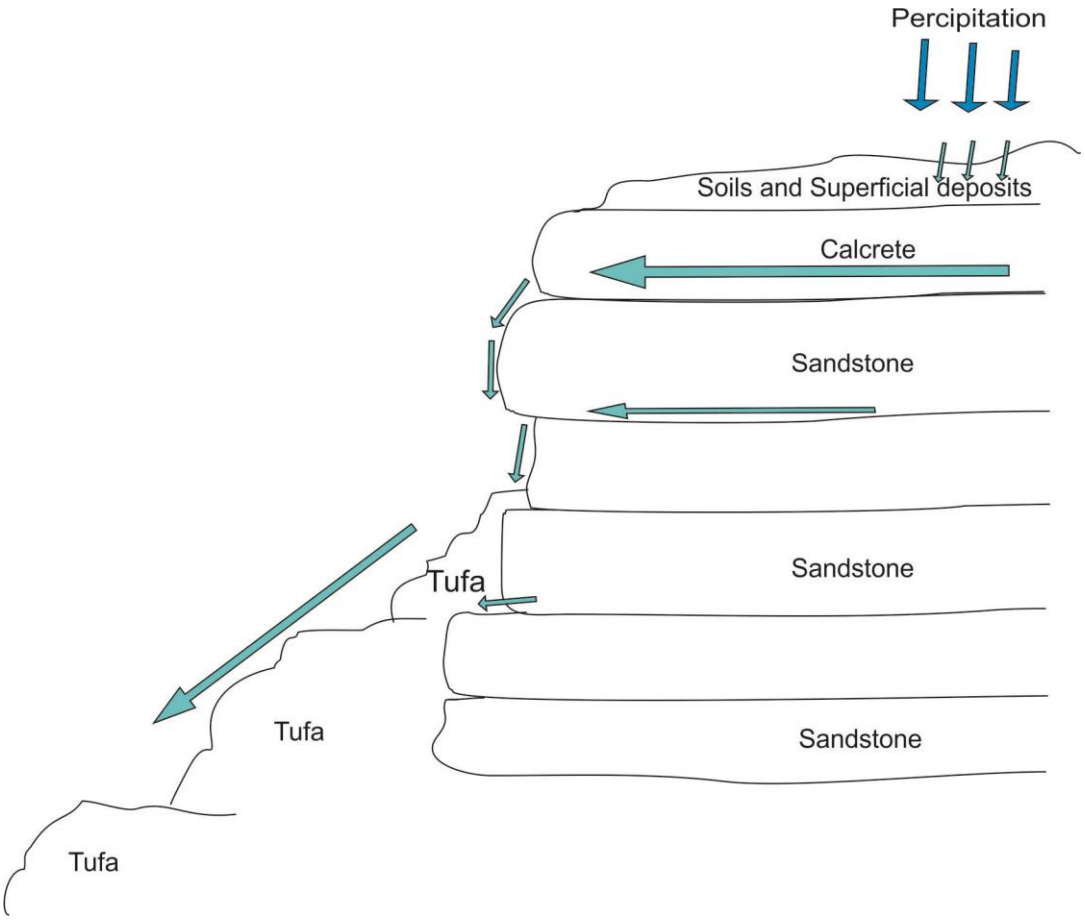



**Figure 66 Hen Allt Common initial site conceptual model**

### 7.9.3 **Land use and pressures**

Hen-Allt Common is grazed by sheep although there is currently no evidence of extensive poaching at the site. There is no evidence for burning or obvious signs of nutrient enrichment at any part of the site. There is a private water supply located downgradient from the site. The supply which is possibly a spring collection pit or similar takes water from the base of the site and it flows under gravity to a neighbouring property. The supply is fenced off to protect it from grazing animals and the installation is downgradient from the main area of tufa deposition. Although the abstraction should not have a negative impact on the site, or effect the formation of tufa or supply to the upper part of the site, it is possible that the location of the private water supply is preventing water that would be flowing across the surface in small runnels from reaching further down the small gully and thus limiting the potential downstream area for *Palustriella.*

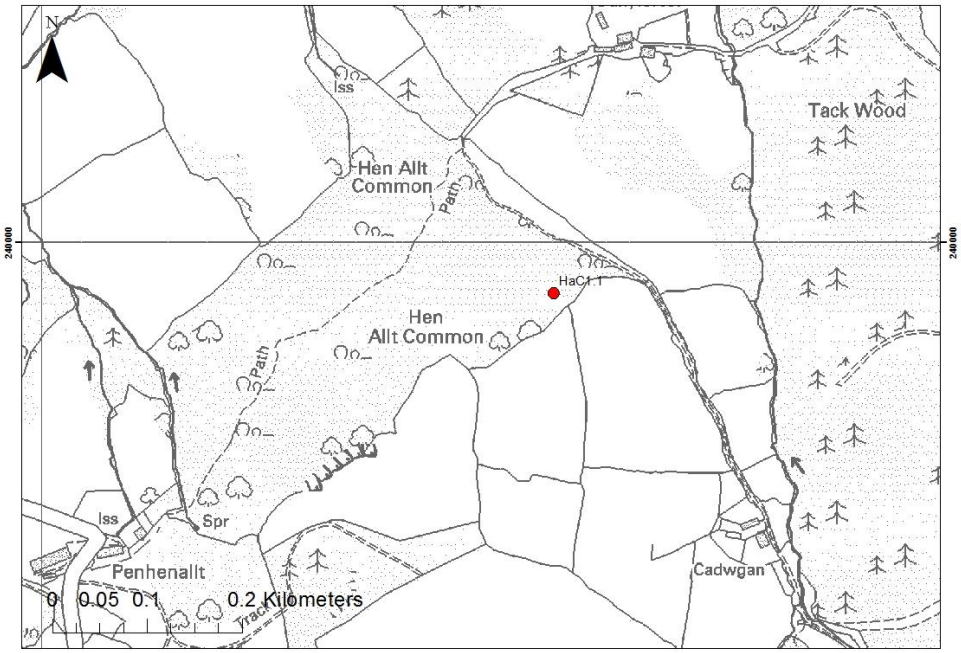



**Figure 67 Hen-Allt Common Ordnance Survey map and GPS survey points. ©Ordnance Survey.**


**Figure 68 Hen-Allt Common aerial photograph**

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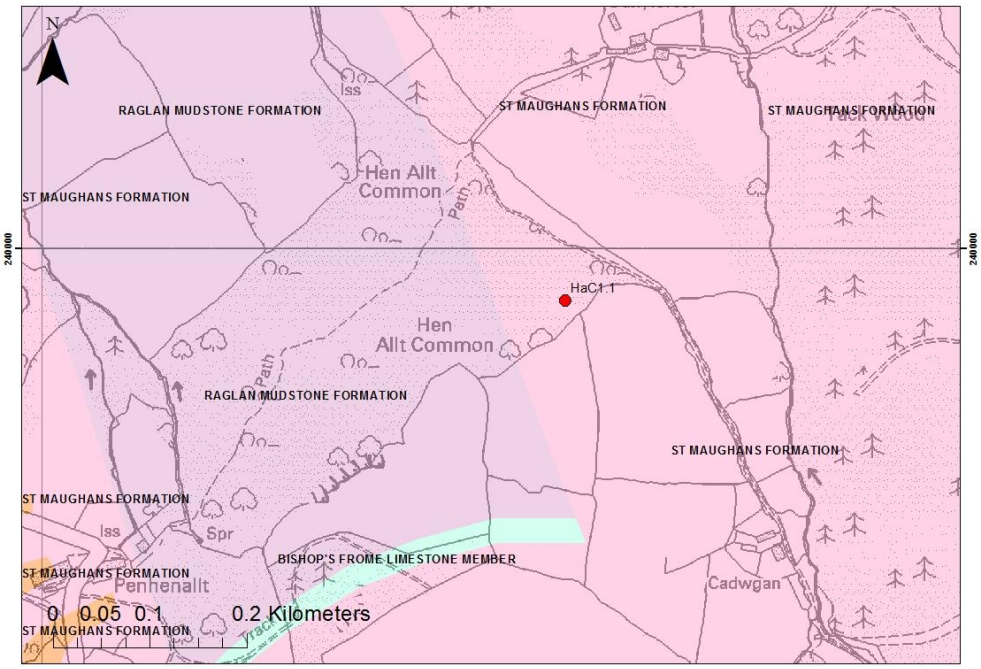



**Figure 69 Hen -Allt Common Bedrock Geology 1:50,000. ©BGS. ©Ordnance Survey.**

| Survey Site | Survey Ref | Date | Temperature of Water | SEC | Ammoniacal Nitrogen as N | Nitrogen, Total Oxidised as N | Nitrate as NO3 | Nitrate as N | Nitrite as N | Hardness, Total as CaCO3 | Alkalinity to pH 4.5 as CaCO3 | Chloride | Orthophosphate, reactive as P | Orthophospahte as PO4 | Sulphate as SO4 | Phosphate :- {TIP} |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CEL | uS/Cm | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l |
| Hen Allt Common 1 | HaC1.1 | 18/01/2014 | 6.6 | 339.3 | <0.2 | 0.58 | 2.54 | | <0.0152 | 180 | 155 | 5.5 | <0.02 | <0.05 | <10 | <.02 |
| Hen Allt Common 2 | HaC1.2 | 18/01/2014 | 4.4 | 193.0 | <0.2 | 0.54 | 2.38 | | <0.0152 | 95 | 175 | 5.8 | <0.02 | <0.05 | <10 | <.02 |

| Survey Site | Survey Ref | Date | Sodium | Potassium | Magnesium | Calcium | Redox Potential : In Situ | pH : In Situ | Manganese | Iron | Manganese, Dissolved | Iron, Dissolved | Ionic Balance | Bicarbonate as HCO3 | Oxygen, Dissolved, % Saturation | Oxygen, Dissolved as O2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/l | mg/l | ug/l | mg/l | mV | pH | ug/l | ug/l | ug/l | ug/l | % | mg/l | % | mg/l |
| Hen Allt Common 1 | HaC1.1 | 18/01/2014 | 4.9 | 1.13 | 4.31 | 64.8 | 8.3 | 8.17 | 30.3 | 136 | <10 | <30 | | 188.9 | 94.1 | 11.5 |
| Hen Allt Common 2 | HaC1.2 | 18/01/2014 | 3.0 | 0.16 | 0.91 | 36.6 | 75.0 | 8.09 | <10 | 175 | <10 | <30 | | 213.4 | 113.5 | 14.7 |

**Table 55 Hen- Allt Common water quality**

### 7.9.4 Vegetation (spring) for Hen Allt Common

A small site with *Palustriella commutata* dominated vegetation occurring below a spring head which seeps through joints within a large natural rock face. The immediate spring head and semi-shaded rock outcrops have extensive and intricate tufa deposits that are dominated by cushions of *Eucladium verticiallatum* with *Leiocolea badensis* and occasional characteristic woodland flowering plants such as *Geranium robertianum, Potentilla steralis*, occasional *Rubus fruticosus*. Although this is a small site, locally below the rock face, species-rich *Palustriella commutata* dominated vegetation occurs with *Campylium stellatum, Bryum psuedotriquetrum, Fissidens adianthoides, Scorpidium cosonnii* and very locally *Linum Catharticum, Riccardia multifida,*

*Pinguicula vulgaris* (single plant) and *Carex lepidocarpa*. An interesting feature of this flush is the presence of the "acid mire" species *Molinia*, *Succisa* mixed with calcicoles. The charophye *Chara vulgaris* was locally abundant and often becoming petrified as part of active tufa formation.

| | |
|---|---|
| *Agrostis stolonifera* | R (<1%) |
| *Aneura pinguis* | F |
| *Bellis perennis* | R |
| *Bryum pseudotriquetrum* | R |
| *Calliergonella cuspidata* | R |
| *Campylium stellatum* | R |
| *Cardamine pratensis* | R |
| *Carex demissa* | R |
| *Carex flacca* | O |
| *Carex lepidocarpa* (with old fruits) | R |
| *Centaurea nigra* | R |
| *Chara vulgaris* | O |
| *Cirsium palustre* | R |
| *Cratoneuron filicinum* | R |
| *Ctenidium molluscum* | R |
| *Epilobium sp.* | R |
| *Eriophorum angustifolium* | R |
| *Eucladium verticillatum* (spor.) | F |
| *Festuca ovina* | F |
| filamentous algae (Chlorophyta) | F |
| *Fissidens adianthoides* | R |
| *Geranium robertianum* | R |
| *Hypericum sp.* | R |
| *Juncus acutiflorus* | F |
| *Juncus effusus* | O |
| *Juncus inflexus* | R |
| *Leicolea badensis* | O |
| *Linum catharticum* | R |
| *Molinia caerulea* | R |
| *Odontites vernus* | R (<1%) |
| *Palustriella commutata* | F |
| *Palustriella falcata* | R |
| *Pinguicula vulgaris* | R (<1%) |
| *Poa annua* | R (<1%) |
| *Potentilla steralis* | O |
| *Prunella vulgaris* | R |
| *Ranunculus acris* | R |
| *Riccardia multifida* | R |
| *Rubus fruticosus agg.* | R |
| *Scorpidium cossonii* | R |
| *Succisa pratensis* | R |

**Table 56 Hen-Allt Common Species list – Palustriella dominated vegetation**

Rocks within the area of flush/spring but above level of seepage water supporting occasional calcareous bryophytes.

| | |
|---|---|
| *Ctenidium molluscum* | O |
| *Ditrichum gracile* | R |
| *Schistidium sp.* | O |

**Table 57 Hen-Allt Common Species list – Rocks (within area of flush/spring but above level of seepage water)**

### 7.9.5 Vegetation (adjoining spring) for Hen Allt Common

Tall rush pasture (to 35cm) dominated by *Juncus acutiflorus* with a broad number of tall wetland plants including *Cirsium palustre, Equisetum fluviatile, Rumex conglomeratus* and in one place a species of Marsh Orchid (*Dactylorhiza sp.).*

| | |
|---|---|
| *Agrostis stolonifera* | O |
| *Calliergonella cuspidata* | F |
| *Cardamine pratensis* | O |
| *Carex flacca* | F |
| *Cirsium plaustre* | O |
| *Dactylorhiza sp.* (Marsh Orchid) | R |
| *Epilobium cf tetrahit* | R |
| *Equisetum fluviatile* | F |
| *Juncus acutiflorus* | F |
| *Juncus conglomeratus* | R (<1%) |
| *Juncus inflexus* | O |
| *Plantagio lanceolata* | R |
| *Potentilla reptans* | R |
| *Prunella vulgaris* | O |
| *Ranunculus acris* | R |
| *Rumex conglomeratus* | O |
| *Senecio cf aquaticus* | R (<1%) |
| *Succisa pratensis* | O |
| *Thuidium tamariscinum* | O |
| *Veronica beccabunga* | O |

**Table 58 Hen-Allt Common Species list – Marshy grassland below well sink**

Hawthorn scrub with acid grassland (*Molinia*) and Bracken beneath.

| | |
|---|---|
| *Crategus monogyna* | O |
| *Molinia caerulea* | O |
| *Potentilla erecta* | R |
| *Pteridium aquilinum* | A |
| *Rubus fruticosus agg.* | O |
| *Thuidium tamariscinum* | R |
| *Ulex europaeus* | O |
| *Vaccinium myrtillus* | R |

**Table 59 Hen-Allt Common Species list – Hawthorn scrub**

### 7.9.6 **Condition assessment**

The overall assessment is that Hen Allt Common should be classified as being in favourable ecological and hydrogeological condition. However, this is a small site and the existing seepage face (rock outcrop with tufa blocks) is vulnerable to encroachment by Bramble and Hawthorn scrub. The private water supply well located further down from the site may limit the lower extent of the site, however as it appears to be gravity driven (rather than pumped) it is not thought to pose a threat to the hydrological functioning or water supply mechanisms that feed the site.

Intricate tufa blocks at spring head

Close up of main tufa block with abundant cushions of *Eucladium verticillatum*

View of Hen Allt Common main tufa block

View of the private water supply well at the base of Hen Allt common

Open area with tufa and frequent *Palustriella commutata* on gentle slope (middle part of side)

**Figure 70 Hen-Allt Common photographs**

## 7.10 CWM CLYDACH

### 7.10.1 Introduction

Cwm Clydach or the Clydach Gorge is a woodland reserve located along a deep limestone gorge, cut by the Afon Clydach. The reserve is part of the Cwm Clydach SSSI and Cwm Clydach Woodlands National Nature Reserve and SAC, and follows the A465 (heads of the valleys road) eastwards from Brynmawr. There are several tufa forming areas associated with *Palustriella* located along the gorge. If access is gained from Blackrock the first area can be seen to the north of the Afon Clydach just west of the Devils Bridge SO2151112412. During the site visit the Afon Clydach was very high and access to this section was not possible. Walking west another section is located near the mouth of Ogof Clogwyn (SO2133721402) and it is this area that was surveyed for this report. The Ogof Clogwyn site is notable for the occurrence of the two very rare Welsh bryophytes *Thamnobryum maderense* (only site in Wales) and *Orhothecium rufescens* (not seen during the present survey) which occurs at only 2 sites in South Wales (Bosanquet & Motley 2013).

### 7.10.2 Geological and hydrogeological data

In the immediate area of the survey the Clydach Gorge cuts down through the Pembroke Limestone Group of the Carboniferous Limestone, with both the Dowlais Limestone Formation and the Llanelly Formation exposed in the gorge near the survey site. The Carboniferous Twrch Sandstone Formation forms the higher ground to the south and north of the gorge. The Afon Clydach flows from west to east along the base of the gorge also receiving water from the outflow of Ogof Clogwyn (cave) which is a good example of a phreatic cave system and is 165m in length. The primary water supply mechanisms are diffuse seepages that occurs along the cliff face via joints, bedding planes and fractures within the bedrock and also vertically down the cliff face. In addition water from the discharge at Ogof Clogwyn may also be an important supply albeit only to vegetation immediately around or below the cave entrance.

Part of the water quality sample obtained from Cwm Clydach was lost during transit after being delivered to the NRW bottle store and therefore no information on nutrient levels can be provided.

### 7.10.3 Land use and pressures

The Clydach Gorge is dominated by natural woodland and is a protected site, visited by walkers, cavers and outdoor sports enthusiasts. There is plenty of evidence of historic industry all around the gorge with old railway lines and quarries associated with the quarrying of lime for construction and agriculture. There is much less industry in the area today however and small villages such as Blackrock and Gellyfelen are nearby. The A465 main road follows the gorge along its northern boundary.

Ogof Clogwyn is a well known cave suitable for beginners so it is possible that there is at least some foot fall in the immediate area of the study site from cavers. There are no grazing animals along the gorge and there is no evidence of poaching. There are few houses in proximity to the study site so abstractions (or discharges) are not thought to be a pressure within the immediate area.

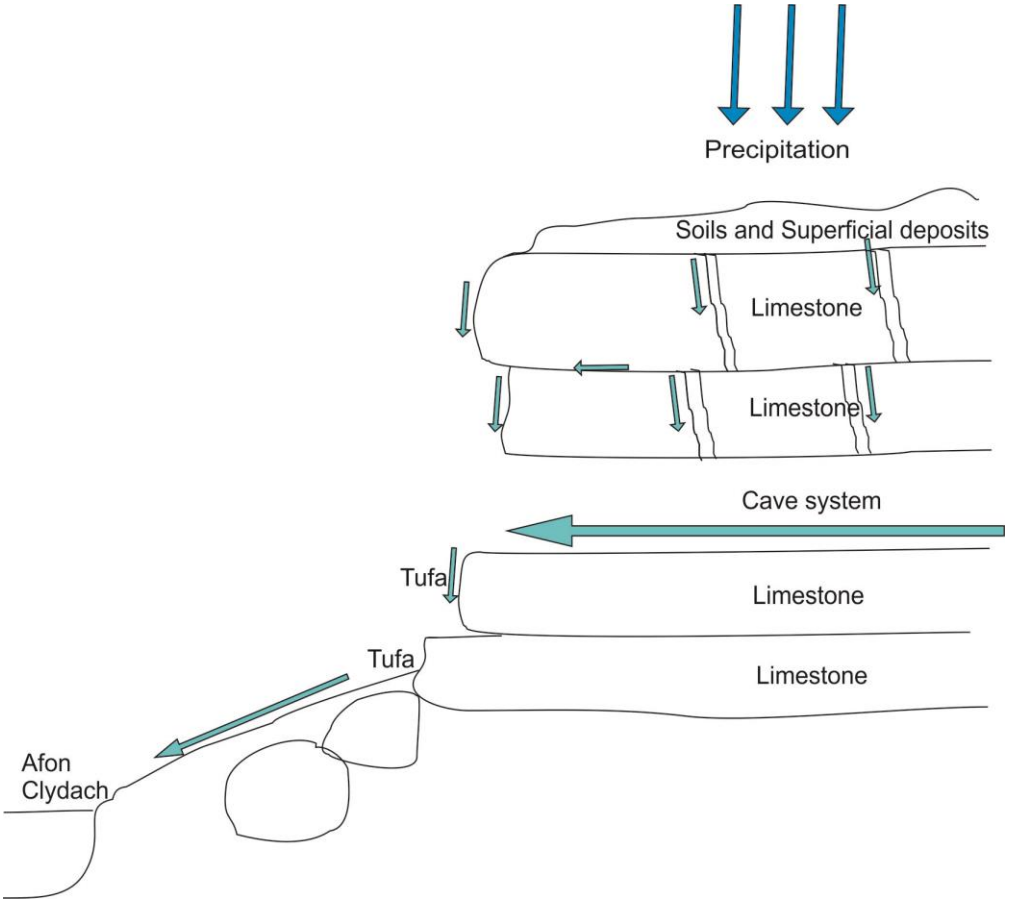



**Figure 71 Cwm Clydach Initial Conceptual Model**

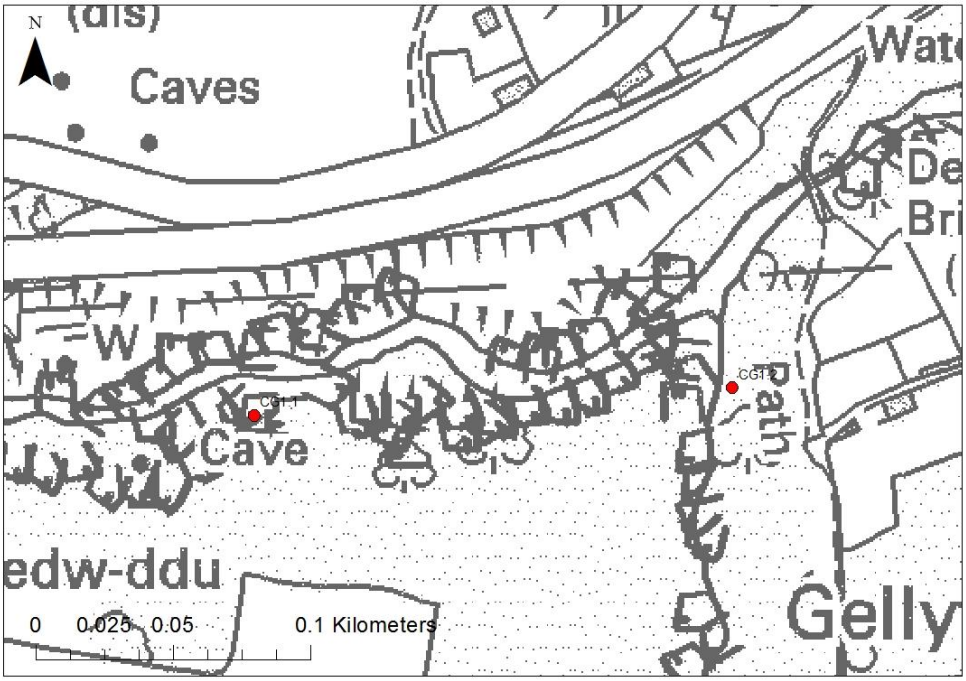



**Figure 72 Cwm Clydach Ordnance Survey map site location. ©Ordnance Survey.**


**Figure 73 Cwm Clydach aerial photograph**

© UKP/Getmapping Licence No. UKP2006/01

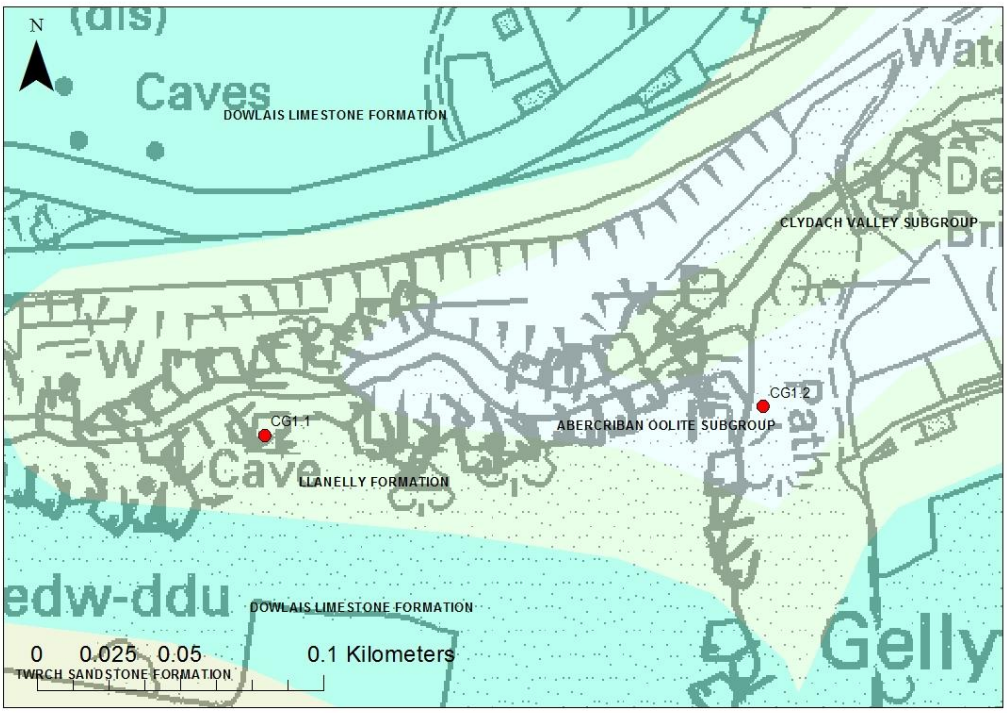
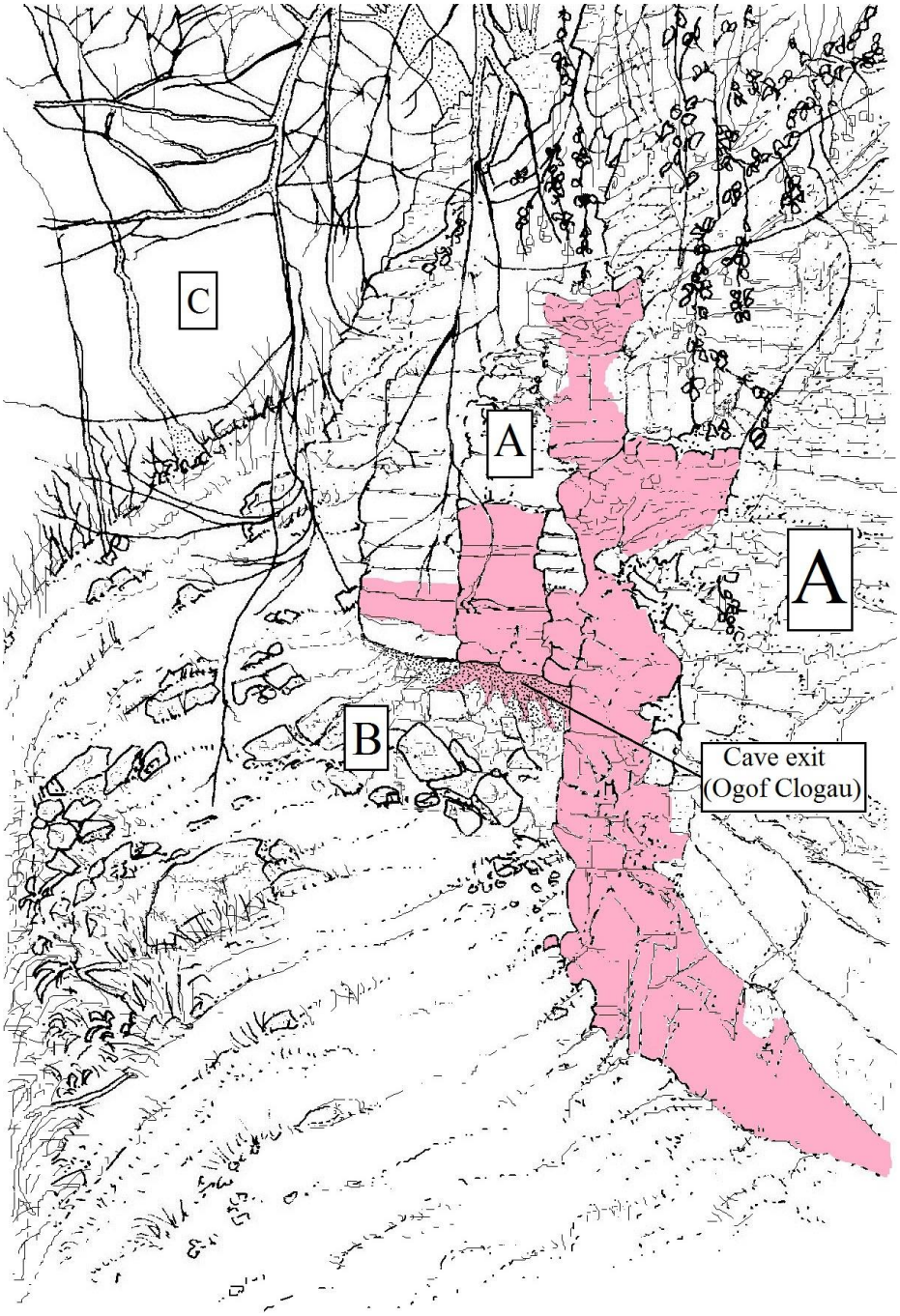



**Figure 74 Cwm Clydach bedrock geology 1:50,000. ©BGS. ©Ordnance Survey.**

| Survey Site | Survey Ref | Date | Temperature of Water | SEC | Ammoniacal Nitrogen as N | Nitrogen, Total Oxidised as N | Nitrate as NO3 | Nitrate as N | Nitrite as N | Hardness, Total as CaCO3 | Alkalinity to pH 4.5 as CaCO3 | Chloride | Orthophosphate, reactive as P | Orthophospahte as PO4 | Sulphate as SO4 | Phosphate :-{TIP} |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CEL | uS/Cm | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l |
| Clydach Gourge | CG1.1 | 17/01/2014 | 6.90 | 319.6 | | | | | | 165 | | | | | <10 | 0.024 |

| Survey Site | Survey Ref | Date | Sodium | Potassium | Magnesium | Calcium | Redox Potential : In Situ | pH : In Situ | Manganese | Iron | Manganese, Dissolved | Iron, Dissolved | Ionic Balance | Bicarbonate as HCO3 | Oxygen, Dissolved, % Saturation | Oxygen, Dissolved as O2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/l | mg/l | ug/l | mg/l | mV | pH | ug/l | ug/l | ug/l | ug/l | % | mg/l | % | mg/l |
| Clydach Gourge | CG1.1 | 17/01/2014 | 4.5 | 0.35 | 18.70 | 35.3 | 11.3 | 8.09 | <10 | <30 | <10 | <30 | | | 87.2 | 10.6 |

**Table 60 Cwm Clydach water quality**




| | | | |
|---|---|---|---|
| | *Palustriella* dominated vegetation with tufa | B | Slumped soil (clay-rich) below seepages (without *Palustriella*) |
| A | Less flushed rocks (without *Palustriella* and no or little tufa) | C | Beech dominated woodland |

**Figure 75 Clydach Gorge vegetation map**

### 7.10.4 Vegetation (spring) for Cwm Clydach

A vertical shaded and dripping rock face within a wooded gorge that has extensive *Palustriella commutata* stands towards the base. There are regular sheets of *Pellia endiviifolia* in shaded rock

joints and extensive areas of tufa associated with appressed stands of the liverwort *Jungermannia atrovirens* and frequent cushions of *Eucladium verticiallutum*. A range of woodland flowering plants occur in small quantity on the tuferous rock face including *Asplenium scolopendrium, Carex sylvatica, Geranium robertianum, Hedera helix* and a few tree species. A very wet section of rock face adjoining a small water fall (surveyed during a period of very high rainfall) has patches of *Conocephalum conicum* and *Chrysosplenium oppositifolium*.

| | |
|---|---|
| *Asplenium scolopendrium* | O |
| *Asplenium trichomanes ssp. trichomanes* | R (<1%) |
| Bare rock | F |
| *Bryoerythrophyllum recurvirostrum* (spor.) | O |
| *Carex sylvatica* | R (<1%) |
| *Chrysosplenium oppositifolium* | O |
| *Conocephalum conicum* | R |
| *Conocephalum salebrosum* | O |
| *Cratoneuron filicinum* | O |
| *Eucladium verticillatum* | A |
| filamentous algae (Chlorophyta) | O |
| *Geranium robertianum* | R |
| *Hedera helix* | O |
| *Ilex aquifolium* (seedling) | R (<1%) |
| *Jungermainia atrovirens* (non fertile) | O |
| *Palustriella commutata* | F |
| *Pellia endiviifolia* | F |
| *Rubus fruticosus agg.* | R |
| *Taxus baccata* | R |

**Table 61 Cwm Clydach Species list – *Palustriella* dominated vegetation**

### 7.10.5 Vegetation (adjoining spring) for Cwm Clydach

Bare vertical rock outcrops with locally dominant stands of *Neckera crispa* with occasional *Thamnobryum alopecurum*, *Ctenidium molluscum*, very locally the liverwort *Lejeunea lamacerina*. *Thamnobryum maderense* occurs in one place near a cave entrance (Ogof Clogau) beside a small water fall which was prominent during the site visit undertaken during very wet weather.

| | |
|---|---|
| *Ctenidium molluscum* | O |
| *Conocephalum salebrosum* | O |
| *Lejeunea lamacerina* | R |
| *Neckera crispa* | O |
| *Thamnobryum alopecurum* | O |
| *Thamnobryum maderense* | R |

**Table 62 Cwm Clydach Species list - Less regularly flushed rocks (without *Palustriella* and no or little tufa)**

Base-rich flushed soil at the base of the bedrock outcrop with frequent *Asplenium scolopendrium, Crysosplenium oppositifolium, Fissidens taxifolius var. taxifoluius.*

| | |
|---|---|
| *Asplenium scolopendrium* | F |
| *Carex sylvatica* | R |
| *Chrysosplenium oppositifolium* | F |
| *Fissidens bryoides* (spor.) | R |
| *Fissidens taxifolius var. taxifolius* | F |
| *Oxyrrhynchium hians* | O |
| *Rhynchostegiella pumilla* | O |

**Table 63 Cwm Clydach Species list slumped soil (clay-rich) below seepages (without *Palustriella*)**

Beech dominated woodland (top of gorge) with an acidic bryophyte dominated ground flora..

| | |
|---|---|
| *Agrostis capillaris* | O |
| *Ctenidium molluscum* | O |
| *Dicranum majus* | R |
| *Eurhynchium striatum* | O |
| *Fagus sylvatica* | F |
| *Fissidens taxifolius* | O |
| *Kindbergia praelonga* | O |
| *Plagiochila asplenioides* | O |
| *Polytrichum formosum* | R |
| *Rhytidiadelphis loreus* | O |
| *Rubus fruticosus agg.* | O |
| Leaf litter | A |

**Table 64 Cwm Clydach Species list - Beech dominated woodland**

### 7.10.6 **Condition assessment**

The overall assessment is that Cwm Clydach should be classified as being in favourable ecological and hydrogeological condition.

Tufa despoit between bedding plane of limestone bedrock

Seepage and water flow across the vertical face of the bedrock, also note tufa below the leaf litter

Phreatic cave exit (Ogof Clogau), with tufa formation in the foreground

Dripping water from the cliff face collected in a container for in situ water quality testing

Top edge of exposed rock face (forming side of gorge) with dripping water and tufa formation

Thin carpets of *Eucladium* coverering a dripping rock face with tufa (lower rock face near to ground level). Note water made holes in tufa.

**Figure 76 Cwm Clydach photographs**

## 7.11 DDOL

### 7.11.1 Introduction

Only a short visit was undertaken at Ddol and as such the notes for this site are shorter than for other sites. Ddol is located in the Wheeler Valley (near Caerwys) in North Wales and the tufa deposits in this valley are well documented for both sites. However Caerwys was not visited during this survey due to land access issues. A short walk over of the Ddol site was undertaken with Stewart Campbell (NRW) and Dr Jackie Maplas (NE Wales RIGS), with only a tiny area of *Palustriella commutata* identified near the weir and outflow to the ponded area at SJ1414071417.

### 7.11.2 Geological and hydrogeological data

Ddol and Caerwys make up one of the largest areas of Tufa in Wales, with the tufa at Ddol including buried soils and an exceptional fossil record recording environmental change in the late-glacial and Holocene (see Campbell & Bowen, 1989). The stratigraphy at Ddol is complex with few discernible lithological boundaries (Preece, 1978). The site is underlain by Silurian Elwy Formation with the Carboniferous Limestone Supergroup (Llanrmon Formation and Foel Formation) just to the east. The tufa desposit is one of the few in Wales that is large enough to be maped on the 1:50,000K superficial geology map of the area.

The current day setting of the site is that of a secondary wooded area, a stream (Afon Pant-gwyn) flows in from the north east after being retained via sluices and dams to supply a large fish hatchery (possibly disused). Within the woodland there is a ponded area formed by creation of a small weir to allow the water to backup. It is just below this weir that a tiny area ( ~1 x 0.5m) of *Palustriella commutata* was identified, and a water quality sample was obtained from overflow of the adjacent weir.

The dominant water supply mechanisms to the tiny area of *Palustriella commutata* were from seepage along the tufa bank of the outflow from the ponded area, and possibly from water flowing over the weir.

The water quality data shows the dominant ions are Calcium and Bicarbonate and a pH of 7.42 was recorded. Although phosphate was below the limit of detection there was 5.76ml/l of Nitrate (N) and this could refelect the agricultural nature of the catchment further to the north.

### 7.11.3 Land use and pressures

The immediate landuse is that of secondary woodland and part of the nature reserve attracts walkers. There are several properties within proximity to the site and it is unknown if they are on a mains water or sewerage supply. It is not thought that there are grazing animals on the site and poaching is not seen as an issue. There was no evidence of burning or other negative activities within the site.

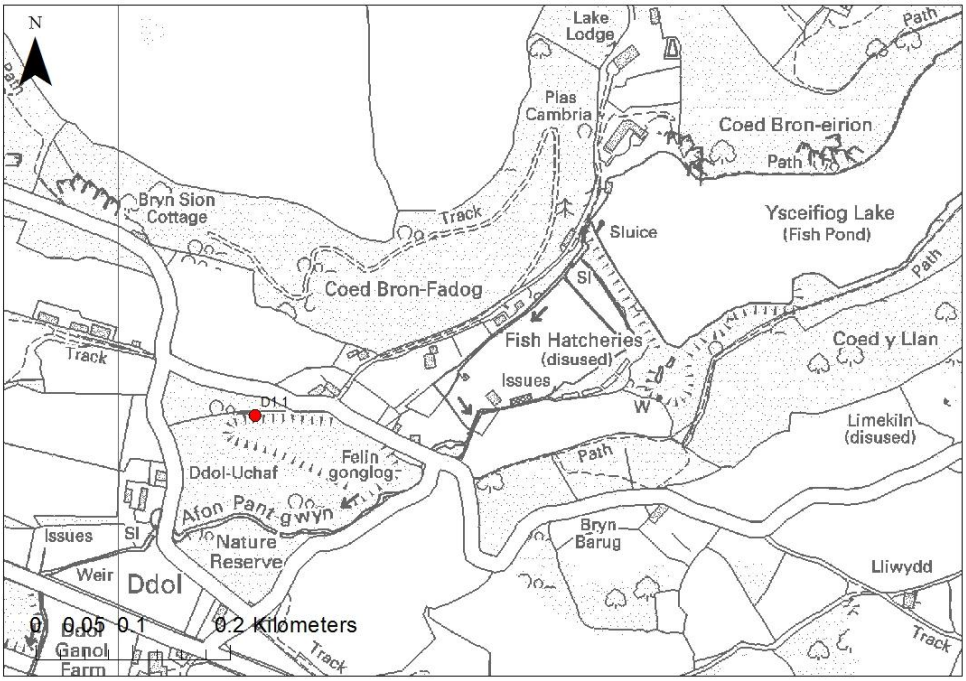



**Figure 77 Ddol Ordnance Survey map and GPS survey point. ©Ordnance Survey.**


**Figure 78 Ddol aerial photograph**

© UKP/Getmapping Licence No. UKP2006/01

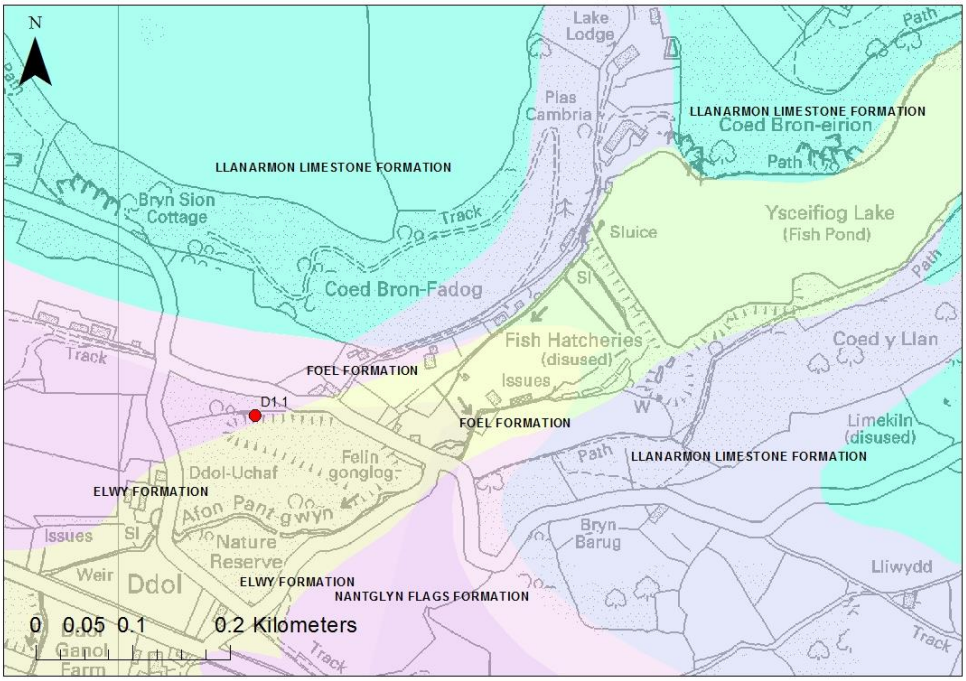



**Figure 79 Ddol bedrock and superficial geology 1:50,0000. ©BGS. ©Ordnance Survey.**

| Survey Site | Survey Ref | Date | Temperature of Water | SEC | Ammoniacal Nitrogen as N | Nitrogen, Total Oxidised as N | Nitrate as NO3 | Nitrate as N | Nitrite as N | Hardness, Total as CaCO3 | Alkalinity to pH 4.5 as CaCO3 | Chloride | Orthophosphate, reactive as P | Orthophospahte as PO4 | Sulphate as SO4 | Phosphate : - {TIP} |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CEL | uS/Cm | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l |
| Ddol | D1.1 | 22/01/2014 | 9.8 | 668.3 | <0.2 | 5.98 | ### | 5.76 | <0.0152 | 354 | 290 | 29.2 | <.02 | <0.05 | 25.7 | <.02 |

| Survey Site | Survey Ref | Date | Sodium | Potassium | Magnesium | Calcium | Redox Potential : In Situ | pH : In Situ | Manganese | Iron | Manganese, Dissolved | Iron, Dissolved | Ionic Balance | Bicarbonate as HCO3 | Oxygen, Dissolved, % Saturation | Oxygen, Dissolved as O2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/l | mg/l | ug/l | mg/l | mV | pH | ug/l | ug/l | ug/l | ug/l | % | mg/l | % | mg/l |
| Ddol | D1.1 | 22/01/2014 | 15.9 | 2.17 | 10.70 | 124.0 | 20.7 | 7.42 | <10 | <30 | <10 | <30 | 1.6 | 354 | 68.3 | 7.7 |

**Table 65 Ddol water quality**

### 7.11.4 Vegetation (spring) for Ddol

An old quarried tufa site that has developled into secondary woodland. A tiny stand of *Palustriella commutata* was found at the base of a damp block of tufa beside a small stream (overflow from a pond nearby). A small number of associates include *Crataneron filicinum, Pellia endiviifolia* and *Chrysosplenium oppositifolium*.

| | |
|---|---|
| *Chrysosplenium oppositifolium* | R |
| *Cratoneuron filicinum* | A |
| *Palustriella commutata* | F |
| *Pellia endiviifolia* | O |
| *Plagiomnium undulatum* | R |

**Table 66 Ddol Species list – *Palustriella* dominated vegetation**

Old (and friable) tufa blocks dominated by *Leicolea turbinataa* and *Fissidens taxifolius var. taxifolius*.

| | |
|---|---|
| *Asplenium scolopendrium* | O |
| *Bryoerythrophyllum recurvirostrum* | R |
| *Bryum capillare* | R |
| *Conocephalum conicum* | O |
| *Fissidens taxifolius var. taxifolius* | F |
| *Geranium robertianum* | R |
| *Hedera helix* | O |
| *Leicolea turbinata* (per., cap.) | F |
| *Thamnobryum alopecurum* | O |

**Table 67 Ddol Species list – Tufa outcrops (within area of flush/spring but without *Palustriella*)**

### 7.11.5 **Vegetation (adjoining spring) for Ddol**

Secondary woodland with a ground flora dominated by *Asplenium scolopendrium*. The ground flora is very sparce and open as the soil (including previously quarried tufa) is very loose and friable.

| | |
|---|---|
| *Asplenium scolopendrium* | F |
| *Brachypodium sylvaticum* | R |
| *Brachythecium rutabulum* | O |
| *Corylus avellana* | O |
| *Didymodon insulanus* | R |
| *Dryopteris felix-mass* | R |
| *Eurhynchium striatum* | O |
| *Fissidena taxifolius var. taxifolius* | F |
| *Fraxinus excelsior* | F |
| *Geranium robertianum* | R |
| *Geum urbanum* | R |
| *Hedera helix* | A |
| *Lapsana communis* | R |
| *Lophocolea bidentata* | R |
| *Oxyrrhynchium hians* | R |
| *Pellia endiviifolia* | O |
| *Polystichum setiferum* | R |
| *Potentilla steralis* | R |
| *Ribes uva-crispa* | R |
| *Rosa canina agg.* | R |
| *Taraxacum sp.* | R |
| *Urtica dioica* | R |

**Table 68 Ddol Species list – Surrounding woodland ground flora (on soil/tufa quarry spoil)**

Emergent and aquatic vegetation associated with a small stream (overflow from a pond nearby).

| | |
|---|---|
| *Epilobium hirsutum* | R |
| *Lemna trisulca* | R |
| *Ranunculus repens* | R |
| *Ranunculus sp.* (Subgenus Batrachium) | R |
| *Veronica beccabunga* | O |

**Table 69 Ddol Species list – Tufa outcrops (within area of flush/spring but without *Palustriella*)**

### 7.11.6 **Condition assessment**

The overall assessment is that Ddol should be classified as being in favourable ecological and hydrogeological condition.

Main face of tufa

Water sampling from steam beneath tufa face. Patch of *Palustriella commutata* visible to bottom centre of photo beside meter probes

Block of tufa with *Fissides taxifolius var. taxifoluis, Leiocolea turbinata, Bryoerythrophyllum recurvirostrum*

**Figure 80 Ddol site photographs**

## 7.12 FEDW FAWR BEACH

### 7.12.1 Introduction

'Fedw Fawr' beach is the name of a section of shoreline in the eastern part of Anglesey (nr SH6049081944), near to 'Fedw Fawr (SSSI). Car parking is available near the Fedw Fawr site and steps lead to the beach and the three sites that are included within this section. Tim Blackstock (ex CCW) and Dr Peter Jones (NRW) both provided on site discussion and helped with the location of sites. Actively forming tufa was identified at all three sites.

### 7.12.2 Geological and hydrogeological data

The coastal exposure along this area is dominated by sandstones of the lower Carboniferous Loggerheads Limestone formation, the limestone itself is not exposed at sea level along this section of the coast and occurs slightly higher up within the stratigraphic sequence, overlying the sandstones. Sites 1 and 2 (FF1 and FF2) are both examples of tufa deposition with *Palustriella commutata* on sandstone bedrock cliff faces. The overlying Carboniferous Loggerheads Limestone Formation is visible on the edge of the small gorge that runs down to the beach (above Site 3 FF3 nr SH6073581784) although access to the outcrop is difficult.

Although all three areas of tufa formation occur on or near to the sandstone units the source of the water is most likely to be primarily within the overlying Carboniferous Loggerheads Limestone Formation. There are several wells and springs marked on the Ordnance Survey map that drain from the limestone and flow towards the coast via a series of small drains, culminating in the small waterfall feature at site 1 (site FF1.1). Seepage between the sandstone bedding planes, via joints and fractures also offer pathways for water, as does seepage directly down the face of the cliff.

Walking eastwards the tufa deposits at site FF2.1 occur closest to the beach almost adjacent to the high tide mark. The seepage of water on the cliff face can be traced back up to the top of the cliff, along a small runnel that terminates in a large damp area just below the road where there is a spring marked as a well on the Ordnance Survey map (SH60638181800). This spring is the primary source of water for site 2 however more diffuse seepage and sea spray will also contribute to this coastal exposure.

Site FF3 is located on the westerly side of a small gorge or valley that runs down from the higher farm land to the beach (SH6073581784). The start of the site is identifiable by a small outflow of water onto the beach. There is a large area of tufa in a small wooded area on the cliff side where it has formed as a large block with definable steps and water seepage occurs across this tufa block. A broken field drain protrudes from the top of the wooded section, it is not working but is an indicator that the fields above were possibly wet enough to warrant drainage. Seepage along the break in slope is marked by very wet ground and an extensive area of *Palustriella commutata.* The contact with the overlying limestone can be seen about half the way up this gorge at the top of the cliff section.

All three sites are supplied by water that has most likely originated in the overlying Carboniferous Loggerheads Limestone Formation.

A water quality sample was taken at each site, pH ranged from 8.29-8.45, Nitrate 1.16 -3.18mg/l N with only low amounts of Phosphate (0.03-0.04mg/l). The ions are all dominated by Calcium and Bicarbonate.

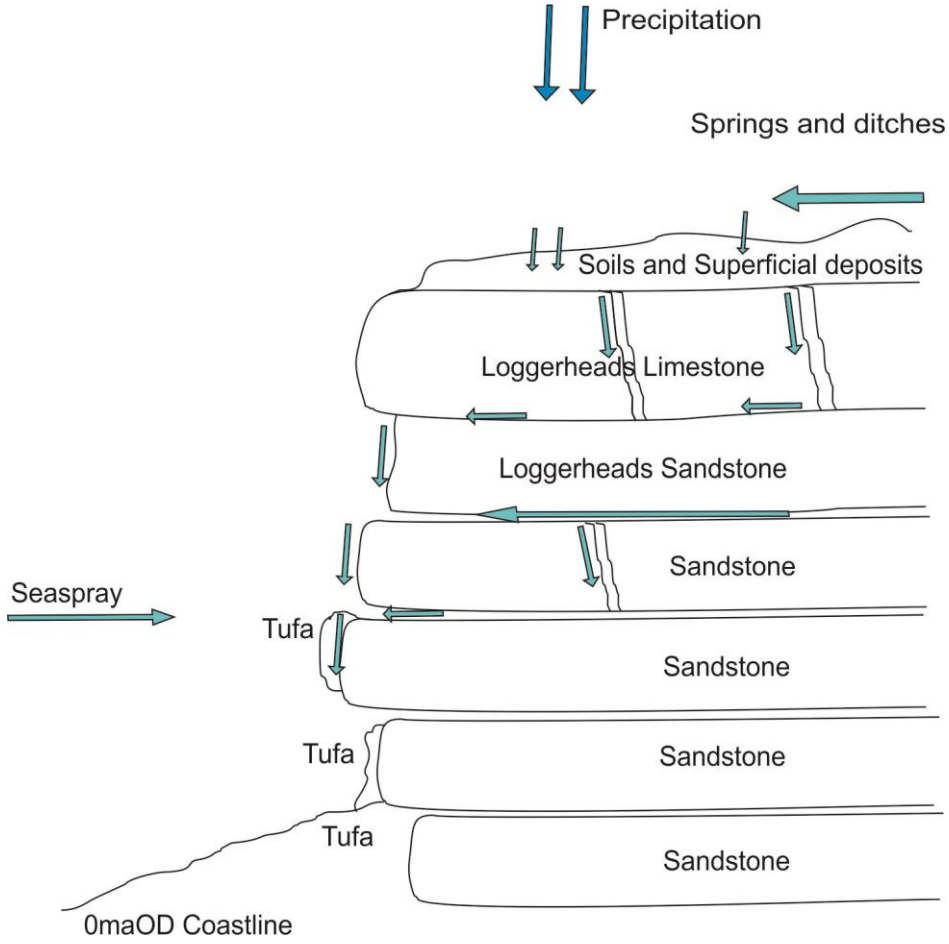



**Figure 81 Fedw Fawr Generic site conceptual model**

### 7.12.3 **Land use and pressures**

All three sites are located along a coastal section where access to walkers is the primary landuse. There are no grazing animals and no evidence of poaching. The area is dominantly agricultural although nutrient levels were not particularly elevated in any of the water quality samples. It is possible that some of the farms and more remote properties have both private water supplies and sewage treatment systems although there is nothing to suggest that these activities are having any form of negative impact on the supply of water to the sites.

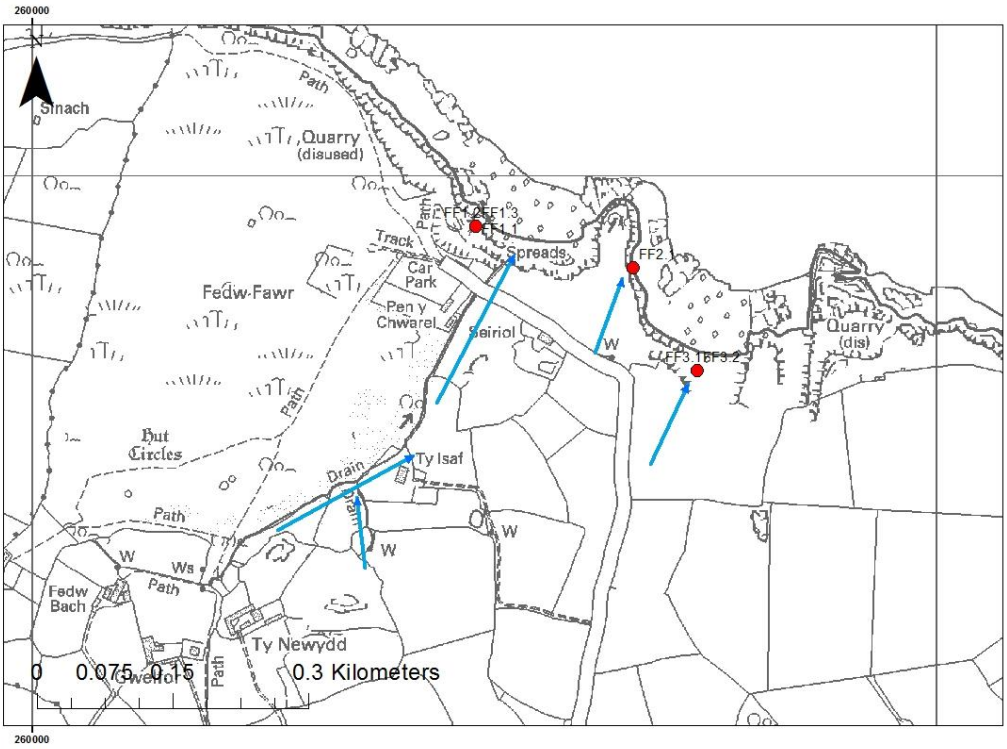



**Figure 82 Fedw Fawr Beach Ordnance Survey map and GPS survey points. ©Ordnance Survey.**


**Figure 83 Fedw Fawr Beach aerial photograph**

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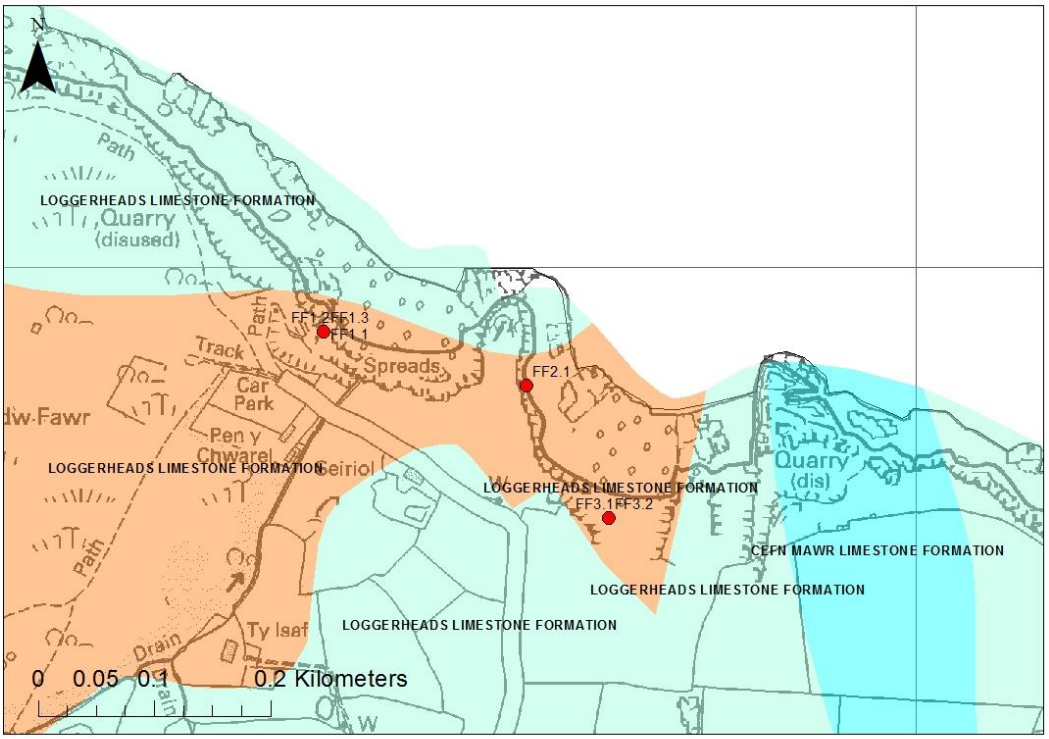
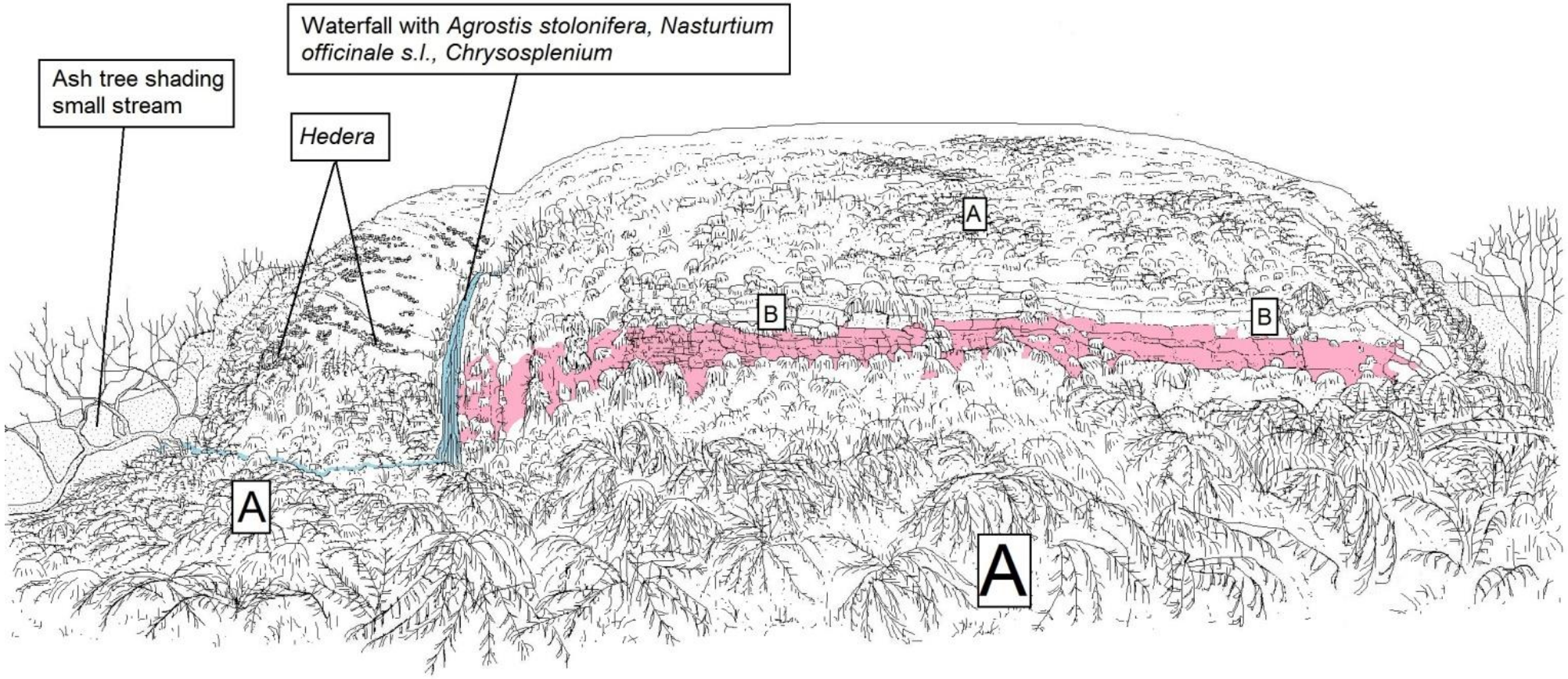



**Figure 84 Fedw Far Beach Bedrock geology 1:50,000 (sandstone units occur within the Loggerheads Limestone Formation and can be seen on the coastal section). ©BGS. ©Ordnance Survey.**

| Survey Site | Survey Ref | Date | Temperature of Water | SEC | Ammoniacal Nitrogen as N | Nitrogen, Total Oxidised as N | Nitrate as NO3 | Nitrate as N | Nitrite as N | Hardness, Total as CaCO3 | Alkalinity to pH 4.5 as CaCO3 | Chloride | Orthophosphate, reactive as P | Orthophospahte as PO4 | Sulphate as SO4 | Phosphate :- {TIP} |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CEL | uS/Cm | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l |
| Fedw Fawr Beach 1 | FF1.1 | 21/01/2014 | 7.1 | 539.4 | <0.2 | 1.36 | 5.99 | 1.16 | <0.0152 | 273 | 218 | 38.1 | <.02 | <0.05 | 15 | <.02 |
| Fedw Faw Beach 2 | FF2.1 | 21/01/2014 | 7.4 | 547.3 | <0.2 | 3.54 | 15.60 | 3.18 | <0.0152 | 260 | 212 | 37.0 | 0.021 | <0.05 | 16 | 0.044 |
| Fedw Faw Beach 3 | FF3.1 | 21/01/2014 | 8.5 | 482.0 | <0.2 | 2.09 | 9.23 | 1.92 | <0.0152 | 237 | 197 | 32.8 | <.02 | <0.05 | 15.1 | 0.026 |

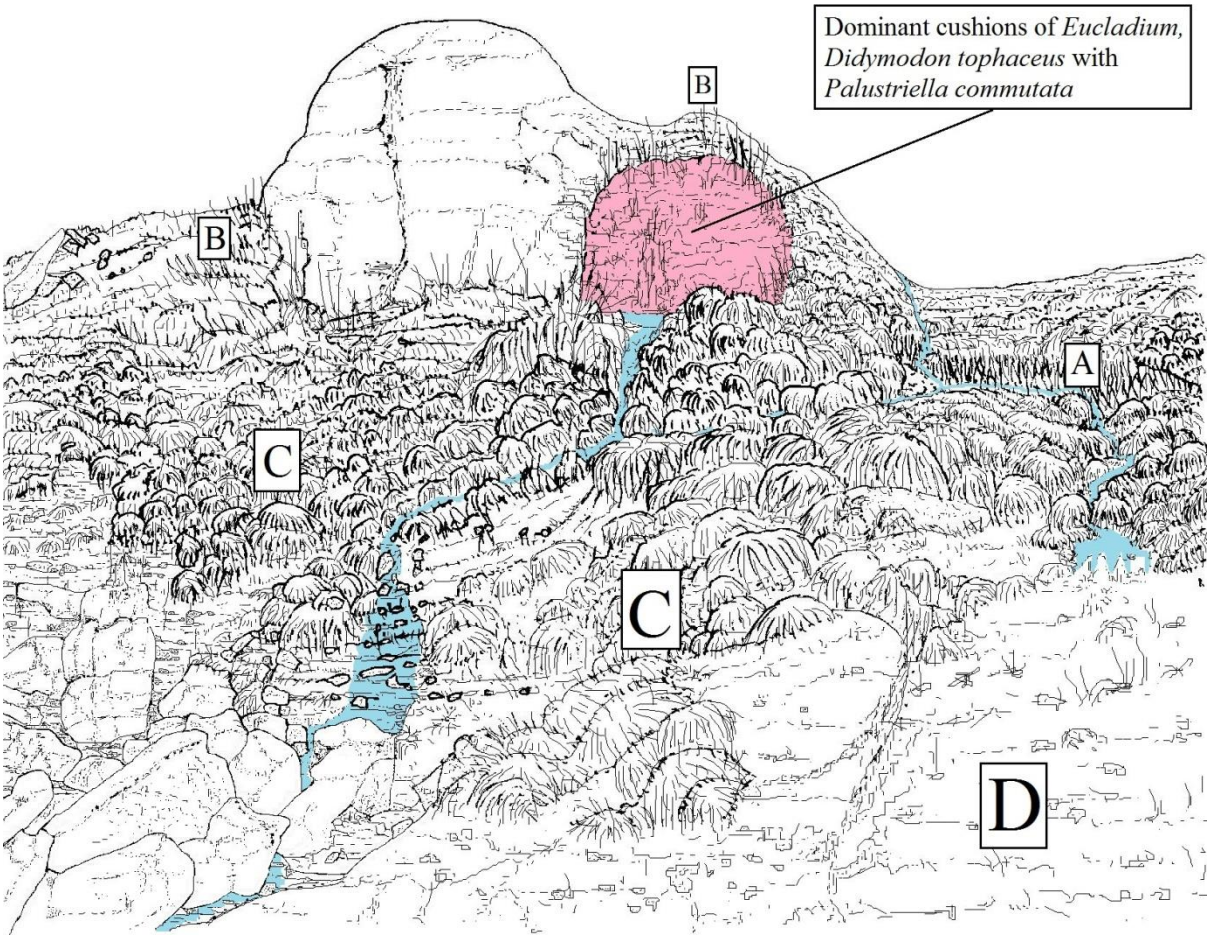
| Survey Site | Survey Ref | Date | Sodium | Potassium | Magnesium | Calcium | Redox Potential : In Situ | pH : In Situ | Manganese | Iron | Manganese, Dissolved | Iron, Dissolved | Ionic Balance | Bicarbonate as HCO3 | Oxygen, Dissolved, % Saturation | Oxygen, Dissolved as O2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/l | mg/l | ug/l | mg/l | mV | pH | ug/l | ug/l | ug/l | ug/l | % | mg/l | % | mg/l |
| Fedw Fawr Beach 1 | FF1.1 | 21/01/2014 | 19.2 | 2.60 | 11.50 | 90.4 | 12.8 | 8.45 | 35.8 | 171 | <10 | <30 | 4.35 | 266 | 99.4 | 12.0 |
| Fedw Faw Beach 2 | FF2.1 | 21/01/2014 | 17.3 | 5.69 | 7.77 | 91.2 | 12.7 | 8.29 | 37.4 | 219 | <10 | <30 | 2.06 | 259 | 100.4 | 12.0 |
| Fedw Faw Beach 3 | FF3.1 | 21/01/2014 | 18.8 | 0.93 | 13.80 | 72.0 | 15.7 | 8.35 | 14.8 | 164 | <10 | 164 | 2.33 | 240 | 98.0 | 11.4 |

**Table 70 Fedw Fawr Beach**




| | | | |
|---|---|---|---|
| | *Palustriella* dominated vegetation | A | Bracken dominated vegetation |
| | Stream (waterfall) and shaded stream (under Ash tree) | B | Exposed acidic rock outcrop (directly above tufa forming band) |

**Figure 85 Fedw Fawr beach site 1 Vegetation map**




| | | | |
|---|---|---|---|
| | *Palustriella* dominated vegetation | B | Bracken dominated vegetation |
| | Runnels and dripping water | C | Rough maritime cliff grassland |
| A | Stream | D | Maritime rocks with *Ulva intestinalis* |

**Figure 86 Fedw Fawr beach site 2 Vegetation map**

### 7.12.4 Vegetation – spring Fedw Fawr Site 1

Dripping spring vegetation and seepages dominated by *Palustriella commutata* and forming a narrow band (c. 2-3m) along the base of coastal cliffs (often in an underhang situation). Other frequent species include *Pellia endiviifolia, Conocephalum conicum, Leicolea turbinata* and substantial tufa deposits have frequent cushions of *Eucladium verticillatum* and occasional *Didymodon tophaceus*. Where these rock faces are partly shaded, a small number of characteristic woodland species are present in small quantity and include *Asplenium scolopendrium*, *Hedera helix, Geranium robertianum* and locally *Hypericum andosaemum*.

| | |
|---|---|
| *Agrostis stolonifera* | O |
| *Anera pinguis* | O |
| *Asplenium scolopendrium* | F |
| *Conocephalum conicum* | F |
| *Cratoneuron filicinum* | O |
| *Didymodon tophaceus* | R |
| *Eucladium verticillatum* (spor.) | A |
| *Festuca rubra* | F |
| filamentous algae (Chlorophyta) | O |
| *Fissidens adianthoides*(spor.) | O |
| *Fissidens taxifolius var. taxifolius* | R (<1%) |
| *Geranium robertianum* | R |
| *Hedera helix* | O |
| *Hypericum androsaemum* | R (<1%) |
| *Juncus effusus* | R (<1%) |
| *Jungermania atrovirens* (non fertile) | R (<1%) |
| *Leicolea turbinata* (spor.) | F |
| *Nostoc sp.* | O |
| *Palustriella commutata* | D |
| *Pellia endiviifolia* | O |
| *Riccardia multifida* | R (<1%) |
| *Rubus fruticosus agg.* | R (<1%) |

**Table 71 Fedw Fawr Site 1 Species list – Palustriella dominated vegetation Fedw Fawr**

### 7.12.5 Vegetation adjoining spring spring Fedw Fawr Site 1

The spring flows and seepages along the base of the coastal cliff produce a small stream channel below. Associated small waterfalls and open running water support emergents such as *Apium nodiflorum, Nasturtium officinale s.l., Agrostis stolonifera, Samolus valerandi*, occasional *Epilobium hirsutum.* Stands of *Chysosoplenium oppositifolium* and *Hookeria lucens* are often present at the base of small waterfalls where water seeps away into soil. Rocks within fast flowing water are dominated by *Rhynchostegium riparioides* with occasional *Brachythecium rivulare.*

| | |
|---|---|
| *Agrostis stolonifera* | R |
| *Allium ursinum* | O |
| *Apium nodiflorum* | R |
| *Brachythecium rivulare* | O |
| *Chiloscyphus sp.* (non fertle) | R |
| *Chrysosplenium oppositifolium* | O |
| *Conocephalum conicum* | O |
| *Cratoneuron filicinum* | O |
| *Dryopteris dilatata* (seedling) | R |
| *Epilobium hirsutum* | R |
| *Ficaria verna* | O |
| *Fissidens taxifolius var. taxifolius* | F |
| *Galium aparine* | R |
| *Hookeria lucens* | R |

| | |
|---|---|
| *Nasturtium officinale s.l.* | O |
| *Oxyrrhynchium hians* | O |
| *Pellia endiviifolia* | O |
| *Primula vulgaris* | R |
| *Ranunculus repens* | O |
| *Rhynchostegiella pumilla* | O |
| *Rhynchostegium riparioides* | F |
| *Samolus valerandi* | R |
| *Urtica dioica* | R |

**Table 72 Fedw Fawr Site 1 Species list – Stream (waterfall) and shaded stream (under Ash tree)**

Outcropping acid rocks (a narrow band c. 1m) along the base of coastal cliffs (often overhanging a lower band with calcareous seepages and tufa). A small number of calcifuge species are present including *Calluna vulgaris, Potentilla erecta, Diplophyllum albicans* and *Dicranella heteromalla*. Where there is seepage of water (acidic), cushions of *Sphagnum subnitens* have developed along with scattered plants of *Succisa.*

| | |
|---|---|
| *Asplenium adiantum-nigrum* | R |
| Bare rock | F |
| *Calluna vulgaris* | R |
| *Dicranella heteromalla* | O |
| *Diplophyllum albicans* | F |
| *Hieracium sp.* | R |
| *Mnium hornum* | O |
| *Pellia cf epiphylla (non fertile)* | R |
| *Potentilla erecta* | R |
| *Sphagnum subnitens* | R |
| *Succisa pratensis* | R |

**Table 73 Fedw Fawr Site 1 Species list – Exposed acidic rock outcrop (directly above tufa forming band)**

Tall Bracken dominated vegetation (to 1m height) on acidic soil on the top of coastal cliffs. A small number of typically calcifuge woodland species occur beneith the Bracken fronds (always in small quantity) and include *Mnium hornum, Lonicera periclymenum, Dicranum majus, Plagiochila asplenioides* and *Silene dioica*. Locally, flushing occurs with dominant stands of *Hookeria lucens*.

| | |
|---|---|
| *Brachypodium sylvaticum* | R |
| *Dicranum majus* | R |
| *Hookeria lucens (acid flush)* | O |
| *Hypnum jutlandicum* | O |
| *Kindbergia praelonga* | O |
| *Lonicera periclymenum* | R |
| *Lophocolea bidentata* | R |

| | |
|---|---|
| *Mnium hornum* | O |
| *Plagiochila asplenioides* | R |
| *Pteridium aquilinum* | D |
| *Rubus fruticosus agg.* | O |
| *Salix cinerea s.l.* | R |
| *Silene dioica* | O |
| *Thuidium tamariscinum* | O |

**Table 74 Fedw Fawr Site 1 Species list – Pteridium dominated vegetation Fedw Fawr Site**

### 7.12.6 Vegetation (spring) for Fedw Fawr Beach site 2

Dripping vegetation and seepages dominated by *Palustriella commutata* and forming a narrow band (c. 2-3m) along the base of coastal cliffs. Other frequent species include *Pellia endiviifolia, Conocephalum conicum, Crataneron filicinum* and substantial tufa deposits have frequent cushions of *Eucladium vericillatum*, *Didymodon tophaceus*. Where the rock face is partly shaded, a small number of characteristic woodland species are present in small quantity and include *Asplenium scolopendrium*, *Hedera helix, Ficaria verna*. Larger seepages (with more or less constantly dripping water) support emergents such as *Apium nodiflorum, Nasturtium officinale s.l., Agrostis stolonifera, Samolus valerandi* and large stands of *Chysosoplenium oppositifolium* are often present at their base.

| | |
|---|---|
| *Agrostis stolonifera* | O |
| *Anera pinguis* | O |
| *Apium nodiflorum* | R |
| *Asplenium scolopendrium* | F |
| *Chrysosplenium oppositifolium* | R |
| *Conocephalum conicum* | F |
| *Cratoneuron filicinum* | O |
| *Didymodon tophaceus* | F |
| *Eucladium verticillatum* | O |
| *Festuca rubra* | F |
| *Ficaria verna* | R |
| filamentous algae (Chlorophyta) | F |
| *Fissidens adianthoides* | R |
| *Fissidens taxifolius var. taxifolius* | O |
| *Hedera helix* | R |
| *Jungermania atrovirens* (non fertile) | R (<1%) |
| *Leicolea turbinata* (spor.) | F |
| *Nasturtium officinale s.l.* | O |
| *Palustriella commutata* | D |
| *Pellia endiviifolia* | O |
| *Samolus valerandi* | R |

**Table 75 Fedw Fawr Site 2 Species list – Palustriella dominated vegetation**

### 7.12.7 **Vegetation (adjoining spring) for Fedw Fawr Beach site 2**

A small stream channel cutting deeply into coastal cliffs (with small falls in places) and continuing below to the sea. The open running water supports emergents such as *Apium nodiflorum, Nasturtium officinale s. l.* and regularly submerged rocks or tufa have stands of *Rhynchostegium riparioides* and occasional *Brachythecium rivulare.* Adjoining to the left of this small stream (at the base of the cliff and where the water seeps away into soil), a small area of marshy rush dominated vegetation has developed with *Juncus acutiflorus, Juncus subnodulosus, Calliergonella cuspidata, Filipendula ulmaria, Epilobium hirsutum* and *Senecio cf aquaticus.*

| | |
|---|---|
| *Angelica sylvestris* | R |
| *Apium nodiflorum* | F |
| *Brachythecium rivulare* | F |
| *Calliergonella cuspidata* | O |
| *Carex cf acutiformis* | R |
| *Cirsium palustre* | R |
| *Conocephalum conicum* | O |
| *Cratoneuron filicinum* | O |
| *Epilobium hirsutum* | O |
| *Ficaria verna* | R |
| *Filipendula ulmaria* | O |
| *Fissidens taxifolius var. taxifolius* | R |
| *Hypericum tetrapterum* | R |
| *Juncus acutiflorus* | F |
| *Juncus subnodulosus* | O |
| *Nasturtium officinale s.l.* | F |
| *Pellia endiviifolia* | O |
| *Rhynchostegiella pumilla* | R |
| *Rhynchostegium riparioides* | R |
| *Rumex cf conglomeratus* | R |
| *Senecio cf aquaticus* | R |

**Table 76 Fedw Fawr Site 2 Species list – Stream**

Tall bracken dominated vegetation (to 1m height) on acidic soil on the top of coastal cliffs. A small number of woodland species occur beneath the Bracken fronds (always in small quantity) and include *Hedera helix, Brachypodium sylvaticum, Rubus fruticosus*.

| | | |
|---|---|---|
| *Brachypodium sylvaticum* | R | |
| *Hedera helix* | O | |
| *Kindbergia praelonga* | O | |
| *Pteridium aquilinum* | D | |
| *Rubus fruticosus agg.* | O | R |

**Table 77 Fedw Fawr Site 2 Species list – Pteridium dominated vegetation**

Tussocky maritime grassland dominated by *Festuca rubra* on rock outcrops and on the tops of boulders at the base of coastal cliffs. A small number of other species are present (*Agrimonia eupatoiria, Dactylis glomerata, Plantago lanceolata, Centaurea nigra*) and includes several characteristic maritime cliff species (*Armeria maritima, Plantago maritima*).

| | |
|---|---|
| *Agrimonia eupatoria* | O |
| *Agrostis stolonifera* | O |
| *Armeria martima* | R |
| *Centaurea nigra* | R |
| *Cerastium fontanum* | R |
| *Dactylis glomerata* | O |
| *Festuca rubra* | A |
| *Hedera helix* | R (<1%) |
| *Plantago lanceolata* | R |
| *Plantago maritima* | O |

**Table 78 Fedw Fawr Site 2 Species list – Rough maritime cliff grassland**

Dripping coastal rocks and boulders (forming part of the sea shore) and associated with the outfall of a small stream channel which cuts deeply into coastal cliffs. These rocks are subject to saline ingress and sea spray which "checks" the vegetation. The only species present is the alga *Ulva intestinals* which is locally dominant.

*Ulva intestinalis F*

Bare rock A

**Table 79 Fedw Fawr Site 2 Species list – Rocks at base of flushed ground (adjoining sea shore)**

### 7.12.8 Vegetation (spring) for Fedw Fawr Beach site 3

Dripping spring vegetation and seepages dominated by *Palustriella commutata* and forming a narrow band (c. 2-3m) along coastal cliffs (within mature woodland). Other frequent species include *Pellia endiviifolia, Conocephalum conicum, Crataneron filicinum* and substantial tufa deposits have frequent cushions of *Eucladium vericillatum* and *Didymodon tophaceus*. These shaded rock and tufa blocks have a small number of characteristic woodland species (spread from the adjoining mature woodland) including *Asplenium scolopendrium*, *Hedera helix, Fissidens taxifolius var. taxifolius* and *Geranium robertianum*.

| | |
|---|---|
| *Anera pinguis* | F |
| *Asplenium scolopendrium* | A |
| *Conocephalum conicum* | A |
| *Cratoneuron filicinum* | O |
| *Didymodon tophaceus* | R |
| *Eucladium verticillatum* (spor.) | O |
| *Festuca rubra* | O |
| filamentous algae (Chlorophyta) | O |
| *Fissidena taxifolius var. taxifolius* | R (<1%) |
| *Geranium robertianum* | R |
| *Hedera helix* | O |
| *Leicolea turbinata* (per.) | O |
| *Palustriella commutata* | A |
| *Pellia endiviifolia* | O |

**Table 80 Species list – Palustriella dominated vegetation**

### 7.12.9 Vegetation (adjoining spring) for Beach site 3

A small stream channel cutting deeply into coastal cliffs within mature woodland with a large fall of water (c. 5m drop) in one place. The waterfall is heavily shaded by adjoining woodland and dominated by *Conoceophalum conicum* with occasional *Crataneron filicinum* and *Chrysosplenium oppositifolium*. The resulting stream below is more open and where the water seeps away into soil, marshy rush dominated vegetation has developed with *Juncus acutiflorus, Juncus inflexus, Cirsium palustre, Lythrum salicaria, Epilobium hirsutum* and locally dominant stands of *Equisetum telmateia*.

| | |
|---|---|
| *Agrostis stolonifera* | O |
| *Allium ursinum* | O |
| *Brachythecium rivulare* | R |
| *Carex cf acutiformis* | R |
| *Chrysosplenium oppositifolium* | R |
| *Cirsium palustre* | R |
| *Conocephalum conicum* | A |
| *Cratoneuron filicinum* | O |
| *Epilobium hirsutum* | O |
| *Equisetum telmateia* | O |
| *Eupatorium cannabinum* | R |
| *Filipendula ulmaria* | O |
| *Fissidens taxifolius var. taxifolius* | O |

| | |
|---|---|
| *Juncus acutiflorus* | R |
| *Juncus inflexus* | R |
| *Lythrum salicaria* | R |
| *Pellia endiviifolia* | O |
| *Rhynchostegium riparioides* | F |

**Table 81 Species list – Stream (waterfall) and shaded stream (under woodland)**

A open soil slipped area to the left of a spring on a steep slope of a coastal cliff. The open soil is clay-rich, calcareous and mostly dominated by a small number of bryophytes including *Leicolea turbinata, Aneura pinguis, Dicranella varia* and *Didymodon fallax*.

| | |
|---|---|
| *Leicolea turbinata* (per.) | A |
| *Anera pinguis* | O |
| *Barbula unguiculata (spor.)* | R |
| *Calamagrostis epigejos* | O |
| *Dicranella varia* (spor.) | O |
| *Didymodon fallax (spor.)* | O |
| *Didymodon insulanus* | R |
| *Festuca rubra* | O |
| *Pellia endiviifolia* | F |
| *Senecio jacobaea* | R |
| *Tussilago farfara* | R (<1%) |

**Table 82 Species list – Open base-rich soil/ soil slip (left of stream)**

Tall Bracken dominated vegetation (to 1m height) with scattered *Ulex europaea* on acidic soil on the top of coastal cliffs. A small number of typically calcifuge woodland species occur beneith the Bracken fronds (always in small quantity) and includes *Mnium hornum, Hyacinthoides non-scripta, Plagiochila asplenioides* and *Thuidium tamariscinum*. Locally, flushing occurs with domaint stands of *Hookeria lucens*.

| | |
|---|---|
| *Hedera helix* | R |
| *Hookeria lucens (acid flush)* | R |
| *Hyacinthoides non-scripta* | R |
| *Mnium hornum* | R |
| *Plagiochila asplenioides* | R |
| *Pteridium aquilinum* | D |
| *Rubus fruticosus agg.* | O |
| *Thuidium tamariscinum* | R |
| *Ulex europaea* | O |

**Table 83 Species list – Pteridium dominated vegetation**

Mature and open Ash-Field Maple woodland on steep slopes of coastal cliffs. A sparse calcareous ground flora is present dominated by *Hedera helix, Dryopteris felix-mass, Geranium robertianum, Asplenium scolopendrium with Primula vulgaris* and *Rubus fruticosus*. Epiphytes are very well developed with *Fruallania dilatata, Metzgeria furcata, Ulota phyllantha, Parmelia perlata* and *Cololejeunea minutissima*.

| | |
|---|---|
| *Acer campestre* | F |
| *Acer psedoplatanus* | R |
| *Asplenium scolopendrium* | O |
| *Brachypodium sylvaticum* | R |
| *Cololejeunea minutissima* (non fertile) | R |
| *Corylus avellana* | O |
| *Dryopteris felix-mass* | R |
| *Fraxinus excelsior* | O |
| *Frullania dilatata* | O |
| *Geranium robertianum* | R |
| *Hedera helix* | O |
| *Hypnum cupressiforme* | F |
| *Kindbergia praelonga* | R |
| *Lophocolea bidentata* | R |
| *Metzgeria furcata* | O |
| *Orthotrichum affine* | F |
| *Oxyrrhynchium hians* | O |
| *Parmelia perlata* | O |
| *Plagiochila asplenioides* | R |
| *Primula vulgaris* | R |
| *Rhynchostegiella pumilla* | R |
| *Rubus fruticosus agg.* | O |
| *Salix cinerea s.l.* | R (<1%) |
| *Silene dioica* | R |
| *Ulota phyllantha* | F |

**Table 84 Species list – Ash- Field Maple woodland**

Rock outcrops and boulders at the base of coastal cliffs (adjoining the sea shore). A single species *Cochlearia officinalis s.l.* was recorded.

| | |
|---|---|
| *Cochlearea officinalis s.l.* | R (<1%) |
| Bare rock | D |

**Table 85 Species list – Rocks at base of flushed ground (adjoining sea shore)**

### 7.12.10 Condition assessment

The overall assessment is that Fedw Fawr Beach (sites 1-3) should be classified as being in favourable ecological and hydrogeological condition.

Carboniferous sandstone (stratigraphically below the Carboniferous Limestone) site 1

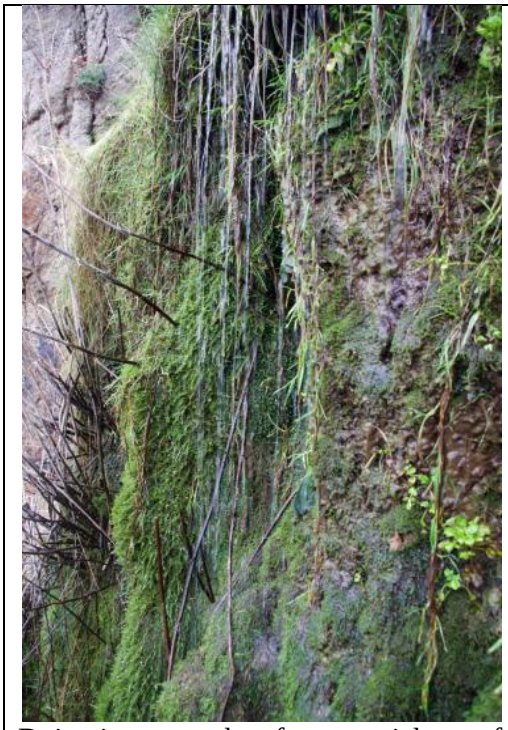
Waterfall with *Nasturtium officinale s. l., Agrostis stolonifera, Chrysosplenium*.

Underhang cliff face with tufa and abundant *Conocephalum conicum, Pellia endiviifolia* – base of cliff face

Mixtures of calcifuge (*Diplophyllum albicans, Succisa, Pteridium* left) and calcicole (*Palustriella commutata* right) in close proximity (central rock face of site)

Seepage of water along the bedding plane and down the face of a Carboniferous sandstone (Site2)

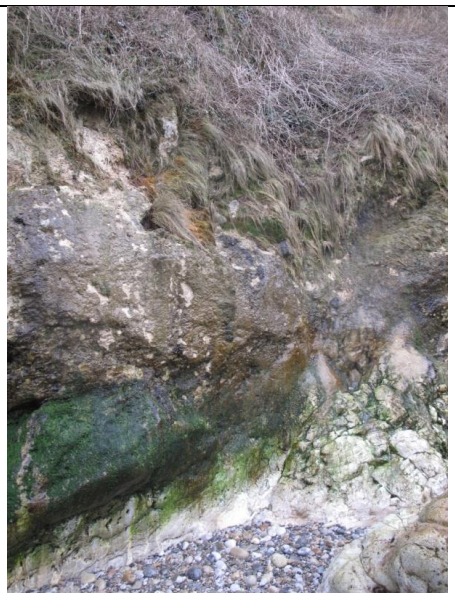
**Figure 87 Fedw Fawr Beach Site 1 photographs**



Dripping rock face with tufa and abundant *Palustriella commutata, Eucladium.*

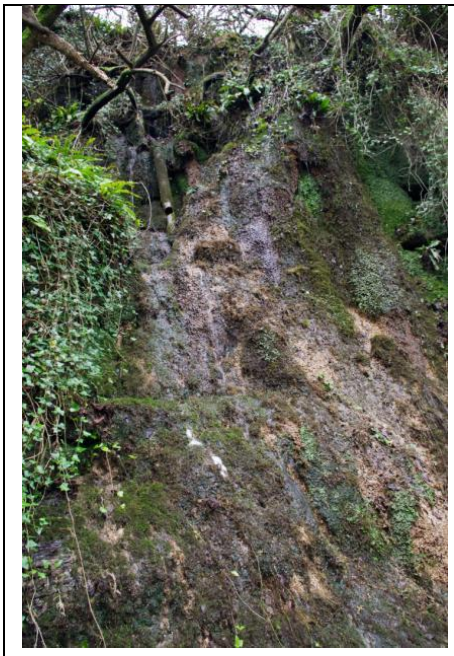
*Festuca rubra* dominanted maritime grassland (non flushes) on lower cliff below tufa flush (top right hand corner)

Close up of tufa face dominated by *Didymodon tophaceus with Pellia endiviifolia, Eucladium.*



Seepage from the Carboinferous Sandstone bedrock and tufa formation

**Figure 88 Fedw Fawr Beach Site 2 Photograph**



Vertical dripping rock face with abundant tufa and dominated by *Conocephalum conicum* (top of site in mature woodland). Note old field drain pipe at top of photo.

Final outfall of spring water to beach below cliff. Note exposure of rock and tufa dominated by *Palustriella commutata* (above fall of water).

Rock outcrops with tufa dominated by *Palustriella commutata* (centre of site in mature woodland).

*Palustriella* growing along a seepage face in a small gourge

**Figure 89 Fedw Fawr Beach Site 3 Photographs**

## 7.13 CORS ERDDREINIOG

### 7.13.1 Introduction

Cors Erddreiniog (SSSI, SAC and NNR) has been subject to numerous ecological and hydrological investigations (e.g. Gillman and Newson, 1981, SWS, 2010, Rigare, 2010) and as such there is a comparative wealth of information on both the ecology and hydrology of Cors Erddreiniog. Monitoring of both groundwater quality and groundwater levels has been in place since 2006 and 2008 respectively. This survey included the area along the eastern margin of Cors Erddreiniog, south of the Cae Gwyn restoration project and immediately east of the lake Llyn-yr-Wyth Eidion.

### 7.13.2 Geological and hydrogeological data

The boundary between the Carboniferous Clwyd Limestone Group and underlying Lligwy Sandstone runs parallel to the boundary of the site and it is most likely that discharge from these units is the principal groundwater feed responsible for the historic and current marl deposits. Piezometers drilled along this margin (e.g. ED4, ED4a) prove up to 2.5m of clays, sands and marl overlying weathered limestone within a clay matrix. Groundwater discharges from the Carboniferous Limestone aquifer via discrete springs and large seepage areas occur across the eastern boundary of Cors Erddreiniog. Previous analysis in 2008 (BGS) of CFCs and SF6 at the 'spring north of Hazelwood' (Site CE2.2) suggested an age for the water between 1975-2006 indicating that there is both an older and younger component to the groundwater along this margin of Cors Erddreiniog.

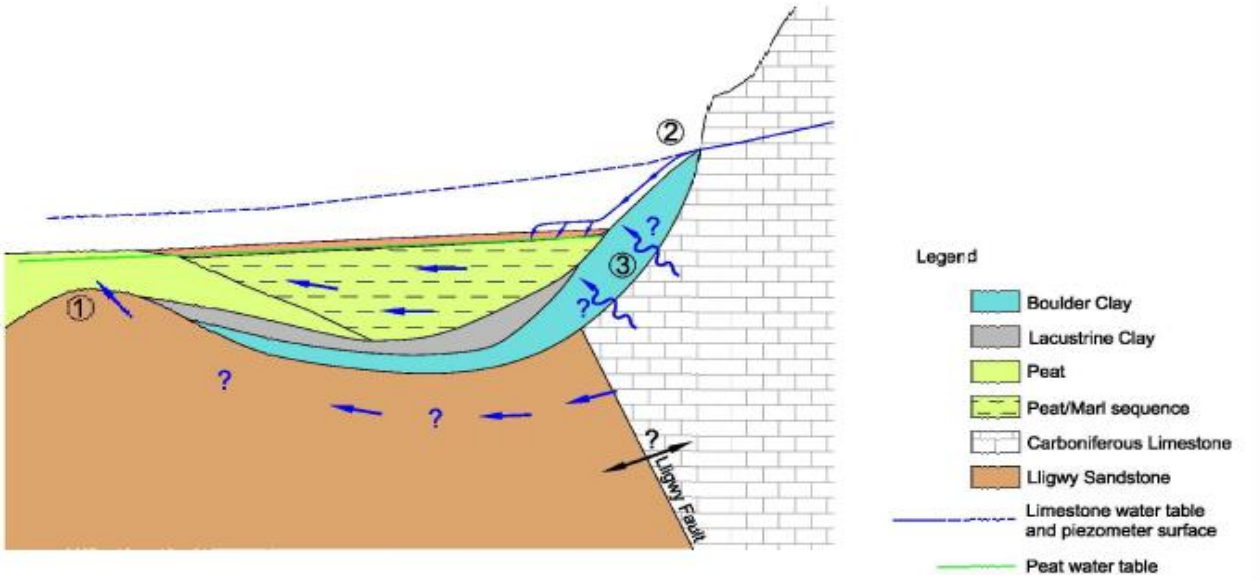



**Figure 90 Hydrogeological conceptual model for Cae Gwyn re-profiling at Cors Erddreiniog (Rigare, 2010)**

During the survey two full samples were collected (sites CE3.3-A and CE5.3-B) and two nutrient only samples (sites CE1.1 and 2.1). pH values ranged from 7.14-8.14 and the dominant ions are calcium and bicarbonate. During this survey phosphate, orthophosphate and nitrite were all below their respective limits of detection (<0.02mg/l, <0.02mg/l and <0.004mg/l). Nitrate N mg/l occurred in all four samples and ranged from 1.93 – 7.35mg/l N. Groundwater monitoring between 2006-2013 (see Figure 91) has shown a gradual decrease in the levels of Nitrate-N mg/l. Phosphate (P) mg/l has returned values below the limit of detection for the majority of the monitoring period. This is the only site within the survey that has the benefit of associated groundwater chemistry data from a pre existing monitoring network.

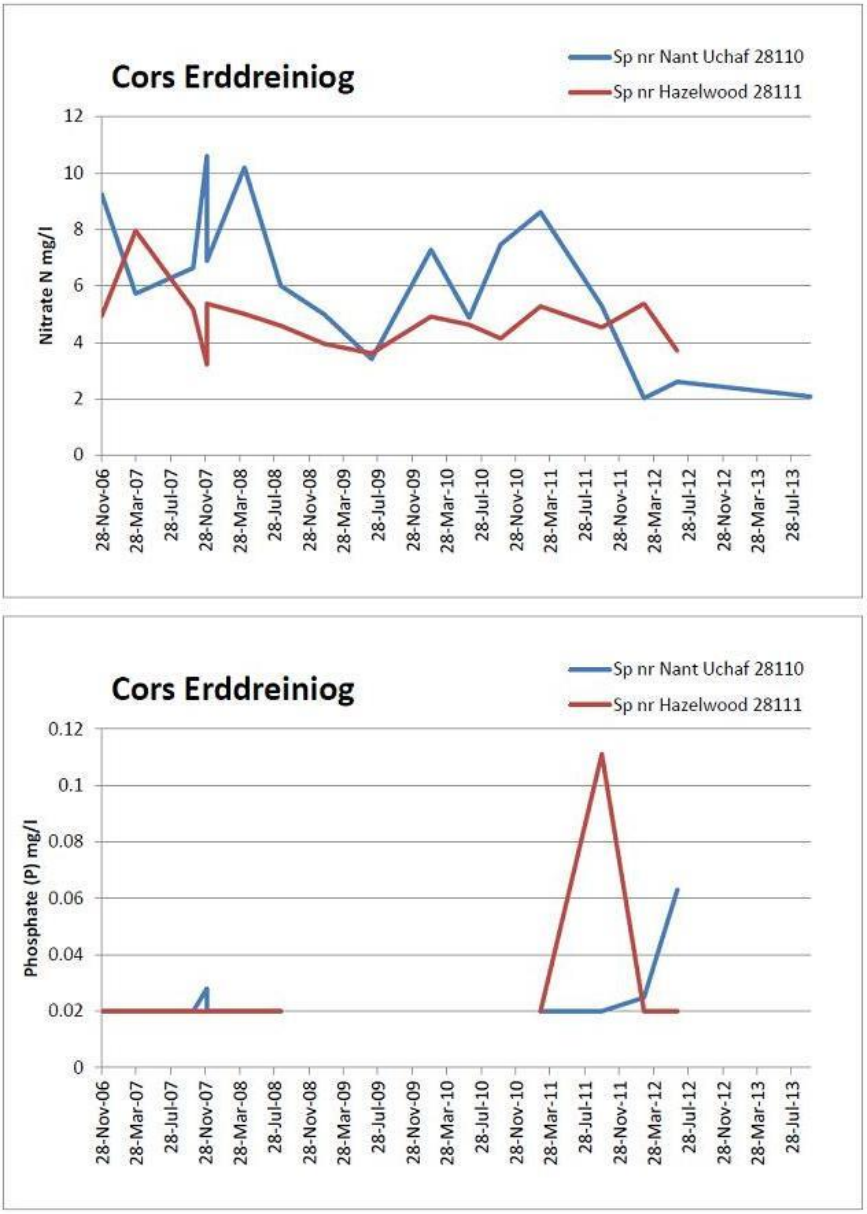



**Figure 91 Water quality sampling at Cors Erddreiniog 2006-2013 NRW**

### 7.13.3 Land use and pressures

The survey site is located on the far eastern boundary of the Cors Erddreiniog SAC boundary and all the land within this is managed by NRW. However the land directly to the east of the boundary is managed for agricultural purposes. The survey site benefits with being located far from the nearest footpath and thus footfall at the site is very low. There is limited evidence of poaching along the break in slope most likely from grazing animals managed by NRW at Cors Erddreiniog. There is no evidence of burning. There are several historic private water supplies (wells and springs) along this margin however none are currently in use.

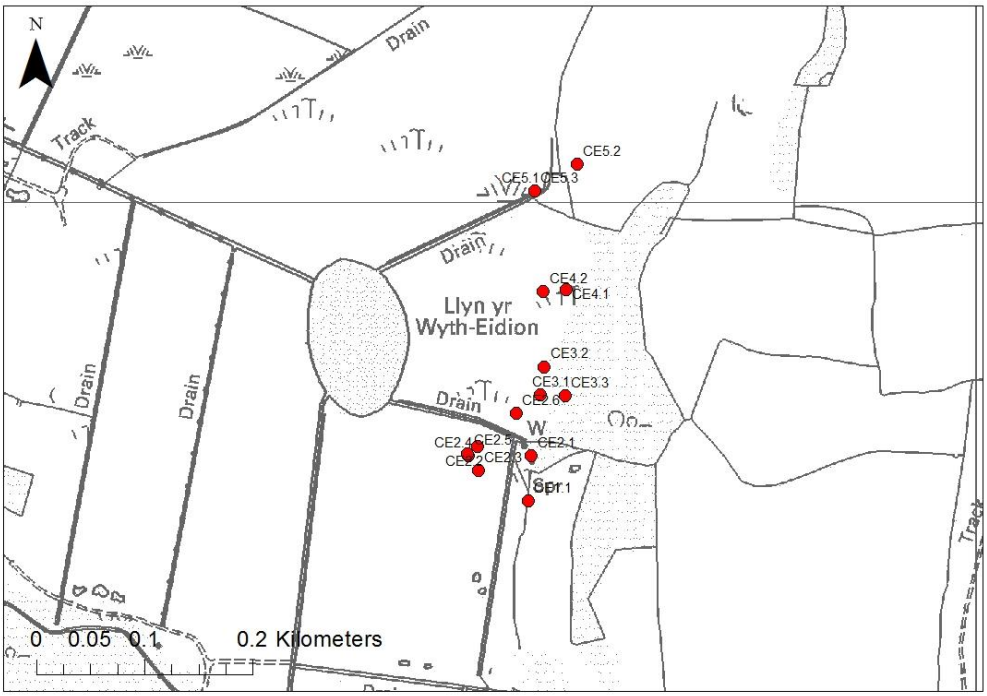



**Figure 92 Cors Erddreiniog Ordnance Survey map and GPS locations. ©Ordnance Survey.**


**Figure 93 Cors Erddreiniog aerial photograph**

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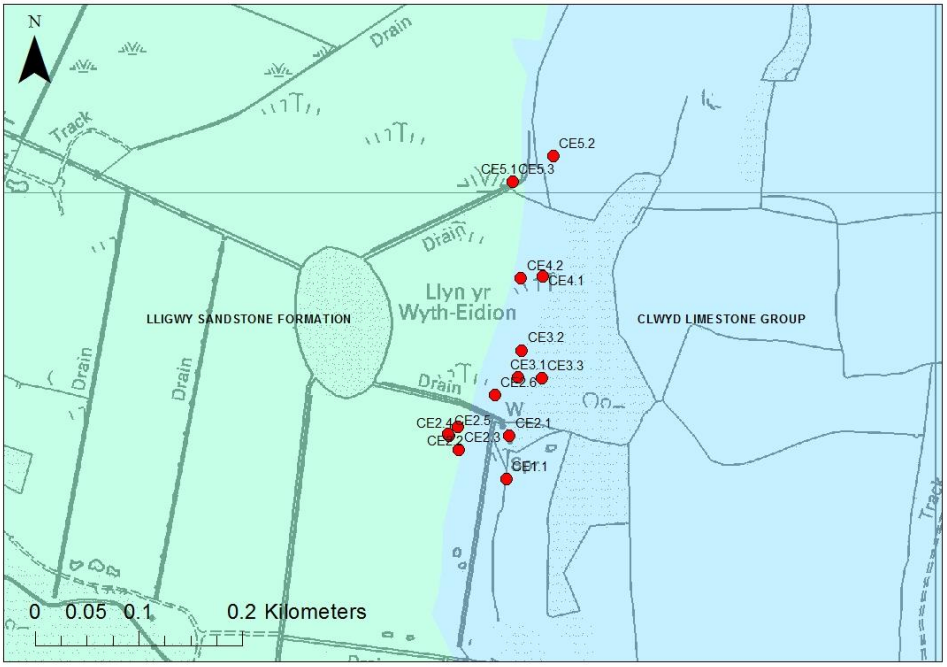
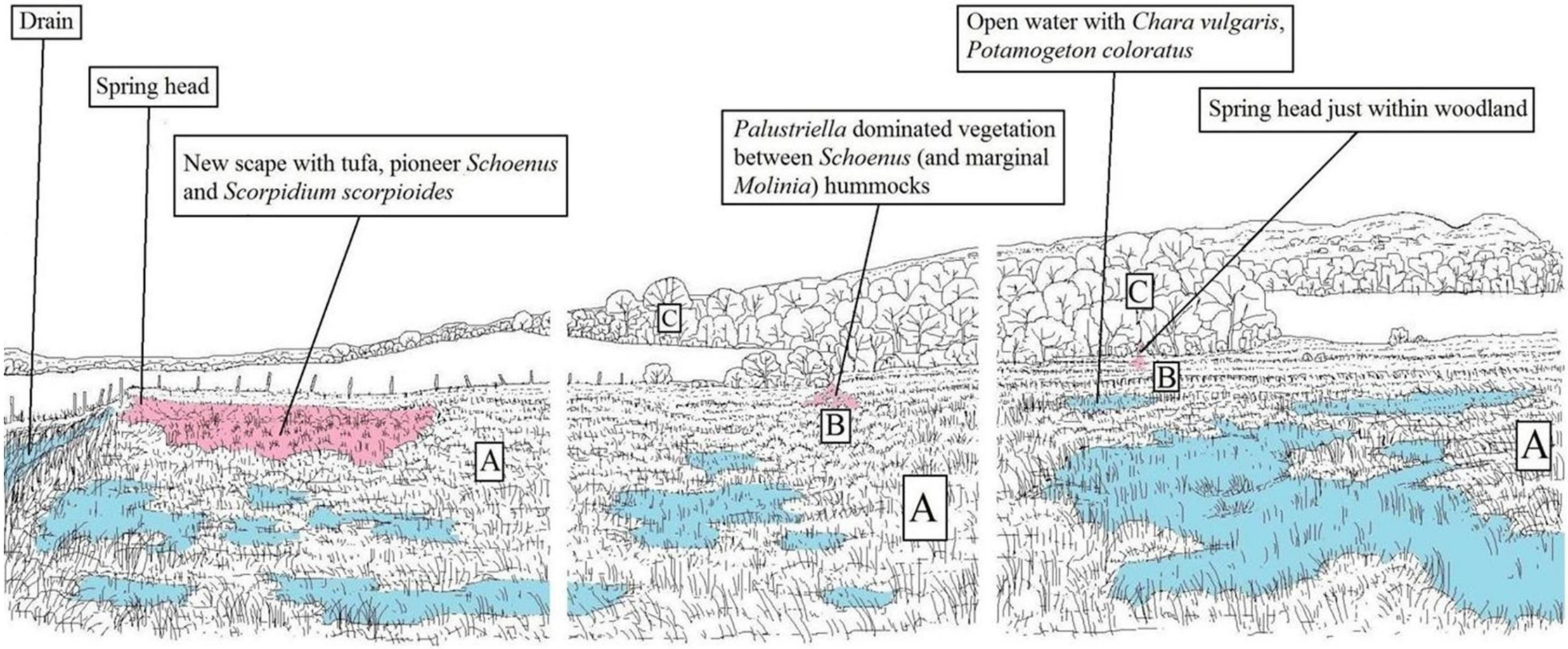



**Figure 94 Cors Erddreiniog bedrock geology map 1:50,000. ©BGS. ©Ordnance Survey.**

| Survey Site | Survey Ref | Date | Temperature of Water | uSEC | Ammoniacal Nitrogen as N | Nitrogen, Total Oxidised as N | Nitrate as NO3 | Nitrate as N | Nitrite as N | Hardness, Total as CaCO3 | Alkalinity to pH 4.5 as CaCO3 | Chloride | Orthophosphate, reactive as P | Orthophospahte as PO4 | Sulphate as SO4 | Phosphate : - {TIP} |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CEL | uS/Cm | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l |
| Cors Erddreiniog - Pipe | CE1.1 | 20/01/2014 | | | <0.2 | 5.23 | 23.10 | | <0.0152 | | 1040 | 29.2 | <0.02 | <0.05 | | |
| Cors Erddreiniog Spring at hazel wood | CE2.1 | 20/01/2014 | | | <0.2 | 6.93 | 30.6 | | <0.0152 | | 260 | 29.8 | <0.02 | <0.05 | | |
| Cors Erddreiniog 3 | CE3.3 (A) | 19/01/2014 | 6.9 | 514 | <0.2 | 7.34 | 32.50 | | <0.0152 | 140 | 270 | 28.5 | <0.02 | <0.05 | <10 | <.02 |
| Cors Erddreiniog 4 | CE5.3 (B) | 20/01/2014 | 7 | 488 | <0.2 | 2.07 | 9.15 | 1.93 | <0.0152 | 259 | 214 | 22.1 | <.02 | <0.05 | 17.6 | <.02 |

| Survey Site | Survey Ref | Date | Sodium | Potassium | Magnesium | Calcium | Redox Potential : In Situ | pH | Manganese | Iron | Manganese, Dissolved | Iron, Dissolved | Ionic Balance | Bicarbonate as HCO3 | Oxygen, Dissolved, % Saturation | Oxygen, Dissolved as O2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/l | mg/l | ug/l | mg/l | mV | pH | ug/l | ug/l | ug/l | ug/l | % | mg/l | % | mg/l |
| Cors Erddreiniog - Pipe | CE1.1 | 20/01/2014 | | | | | | | | | | | | | | |
| Cors Erddreiniog Spring at hazel wood | CE2.1 | 20/01/2014 | | | | | | | | | | | | | | |
| Cors Erddreiniog 3 | CE3.3 (A) | 19/01/2014 | 57.7 | 0.40 | 0.83 | 54.9 | 0.4 | 8 | <10 | 54 | <10 | <30 | | | 107.5 | 13.1 |
| Cors Erddreiniog 4 | CE5.3 (B) | 20/01/2014 | 9.8 | 0.85 | 3.53 | 98.0 | 19.0 | 8.14 | 38.2 | 667 | <10 | <30 | 2.02 | 261 | 101.7 | 12.3 |

Table 86 Cors Erddreiniog water quality




Les' Scrape (Site E)

Spring at Hazelwood (Site B)

'Pipe' (Site A)

**Figure 95 Cors Erddreiniog Vegetation Map**

### 7.13.4 **Vegetation (spring) for Cors Erddériniog**

Six samples (A-F) were taken from along the margin of a single site (Cors Erddériniog), a lowland calcareous fen. Four samples (B-D) had good stands of *Palustriella commutata* while a single sample (F) had only a single patch of *Palustrtiella commutata* representing a pioneer within a area recently scraped as part of conservation management. The 4 main sites (B-D) are associated with springs and seepages flowing onto the fen from the east down a gentle slope parallel to the woodland. The spring heads have dominant patches of *Palustriella commutata* with *Conocephalum salebrosum* (especially where rocky or wooded) and the *Palustriella* vegetation then continues along the margins of the spring runnels before quickly being replaced by *Camplylium stellatum, Bryum psedotriquetrum* and then a rapid transition into tall fen vegetation (dominated by *Juncus* species) or open water communities. The *Palustriella commutata* dominated vegetation is associated with *Campylium stellatum, Fissidens adianthoides, Cratoneuron filicinum, Ctenidium molluscum, Scorpidium cossonii* and locally *Scorpidium scorpioides, Philonotis calcarea. Palustriella commutata* dominated vegetation often grows at ground level between tussocks of *Schoenus nigricans*.

| **Species** | **A** | **B** | **C** | **D** | **E** | **F** |
|---|---|---|---|---|---|---|
| *Palustriella commutata* | | A | A | A | A | R (<1%) |
| *Schoenus nigricans* | | | F | F | F | |
| *Pellia endiviifolia* | | O | O | R | O | |
| *Carex flacca* | | O | O | O | O | R (<1%) |
| *Anagallis tenella* | | O | O | O | O | O |
| *Juncus acutiflorus* | | O | O | O | F | A |
| *Fissidens adianthoides (spor.)* | | O | R | O | R | |
| *Anera pinguis* | | O | R | R | R | |
| *Chara vulgaris* | | R | | | | O |
| *Bellis perennis* | | R | | | R | O |
| *Cratoneuron filicinum* | | F | | R | O | |
| *Scorpidium cosonni* | | | | | O | R (<1%) |
| *Camplylium stellatum* | | | | | O | R (<1%) |
| filamentous algae (Chlorophyta) | | O | R | R | R | |
| *Brachythecium rivulare* | | R (<1%) | | | | |
| *Calliergonella cupidata* | | R | R | | R | |
| *Carex demmisa* | | R | R | | R | |
| *Centaurea nigra* | | R (<1%) | | | | |
| *Cirsium palustre* | | R | R | R | R | |
| *Conocephalum salebrosum* | | O | | | | |
| *Ctenidium molluscum* | | R | | R | | |
| *Festuca rubra* | | R | R (<1%) | R (<1%) | R (<1%) | |
| *Epilobium sp.* | | | R | | | R |
| *Holcus lanatus* | | R (<1%) | | | | |
| *Juncus effusus* | | | | R | | |
| *Juncus inflexus* | | R (<1%) | R (<1%) | | | |
| *Agrostis stolonifera* | | R (<1%) | | R (<1%) | | |
| *Philonotis calcarea* | | | | | R | |
| *Plantago lanceolata* | | R (<1%) | R (<1%) | R (<1%) | R (<1%) | |
| *Trifolium repens* | | R (<1%) | | | | |
| *Senecio cf aquaticus* | | | | R | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Scorpidium scorpioides* | | | | | R | |
| *Succisa pratensis* | | | | | R | |
| *Triglochin palustre* | | | | | R | |

**Table 87 Cors Erddreiniog Species list – Palustriella dominated vegetation**

Molinia and Schoenus tussocks, many of which are old and partly decaying that provided a habitat for bryophytes and flowering plants above the level of regular seepage water (i.e receiving rain water) A broad number of typically califuge species occur including *Potentilla erecta*, *Erica tetralix*, *Succisa* and tiny plants of *Pteridium*. However, the presence of some generally calcicole species (such as *Ctenidium molluscum*, *Eurhychium striatum*) suggests that these tussocks may be able to draw base-rich water above the level of seepage.

| Species | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| *Molinia caerulea* | O | F | O | O | R | |
| *Schoenus nigricans* | | | F | O | O | |
| *Ctenidium molluscum* | | | O | A | O | |
| *Thuidium tamariscinum* | | O | O | | | |
| *Eurhynchium striatum* | | | R | O | | |
| *Potentilla erecta* | | O | R | R | R | |
| *Anera pinguis* | | | R | R | | |
| *Brachythecium rivulare* | | | | | R | |
| *cf Pedicularis palustris* | | | | | R | |
| *Campylium protensum* | | | R | | | |
| *Centaurea nigra* | R | | | R | | |
| *Cratoneuron filicinum* | | | | | R | |
| *Erica tetralix* | | | R | R | R | |
| *Filipendula ulmaria* | R | | | | | |
| *Ctenidium molluscum* | | R | | | | |
| *Lotus cf pedunculatus* | | R (<1%) | | | R (<1%) | |
| *Plagiomnium elatum* | | | | | R | |
| *Polygala serpyllifolia* | | | R | | R | |
| *Primula sp.* | | R | | | | |
| *Pteridium aquilinum* | | | | R (<1%) | | |
| *Rubus fruticosus* | | | | R (<1%) | | |
| *Scleropdium purum* | | | R | R | | |
| *Succisa pratensis* | | R | R | | R | |

**Table 88 Cors Erddreiniog Species list – Molinia & Schoenus nigricans tussocks (within area of spring but above level of seepage water)**

### 7.13.5 **Vegetation adjoining spring for Cors Erddereniog**

Low growing bryophyte dominated vegetation (without Palustriella) and *Campylium stellatum, Bryum psuedotriquetrum, Fissidens adianthoides, Cratoneuron filicinum, Calliergonella cuspidata.*

| Species | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| *Camplylium stellatum* | | F | | A | | |
| *Calliergonella cupidata* | O | | A | | | |
| *Anagallis tenella* | O | | O | | | |
| *Bryum pseudotriquetrum* | R | O | O | | | |
| filamentous algae (Chlorophyta) | | | | O | | |
| *Fissidens adianthoides* | | | O | | | |
| *Cratoneuron filicinum* | O | | | | | |
| *Pellia endiviifolia* | | O | | | | |
| *Prunella vulgaris* | O | | | | | |
| *Juncus acutiflorus* | O | | | | | |
| *Anera pinguis* | | R | R | R | | |
| *Agrostis stolonifera* | R (<1%) | | | | | |
| *Carex demmisa* | R | | | | | |
| *Carex flacca* | F | | | | | |
| *cf Oenanthe sp.* | R | | | | | |
| *Cirsium palustre* | R | | | | | |
| *Ctenidium molluscum* | | R | | | | |
| *Epilobium sp.* | R | | | | | |
| *Festuca rubra* | R (<1%) | | | | | |
| *Juncus effusus* | F | | | | | |
| *Juncus inflexus* | R | | | | | |
| *Mentha aquatica* | R (<1%) | | | | | |
| *Ranuculus cf acris* | R (<1%) | | | | | |
| *Ranunculus flammula* | R | | | | | |
| *Taraxacum sp.* | R (<1%) | | | | | |
| *Equisetum palustre* | | R | | | | |

**Table 89 Cors Erddreiniog Species list – Campylium stellatum - Bryum Psudotriquetrum seepage (without Palustriella)**

Open water communities dominated by flowering plants with a preference for calcareous water including *Chara vulgaris, Potamogeton coloratus*.

| Species | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| *Chara vulgaris* | O | F | O | O | R | |
| *Calliergonella cupidata* | | | F | O | O | |
| filamentous algae (Chlorophyta) | | | O | A | O | |
| *Juncus subnodulosus* | | O | O | | | |
| *Nasturtium officinale s.l.* | | | R | O | | |
| *Potamogeton coloratus* | | O | R | R | R | |
| *Ranunculus flammula* | | | R | R | | |
| *Veronica beccabunga* | | | | | R | |
| *Typha latifolia* | | | | | R | |
| *Agrostis stolonifera* | | | R | | | |
| *Apium nodiflorum* | R | | | R | | |
| *Angelica sylvestris* | | | | | R | |
| *Epilobium sp.* | | | R | R | R | |
| *Equisetum fluviatile* | R | | | | | |
| *Galium palustre ssp. palustre* | | R | | | | |
| *Glyceria fluitans* | | R (<1%) | | | R (<1%) | |
| *Hypericum tetrapterum* | | | | | R | |
| *Mentha aquatica* | | | R | | R | |
| *Ranunculus repens* | | R | | | | |
| | | | | R (<1%) | | |
| | | | | R (<1%) | | |
| | | | R | R | | |
| | | R | R | | R | |

**Table 90 Cors Erddreiniog Species list – Open Water runnel**

Tall calcareous fen community dominayed by *Juncus* species and occasional *Cladium mariscus*.

| Species | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| *Juncus acutiflorus* | R | A | F | F | | |
| *Juncus effusus* | F | | | F | | |
| *Juncus inflexus* | O | F | F | | | |
| *Triglochin palustre* | R | F | | | | |
| *Cladium mariscus* | | | O | O | | |
| *Juncus subnodulosus* | | O | R | | | |
| *Molinia caerulea* | O | | | | | |
| filamentous algae (Chlorophyta) | R | | | | | |
| *Filipendula ulmaria* | R | O | | | | |
| *Hypericum tetrapterum* | R | R | | | | |
| *Calliergonella cupidata* | | | | R | | |
| *Nasturtium officinale s.l.* | R | | | | | |
| *Senecio cf aquaticus* | | R | | | | |

**Table 91 Cors Erddreiniog Species list – Tall Fen Community**

Scrub Woodland (Blackthorn & Hazel) occurs on the eastern margin of Cors Erdderiniog and surrounded a spring head in one sample point (B). The ground flora was dominated by Bramble with a few other species (*Primula vulgaris, Hedera, Brachypodium sylvaticum*) and scattered Bracken.

| Species | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| *Prunus spinosa* | | F | | | | |
| *Hedera helix* | | O | | | | |
| *Rubus fruticosus agg.* | | O | | | | |
| *Betula cf pubescens* | | R | | | | |
| *Brachypodium sylvaticum* | | R | | | | |
| *Corylus avellana* | | R | | | | |
| *Fissidena taxifolius var. taxifolius* | | R | | | | |
| *Primula vulgaris* | | R | | | | |
| *Pteridium aquilinum* | | R | | | | |

**Table 92 Cors Erddreiniog Species list – Surrounding woodland ground flora (above level of seepage water)**

### 7.13.6 Condition assessment

The overall assessment is that Cors Erdderiniog (sites A-F) as being in favourable ecological and hydrogeological condition.

Sample at ‘pipe’ in situ pH, EC, temp, DO and Eh (CE1.1 or Site A) SH4758781724

Sample at ‘Les’ Scrape’ in situ pH, EC, temp, DO and Eh. (CE5.1 or site E) SH4763331998.

Recently exposed tufa colonised by *Schoenus nigricans* and *Palustriella commutata* –‘ Les’ scrape’. (CE5.1 or site E) SH4763331998

Sample point at’spring at hazelwood’ (CE2.1 orSiteB)-SH4759081766.

A large tussock amongst diffuse seepage and spring water that supplies a large area near the field boundary in the field opposite ‘Llyn yr Wyth-Eidion’.

Patch of *Scorpidium scorpioides* colonising recently exposed tufa –‘ Les’ scrape’. (CE5.1 or site E) SH4763331998

Drain with *Typha latifolia*, below 'Les' scrape'.

Dominant marginal stand *of Palustriella commutata* (upper runnel of 'spring at hazel wood' at the point where the woodland joins the fen

Lower limit of *Palustriella commutata* dominated vegetation (between *Molinia* hummocks) 'spring at hazel wood' transitioning into open water and tall fen community (looking north)

Large drain within the fen dominated by *Chrara vulgaris* – below 'spring at hazel wood'

Lower limit of *Palustriella commutata* dominated vegetation (between *Schoenus nigricans* hummocks) 'spring C/D' transitioning into tall fen community (looking north i.e. into the middle of the fen towards lake).

**Figure 96 Cors Erddreiniog photograph**

## 7.14 NANT PERIS

### 7.14.1 Introduction

The eight upland 'petrifying springs' at Nant Peris have been surveyed and monitored both by Lewis, (2003) and more recently by Creer, (2012) as part of SAC monitoring for H7220. They represent the highest altitude sites visited as part of this survey (681-689maOD). The most recent survey (Creer, 2012) concluded that 'two out of eight springs had increased in extent since 2003, six had contracted in size and two were unknown, with only one of the eight springs concluded to be in favourable condition mainly due to the presence of negative indicator species namely grasses and *Epilobium brunnescens*. During this survey only a selection of the springs were assessed and they include springs No 1, 4 and 7 (comparable with the IDs used for the SAC monitoring). The sites survey was undertaken with Julie Creer (NRW). There was no evidence of tufa depsoitsion at either springs 1, 4 or 7.

### 7.14.2 Geological and hydrogeological data

All of the springs are located in an area underlain by strata from the 'Bedded Pyroclastic Formation' from the Ordovician Snowdon Volcanic Group. There are large boulders and in situ bedrock within the area of the springs, the rocks were tested with HCI and were not carbonaceous. The Bedded Pyroclastic Formation (BP) is up to 450m thick however despite its name pyroclastic elements form only a small part of the formation with basaltic tuffaceous sediments, hyaloclastites and basic tuffites abundant in places (Howells et al 1991). Analysis of a bedrock sample, collected near the survey site is also provided by Howells et al 1991 (Sample Reference KB801 Cwm Idwal 6398, 5868) and shows that the bedrock is dominated by silicates (44.91%). Peat, till and head deposits are mapped in the area however the majority of land at this altitude and on the exposed hillside comprises of bedrock.

| | % weight |
|---|---|
| $SiO_2$ | 44.91 |
| $Al_2O_3$ | 14.9 |
| $TiO_2$ | 2.08 |
| FeO | 12.17 |
| MgO | 10.92 |
| CaO | 5.98 |
| $Na_2O$ | 3.78 |
| $K_2O$ | 0.53 |
| MnO | 0.18 |
| $P_2O_5$ | 0.24 |
| LOI | 4.30 |
| Total | 99.99% |

**Table 93 Analysis of the Bedded Pyroclastic Formation. Sample Reference KB801 Cwm Idwal 6398, 5868. Howells et al 1991.**

The general direction of groundwater and surface water flow is most likley to be topgraphically driven, downslope from NE to SW. Sites 1, 4 and 7 were surveyed and at each site it was possible to trace a small runnel than fed into the upslope side of the 'spring' and then continued on the downslope side. The runnels at all sites generally had a very low flow of water 0.2-0.2l/s.

Based on this observation one could question the classification of these sites (1, 4 and 7) as true 'springs' as mounds tend to be located 'midway' along established, although small runnels rather

than in an area where one would identify a true spring. There was no evidence of tufa deposition at or nearby the mounds and classification of this site as petrifying (tufa depositing) should be avoided.

The processes or controls that lead to the formation of these mounds are not known, and sites 1, 4 and 7 appeared to be in various stages of development. Site 1 is fed by a small runnel to the north and also perhaps seepage from the base of the bedrock outcrop, the mound looks intact and is 0.48m in thickness, measured from the competent base to the surface of the *Palustriella* mat. Site 4 appears to have experienced a collapse in the lower (or frontal) part of the mound and it is possible that this collapse will propagate backwards.

Two water quality samples were collected at sites 1 and 7. Both samples are weekly mineralised as would be expected at high elevation in a hardrock aquifer. pH values are neutral 7.04 and 7.24 and all the ions are in low levels perhaps indicating a young water recently derived from rainfall. Sample NP1.1 has no dominant water facies and sample NP7.1 is trending towards weak calcium bicarbonate type water. Nutreint levels are all low or below levels of detection. The water would not be described as rich in either calcium (15.1-26mg/l) or bicarbonate (15-67.7mg/l) both of which were towards the lowest levels for any samples within this study.

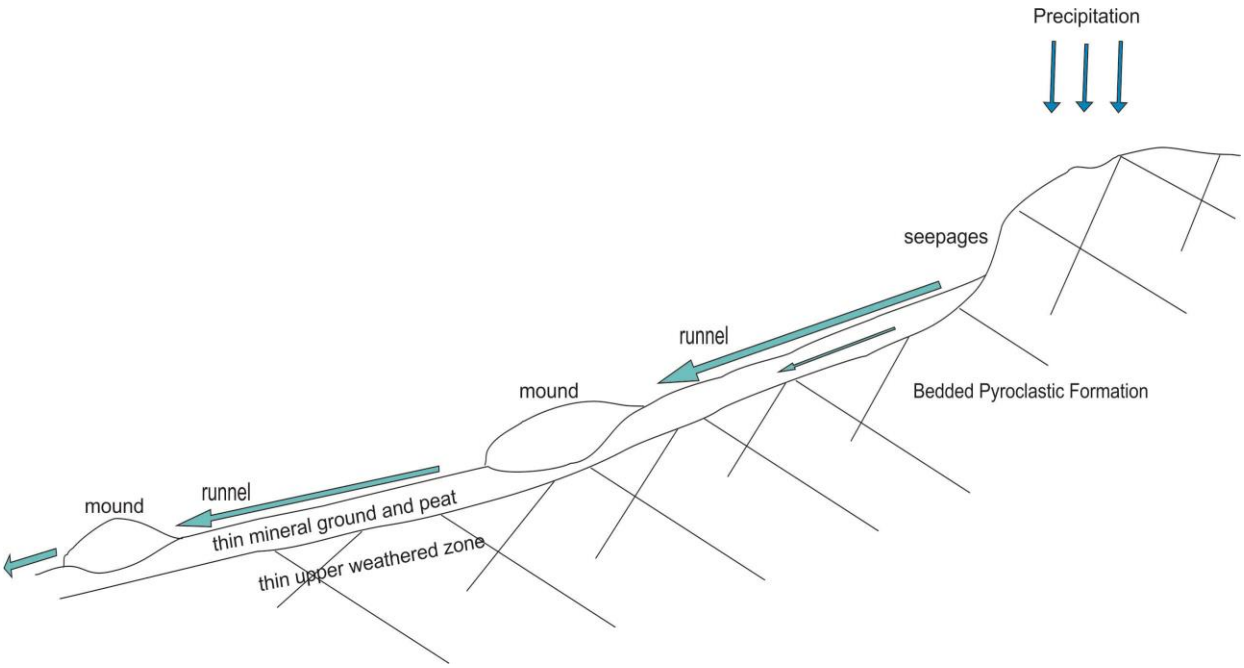



**Figure 97 Nant Peris initial site conceptual model**

### 7.14.3 Land use and pressures

The area surrounding the mounds is heavily grazed by sheep and also used by walkers. There is no evidence of poaching or burning within the general area and while the surrounding acid grassland and bog shows signs of overgrazing by sheep, the areas of *Palustriella* vegetation show little or no signs of poaching. There are no properties nearby and thus no evidence of any private water supplies or sewage systems within 500m. It is not thought that there are any hydrological pressures within close proximity to the sites. The greatest threat may come from grazing animals or walkers.

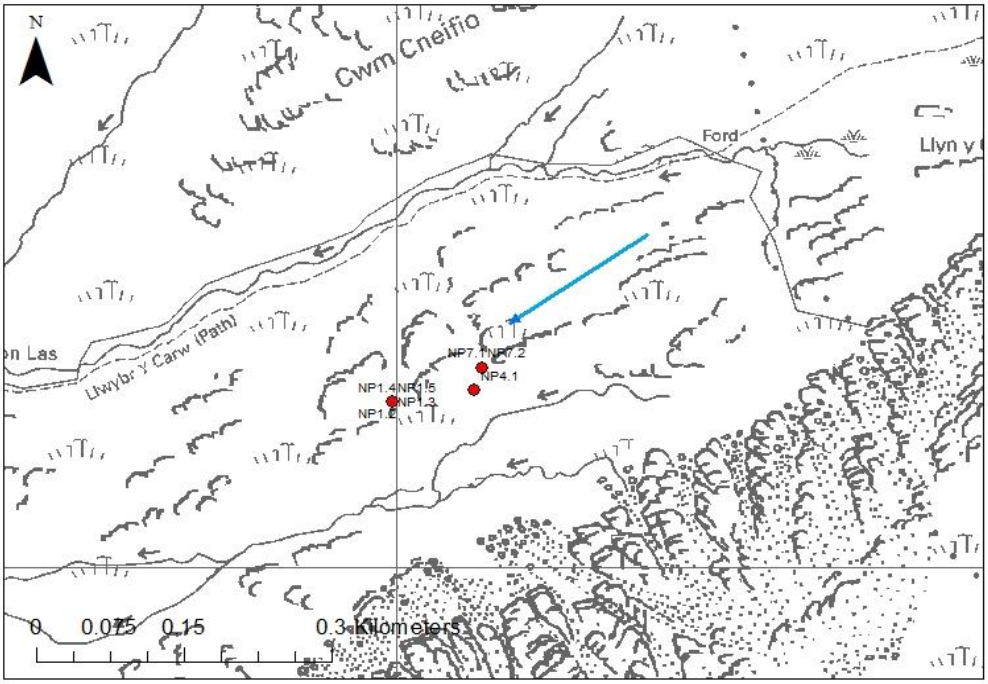



**Figure 98 Nant Peris Ordnance Survey map and GPS locations. ©Ordnance Survey.**

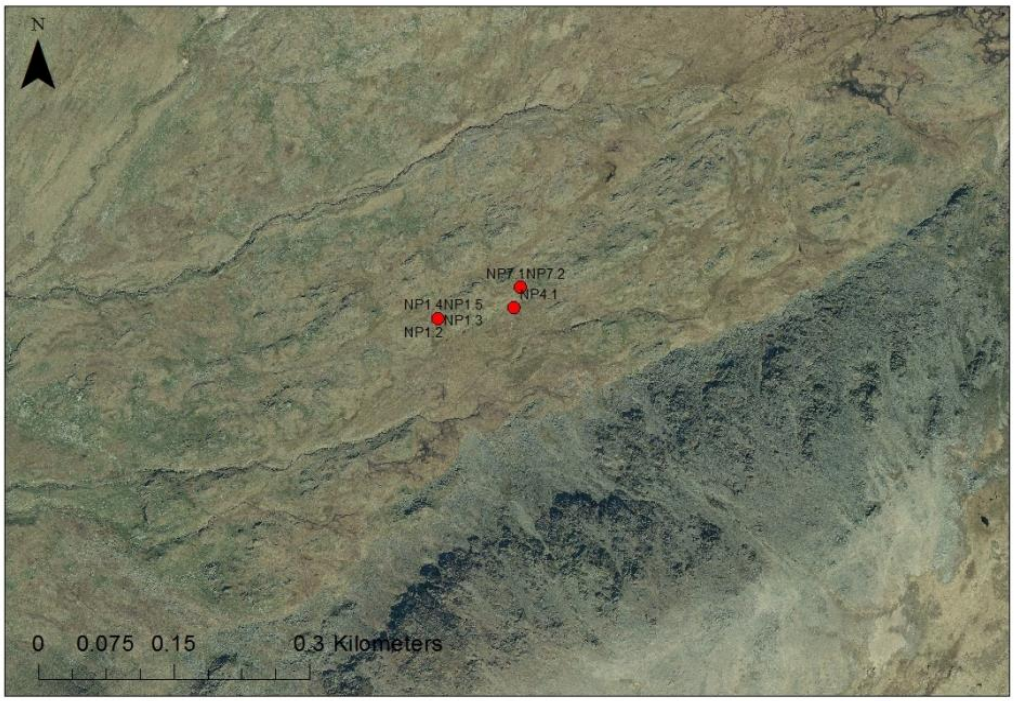



**Figure 99 Nant Peris aerial photograph**

© UKP/Getmapping Licence No. UKP2006/01

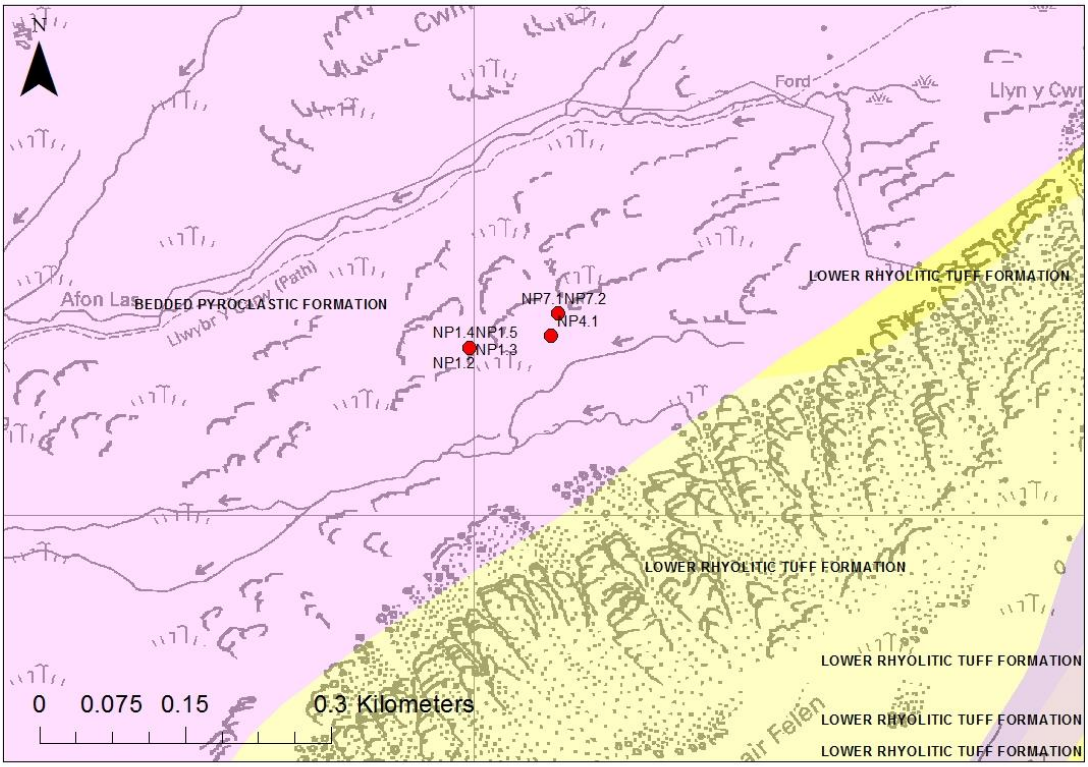
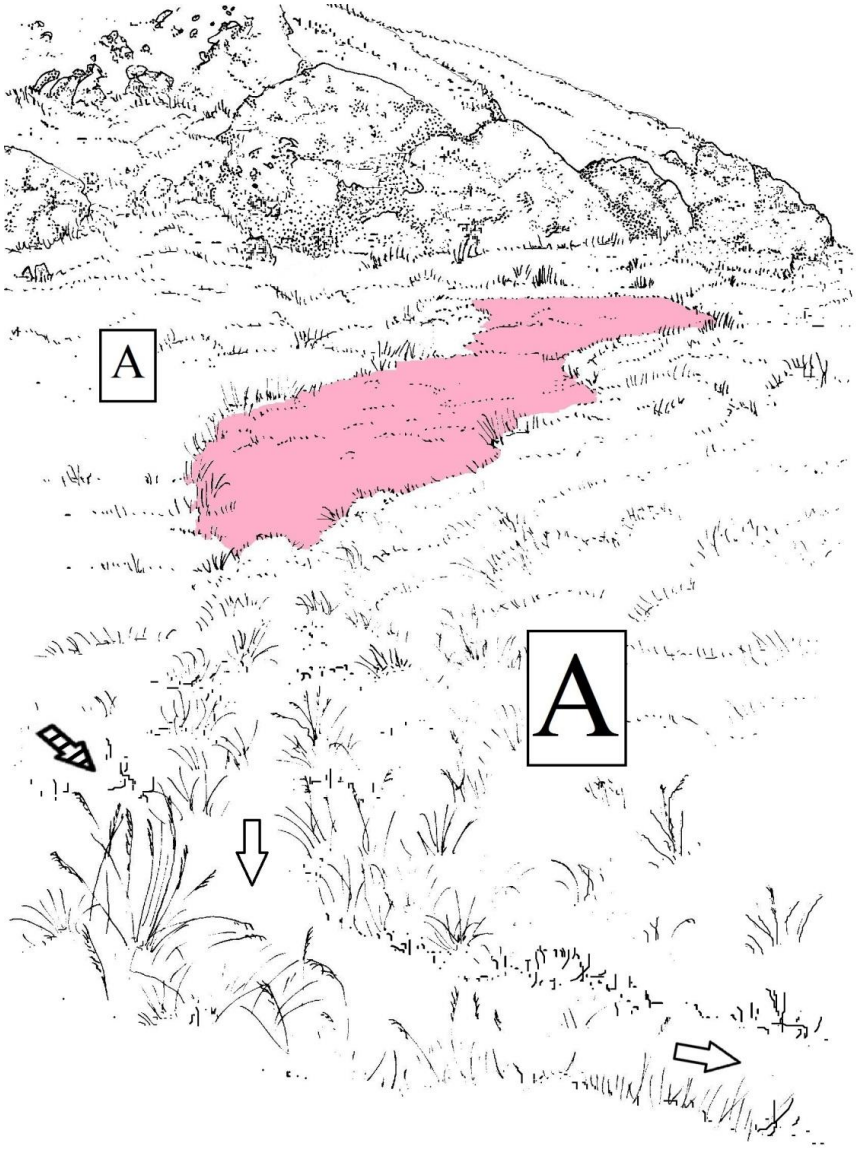



**Figure 100 Nant Peris Bedrock Geology 1:50,000. ©BGS. ©Ordnance Survey.**

| Survey Site | Survey Ref | Date | Temperature of Water | SEC | Ammoniacal Nitrogen as N | Nitrogen, Total Oxidised as N | Nitrate as NO3 | Nitrate as N | Nitrite as N | Hardness, Total as CaCO3 | Alkalinity to pH 4.5 as CaCO3 | Chloride | Orthophosphate, reactive as P | Orthophospahte as PO4 | Sulphate as SO4 | Phosphate : - {TIP} |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CEL | uS/Cm | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l |
| Nant Peris Spring 1 | NP1.1 | 23/01/2014 | 4.70 | 104.20 | <0.2 | 0.11 | 0.49 | 0.11 | <0.0152 | 46 | 42.50 | 5.60 | <0.02 | <0.05 | <10 | 0.05 |
| Nant Peris Spring 7 | NP7.1 | 23/01/2014 | 6.20 | 134.0 | <0.2 | 0.13 | 0.55 | 0.55 | <0.0152 | 74 | 55.00 | 6.30 | <0.02 | <0.05 | <10 | <0.05 |

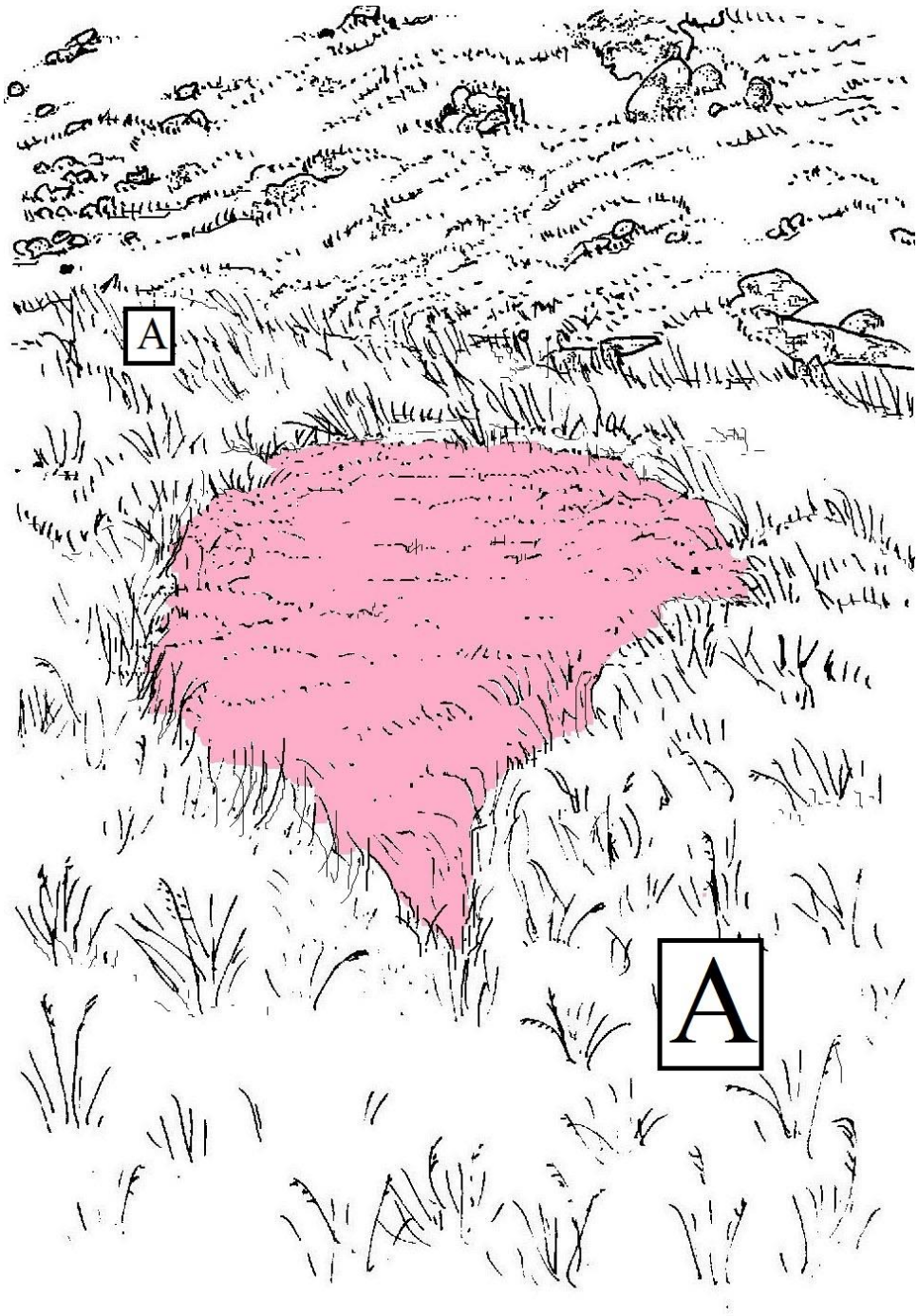
| Survey Site | Survey Ref | Date | Sodium | Potassium | Magnesium | Calcium | Redox Potential : In Situ | pH : In Situ | Manganese | Iron | Manganese, Dissolved | Iron, Dissolved | Ionic Balance | Bicarbonate as HCO3 | Oxygen, Dissolved, % Saturation | Oxygen, Dissolved as O2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/l | mg/l | ug/l | mg/l | mV | pH | ug/l | ug/l | ug/l | ug/l | % | mg/l | % | mg/l |
| Nant Peris Spring 1 | NP1.1 | 23/01/2014 | 3.80 | 0.26 | 1.90 | 15.10 | 31.3 | 7.24 | 27 | 209 | 10.00 | 30.00 | -6.55 | 15.1 | 94.80 | 11.20 |
| Nant Peris Spring 7 | NP7.1 | 23/01/2014 | 4.06 | 0.43 | 2.28 | 26.00 | 37.1 | 7.04 | 184 | 2770 | <10 | <30 | 5.59 | 67.7 | 87.80 | 9.97 |

**Table 94 Nant Peris water quality**



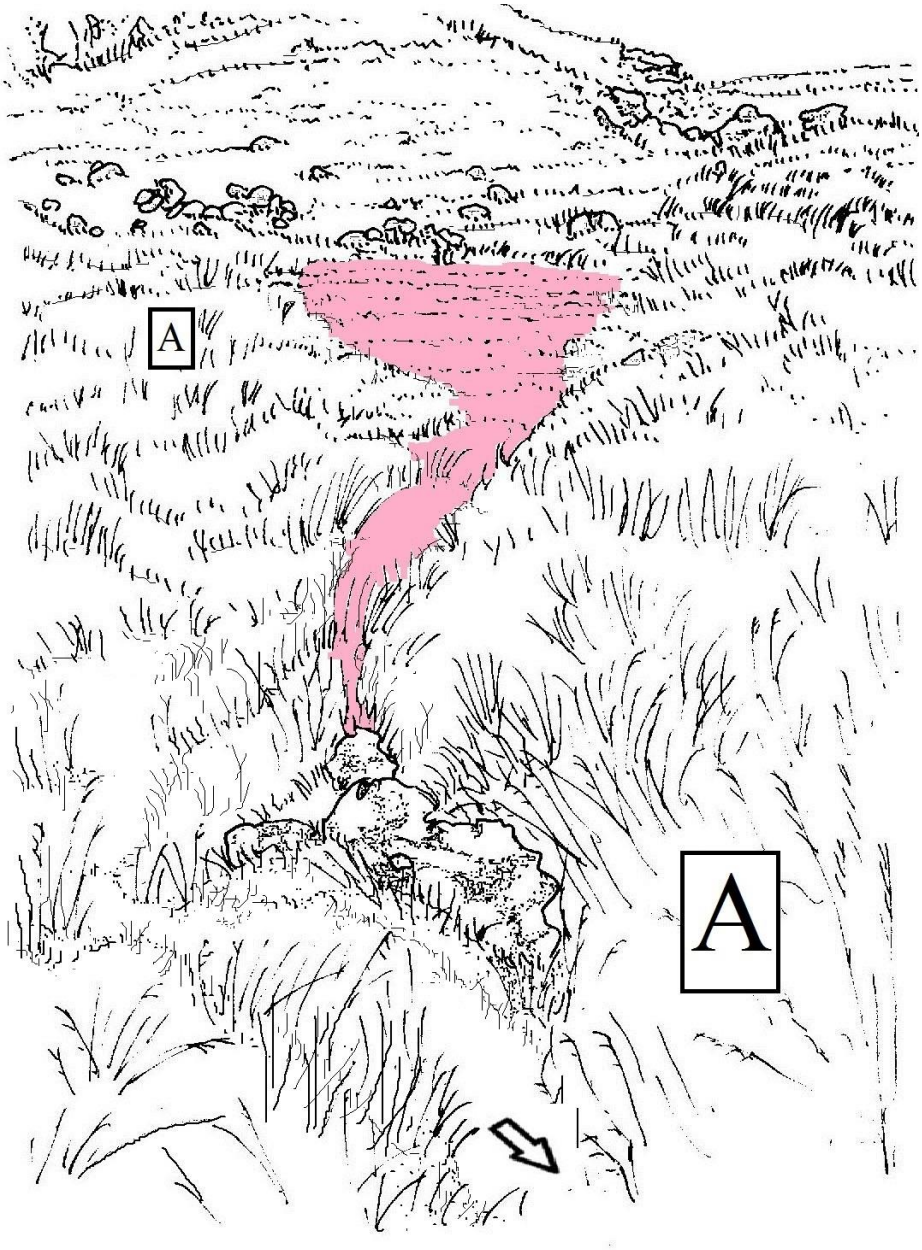

| | | | |
|---|---|---|---|
| | *Palustriella* dominated vegetation | A | Acid grassland and bog |
| | | | Acid side spring with *Eriophorum angustifolium, Sphagnum inundatum* |
| | | | Direction of flow of surface water (runnel without *Palustriella*) |

**Figure 101 Nant Peris site 1 Vegetation map**




| | | | |
|---|---|---|---|
| | *Palustriella* dominated vegetation | A | Acid grassland and bog |

**Figure 102 Nant Peris site 2 Vegetation map**




| | | | |
|---|---|---|---|
| | *Palustriella* dominated vegetation | A | Acid grassland and bog |
| | | ⇨ | Main direction of flow of surface water (runnel without *Palustriella*) |

**Figure 103 Nant Peris site 3 Vegetation map (upper of 2 patches of Palustriella dominated vegetation)**

### 7.14.4 **Vegetation (spring) for Nant Peris site 1**

Nant Peris Site 1 corresponds with Spring No 1 on existing NRW surveys. It comprises flushed vegetation associated with upland springs on open hills at altitude (c. 600 maOD, Snowdon range) exclusively dominated by *Palustriella falcata* forming dome shaped floating mats of vegetation above spring water. A number of vascular plants are prominent including *Montia fontana, Saxifraga sp.* and the invasive alien *Epilobium brunescens*. A number of typical *Palustriella* associated bryophytes occur (i.e those typically associated with base-rich water) including *Crataneron filicinum, Campylium stellatum, Scorpidium revolvens, Fissidens adianthoides, Bryum pseudotriquetrum, Scorpidium, scorpioides, Philonotis fontana* but also a number of less markedly calcicole species (*Rhizomnium punctatum, Brachythecium rivulare*). These last two species are not unusual within upland flushes (and indeed were recorded in small quantity from a number of other sites during this survey). However, the presence of *Straminergon stramineum* (a marked calcifuge) in good quantity mixed with *Palustriella falcata* and *Brachythecium rivulare* is exceptional.

| | |
|---|---|
| *Agrostis stolonifera* | R (<1%) |
| *Aneura pinguis* | F |
| *Brachythecium rivulare* | O |
| *Bryum psudotriquetrum* | R |
| *Calliergonella cuspidata* | R |
| *Campylium stellatum* | R |
| *Cardamine pratensis* | R |
| *Carex demissa* | R |
| *Carex flacca* | O |
| *Cirsium palustre* | R (<1%) |
| *Cratoneuron filicinum* | O |
| *Epilobium brunescens* | O |
| *Eriophorum angustifolium* | R |
| *Festuca ovina* | R |
| *Fissidens adianthoides* | O |
| *Juncus acutiflorus* | R |
| *Montia fontana* | O |
| *Palustriella falcata* | A |
| *Philonotis fontana* | R |
| *Rhizomnium puntatum* | R |
| *Rhytidiadelphus squarosus* | R |
| *Ricardia mutifida* | O |
| *Saxifraga stellaris* | R |
| *Scorpidium revolvens* | O |
| *Scorpidium scorpioides* | R |
| *Straminergon stramineum* | O |

**Table 95 Nant Peris Site 1 Species list – Palustriella dominated vegetation**

### 7.14.5 **Vegetation (adjoining spring) for Nant Peris 1**

Acid grassland (dominated by *Nardus stricta*) with regular boggy vegetation (*Polytrichum commune*, *Polytrichum strictum* and *Sphagnum* species).

| | |
|---|---|
| *Camplopus atrovirens* | R |
| *Carex binervis* | R |
| *Cladonia portentosa* | O |
| *Cladonia uncialis* | R |
| *Erica tetralix* | R |
| *Huperzia selago* | R |
| *Juncus squarrosus* | F |
| *Nardus stricta* | O |
| *Polytrichum commune* | R |
| *Polytrichum strictum* | R |
| *Racomitrium lanuginosum* | R |
| *Rhytidiadelphus loreus* | O |
| *Sphagnum capillifolium ssp. rubellum* | R |
| *Sphagnum inundatum* | R |
| *Sphagnum papillosum* | O |
| *Thuidium tamaraiscinum* | R |

**Table 96 Nant Peris Site 1 Species list – Acid grassland and bog**

### 7.14.6 **Vegetation (spring) for Nant Peris site 2**

Nant Peris Site 2 corresponds with Spring No 4 on existing NRW surveys. It also comprises flushed vegetation associated with upland springs on open hills at altitude (c. 600 maOD, Snowdon range) exclusively dominated by *Palustriella falcata* forming dome shaped floating mats of vegetation above spring water. A number of vascular plants are prominent includimg *Montia fontana, Saxifraga sp*. the invasive alien *Epilobium brunescens* as well as occasional *Selaginella selaginoides* at the margins. A number of typical *Palustriella* associated bryophytes occur (i.e those typically associated with base-rich water) including *Crataneron filicinum, Campylium stellatum, Scorpidium revolvens, Bryum pseudotriquetrum, Scorpidium, scorpioides* and *Philonotis fontana.* The presence of *Straminergon stramineum* (a marked calcfuge) in good quantity mixed with *Palustriella falcata* and *Brachythecium rivulare* however is exceptional.

| | |
|---|---|
| *Agrostis stolonifera* | R (<1%) |
| *Aneura pinguis* | F |
| *Brachythecium rivulare* | O |
| *Bryum psudotriquetrum* | R |
| *Campylium stellatum* | R |
| *Cardamine pratensis* | F |
| *Carex demissa* | O |
| *Carex flacca* | O |
| *Cratoneuron filicinum* | O |
| *Epilobium brunescens* | F |
| *Eriophorum angustifolium* | O |
| *Festuca ovina* | O |
| *Festuca rubra* | R |
| *Juncus acutiflorus* | O |
| *Montia fontana* | O |
| *Palustriella falcata* | A |
| *Philonotis fontana* | O |
| *Rhytidiadelphus squarosus* | R |
| *Saxifraga stellaris* | O |
| *Scorpidium revolvens* | O |
| *Selaginella selaginoides* | R |
| *Straminergon stramineum* | O |

**Table 97 Nant Peris Site 2 Species list – Palustriella dominated vegetation**

### 7.14.7 Vegetation (adjoining spring) for Nant Peris site 2

Acid grassland (dominated by *Nardus stricta, Juncus squarrosus*) with regular boggy vegetation (*Polytrichum commune, Sphagnum* species and occasional *Pteridium, Huperzia selago*).

| | |
|---|---|
| *Camplopus atrovirens* | R |
| *Carex binervis* | O |
| *Galium saxatile* | O |
| *Huperzia selago* | R |
| *Hylocomium slpendens* | O |
| *Juncus squarrosus* | F |
| *Nardus stricta* | F |
| *Polygala serpyllifolia* | R |
| *Polytrichum commune* | R (<1%) |
| *Potenilla erecta* | O |
| *Pteridium aquilinum* | R (<1%) |
| *Racomitrium lanuginosum* | R |
| *Sphagnum capillifolium ssp. rubellum* | R |
| *Sphagnum inundatum* | R (<1%) |
| *Sphagnum papillosum* | O |
| *Sphagum tenellum* | R |
| *Thuidium tamarscinum* | R (<1%) |

**Table 98 Nant Peris Site 2 Species list – Acid grassland and bog**

### 7.14.8 **Vegetation (spring) for Nant Peris 3**

Flushed vegetation associated with upland springs on open hills at altitude (c. 600 maOD, Snowdon range) exclusively dominated by *Palustriella falcata* forming dome shaped floating mats of vegetation above spring water. A number of vascular plants are prominent including *Montia Fontana* and *Saxifraga sp.* A number of typical *Palustriella* associated bryophytes occur (i.e those typically associated with base-rich water) including *Crataneron filicinum, Fissidens adianthoides, Campylium stellatum,* a non fertile *Chilosyphos sp., Scorpidium revolvens, Bryum pseudotriquetrum, Scorpidium, scorpioides, Philonotis Fontana* but also a number of less markedly calcicole species (*Rhizomnium punctatum, Plagiomnium undulatum, Brachythecium rivulare*). The presence of *Straminergon stramineum* (a marked calcfuge) in good quantity mixed with *Palustriella falcata* and *Brachythecium rivulare* is exceptional.

| | |
|---|---|
| *Agrostis stolonifera* | R (<1%) |
| *Aneura pinguis* | O |
| *Brachythecium rivulare* | R |
| *Bryum psudotriquetrum* | R |
| *Calliergonella cuspidata* | R |
| *Campylium stellatum* | R |
| *Cardamine pratensis* | O |
| *Carex demissa* | R |
| *Carex flacca* | O |
| *Chilosyphos sp.* | R |
| *Cratoneuron filicinum* | O |
| *Ctenidium molluscum* | R |
| *Festuca ovina* | R |
| *Fissidens adianthoides* | R |
| *Juncus acutiflorus* | O |
| *Montia fontana* | O |
| *Palustriella falcata* | A |
| *Philonotis fontana* | R |
| *Plagiomnium undulatum* | R |
| *Prunella vulgaris* | R (<1%) |
| *Rhizomnium puntatum* | R |
| *Rhytidiadelphus squarosus* | R |
| *Ricardia mutifida* | R |
| *Saxifraga stellaris* | R |
| *Scorpidium revolvens* | O |

**Table 99 Nant Peris Site 3 Species list – Palustriella dominated vegetation**

### 7.14.9 **Vegetation (adjoining spring) for Nant Peris 3**

Acid grassland (dominated by *Nardus stricta, Juncus squarrosus, Carex binervis*) with regular boggy vegetation (*Polytrichum commune*, *Sphagnum* species and occasional *Camplyopus atrovirens*).

| | |
|---|---|
| *Camplopus atrovirens* | R |
| *Carex binervis* | R |
| *Juncus squarrosus* | F |
| *Nardus stricta* | O |
| *Polygala sepyllifolia* | R |
| *Polytrichum commune* | R |
| *Racomitrium lanuginosum* | R |
| *Sphagnum capillifolium ssp. rubellum* | R |
| *Sphagnum inundatum* | R |
| *Sphagnum papillosum* | O |
| *Thuidium tamariscinum* | R |
| *Rhytidiadelphus loreus* | R |
| *Veronica officinalis* | R |

**Table 100 Nant Peris Site 3 Species list – Acid grassland and bog**

### 7.14.10 **Condition assessment**

The 3 sites surveyed are included within the Eryri SAC 2007-2012 monitoring cycle (Creer, 2012). Only one of eight sites was recorded as having a favourable conservation status, the others being classed as unfavourable principally on the basis of the presence of the invasive alien *Epilobium brunescens.*

The three sites surveyed (SAC sites 1, 4 and 7) very small sites (< 5x5 square metres) and appear susceptible to loss through natural vegetation succession. Site observations found evidence of a number of similar features that previously supported flush vegetation and likely *Palustriella*. In addition, SAC monitoring of vegetation extent for the period 2003-2012 noted that individual sites changed both positively and negatively with regard to extent. However there is little information on the hydrological factors that may allow for the formation of these sites.

Of the 3 sites surveyed, the *Palustriella* dominated vegetation of Sites 1 and 2 had occasional to frequent cover of *Epilobium brunescens*. Consequently, following Eryri SAC monitoring guidance (based on Common Standards monitoring), Nant Peris (sites 1 & 2) should be classified as being in unfavourable ecological status (in relation to vegetation) and Nant Peris (site 3) should be classified as being in favourable ecological status (in relation to vegetation).

All three Nant Peris sites should be classified as being in good hydrological condition.

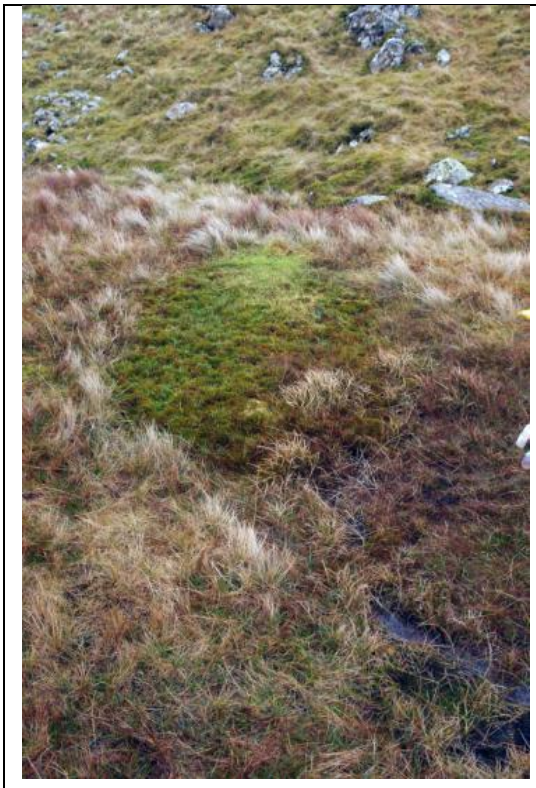
This spring is also known as Spring No 4 on NRW SAC monitoring report, located at SH6299558172

Wet hollow dominated by *Montia perfoliata.*

Domed floating matt of *Palustriella falcata* dominated vegetation over spring head

Vegetation at immediate spring head dominated by *Philonotis Fontana*, *Festuca ovina*, *Brachythecium rivulare* and the invasive alien *Epilobium brunescens*.

**Figure 104 Nant Peris Site 1 Photographs**

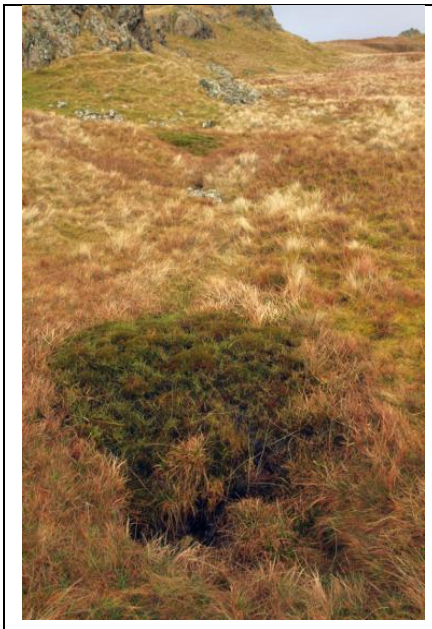


Domed floating matt of *Palustriella falcata* dominated vegetation over spring head. This spring is also known as Spring No 7 (NRW SAC monitoring report) located at SH6308658207

*Palustriella falcata* dominated vegetation with *Festica ovina* (centre of site)

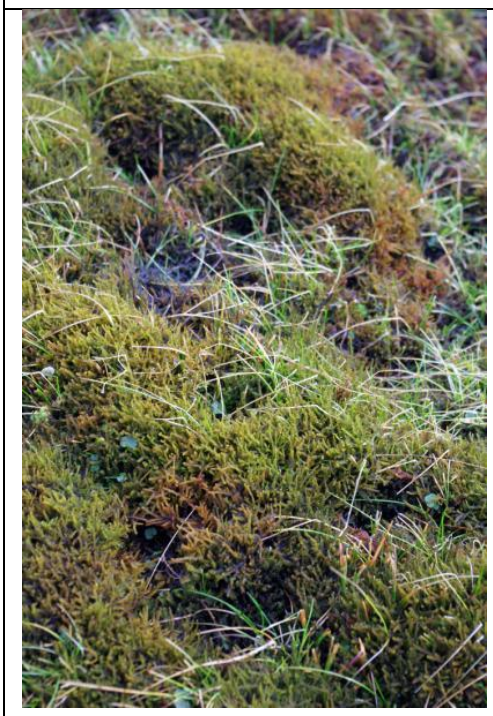
Shallow runnel with *Scorpidium revolvens, Scorpidium scorpioides*, (immediately below domed floating matt of *Palustriella falcata* dominated vegetation

**Figure 105 Nant Peris Site 2 Photographs**



Twin domes floating matt of *Palustriella falcata* dominated vegetation connected by a sunken runnel

Wet hollow dominated by *Montia perfoliata, Festuca ovina.*



*Palustriella falcata* dominated vegetation with *Festica ovina, Cardamine pratense* (centre of site)

Nant Peris also known as Spring No 4 in NRW SAC monitoring report located at SH6307958184. This spring dome has a collapsed front 'lobe' in the area where the water drains.

**Figure 106 Nant Peris Site 3 Photographs**

## 7.15 MC WALTERS DINGLE

### 7.15.1 Introduction

Mc Walters' Dingle is located in a wooded section of the Afon y Garth gorge and there are two sections of tufa. Only the main block of tufa was included in any detail within this survey although notes are made on the second smaller site. Chris Twigg, Stewart Campbell (NRW) and Dr Jackie Maplas (NE Wales RIGS) also accompanied us on the site visit.

### 7.15.2 Geological and hydrogeological data

Mc Walters Dingle is located within a north east – south west trending gorge along which several small tributaries flow, feeding the Afon y Garth that flows north east into the Dee Estuary. The tributaries are sourced in the Lower Carboniferous Pentre Chert and Bowland Shale Formation to the west. In the area of the main tufa block deposit the gorge cuts through the Carboniferous Pennine Lower Coal Measures and further down the gorge into the Gwespyr Sandstone. Glacial till is mapped across the majority of area outside of the gorge masking the majority of the surface exposure, however it can be seen in Nant-Felyn-blym (Howard, et al 2007) which joins the Afon y Garth about 1Km downstream of the tufa deposit. Localised deposits of head are mapped following the trend of the gorge. The tufa block at Mc Walters Dingle has been surveyed by Mr C. Twigg and the survey diagram is presented within this chapter.

The principal tufa block is located on the northern side of the Afon y Garth and has been surveyed by Mr C Twigg. The survey suggests that the tufa block is at least 27m in length, starting at the break of slope on the northern side of the gorge and terminating in a steep face when it meets the Afon y Garth.

The tufa block is situated within a wooded section of the gorge and is covered in leaf litter. The most northern part of the tufa, coincident with the break in slope is very wet and water can be seen issuing across this margin. The water discharges from the break in slope and flows across the tufa block towards the stream via runnels and across the surface of the deposit. The seepage water at the break in slope had a pH of 7.66 and EC of 895uscm. Water discharges across the face of the tufa block where it meets the Afon y Garth with values of pH 7.83 and 886us/cm were recorded. A full sample was obtained from the outflow point of the tufa block by collecting seepage water that had passed over or through the tufa block. The results show that the water is hard and dominated by Calcium (136mg/l) and Bicarbonate (404mg/l) ions but also has significant quantities of Sulphate (65mg/l) and Chloride (60.2mg/l). Phosphate and orthophosphate are both below their respective limits of detection, there is however 2.9mg/l Nitrate – N.

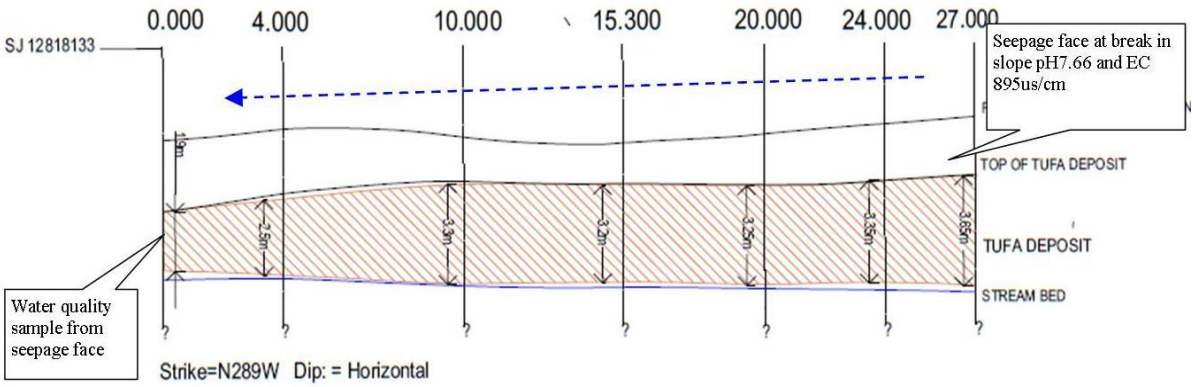



**Figure 107 Surveyed section of the Mc Walters Dingle tufa deposit annotated with blue line to represent generic flow direction of water, with kind permission of Mr Chris Twigg (measurements in meters).**

### 7.15.3 Land use and pressures

The dingle can be used by walkers although the footfall is presumed to be low in the area of the survey site. It does not appear that there are any grazing animals and poaching is not considered to be a known pressure. There is no evidence of burning. There is old infrastructure for the pumping of water within the base of the dingle associated with past industry. However none of the infrastructure appears to be working or in use and thus is not considered to be a pressure.

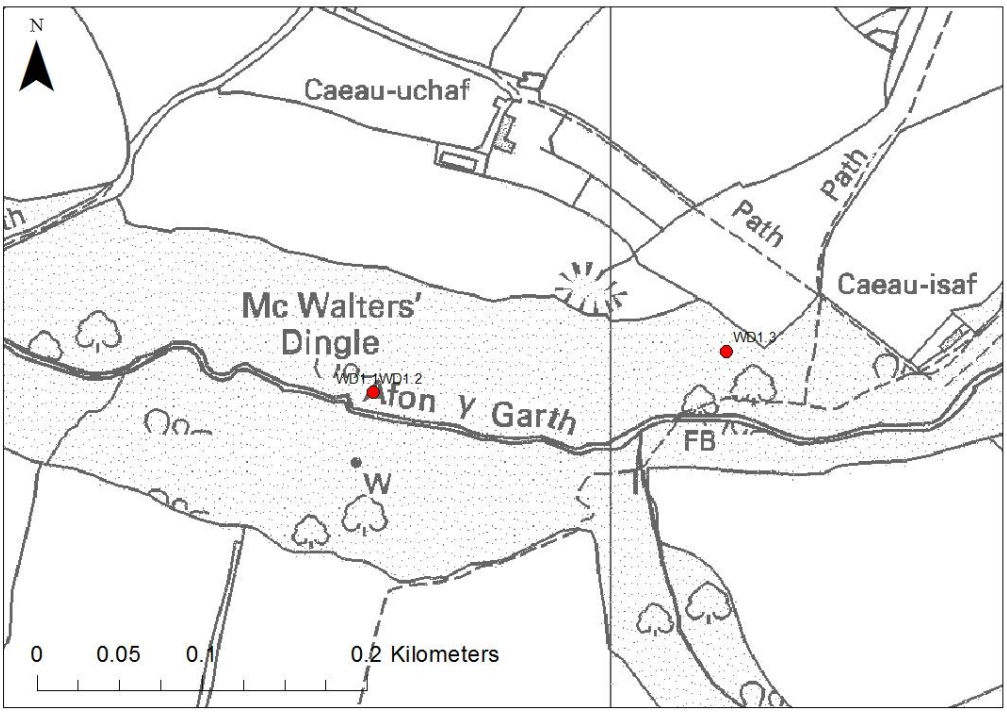



**Figure 108Mc Walters' Dingle Ordnance Survey map and GPS location. ©Ordnance Survey.**


**Figure 109 Mc Walters' Dingle aerial photograph**

© UKP/Getmapping Licence No. UKP2006/01

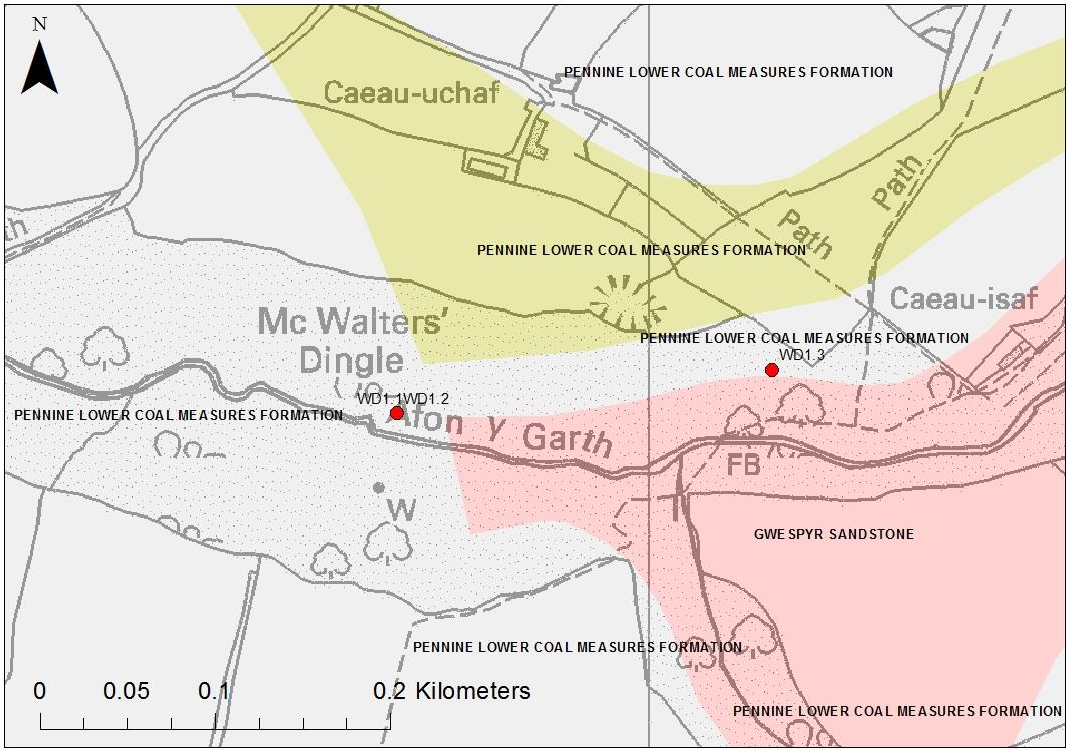



**Figure 110 Mc Walters' Dingle Bedrock geology 1:50,000. ©BGS. ©Ordnance Survey.**

| Survey Site | Survey Ref | Date | Temperature of Water | SEC | Ammoniacal Nitrogen as N | Nitrogen, Total Oxidised as N | Nitrate as NO3 | Nitrate as N | Nitrite as N | Hardness, Total as CaCO3 | Alkalinity to pH 4.5 as CaCO3 | Chloride | Orthophosphate, reactive as P | Orthophospahte as PO4 | Sulphate as SO4 | Phosphate :- {TIP} |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CEL | uS/Cm | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l |
| McWalters Dingle | WD1.1 | 22/01/2014 | 8.8 | 886.0 | <0.2 | 3.54 | 15.60 | 2.9 | <0.0152 | 471 | 331 | 60.2 | 0.021 | <0.05 | 65.1 | <.02 |

| Survey Site | Survey Ref | Date | Sodium | Potassium | Magnesium | Calcium | Redox Potential : In Situ | pH : In Situ | Manganese | Iron | Manganese, Dissolved | Iron, Dissolved | Ionic Balance | Bicarbonate as HCO3 | Oxygen, Dissolved, % Saturation | Oxygen, Dissolved as O2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/l | mg/l | ug/l | mg/l | mV | pH | ug/l | ug/l | ug/l | ug/l | % | mg/l | % | mg/l |
| McWalters Dingle | WD1.1 | 22/01/2014 | 28.5 | 6.94 | 31.90 | 136.0 | 1.2 | 7.83 | 15.6 | <30 | <10 | <30 | 4.59 | 404 | 84.3 | 9.8 |

**Table 101 Mc Walters Dingle water quality**

### 7.15.4 Vegetation (spring) for MC Walters Dingle site 1

Seepages with substantial tufa deposits dominated by *Palustriella commutata* beside a stream in a wooded gorge. A small number of other species include *Pellia endiviifolia, Conocephalum conicum* and *Crataneron filicinum.* There is deep leaf litter (with tussocks of *Palustriella commutata* proliferating in gaps between the leaf litter) and where water seeps through surface

clay (in the absence of significant tufa), *Filipendula ulmaria* and *Deschampsia cespitosa* are rather more unusual associates.

| | |
|---|---|
| *Chrysosplenium oppositifolium* | R |
| *Conocephalum conicum* | O |
| *Cratoneuron filicinum* | O |
| *Deschampsia cespitosa* | O |
| *Filipendula ulmaria* | O |
| *Palustriella commutata* | D |
| *Pellia endiviifolia* | R |
| *Plagiomnium undulatum* | R |
| Leaf litter (from previous season) | F |

**Table 102 Mc Walters' Dingle Site 1 Species list – Palustriella dominated vegetation**

Rocks with substantial formations of tufa at the margins of a stream within a woodland gorge. These rocky/tufa areas generally are not so strongly flushed by adjoining springs, lack *Palustriella* and are dominated by a small number of species including *Asplenium scolopendrium, Conocephalum conicum, Fissidens taxifolius var. taxifolius, Pellia endiviifolia, Hedera helix, Geranium robertianum, Tortella tortuosa* and locally *Fissidens gracilifolius*.

| | |
|---|---|
| *Asplenium scolopendrium* | F |
| *Bryoerythrophyllum recurvirostrum* | O |
| *Conocephalum conicum* | F |
| *Didymodon spadaceus* | R |
| *Fissidens taxifolius var. taxifolius* | F |
| *Fissidens gracilifolius* (spor.) | O |
| *Geranium robertianum* | R |
| *Hedera helix* | O |
| *Pellia endiivifolia* | O |
| *Rhynchostegium riparioides* | R |
| *Thamnobryum alopecurum* | O |
| *Tortella tortuosa* | R |

**Table 103 Mc Walters' Dingle Site 1 Species list – Tufa outcrops (within area of flush/spring but without Palustriella)**

A small number of common bryophytes on tree bases (within area of flush/spring but above the level of seepage water).

| | |
|---|---|
| *Isothecium myosuroides* | A |
| *Kindbergia praelonga* | O |
| *Lophocolea bidentata* | R |

**Table 104 Mc Walters' Dingle Site 1 Species list – Bases of living tree trunks (within area of flush/spring but above level of seepage water)**

A small number of common (mainly calcifuge) ferns and bryophytes on rotting logs and tree stumps (within area of flush/spring but above level the of seepage water).

| | |
|---|---|
| *Dryopteris dilatata* | R |
| *Kindbergia praelonga* | F |
| *Mnium hornum* | A |
| *Plagiomnium undulatum* | R |
| *Plagiothecium succulentum* (spor.) | F |
| *Rhizomnium punctatum* | R |

**Table 105 Mc Walters' Dingle Site 1 Species list – Rotting logs and tree stumps (within area of flush/spring but above level of seepage water)**

### 7.15.5 Vegetation (adjoining spring) for MC Walters dingle site 1

Spring line within mature woodland dominated by *Equisetum arvense* with occasional *Carex pendula.*

| | |
|---|---|
| *Equisetum arvense* | A |
| *Carex pendula* | O |

**Table 106 Mc Walters' Dingle Site 1 Species list – Equisetum arvense spring line**

Ancient Ash–Hazel dominated woodland with a rich ground flora including *Mercurialis perennis, Ficaria verna, Galium odoratum, Geum urbanum, Oxalis acetosa, Viola riviniana, Fissidens taxifolius var. taxifolius, Thamnobryum alopecurum.*

| | |
|---|---|
| *Asplenium scolopendrium* | F |
| *Brachypodium sylvaticum* | O |
| *Cardamine flexuosa* | R |
| *Carex sylvatica* | R |
| *Corylus avellana* | O |
| *Dryopteris felix-mass* | R |
| *Eurhynchium striatum* | F |
| *Ficaria verna* | R |
| *Fissidena taxifolius var. taxifolius* | R |
| *Fraxinus excelsior* | F |
| *Galium odoratum* | R |
| *Geum urbanum* | O |
| *Hedera helix* | F |
| *Ilex aquifolium* | R |
| *Mercurialis perennis* | R |
| *Oxalis acetosa* | R |
| *Oxyrrhynchium hians* | O |
| *Plagiochila asplenioides* | R |
| *Plagiomnium undulatum* | O |
| *Ranunculus repens* | R |
| *Rubus fruticosus agg.* | O |
| *Thamnobryum alopecurum* | O |
| *Viola riviniana* | R |

**Table 107 Species list – Surrounding woodland ground flora (above level of seepage water)**

### 7.15.6 Vegetation (spring) for Mc Walters Dingle site 2

A small area (c. 3x2m) with frequent *Palustriella commutata* where Seepages with tufa adjoin the margin of a stream in a wooded gorge. A small number of other species include *Pellia endiviifolia, Conocephalum conicum, Cratoneuron filicinum* and locally *Chrysosplenium oppositifolium and Deschampsia cespitosa*.

| | |
|---|---|
| *Chrysosplenium oppositifolium* | R |
| *Conocephalum conicum* | O |
| *Cratoneuron filicinum* | O |
| *Deschampsia cespitosa* | R |
| *Palustriella commutata* | F |
| *Pellia endiviifolia* | R |

**Table 108 Mc Walters' Dingle Site 2 Species list – Palustriella dominated vegetation**

Rocks with substantial formations of tufa at the margins of a stream within a woodland gorge. These rocky/tufa areas generally are not so strongly flushed by adjoining springs, lack *Palustriella* and are dominated by a small number of species including *Asplenium scolopendrium, Bryoerythrophyllum recurvirostrum, Conocephalum conicum, Fissidens taxifolius var. taxifolius, Pellia endiviifolia, Hedera helix, Geranium robertianum* and *Thanmnobryum alopecurum*.

| | |
|---|---|
| *Asplenium scolopendrium* | F |
| *Bryoerythrophyllum recurvirostrum* | O |
| *Conocephalum conicum* | F |
| *Fissidens taxifolius var. taxifolius* | F |
| *Fissidens gracilifolius* (spor.) | O |
| *Geranium robertianum* | R |
| *Hedera helix* | O |
| *Pellia endiviifolia* | O |
| *Thamnobryum alopecurum* | R |

**Table 109 Mc Walters' Dingle Site 2 Species list – Tufa outcrops (within area of flush/spring but without Palustriella)**

### 7.15.7 Vegetation (adjoining spring) for MC Walters Dingle site 2

Ancient Ash – Hazel dominated woodland with a rich ground flora including *Mercurialis perennis, Ficaria verna, Galium odoratum, Geum urbanum, Oxalis acetosa, Carex pendula, Cardamine flexuosa, Fissidens taxifolius var. taxifolius* and *Thamnobryum alopecurum.*

| | |
|---|---|
| *Asplenium scolopendrium* | F |
| *Brachypodium sylvaticum* | O |
| *Cardamine flexuosa* | R |
| *Corylus avellana* | O |
| *Dryopteris felix-mass* | R |
| *Eurhynchium striatum* | F |
| *Ficaria verna* | R |
| *Fissidena taxifolius var. taxifolius* | R |
| *Fraxinus excelsior* | F |
| *Galium odoratum* | R |

| | |
|---|---|
| *Geum urbanum* | R |
| *Hedera helix* | F |
| *Mercurialis perennis* | R |
| *Oxalis acetosa* | R |
| *Oxyrrhynchium hians* | O |
| *Plagiomnium undulatum* | O |
| *Rubus fruticosus agg.* | O |
| *Thamnobryum alopecurum* | O |
| *Carex pendula* | R |

**Table 110 Mc Walters' Dingle Site 2 Species list – Surrounding woodland ground flora (above level of seepage water)**

### 7.15.8 Condition assessment

The overall assessment is that MC Walters Dingle (sites 1 & 2) should be classified as being in favourable ecological and hydrogeological condition.

Site 1: Collecting a sample from seepage at the base of the tufa block (photogrpah Stewart Campbel)

Site 1: View towards base of the tufa block (photograph Stewart Campbell)

Site 1: 'Tufa terrace' formed by flushing water over tree roots (centre of site).

Site 1: Flushed soil with tufa and

frequent small hummocks of *Palustriella commutata* with *Deschampsia cespitosa, Filipendula ulmaria*. Note abundant leaf litter.

Site 1: Tufa block (upper margin of rocky stream gorge and away from direct flushing) with *Conocephalum, Bryoerthyrophyllum recurvirostrum*, occasional *Tortella tortuosa*.

Site 2: McWalters Dingle

Site 1: Side spring line (without *Palustriella*) and dominated by *Equisetum arvense*.

Site 1: One of several old rotten tree stumps (above the level of flushing spring water) supporting calcifuge species such as *Dryopteris dilata, Mnium hornum*.

**Figure 111 Mc Walters Dingle Photographs**

# 8 Discussions

## 8.1 PAULUSTRIELLA DOMINATED VEGETATION: GROUPING

The vegetation at 14 sites was sampled (comprising 29 sample sites in total). Of these, 2 sites (Cors Erddériniog sites 7a & 7f) were excluded as, although they were part of a larger site with *Palustriella* dominated springs, they individually were not dominated by *Palustriella* and therefore deemed not to qualify.

Figure 108 lists all species (in decreasing order of frequency) recorded from *Palustriella* dominated vegetation for these 27 samples along with their frequency (DAFOR). A total of 130 species are recorded comprising 77 flowering plants (Angiosperms), 46 bryophytes (Bryophyta), a club moss (Lycophyta), 2 Leptosporangiate (True) ferns, 3 horsetails (Calamophyta), 2 blue-green algae (Cynophyta) and a single charophyte (Chlorophyta).

Based on the characteristics of sampled *Palustriella* dominated vegetation, the 27 sites have been loosely divided into 2 main groups and 4 subgroups (highlighted in red and blue in Figure 108).

A first broad Group 1 (comprising 16 samples) is characterised by being dominated by *Palustriella falcata* and associated mainly with upland spring sites on open hills. The flushed vegetation resulting from these upland springs is particularly species rich and typically has a significant flowering plant component (especially *Juncus* and *Carex* species). Two samples dominated by *Palustriella commutata* and in the absence of *P. falcata* (Hen Allt Common and Tarren yr Esgob) have been included in this first group as they closely share wider species characteristics.

A second broad Group 2 (comprising 11 samples) is characterised by being dominated exclusively by *Palustriella commutata* and associated mainly with lowland sites. Apart from Cors Erddriniog (Anglesey), most of these sites are generally not open (being partially shaded) and often rocky (typically occurring within partly wooded sites, wooded gorges or associated with rock outcrops and cliffs). The *Palustriella commutata* dominated vegetation occurring at these sites is notably less species rich than the *Palustiella falcata* dominated vegetation of open upland sites, is dominated by bryophytes, has few associated flowering plants generally and often includes flowering plants characteristic of woodland habitat (a consequence of shading). The fewer species overall is likely to be partly a consequence of the rocky nature of many of these sites and an associated high frequency of bare rock or tufa.

| | GROUP 1 | | | | | | | | | | | | | | | GROUP 2 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SUBGROUP A | | | | | | | | | | | | | SUBGROUP B | | | SUBGROUP C | | | | | | | SUBGROUP D | | | |
| | Foel Fawr Site 1 | Foel Fawr Site 2 | Foel Fawr (Foel Garnach) | Foel Fawr (Brest Rhiw) | Pont Clydach site 1 | Pont Clydach site 2 | Pont Clydach site 3 | Blaen Onnen | Llyn-yr-Fan Fach site 1 | Llyn-yr-Fan Fach site 2 | Waun Ddu (Craig-yr-Ciliau) | Hen Allt Common | Tarren y Esgob | Nant peris site 1 | Nant peris site 2 | Nant peris site 3 | Cwm Clydach | Ddol Uchaf | MC Walters Dingle site 1 | MC Walters Dingle site 2 | Anglesey Beach site 1 | Anglesey Beach site 2 | Anglesey Beach site 3 | Cors Erddreiniog 7b | Cors Erddreiniog 7c | Cors Erddreiniog 7d | Cors Erddreiniog 7e |
| *Palustriella falcata* | A | D | A | A | A | A | A | A | D | A | A | R | | A | A | A | | | | | | | | | | | |
| *Palustriella commutata* | O | O | O | O | O | O | O | O | F | O | R | F | A | | | | F | F | F | F | D | D | A | A | A | A | A |
| *Aneura pinguis* | | | F | F | O | F | | F | F | O | F | F | F | F | F | O | | | | | O | O | F | O | R | R | R |
| *Jungermannia atrovirens* | A | A | | A | | | | | | R | R | | A | | | | O | | | | R (<1%) | R (<1%) | | | | | |
| *Campylium stellatum* | F | O | O | F | O | O | F | A | F | | F | R | | R | R | R | | | | | | | | | | | O |
| *Juncus acutiflorus* | F | F | F | F | O | O | R | O | O | O | F | F | F | R | O | O | | | | | | | | O | O | O | F |
| *Carex flacca* | F | F | O | F | O | O | O | O | O | O | O | O | F | O | O | O | | | | | | | | O | O | O | O |
| *Carex demissa* | O | F | O | O | R | R | O | O | O | R | O | R | | R | O | R | | | | | | | | R | R | | R |
| *filamentous algae (Chlorophyta)* | R | O | F | A | O | R | R | R | R | R | O | F | O | | | | O | | O | | O | F | O | O | R | R | R |
| *Hymenostylium recurvirostrum* | F | F | O | F | | | | | | | | | F | | | | | | | | | | | | | | |
| *Crataneuron filicinum* | O | F | O | O | R | O | O | O | R (<1%) | F | O | R | | O | O | O | O | A | O | | O | O | O | F | | R | O |
| *Anagallis tenella* | | R | R | R | F | O | O | R | R | F | O | | | | | | | | | | | | | O | O | O | O |
| *Bryum pseudotriquetrum* | O | O | R | R | R | R | O | O | O | | R | R | R | R | R | R | | | | | | | | | | | |
| *Scorpidium cosonii* | O | O | O | F | O | O | O | A | F | O | F | R | | | | | | | | | | | | | | | O |
| *Philonotis calcarea* | F | F | R | O | | O | F | R | F | O | O | | R | | | | | | | | | | | | | | R |
| *Scorpidium revolvens* | O | O | F | O | O | R | O | O | O | R | F | | | O | O | O | | | | | | | | | | | |
| *Philonotis fontana* | R | O | O | O | O | R | O | O | R | F | R | | | R | O | R | | | | | | | | | | | |
| *Leicolea badensis* | F | O | O | O | | | | R | | | | O | | | | | | | | | | | | | | | |
| *Bellis perennis* | O | R | R | O | | | R | R | | R | O | R | | | | | | | | | | | | R | | | R |
| *Eucladium verticillatum* | O | R | | | | | | | | | | F | | | | | A | | | | A | O | O | | | | |
| *Fissidens adianthoides* | O | O | O | O | | R | R | R | O | R | O | R | O | O | | R | | | | | O | R | | O | R | O | R |
| *Calliergonella cuspidata* | R | O | R | R | R | R | R | R | R | O | R | R | R | R | | R | | | | | | | | R | R | | R |
| *Pressia quadrata* | R | O | O | F | | | R | O | R | | R | | R | | | | | | | | | | | | | | |
| *Sagina cf nodosa* | O | | | | R (<1%) | | | R (<1%) | | | R | | | | | | | | | | | | | | | | |
| *Cardamine pratensis* | R | O | R | O | R | O | R | R | | O | O | R | R | R | F | O | | | | | | | | | | | |
| *Cirsium palustre* | R | R | R | R | R | R | R | | R | O | R | R | R | R (<1%) | | | | | | R | | | | R | R | R | R |
| *Juncus effusus* | R (<1%) | O | O | R (<1%) | O | | R | R | | F | O | O | | | | | | | | | R (<1%) | | | | | R | |
| *Festuca ovina* | R (<1%) | R | F | R | | | R (<1%) | | | | F | F | R (<1%) | R | O | R | | | | | | | | | | | |
| *Schoenus nigricans* | | | | | | | | | | | | | | | | | | | | | | | | | F | F | F |
| *Rivularia haematites* | | R | | | | | | R | | | | | F | | | | | | | | | | | | | | |
| *Dicranella varia* | | O | O | | | | | | | | | | | | | | | | | R | | | | | | | |
| *Asplenium scolopendrium* | | | | | | | | | | | | | | | | | O | | | | F | F | A | | | | |
| *Conocephalum conicum* | | | | | | | | | | | | | | | | | R | | O | O | F | F | A | | | | |
| *Conocephalum salebrosum* | | | | | | | | | | | | | | | | | O | | | O | | | | O | | | |
| *Jungermannia exsertifolia ssp. cordifolia* | | | | | | O | | R | | | | | R | | | | | | | | | | | | | | |
| *Pellia endiviifolia* | | R | | R | | | | R (<1%) | R (<1%) | R | | | R | | | | F | O | R | | O | O | O | O | O | R | O |
| *Festuca rubra* | | | | | R (<1%) | | | | | R | | | R | | R | | | | | | F | F | O | R | R (<1%) | R (<1%) | R (<1%) |
| *Apium nodiflorum* | | | | | | | | R | | | O | | | | | | | | | | | R | | | | | |
| *Nostoc sp.* | R | O | O | O | R | | | | | | | | O | | | | | | | | O | | | | | | |
| *Deschampsia cespitosa* | | | | | | | | | | | | | O | | | | | | O | | | | | | | | |
| *Prunella vulgaris* | R | R | R | R | | | R | | R | O | R | R | R | | | R (<1%) | | | | | | | | | | | |
| *Ficaria verna* | | O | | | | | | | | | | | | | | | | | | | | R | | | | | |
| *Galium palustre ssp. palustre* | | O | | | R | | | R | R | R | | | | | | | | | | | | O | | | | | |
| *Gymnostomum aeruginosum* | | O | | | | | | | | | | | R | | | | | | | | | | | | | | |
| *Eriophorum angustifolium* | | | O | | | | | | | | | R | | R | O | | | | | | | | | | | | |
| *Ranunculus flammula* | R | R | | | O | R | R | R | | | O | | | | | | | | | | | | | | | | |
| *Rhytidiadelphus squarrosus* | | | R (<1%) | R (<1%) | O | | | | R (<1%) | | | | | R | R | R | | | | | | | | | | | |
| *Epilobium brunescens* | | | | | | | | | | | | | | O | F | | | | | | | | | | | | |
| *Leicolea bantriensis* | | R | R | | | | | | O | | | | | | | | | | | | | | | | | | |
| *Chrysosplenium oppositifolium* | | | | | | | R | | | O | | | | | | R | O | R | R | | | R | | | | | |
| *Leicolea turbinata* | | | | | | | | | | | | | | | | | | | | | F | F | O | | | | |
| *Chara vulgaris* | | | | | | | | | | | | O | | | | | | | | | | | | R | | | |
| *Potentilla steralis* | | | | | | | | | | | | O | | | | | | | | | | | | | | | |
| *Ctenidium molluscum* | R (<1%) | R (<1%) | R | R | | R | R | R | R (<1%) | R (<1%) | O | R | R | | | R | | | | O | | | | R | | R | |
| *Montia fontana* | | | | | | | | | | | | | | O | O | O | | | | | | | | | | | |
| *Riccardia multifida* | R (<1%) | R | | | R | | | R (<1%) | R | | | R | R | O | | R | | | | | R (<1%) | | | | | | |
| *Didymodon tophaceus* | | | | | | | | | | | | | | | | | | | | | R | F | R | | | | |
| *Brachythecium rivulare* | | | | | | | | | | | | | | O | O | R | | | | | | | | R (<1%) | | | |
| *Bryoerythrophyllum recurvirostrum* | | | | | | | | | | | | | | | | | O | | | | | | | | | | |
| *Straminergon stramineum* | | | | | | | | | | | | | | O | O | | | | | | | | | | | | |
| *Nasturtium officinale s.l.* | | | | | | R | R | R | | R | | | | | | | | | | | | O | | | | | |
| *Chiloscyhus sp. (non fertile)* | | | | | | | | | | | O | | | | | | | | | | | | | | | | |
| *Mentha aquatica* | | | | | | R | | R | | O | | | | | | | | | | | | | | | | | |
| *Rumex acetosa* | | | | | R | | | | | O | | | | | | | | | | | | | | | | | |
| *Scorzoneroides autumnalis* | R | R | R | | | | R | R | | O | R | | | | | | | | | | | | | | | | |
| *Hedera helix* | | | | | | | | | | | | | | | | | O | | | | O | R | O | | | | |
| *Potamogeton polygonifolius* | | | | | | | R | R | | | O | | | | | | | | | | | | | | | | |
| *Veronica beccabunga* | | | | R | | R | | R | | | O | | | | | | | | | | | | | | | | |
| *Carex nigra* | R (<1%) | R (<1%) | R | | | | | | | | | | | | | | | | | | | | | | | | |
| *Scorpidium scorpioides* | R | R | | | | | R | | | | | | | R | | | | | | | | | | | | | R |
| *Plagiomnium undulatum* | | | | | | R | | | | | | | | | | R | | R | R | | | | | | | | |
| *Myosotis sp.* | | | | | R | | R | R | | | | | | | | | | | | | | | | | | | |
| *Plantago lanceolata* | R | R | R | R | R | | | | R (<1%) | R | R | | R | | | | | | | | | | | R (<1%) | R (<1%) | R (<1%) | R (<1%) |
| *Saxifraga sp.* | | | | | | | | | | | | | | R | O | R | | | | | | | | | | | |
| *Selaginella selaginoides* | | | | | | | | | | | | | | | R | | | | | | | | | | | | |
| *Ranunculus acris* | R (<1%) | R (<1%) | | R | | | | R | | R | | R | | | | | | | | | | | | | | | |
| *Agrostis stolonifera* | R (<1%) | R (<1%) | R (<1%) | R (<1%) | | R (<1%) | R (<1%) | R (<1%) | R (<1%) | R (<1%) | R (<1%) | R (<1%) | R (<1%) | R (<1%) | R (<1%) | R (<1%) | R (<1%) | R (<1%) | R (<1%) | | O | O | | R (<1%) | | R (<1%) | |
| *Taraxacum sp.* | R (<1%) | R | | R | R | | R | R | | R | R | | | | | | | | | | | | | | | | |
| *Triglochin palustre* | | | | | | | | | | | | | | | | | | | | | | | | | | | R |
| *Cynosurus cristatus* | | | | R (<1%) | R (<1%) | | | | R (<1%) | | R (<1%) | | | | | | | | | | | | | | | | |
| *Holcus lanatus* | | | | R (<1%) | R (<1%) | | | | R (<1%) | | | | | | | | | | | | | | | R (<1%) | | | |
| *Trifolium repens* | | R (<1%) | R (<1%) | R (<1%) | R (<1%) | R (<1%) | | | R (<1%) | R (<1%) | | | R (<1%) | | | | | | | | | | | R (<1%) | | | |
| *Rhizomnium puntatum* | | | | | | | | | | | | | | R | | R | | | | | | | | | | | |
| *Bryum dichotomum* | R | R | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pinguicula vulgaris* | R | R | | | | | | | | | | R (<1%) | | | | | | | | | | | | | | | |
| *Climacium dendroides* | R (<1%) | R (<1%) | | R (<1%) | | | | | | | | | | | | | | | | | | | | | | | |
| *Plagiomnium ellipticum (non fertile)* | | | | | | | | | | | R | | | | | | | | | | | | | | | | |
| *Succisa pratensis* | | | | | | | R (<1%) | | | | R | R | | | | | | | | | | | | | R | | |
| *Hydrocotyle vulgaris* | | | | | | R | | R | | R | R | | | | | | | | | | | | | | | | |
| *Carex lepidocarpa* | | | | | | | | | | | | R | | | | | | | | | | | | | | | |
| *Campylium protensum* | R | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Didymodon fallax* | R (<1%) | | | | | | R | | | | | | | | | | | | | | | | | | | | |
| *Thuidium tamariscinum* | | | | | R | R | | | R (<1%) | | | | | | | | | | | | | | | | | | |
| *Moerckia flotoviana* | | R | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Equisetum cf variegatum* | | R (<1%) | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Tussilago farfara* | | R (<1%) | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cerastium cf glomeratum* | | | | R (<1%) | | | | | | | | | | | | | | | | | | | | | | | |
| *Ranunculus repens* | | | | R (<1%) | | | | | | | | | R (<1%) | | | | | | | | | | | | | | |
| *Stellaria media* | | | | | R (<1%) | | | | | R (<1%) | | | | | | | | | | | | | | | | | |
| *Briza media* | | | | | | | | | R (<1%) | R | | | | | | | | | | | | | | | | | |
| *Breutelia chrysoscoma* | | | | | | | | | R (<1%) | | | | | | | | | | | | | | | | | | |
| *Cerastium fontanum* | | | | | | | | | R (<1%) | | | | | | | | | | | | | | | | | | |
| *Eriophorum cf latifolium* | | | | | | | R (<1%) | | | | | | | | | | | | | | | | | | | | |
| *Geranium robertianum* | | | | | | | | | | | | R | | | | | R | | | | R | | R | | | | |
| *Glyceria fluitans* | | | | | | | | R | | | R | | | | | | | | | | | | | | | | |
| *Fissidens taxifolius var. taxifolius* | | | | | | | | | | | | | | | | | | | | | R (<1%) | O | R (<1%) | | | | |
| *Juncus inflexus* | | | | | | | | R (<1%) | | | | R | | | | | | | | | | | | R (<1%) | R (<1%) | | |
| *Centaurea nigra* | | | | | | | | | | | | R | | | | | | | | | | | | R (<1%) | | | |
| *Epilobium sp.* | | | | | | | | | | R | | R | | | | | | | | | | | | | R | | |
| *Senecio cf aquaticus* | | | | | | | | | | | | | | | | | | | | | | | | | | R | |
| *Equisetum palustre* | | | | | | | R | | | R | | | | | | | | | | | | | | | | | |
| *Hypericum elodes* | | | | | | | R | | | | | | | | | | | | | | | | | | | | |
| *Hypericum sp.* | | | | | | | | | | | | R | | | | | | | | | | | | | | | |
| *Hypericum androsaemum* | | | | | | | | | | | | | | | | | | | | | R (<1%) | | | | | | |
| *Juncus bulbosus* | | | | | | | R (<1%) | | | | | | | | | | | | | | | | | | | | |
| *Lotus pedunculatus* | | | | | | | R (<1%) | | | | | | | | | | | | | | | | | | | | |
| *Molinia caerulea* | | | | | | | | | R (<1%) | | | R | | | | | | | | | | | | | | | |
| *Wahlendbergia hederacea* | | | | | | | | R (<1%) | R (<1%) | | | | | | | | | | | | | | | | | | |
| *Rubus fruiticosus agg.* | | | | | | | | | | | | R | | | | | R | | | | R (<1%) | | | | | | |
| *Samolus valerandi* | | | | | | | | | | | | | | | | | | | | | | R | | | | | |
| *Primula sp.* | | | | | | | | | | | | | R | | | | | | | | | | | | | | |
| *Linum catharticum* | | | | | | | | | | | | R | | | | | | | | | | | | | | | |
| *Odontites vernus* | | | | | | | | | | | | R (<1%) | | | | | | | | | | | | | | | |
| *Poa annua* | | | | | | | | | | | | R (<1%) | | | | | | | | | | | | | | | |
| *Taxus baccata* | | | | | | | | | | | | | | | | | R | | | | | | | | | | |
| *Asplenium trichomanes ssp. trichomanes* | | | | | | | | | | | | | | | | | R (<1%) | | | | | | | | | | |
| *Carex sylvatica* | | | | | | | | | | | | | | | | | R (<1%) | | | | | | | | | | |
| *Ilex aquifolium (seedling)* | | | | | | | | | | | | | | | | | R (<1%) | | | | | | | | | | |
| **Bare rock** | | | | | | | | | | | | | | | | | F | | | | | | | | | | |
| **Leaf litter (from previous season)** | | | | | | | | | | | | | | | | | | | F | | | | | | | | |

**Figure 112 Grouping of *Palustriella* dominated vegetation - 27 samples as two main groups 1 & 2 (highlighted red) and 4 subgroups A-D (highlighted blue)**

**Subgroup A** - 13 samples in 9 sites (Foel Fawr, Moel Garnach, Brest Rhiw, Pont Clydach, Blaen Onnen, Llyn-yr-Fan Fach, Waun Ddu (Craig-yr-Cilau), Hen Allt Common and Tarren-yr Esgob).

Flushed vegetation associated with upland spring sites on open hills almost exclusively dominated by *Palustriella falcata. Palustriella commutata* may also be present alongside *Palustriella falcata* at these sites but typically occurs as smaller patches, often associated with spring heads, especially where these are rocky. These flushes are species-rich with a significant flowering plant component (including *Juncus acutiflorus, Juncus effuses, Carex flacca, Carex demisa, Anagallis tenella, Cardamine pratensis, Ranuncus flammula, Ficaria verna, Galium palustre ssp. palustre*) as well as a broad suite of associated bryophytes (including *Fissidens adianthoides, Ctenidium molluscum, Scorpidium cossonnii, Leicolea bantriensis, Campylium stellatum, Jungermannia exsertifolia ssp. cordifolia, Bryum pseutotriquetrum).*

Immediate spring heads often have a slightly modified flora typically with a greater proliferation of *Palustriella commutata* and lawns of dominant *Cratoneuron filicinum, Philonotis fontana.* Elsewhere smaller hollows or runnels are characterised by a greater domination of *Campylium stellatum*, dominant stands of *Scorpidium cossonii* and occasonal stands of *Scorpidium scorpioides*. Deeper central runnels (especially those with a perminant flow of water) regularly support emergent flowering plants (including *Apium nodiflorum, Nasturtium officinale s..l, Potamogeton polygonifolius, Veronicca beccabunga, Mentha aquatica, Glyceria fluitans* and occasionally *Hypericum elodes*.)

The cushion forming moss *Hymenostylium recurvirostrum,* the liverworts *Jungermannia atrovirens, Presisia quadrata* and alga *Rivularia haematites* are often associated with tufa occurring at these sites.

A number of interesting plants were recorded from these sample sites including *Pinguicula vulgaris, Moerckia flotoviana, Wahlenbergia hederacea, Philonotis calcarea, Equisetum cf variegatum, Eriophorum cf latifolium* and *Carex lepidocarpa.*

**Subgroup B**- 3 samples from a single site (Nant Peris)

Flushed vegetation associated with upland spring sites on open hills at altitude (681-689maOD, Snowdon range) exclusively dominated by *Palustriella falcata*. These 3 sample sites are very similar to each other and share some species similarities with subgroup A but hava a number of additional northern (and more upland) vascular plant species includimg *Montia fontana, Saxifraga sp.* and the invasive alien *Epilobium brunescens*. The 3 sample sites are unique within this survey by comprising dome shaped floating mats of *Palustriella falcata* dominated vegetation above a spring.

A number of typical *Palustriella* associated bryophytes occur (i.e. those typically associated with base-rich water) including *Crataneron filicinum, Campylium stellatum, Scorpidium revolvens, Fissidens adianthoides, Bryum pseudotriquetrum, Scorpidium, scorpioides, Philonotis fontana* despite the water quality actually having a very low base status. In contrast, a number of less markadely calcicole species (*Rhizomnium punctatum, Brachythecium rivulare, Plagiomnioum undulatum*) were also recorded. These species are not unusual within upland flushes (and indeed were recorded in small quantity from a number of other sites during this survey). However, the presence of *Straminergon stramineum* (a marked calcifuge) in good quantity mixed with *Palustriella falcata* and *Brachythecium rivulare* at 2 of the sites was exceptional.

The floating vegetation mat present at these sites was estimated to be at least 25cm thick and may of developed quickly as stems of both *Straminergon stramineum* and *Bryum* pseudotriquetrum of this length were pulled from the surface that still had some active leaves at their base.

**Subgroup C**- 7 samples from 4 sites (Cwm Clydach, Ddol, MC Walters Dingle, Anglesey Beach)

*Palustriella commutata* dominated vegetation on rocky and shaded sites (including rock outcrops in woodland, wooded river gorges and coastal cliffs) that is typically not species-rich. Other common associated include *Pellia endiviifolia, Cratoneuron filicinum, Conocephalum* species and *Chrysosplenium oppositifolium*. The shaded and rocky nature of these sites favour woodland species that occur in small quantity including ferns (*Asplenium scolopendrium, Asplenium trichomanes ssp. trichomanes*) as well as *Hedera helix, Rubus fruticosus, Geranium robertianum* and at one site each *Carex sylvatica, Hypericum androsaemum*.

Many of these sites have tufa formations. However, they have more of a lowland plant assembledge with tufa supporting extensive fruiting cushions of *Eucaldium verticillatum, Didymodon tophaceus, Fissidens taxifolius var. taxifoluis, Leicolea turbinata*, occasional *Bryoerythophyllum recurvirostrum* (contrasting with the *Hymenostylium, Gymnostomum aeruginosum, Rivularia haemaetes* communities on upland tufa – subgroup A). In addition, the only *Jungermannia* species recorded from these sites was *J .atroviens* and typically (again in contrast to upland springs – subgroup A) usually occcuerd only in small quantity.

**Subgroup D**- 4 samples from a single site (Cors Erdderiniog)

The 4 sample sites (B-D) are associated with springs running into a calcareous fen from the east down a gentle slope and sometimes springs running out from woodland at a single site (Cors Erdderiniog).

The spring heads have dominant patches of *Palustriella commutata* with *Conocephalum salebrosum* (especially where rocky or wooded) and the *Palustriella* vegetation then continues along the margins of the spring runnels before quickly being replaced by *Camplylium stellatum, Bryum psedotriquetrum* and then a rapid transition into tall fen vegetation (dominated by *Juncus* species) or open water communities. The *Palustriella commutata* dominated vegetation is associated with *Campylium stellatum, Fissidens adianthoides, Cratoneuron filicinum, Ctenidium molluscum, Scorpidium cossonii* and locally *Scorpidium scorpioides. Palustiella or Campylium stellatum* dominated vegetation ofen grows at ground level between tussocks of *Schoenus nigricans* within the zone of flushing by calcareous spring water. In contrast, the upper tussocks of Molinia (and occasionally *Schoenus*) recive a greater proportion of rain water than calcareous spring water, are without *Palustriella* and support a small number of calcifuge species (including *Erica tetralix, Succisa, Potentilla erecta*).

The altitude ranges covered by each vegetation group and subgroup are shown below in Table 111.

| | Minimum maOD | Maximum maOD | Average moAD |
|---|---|---|---|
| Group 1 | 275 | 690 | 426 |
| Subgroup A | 275 | 495 | 366 |
| Subgrouup B | 682 | 690 | 685 |
| Group 2 | 5 | 402 | 85 |
| Subgroup C | 5 | 402 | 97 |
| Subgroup D | 65 | 66 | 65 |

**Table 111 Altitude ranges for vegetation groups/subgroups**

## 8.2 CONSERVATION VALUE OF PALUSTRIELLA DOMINATED SPRINGS

*Palustriella* dominated spring vegetation is an interesting habitat because it requires specific geological and hydrogeological settings and is therefore more restricted than many other vegetation types. In addition, this type of vegetation occurs in small, intricate and often difficult to map stands.

When compared to other vegetation types (notably lowland or calcareous types of grassland) *Palustriella* dominated springs cannot be considered species-rich. During this survey group 1 sites had a total number of species (22-52), group 2 has a total number of species (6-24) and no species recorded were listed in a category above Least Concern in The vascular plant red data list for Great Britain (Cheffings & Farrell 2005). However, a number of bryophytes associated with these flushes (including *Philonotis fontana, Philonotis calcarea, Scorpidium cossonii, Scorpidium revolvens, Scorpidium scorpioides*), while still of relatively wide occurrence within Wales, have been lost from many lowland sites (principally heathland sites) in England since 1950 as a result of urban development and land drainage.

## 8.3 COMPARISON OF PALUSTRIELLA DOMINATED SAMPLES WITH THE NATIONAL VEGETATION CLASSIFICATION (NVC)

The European Commission has defined the Annex I habitat *H7220 Petrifying springs with tufa formation (Cratoneurion)* as *"*springs with active formation of tufa" and many sources interpret this habitat to be analogous with M37 *Cratoneuron commutatum-Festuca rubra* and M38 *Cratoneuron commutatum-Carex nigra* spring communities in the UK (as defined by Rodwell, 1998).

The distinctions between M37 and M38 are subtle and difficult to separate for the following reasons:

- M37 and M38 are bryophyte dominated communities and field data for which the NVC is based did not comprehensively sample bryophytes
- Field data for which the NVC is based does not separate the two species *Paulustriella commutata* and *Palustriella falcata*
- Stands of M37 and M38 are typically small in extent and both communities are under sampled within the UK
- Characterisation of M37 and M38 has a strong basis on sward structure (including openness and grazing pressure) which is subjective and more difficult to measure compared with species composition of the sward.

However, based on a combination of field observation, literature search, NVC descriptions and floristic tables for M37 and M38 (Rodwell) and a summary of M37 and M38 (JNCC, 2001), a number of generalisations have been made to separate the two communities. These are summarised in Table 112.

| | | | | |
|---|---|---|---|---|
| M37 | Number of small *Carex* species<br><br>Number of flowering plant species<br><br>"Openness" of sward<br><br>Grazing pressure | **Increasing**<br>→ | Number of small *Carex* species<br><br>Number of flowering plant species<br><br>"Openness" of sward<br><br>Grazing pressure | M38 |
| | *Festuca rubra* | | *Festuca ovina* | |
| | *Chrysosplenium oppositifolium*<br>*Deschampsia cespitosa* | ↔ | *Anthoxanthum odoratum*<br>*Cardamine pratensis*<br>*Cerastium fontanum*<br>*Cirsium palustre*<br>*Galium palustre*<br>*Prunella vulgaris*<br>*Ranunculus acris*<br>*Ranunculus flammula*<br>*Sagina nodosa*<br>Scorzoneroides *autumnalis*<br>*Selaginella selaginoides*<br>*Trifolium repens* | |
| | Lowland | | Upland | |

**Table 112 Generalised differences between M37 and M38**

The generalisations for M37 and M38 (Table 112) along with TableFit (statistical computer software developed by Dr mark Hill CEH) have been applied to the full data set for *Palustriella* dominated vegetation (Table 108) and there is strong correlation between Group 1 and NVC community M38 and between Groups 2 and NVC community M37 (as displayed in Table 113). However, it must be stressed that this is a generalised assessment as the collected species data is based on walk over site surveys (DAFOR) and did not include quadrat data.

Two other NVC communities were noted as occurring in small extent within *Palustriella* dominated vegetation but were not mapped separately. M10 *Carex dioica - Pinguicula vulgaris* mire was noted in small quantity in at least 2 sites: with *Pinguicula vulgaris* at the margins of *Palustriella* dominated vegetation at Foel Fawr site 2; with *Pinguicula vulgaris* and *Carex lepidocarpa* at the margins of *Palustriella* dominated vegetation at Hen Allt Common. Also, M29 *Hypericum elodes – Potamogeton polygonifolius* soakway was noted associated with open water of central runnels within *Palustriella* dominated vegetation at several sites: with *Potamogeton polygonifolius* at Blaenonnen and Wun Ddu (Craig y-Cilau): with *Potamogeton polygonifolius* and *Hypericum elodes* at Pont Clydach site 3.

| | Foel Fawr Site 1 | Foel Fawr Site 2 | Foel Fawr (Foel Garnach) | Foel Fawr (Brest Rhiw) | Pont Clydach site 1 | Pont Clydach site 2 | Pont Clydach site 3 | Blaen Onnen | Llyn-yr-Fan Fach site 1 | Llyn-yr-Fan Fach site 2 | Waun Ddu (Craig-yr-Ciau) | Hen Allt Common | Tarren y Esgob | Nant peris site 1 | Nant peris site 2 | Nant peris site 3 | Cwm Clydach | Ddol Uchaf | MC Walters Dingle site 1 | MC Walters Dingle site 2 | Fedw Fawr Beach 1 | Fedw Fawr Beach 2 | Fedw Fawr Beach 3 | Cors Erdderiniog 7b | Cors Erdderiniog 7c | Cors Erdderiniog 7d | Cors Erdderiniog 7e |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *% cover Palustriella falcata* | 80 | 100 | 80 | 80 | 80 | 80 | 80 | 80 | 100 | 80 | 80 | 20 | 0 | 80 | 80 | 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *% cover Palustriella commutata* | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 20 | 60 | 80 | 0 | 0 | 0 | 60 | 60 | 60 | 60 | 100 | 100 | 80 | 80 | 80 | 80 | 80 |
| Number of small *Carex* species | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 1 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 2 |
| Total number of species | 43 | 52 | 37 | 42 | 34 | 30 | 40 | 44 | 37 | 40 | 40 | 41 | 30 | 26 | 22 | 25 | 18 | 5 | 8 | 6 | 22 | 22 | 14 | 24 | 17 | 17 | 21 |
| Number of flowering plants | 18 | 23 | 16 | 20 | 19 | 13 | 24 | 24 | 16 | 26 | 23 | 27 | 13 | 11 | 12 | 10 | 9 | 1 | 2 | 1 | 8 | 10 | 4 | 14 | 11 | 10 | 11 |
| (including club mosses, horsetails & ferns) | (%) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Festuca rubra* | | | | | √ | | | | | √ | | | √ | | √ | | | | | | √ | √ | √ | √ | √ | √ | √ |
| *Festuca ovina* | √ | √ | √ | √ | | | √ | | | | √ | √ | √ | √ | √ | √ | | | | | | | | | | | |
| Number of: *Chrysosplenium oppositifolium* *Deschampsia caespitosa*, | | | | | | | 1 | | | 1 | | | 1 | | | 1 | 1 | 1 | 2 | | | 1 | | | | | |
| Number of: *Anthoxanthum odoratum* *Cardamine pratensis* *Cerastium fontanum* *Cirsium palustre* *Galium palustre* *Prunella vulgaris* *Ranunculus acris* *Ranunculus flammula* *Sagina nodosa* Scorzoneroides *autumnalis* *Selaginella selaginoides* *Trifolium repens* | 7 | 8 | 5 | 5 | 6 | 4 | 6 | 6 | 5 | 8 | 7 | 5 | 4 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 0 | 2 | 0 | 3 | 1 | 1 | 2 |
| Open sward (Y/N) | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | * | Y | Y | Y | Y | N | N | N | N | N | N | N | Y | Y | Y | Y |
| Significant grazing pressure (Y/N) | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | N | N | N | N | N | N | N | * | * | * | * |
| Altitude | 454 | 436 | 467 | 379 | 327 | 293 | 275 | 422 | 331 | 283 | 294 | 302 | 495 | 690 | 685 | 682 | 402 | 115 | 62 | 62 | 21 | 5 | 10 | 65 | 66 | 65 | 65 |
| NVC match | M38 | M38 | M38 | M38 | M38 | M38 | M38 | M38 | M38 | M38 | M38 | M38 | M38 | M38 | M38 | M38 | M37 | M37 | M37 | M37 | M37 | M37 | M37 | M37 | M37 | M37 | M37 |

**Table 113 Generalised differences between M37 and M38**

## 8.4 SPECIES ALTITIUDE RANGES

Elevation data in meters above Ordnance Datum (maOD) was collected at each site and a simple comparison with the species data allows Box plots to be created. Two Box plots are shown, the first (Figure 113) shows that *Palustriella falcata* is absent from all lowland sites, this corresponds with the definition of Group 1. *Palustriella commutata* inhabits a wider range of altitudes in this study, occurring in both lowland and upland sites.

These different altitude preferences for *Palustriella falcata* and *Palustriella commutata* appear to be an important ecological distinction between vegetation groups 1 and 2 and corresponding NVC communities M38 and M37 although NVC floristic tables for NVC communities do not separate the two species. In addition, much existing bryophyte literature highlights the different ecology of these two species in terms of altitude as well as other parameters such as 'openness' of habitat and degree of base enrichment of habitat. The following literature is cited as examples of this:

*P. falcata* (*Hypnum falcatum*) occurs on 'bogs, principally at higher elevations than *H. commutatum*', Dixon 1896

*P. falcata* 'would appear to be less exacting in requirements' (than *P. commutata*) 'occurring more generally in moorland flushes and mountain springs', Watson 1968

*P. falcata* 'is more common' (than *P. commutata*) 'in open habitats and shuns the gorges and woodlands where *P. commutata* sometimes grows', Bosanquet et. al. 2005

*P. falcata* occurs in 'weakly acidic habitats' compared with *P. commutata* which occurs 'in basic habitats', Pedrotti 2006

*P. falcata* 'may occur in slightly less calcareous habitats than *P. commutata'*, Atherton et. al. 2010

Figure 114 displays two Box plots, one for species that occur within Group 1 and one for Group 2. The upper and lower recorded elevations for all 130 bryophyte and flowing plant species recorded during this survey are plotted on the graphs, although the names of the 130 individual species have been omitted from the x axis for clarity. Where a species occurs in both Group 1 and Group 2 its total range is displayed, hence the plots show total ranges of the individual species recorded during this survey. The plots clearly show that the higher elevation Group 1 (*Palustriella falcata)* is more species rich and the lower elevation Group 2 (*Palustriella commutate)* is species poor.

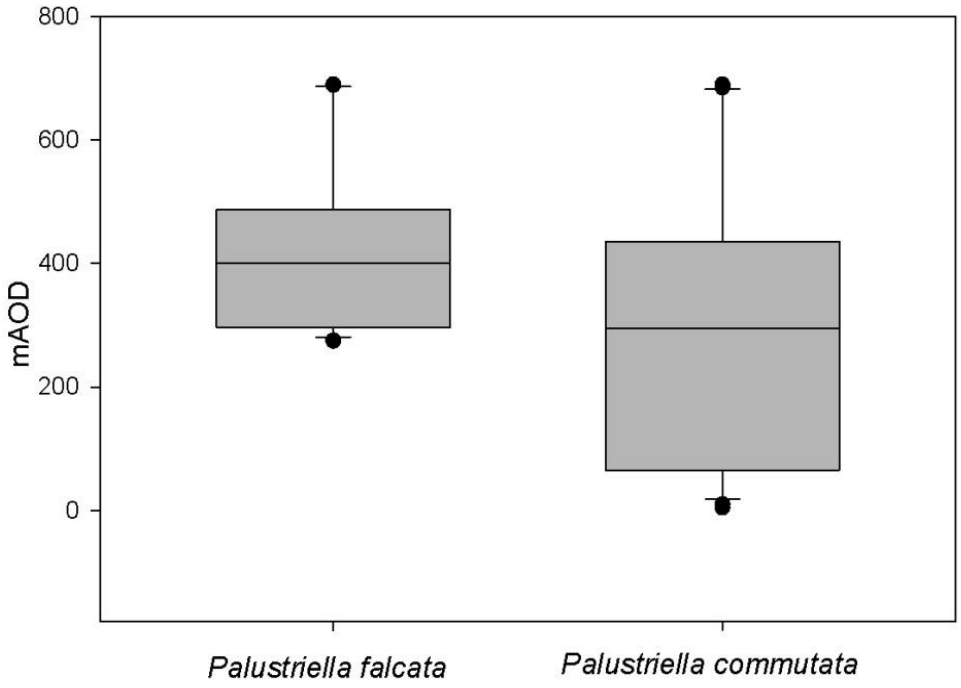



**Figure 113 Box plot showing elevation of *Palustriella falcata* and *Palustriella commutata* recorded during this study**

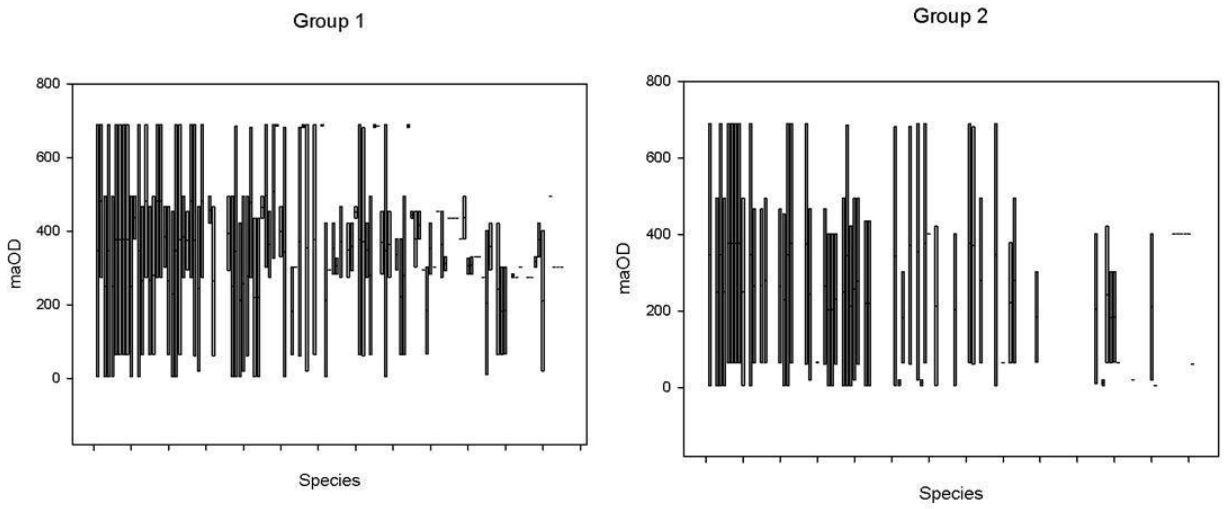



**Figure 114 Box plot showing elevation range of all species for Group 1 and Group 2**

## 8.5 COMPARISON OF WATER QUALITY

In total 32 complete samples were collected during the project with 3 additional sites (BR1.1, CE1.1 and CE2.2) sampled for just for nutrients and not major ions. Tables for each site have been included within the main body of the text and the aim of this section is to bring together the entire dataset to look for similariities and differences within groups of data based on ecological observations and groupings. Before the data is plotted on any graphs, less than (<) values are removed and a figure that is 50% of the value of the limit of detection value is used. For instance if a site is reported to have <0.2mg/l of ammoniacal nitrogen then the figure used in the statistics is 0.1mg/l. We will use two main types of graph to display the data; **Piper Plots** are trilinear diagrams and allow the user to plot cations on the bottom left handside triangle and anions on the bottom right hand side triangle, information from both the triangles are then projected into the upper diamond and enables comparison of waters. **Box Plots** are also used to show the ranges ($5^{th}$ and $95^{th}$ percentiles, median and outliers) of various data groups for instance the range of calcium values for all sites, or the range of nitrate values for all sites. All graphs have been prepared on SigmaPlot.

The first Piper plot (Figure 115) shows all the water quality samples collected from sites that represent H7220. The majority of samples cluster together and can be described as being of calcium-bicarbonate facies ($CaHCO_3$). Two samples circled in the plot, BR1.1 and NP1.1 fall slightly outside of this representing a greater contribution of chloride and less bicarbonate at Nant Peris possibly an indication of recent rainfall recharge and a greater concentration of sulphate and chloride at Brest Rhiw.

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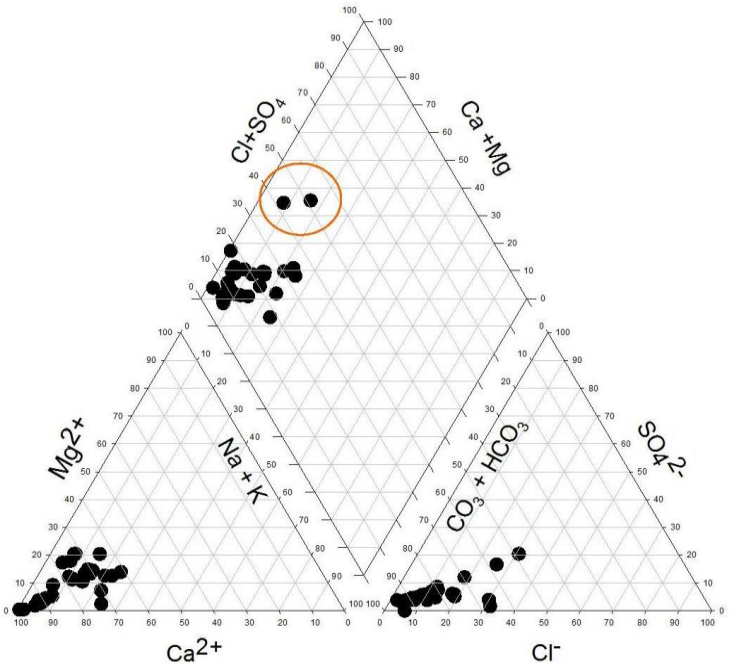


**Figure 115 Piper diagram for all sites designated as H7220.**

The same dataset as displayed on the piper plot in Figure 115 can also be displayed on a Box plot (Figure 116). The Box plot shows that the greatest variation is within calcium and bicarbonate and that there is less variation within the other major ions. Circled are the samples from Nant Peris.

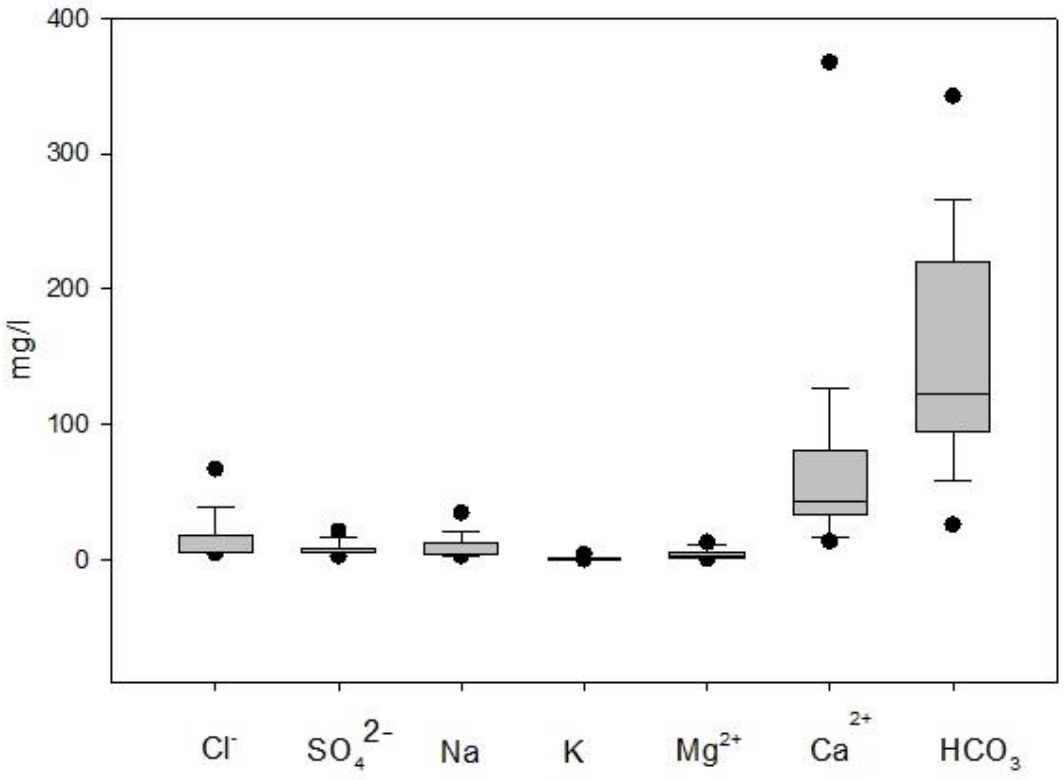


**Figure 116 Box Plot of major ions at all sites designated as H7220**

The previous graphs display the data for all sites designated as H7220 within this report. The next set of graphs display the data split into two groups using the vegetation groupings (see Chapter 8.1 ) proposed for *Palustriella dominated* vegetation, Group 1 and Group 2. Figure 117 shows water quality samples that have been grouped on two separate Piper Plots. Both groups show a preference to waters dominated by calcium bicarbonate however Group 1 has a larger range, with the samples from Nant Peris (NP1.1) and Brest Rhiw (BR1.1) both being projected further into the upper diamond a factor of more dominance of chloride and sulphate in the respective samples. The same data is presented in the adjacent Box Plots (Figure 118) that illustrates the dominance of calcium bicarbonate in Group 1 and to a lesser degree Group 2. The lack of data for Group 2 is the reason that the Box Graph could not display percentile values. In summary there are no major differences between the water chemistry of Group 1 or Group 2 based on the collected within this study although two samples from Group 2 (BR1.1 and NP1.1) display slightly more chloride and sulphate.

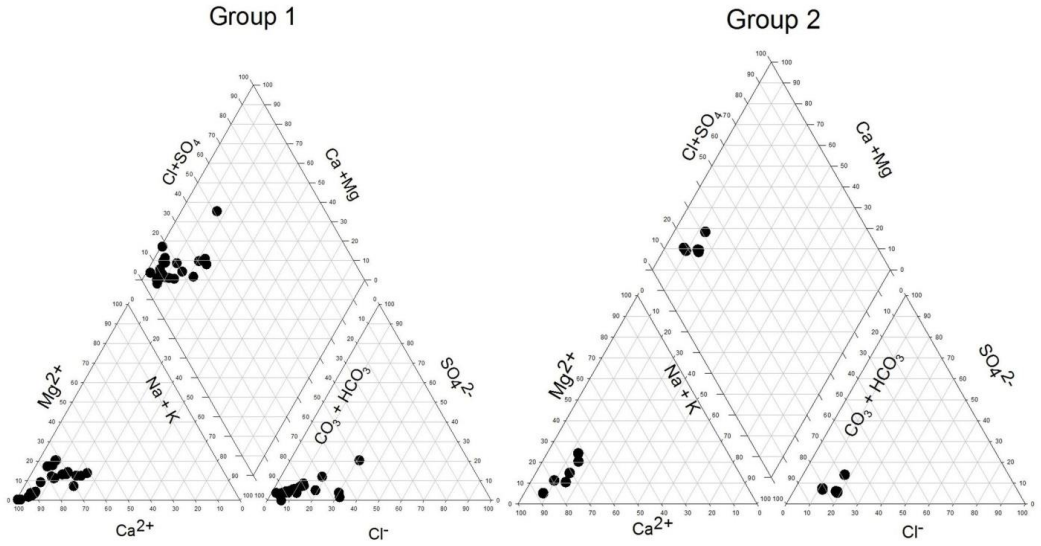


**Figure 117 Piper diagrams. Left is 'Group 1' vegetation and right is 'Group 2' vegetation**

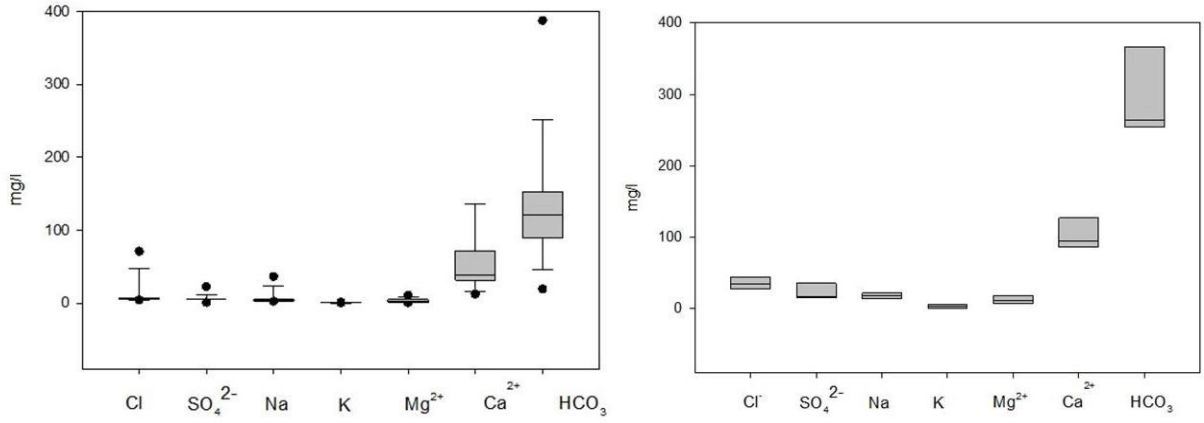


**Figure 118 Box Plot of major ions. Left is 'Group 1' and right is 'Group 2'**

Nutrient samples were taken at 35 locations and allow an initial range of values to be presented for both Group 1 and Group 2 and all of the data is presented together in Figure 119, in addition orthophosphate and phosphate are displayed on an additional graph Figure 120. Overall the suite of nutrients were very low, often less than their limits of detection (LOD), and when this was the case a value of 50% was used to represent these samples statistically. Ammoniacal Nitrogen, Total Oxidized Nitrogen, Nitrate as N and Nitrite were all for the majority of samples very low (i.e <1mg/l) or less than their limit of detection. Only samples from Cors Erddereiniog, Fedw Fawr Beach, McWalters Dingle were >1mg/l with the highest readings from Cors Erddreiniog 1.7-7.4mg/l Nitrate as N. Orthophosphate was generally close to or at its LOD. Phospahte as P varied between <0.02 the lowest limit of detection and 0.07ug/l (LyF2.4 - Llyn y Fan Fach). Further division of the nutrients into Group 1 (dominantly upland) and Group 2 (dominantly lowland) shows a clear division (see Figure 121Figure 121 with the higher nutrient levels reported for lowland sites and this is a clear reflection of the more agricultural landuse in lower elevation land compared to higher elevation land in Wales.

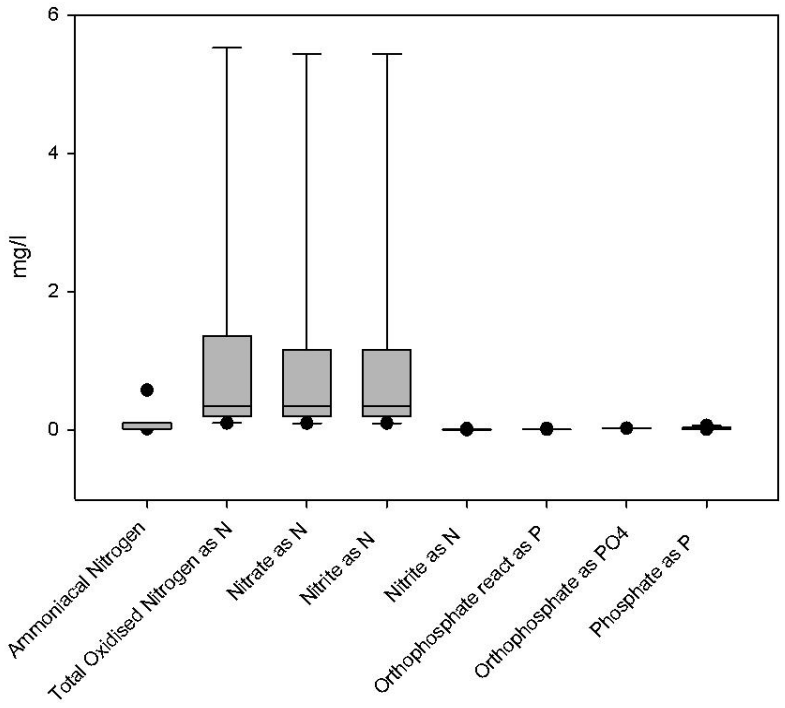


**Figure 119 Box Plot. Nutrients (mg/l) for Group 1 and Group 2**

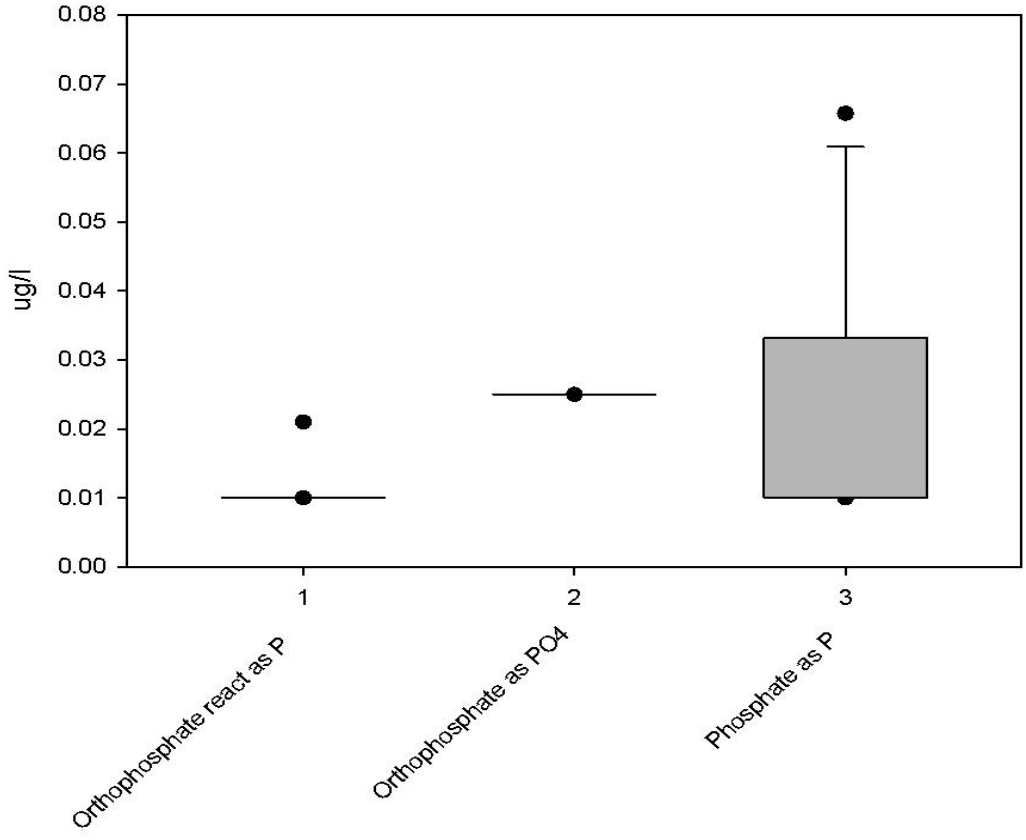


**Figure 120 Box Plot. Phosphate (µg/l) for Group 1 and Group 2**

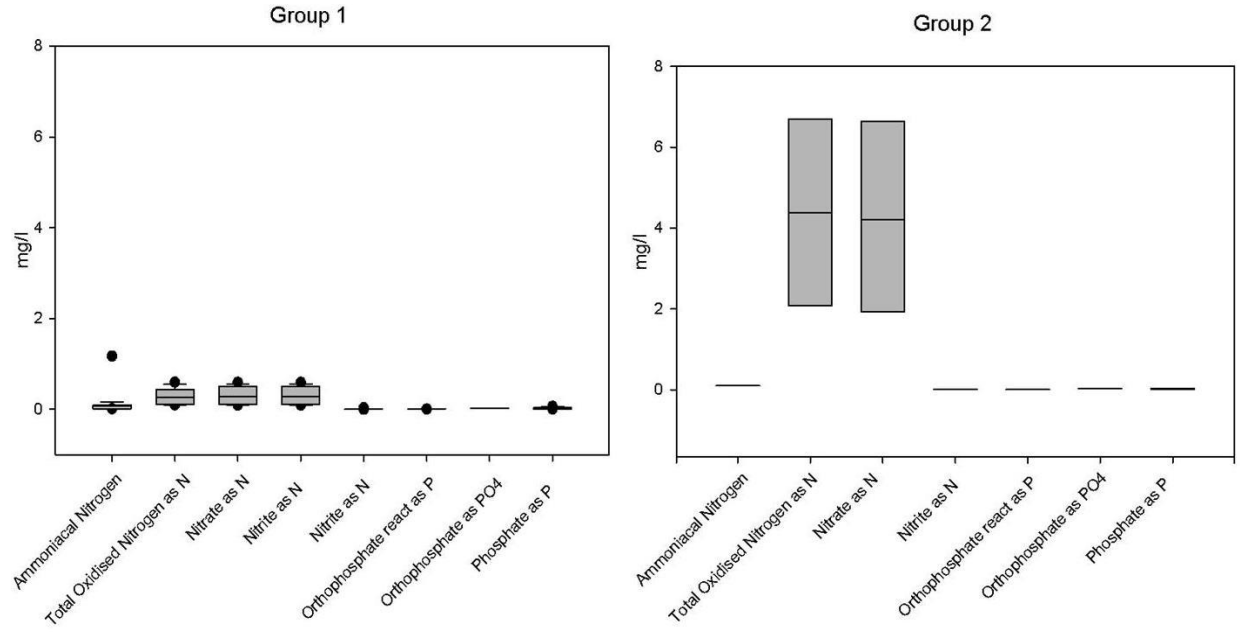


**Figure 121 Box Plot of nutrients, to the left is Group 1 and right is Group 2**

## 8.6 GEOLOGICAL AND HYDROGEOLOGICAL CONTROLS

*Palustriella* dominatedsprings occurred across a range of geologies including both bedrock, superficial and made ground, however active or historic tufa deposition is not associated with all the locations that were included within this study.

Where bedrock aquifers are considered the primary source of water they include the Carboniferous Limestone and associated sandstones and site include; Clydach Gourge, Foel Garnach, Waun Ddu-Craig y Cilau, Cors Erddreiniog and Fedw Fawr 1, 2&3. H7220 is associated with Devonian Old Red Sandstone –where significant calcretes horizons occur (e.g Hen Allt and Tarren y Esgob) and to a lesser degree where they are not present (e.g Llyn y Fan Fach). Interestingly H7220 also occurs in association with the Ordovician Snowdon Volcanic Group (Nant Peris).

The interaction of water from superficial aquifers is hard to quantify however it may have an influence at sites including, but not limited to Pont Clydach 1,2 &4, Llyn y Fan Fach 1&2. The remainder of the sites are closely associated with made ground in the form of lime spoil tips from Carboniferous Limestone quarries and include, Foel Fawr 1 & 2, Brest Rhiw and Blaen Onnen.

Although the association of carbonate dominated geological units (e.g. Carboniferous Limestone) are well illustrated, importantly the occurrence of H7220 is not restricted only to these environments, sites such as Nant Peris are an exception to this rule.

Visual estimates of groundwater discharge and flow from individual springs, seepages faces and within runnels were made at each site. It should be noted that these estimates are very crude and do not account for total groundwater discharge to a site rather for specific runnels or areas adjacent to *Palustriella* vegetation. Visual estimation flow rates varied from <0.1 – 0.5 l/s at Group 1 and <0.1 to 1 l/s in Group 2. Both Group 1 and Group 2 sites shared similar characteristics in that the occurrence of very shallow, but also flowing water was associated with each site and this may well be a hydrological requirement for supporting of H7220 habitats. Although observations have not been made throughout the year (especially during dry periods) many of the sites may experience discharge of water for the majority of the year.

## 8.7 TOPOGRAPHY AND SLOPE

There is clear distinction between Groups 1 and 2 with group 1 sites occurring more generally in open upland locations (with gentler overall slope) and group 2 occurring more generally in less open and less upland locations (with a greater overall slope that can involve vertical rock faces).

At a micro level (individual vegetation patch or runnel), slope can vary greatly and this regularly results in a great range in the degree of base flushing of vegetation (and hence the type of vegetation) across a very small distance. Based on individual transect measurements, it was common to record vegetation with *Sphagnum* (pH 5-6, occasionally 4-5), *Palustriella* dominated vegetation (pH 6-7) and open runnels with *Scorpidium cossonii* (pH 7-8, occasionally 9) within less than 0.5m distance. At a number of sites, particularly dramatic vegetation transitions over a very short distance were observed. These include Wan Ddu (Craig-y-Cilau) where stands of *Sphagnum cuspidatum* (at the margins of a bog) directly adjoin *Palustriella* dominated vegetation at the break of a small slope (pH transition 4.93 to 7.42 and EC 51.2 to 272us/cm) and Moel Gornoch where acid grassland and bog vegetation closely adjoins *Palustriella* dominated vegetation at the break of slope (pH transition 4.74 to 6.30).

In summary, the observed dramatic changes in vegetation type, water quality and supply, emphasise microtopography as being a important factor influencing the character and structure of *Palustriella* dominated springs.

## 8.8 DOES THE OCCURANCE OF TUFA MATTER?

Tufa is deposited when water supersaturated with calcium carbonate degasses on contact with the atmosphere and this process is associated with many, but importantly not all of the sites within this study. The argument is that a water can have elevated levels of calcium carbonate, enough to support *Palustriella* and the other species associated with the tufa forming springs habitat, but without being supersaturated and thus without depositing tufa. Although the geomorphology of tufa formation adds to the attractiveness of any given site it does not seem to be a limiting factor for the presence of the key bryophyte sepcies, i.e based on the sites in this survey you do not have to have active or historic tufa deposition at a site in order to have the characteristic tufa bryophytes.

All group 2 sites (generally considered to be NVC M37) had active tufa present (i.e. tufa associated with plant growth particularly bryophytes) and a proportion of group 1 sites (generally considered to be NVC M38) had similarly active tufa present. However, active tufa was observed at many sites that was not associated with plant growth including deposits on stones, branches and notably an old ten pence piece (Clydach Gorge). At Ddol, active tufa deposits were seen on fallen branches and twigs but not associated with plant growth. In addition, based on the field work, there was a lack of consistency in characteristic tufa bryophytes species (i.e. those frequently cited in literature such as *Palustriella,, Eucladium , Hymenostylium*) as being associated with active tufa formation. Table 112 is in included as a record of species observed as being associated with tufa.

| Species associated with active tufa formation (i.e. leaves and stems becoming petrified – like stone to the touch) | Species recorded from tufa but not active in tufa formation (i.e. secondary colonists on the surface of eroded tufa or within cracks and holes within tufa. |
|---|---|
| *Bryum dichotomum*<br>*Bryum pseudotriquetrum*<br>*Campylium stellatum*<br>*Chara vulgaris*<br>*Didymodon tophaceus*<br>*Eucladium verticillatum*<br>*filamentous algae (Chlorophyta)*<br>*Gymnostomum aeruginosum*<br>*Hymenostylium recurvirostrum*<br>*Jungermannia atrovirens*<br>*Palustriella commutata*<br>*Palustriella falcata*<br>*Philonotis calcarea*<br>*Rivularia haematites*<br>*Scorpidium cossonii* | *Asplenium scolopendrium*<br>*Asplenium trichomanes ssp. trichomanes*<br>*Bryoerythrophyllum recurvirostrum*<br>*Centaurea nigra*<br>*Chrysosplenium oppositifolium*<br>*Conocephalum conicum*<br>*Conocephalum salebrosum*<br>*Ctenidium molluscum*<br>*Dicranella varia*<br>*Didymodon fallax*<br>*Fissidens taxifolius var. taxifolius*<br>*Geranium robertianum*<br>*Hedera helix*<br>*Hypericum androsaemum*<br>*Leicolea badensis*<br>*Leicolea turbinata*<br>*Pellia endiviifolia*<br>*Potentilla steralis*<br>*Pressia quadrata*<br>*Rubus fruticosus agg.* |

**Table 114 – Species associated with tufa deposits**

# 9 Recommendations and knowledge gaps

The following are recommendations that are aimed to improve the knowledge of the extent and functioning of petrifying springs H7220 in Wales.

- **It is likely that the total area covered by H7220 habitat is under recorded**. Further survey is likely to increase the known area of H7220 in Wales and could incorporate sites that were not covered in this study such as Dinefwr, Pont ar Wysg, Craig y Fro, Cwm Sere, Trefil, Cwm Cadlan, Craig yr Hafod, Pont Melin Fechan, Nant Whitton, Cwm Nofydd in South Wales, Waun Eurad and Cors y Farl in Anglesey.

- **Long term ecohydrolgoical monitoring** should be established for at least one site from both Group 1 and Group 2 and if resources allow further division into the four subgroups. Monitoring should incorporate annual repeated bryophyte surveys, seasonal water quality analysis and if possible gauging of the duration and volume of water discharge across sites.

  Potential sites could include:

  Group 1A: Tarren y Esgob
  Gropu 1B: Nant Peris

  Group 2A: Fedw Fawr Beach
  Group 2B: Cors Erddreiniog 7b-e

- **Improvement of the conceptual ecohydrolgoical conceptual models** for key sites within the H7220 habitat to allow classification of key water supply mechanisms and improve our understanding on the functioning of this habitat. Improved conceptual understanding of the habitats also allows the identification of potential pressures and risks likely to cause unfavourable ecological condition or poor hydrgeological status in the future.

- **Further characterization of the wider ecology** of the sites, although not essential could yield interesting information to further the knowledge and characterization of H7220 in Wales. Future surveys could build on existing invertebrates surveys (e.g. Godfrey, 2009) and include new algal surveys.

# 10 Conclusions

*Palustiella* dominated vegetation (based on 27 samples) has loosely been divided into 2 main groups and 4 subgroups. The two main groups (1 & 2) are shown to differ generally in respect to dominanace of individual *Palustriella* species, attitude, site "openness" and number of flowering plant species. The two groups also correlate well to NVC M38 and M37 communities respectively.

*Palustriella* dominated spring vegetation is an interesting habitat due to its strong topographical and hydrogeological components, is generally not species rich (6-52 species) and has very few species of conservation concern although *Blysmus compressus* (not recorded during the present survey) is an associated species of conservation concern listed as vulnerable in the Red Data Book (Cheffings & Farrell, 2005).

Microtopography is an important factor influencing the character and structure of *Palustriella* dominated springs.

The presence of tufa is not considered to be a contolling factor in the occurance of *Palustriella* dominated springs and NVC M37/M38 communities. It is noted that this could be problematic as it does not fit with the European Commission definition of the Annex I habitat *H7220 Petrifying springs with tufa formation (Cratoneurion)* as *being* 'springs with active formation of tufa'.

The sites were divided into Group 1 and Group 2 and the key defining features of each group are summarized in Table 115.

All but one of the sites surveyed were considered to be in favourable ecological condition and all of the sites were considered to be in good hydrological condition, the results are presented in Table 116.

| | Group 1 | Group 2 |
|---|---|---|
| Key species | Dominantly *Palustriella falcata* | Only *Palustriella commutata* |
| NVC Community | M38 | M37 |
| Elevation | Upland | Lowland |
| Elevation range | 275-690maOD | 5-402maOD |
| Average Elevation | 426maOD | 85maOD |
| Vegetation:<br>Total species<br>Flowering plants*<br>Small *Carex* species | Often with *Festuca ovina*<br>21-52<br>11-27<br>2-3 | Often with *Festuca rubra*<br>5-20<br>1-10<br>0-2 |
| Flow | Smaller flows (<0.1 – 0.5l/s) | 'Larger' flows (<0.1 – 1l/s) |
| Occurrence of tufa | Less tufa- some sites with no tufa | More tufa – often deposited in significant quantities under natural conditions |
| Water chemistry | Less base rich (as bicarbonate)? | More base rich (as bicarbonate)? |
| Water Quality | Low nutrient levels | higher nutrient levels |
| Openness of site | Open | Typically not open (incl. woodland, cliffs and gorges) |
| Land use | Upland/ common land | Lowland agricultural |
| Grazing pressure | Significant | Low or none (incl. Many vertical sites) |
| Ecological Pressures | 2 sites (Nant Peris 1 & 2) with invasive alien *Epilobium brunescens* | No pressures identified |
| Hydrological Pressures | No pressures identified | No pressures identified |
| * flowering plants (including club mosses, horsetails and true ferns) | | |

**Table 115 Summary of key ecohydrolgoical divisions between Group 1 and Group 2**

| Site | Tufa forming? | Qualify as habitat H7220 | Ecological condition | Hydrological Status | Overall condition |
|---|---|---|---|---|---|
| Foel Fawr Site 1 | Yes | Yes | Favorable | Good | Favorable |
| Foel Fawr Site 2 | Yes | Yes | Favorable | Good | Favorable |
| Foel Fawr: Foel Garnach | v.small area | Yes | Favorable | Good | Favorable |
| Foel Fawr: Brest Rhiw | Yes | Yes | Favorable | Good | Favorable |
| Pont Clydach 1 | No | Yes | Favorable | Good | Favorable |
| Pont Clydach 2 | No | Yes | Favorable | Good | Favorable |
| Pont Clydach 3 | No | Yes | Favorable | Good | Favorable |
| Blaen Onneu | Yes | Yes | Favorable | Good | Favorable |
| Llyn y Fan Fach 1 | v.small on one plant | Yes | Favorable | Good | Favorable |
| Llyn y Fan Fach 2 | | Yes | Favorable | Good | Favorable |
| Cwm Clydach | Yes | Yes | Favorable | Good | Favorable |
| Waun Ddu / Craig y Cilau | No | Yes | Favourable | Good | Favorable |
| Tarren y Esgob | Yes | Yes | Favourable | Good | Favourable |
| Hen Allt Common | Yes | Yes | Favourable | Good | Favourable |
| Cors Erdderiniog 7A Pipe | Yes | NO – minimal size of *Palustriella* veg | Favourable | Good | Favourable |
| Cors Erdderiniog | Yes | Yes | Favourable | Good | Favourable |
| Cors Erdderiniog | Yes | Yes | Favourable | Good | Favourable |
| Cors Erdderiniog *F* | Yes | NO – minimal size of *Palustriella* veg | Favourable | Good | Favourable |
| Fedw Fawr Beach 1 | Yes | Yes | Favourable | Good | Favourable |
| Fedw Fawr Beach 2 | Yes | Yes | Favourable | Good | Favourable |
| Fedw Fawr Beach 3 | Yes | Yes | Favourable | Good | Favourable |
| Ddol Uchaf | Yes | NO – minimal size of *Palustriella* veg | Favourable | Good | Favourable |
| McWalters Dingle 1 | Yes | Yes | Favourable | Good | Favourable |
| McWalters Dingle 2 | Yes | NO – minimal size of *Palustriella* veg | Favourable | Good | Favourable |
| Nant Peris 1&2 | No | Yes | Unfavourable | Good | Unfavourable |
| Nant Peris 3 | No | Yes | Favourable | Good | Favourable |

**Table 116 Summary of ecological and hydrological status**

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# Appendix 1

| Survey Site | Site Ref | Date | Temperature of Water | SEC | Ammoniacal Nitrogen as N | Nitrogen, Total Oxidised as N | Nitrate as NO3 | Nitrate as N | Nitrite as N | Hardness, Total as CaCO3 | Alkalinity to pH 4.5 as CaCO3 | Chloride | Orthophosphate, reactive as P | Orthophospahte as PO4 | Sulphate as SO4 | Phosphate :- {TIP} | Sodium | Potassium | Magnesium | Calcium | Redox Potential : In Situ | pH : In Situ | Manganese | Iron | Manganese, Dissolved | Iron, Dissolved | Ionic Balance | Bicarbonate as HCO3 | Oxygen, Dissolved, % Saturation | Oxygen, Dissolved as O2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CEL | uS/Cm | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mV | pH | ug/l | ug/l | ug/l | ug/l | % | mg/l | % | mg/l |
| Foel Fawr Site 1 | FF1.1 | 24/11/2013 | 1.90 | 166.5 | <0.03 | 0.35 | | 0.35 | <0.004 | 182 | 73 | 6.4 | <0.02 | | <10 | <0.02 | 3.7 | 0.56 | 0.84 | 71.7 | 51.2 | 8.2 | 33 | 248 | <10 | 39 | 34.20 | 89 | 116.8 | 16.2 |
| Foel Fawr Site 1 | FF1.6 | 24/11/2013 | 2.30 | 199.3 | <0.03 | 0.25 | | 0.25 | <0.004 | 1490 | 62 | 6.0 | <0.02 | | <10 | 0.03 | 3.5 | 0.69 | 1.40 | 594.0 | 12.3 | 9.6 | 360 | 1910 | <10 | <30 | 89.60 | 76 | 102.9 | 14.1 |
| Foel Fawr Site 2 | FF2.1 | 24/11/2013 | 5.30 | 860.0 | 0.31 | 0.25 | | 0.20 | 0.05 | 354 | 342 | 5.7 | <0.02 | | 13.20 | <0.02 | 2.5 | 1.02 | 0.39 | 141.0 | -44.6 | 12.2 | <10 | <30 | <10 | <30 | -0.64 | 417 | 72.3 | 9.2 |
| Foel Fawr Site 2 | FF2.2 | 24/11/2013 | 8.50 | 235.7 | <0.03 | 0.32 | | 0.32 | <0.004 | 107 | 116 | 5.9 | <0.02 | | <10 | <0.02 | 3.1 | 0.56 | 1.24 | 40.7 | 2.9 | 8.8 | 40 | 257 | <10 | <30 | -8.72 | 142 | 103.2 | 12.1 |
| Foel Fawr Site 2 | FF2.3 | 24/11/2013 | 4.20 | 197.4 | 0.04 | <0.2 | | <0.196 | <0.004 | 119 | 77 | 6.1 | <0.02 | | <10 | <0.02 | 3.2 | 0.49 | 0.83 | 46.3 | 7.3 | 9.5 | 46 | 124 | <10 | <30 | 13.30 | 94 | 102.1 | 13.3 |
| Foel Fawr Site 2 | FF2.4 | 24/11/2013 | 5.50 | 182.0 | <0.03 | 0.22 | | 0.22 | <0.004 | 147 | 78 | 5.8 | <0.02 | | <10 | <0.02 | 3.0 | 0.51 | 1.39 | 56.7 | 14.9 | 9.1 | <10 | 91 | <10 | <30 | 22.70 | 95 | 101.9 | 12.8 |
| Pont Clydach Site 1 (runnel at top of site) | PC1.4 | 25/11/2013 | 4.50 | 81.4 | <0.03 | <0.2 | | <0.196 | <0.004 | 35 | 30 | 5.7 | <0.02 | | <10 | 0.04 | 4.0 | 0.35 | 1.36 | 11.9 | 29.1 | 6.9 | 732 | 612 | <10 | <30 | -5.07 | 37 | 96.7 | 12.5 |
| Pont Clydach Site 1 (Spring head at base of | PC1.7 | 25/11/2013 | 9.20 | 125.2 | <0.03 | <0.2 | | <0.196 | <0.004 | 51 | 48 | 5.1 | <0.02 | | <10 | 0.02 | 4.1 | 0.40 | 1.95 | 17.1 | 29.7 | 6.4 | <10 | <30 | <10 | <30 | -4.82 | 59 | 85.4 | 9.8 |
| Pont Clydach Site 2 | PC2.4 | 25/11/2013 | 4.50 | 207.1 | <0.03 | <0.2 | | <0.196 | <0.004 | 78 | 77 | 13.7 | <0.02 | | <10 | 0.03 | 10.0 | 0.37 | 1.78 | 28.4 | 8.9 | 7.3 | 360 | 1200 | <10 | <30 | -3.43 | 94 | | |
| Pont Clydach Site 3 | PC.3.1 | 25/11/2013 | 7.40 | 266.0 | <0.03 | <0.2 | | <0.196 | <0.004 | 111 | 116 | 11.0 | <0.02 | | <10 | <0.02 | 7.9 | 0.76 | 4.15 | 37.7 | -11.2 | 7.2 | 37 | 446 | <10 | <30 | -4.90 | 142 | 87.8 | 10.5 |
| Blaen Onnen (spring at head of site) | BO1.1 | 26/11/2013 | 9.20 | 665.5 | <0.03 | 0.54 | | 0.54 | <0.004 | 254 | 220 | 73.8 | <0.02 | | <10 | 0.06 | 37.9 | 0.87 | 11.40 | 82.8 | -38.4 | 7.2 | 28 | 419 | <10 | <30 | 0.10 | 268 | 87.3 | 10.0 |
| Blaen Onnen (runnel with Paulestriella) | BO1.4 | 26/11/2013 | 6.00 | 564.4 | <0.03 | 0.34 | | 0.34 | <0.004 | 231 | 187 | 60.4 | <0.02 | | 10.70 | 0.06 | 30.7 | 0.94 | 9.09 | 77.4 | -38.4 | 7.8 | 50 | 751 | <10 | <30 | 2.40 | 228 | 90.7 | 11.3 |
| Llyn y Fan Fach Site 1 | LyF1.1 | 27/11/2013 | 7.3 | 222.6 | <.03 | 0.23 | | 0.226 | <.004 | 101 | 99 | 5.5 | <.02 | | <10 | <.02 | 4.54 | 0.75 | 3.31 | 34.8 | 0.2 | 7.1 | 20 | 60.7 | <10 | <30 | 2.92 | 121 | 114.2 | 13.7 |
| Llyn y Fan Fach Site 2 | LyF2.4 | 27/11/2013 | 9.50 | 202.3 | <0.03 | 0.29 | | 0.29 | <0.004 | 92 | 91 | 5.9 | <0.02 | | <10 | 0.07 | 5.0 | 0.74 | 2.87 | 32.0 | -24.6 | 7.4 | 221 | 523 | <10 | <30 | -3.36 | 111 | 94.0 | 10.7 |
| Criag y Cilau | CyC1.5 | 17/01/2014 | 7 | 259.5 | <0.2 | 0.41 | 1.78 | 0.40 | <0.0152 | 133 | 120 | 7.1 | <0.02 | <0.05 | <10 | <.02 | 3.19 | 0.42 | 5.91 | 43.6 | 59.3 | 7.7 | <10 | 52 | <10 | <30 | | 146 | 88.0 | 10.7 |
| Tarren y Esgob 1 (top of site) | TyE1.1 | 18/01/2014 | 6.3 | 244.6 | <0.2 | 0.61 | 2.68 | 0.61 | <0.0152 | 125 | 125 | 4.6 | <0.02 | <0.05 | <10 | <.02 | 4.2 | 0.56 | 6.70 | 39.1 | 12.4 | 8.2 | <10 | <30 | <10 | <30 | | 152 | 90.5 | 11.2 |
| Tarren y Esgob 2 (30-40m down) | TyE1.3 | 18/01/2014 | 5.8 | 199.2 | <0.2 | 0.51 | 2.24 | 0.51 | <0.0152 | | 100 | 4.8 | <0.02 | <0.05 | | <.02 | 3.7 | <1 | 5.49 | 31.8 | 3.0 | 8.3 | <10 | <20 | <10 | <30 | | 122 | 102.1 | 12.8 |
| Tarren y Esgob 3 (bottom of site) | TyE1.6 | 18/01/2014 | 5.1 | 204.1 | <0.2 | 0.53 | 2.31 | 0.52 | <0.0152 | 113 | 100 | 5.0 | <0.02 | <0.05 | <10 | 0.027 | 3.8 | 0.60 | 5.32 | 36.6 | 2.1 | 8.3 | 22 | 155 | <10 | <30 | | 122 | 104.7 | 13.3 |
| Hen Allt Common 1 | HaC1.1 | 18/01/2014 | 6.6 | 339.3 | <0.2 | 0.58 | 2.54 | 0.57 | <0.0152 | 180 | 155 | 5.5 | <0.02 | <0.05 | <10 | <.02 | 4.9 | 1.13 | 4.31 | 64.8 | 8.3 | 8.2 | 30 | 136 | <10 | <30 | | 189 | 94.1 | 11.5 |
| Hen Allt Common 2 | HaC1.2 | 18/01/2014 | 4.4 | 193.0 | <0.2 | 0.54 | 2.38 | 0.54 | <0.0152 | 95 | 175 | 5.8 | <0.02 | <0.05 | <10 | <.02 | 3.0 | 0.16 | 0.91 | 36.6 | 75.0 | 8.1 | <10 | 175 | <10 | <30 | | 213 | 113.5 | 14.7 |
| Moel Garnach 1 (bottom of site) | MG1.1 | 19/01/2014 | 5.8 | 197.8 | <0.2 | 0.20 | 0.87 | 0.20 | <0.0152 | 105 | 85 | 8.1 | <0.02 | <0.05 | <10 | <.02 | 3.0 | 0.13 | 0.77 | 40.6 | 20.5 | 8.2 | <10 | 95 | <10 | <30 | | 104 | 109.2 | 13.6 |
| Moel Garnach 2 (top of site) | MG1.3 | 19/01/2014 | 5.2 | 307.8 | <0.2 | 0.28 | 1.23 | 0.28 | <0.0152 | 131 | 90 | 10.4 | <0.02 | <0.05 | <10 | 0.059 | 19.1 | 0.70 | 1.03 | 50.6 | 9.7 | 8.2 | 428 | 2250 | <10 | <30 | | 110 | 110.2 | 14.0 |
| Brest Rhiw 1 | BR1.1 | 19/01/2014 | 9.7 | 633.8 | 1.64 | 0.11 | 0.48 | 0.11 | <0.0152 | 337 | 115 | 29.1 | <0.02 | <0.05 | 25.1 | <.02 | 13.0 | 1.05 | 4.85 | 127.0 | 22.6 | 7.2 | <10 | 153 | <10 | <30 | 1.66 | 140 | 80.7 | 9.2 |
| Brest Rhiw 2 | BR1.2 | 19/01/2014 | 6.90 | 514.0 | <0.2 | 0.32 | 1.38 | 0.31 | <0.0152 | | 130 | 83.1 | <0.02 | <0.05 | | | | | | | | | | | | | | 159 | | |
| Cors Erddreiniog - Pipe | CE1.1 | 20/01/2014 | 10.40 | 630.2 | <0.2 | 5.23 | 23.10 | 5.23 | <0.0152 | | 1040 | 29.2 | <0.02 | <0.05 | | | | | | | 7.4 | 7.2 | | | | | | 1268 | 73.0 | 8.1 |
| Cors Erddreiniog Spring at hazel wood | CE2.1 | 20/01/2014 | 9.90 | 633.7 | <0.2 | 6.93 | 30.60 | 6.92 | <0.0152 | | 260 | 29.8 | <0.02 | <0.05 | | | | | | | -9.8 | 7.1 | | | | | | 317 | 78.2 | 8.7 |
| Cors Erddreiniog 3 | CE3.3 (A) | 19/01/2014 | 6.9 | 514.0 | <0.2 | 7.34 | 32.50 | 7.35 | <0.0152 | 140 | 270 | 28.5 | <0.02 | <0.05 | <10 | <.02 | 57.7 | 0.40 | 0.83 | 54.9 | 0.4 | 8.0 | <10 | 54 | <10 | <30 | | 329 | 107.5 | 13.1 |
| Cors Erddreiniog 4 | CE5.3 (B) | 20/01/2014 | 7 | 488.7 | <0.2 | 2.07 | 9.15 | 1.93 | <0.0152 | 259 | 214 | 22.1 | <.02 | <0.05 | 17.6 | <.02 | 9.8 | 0.85 | 3.53 | 98.0 | 19.0 | 8.1 | 38 | 667 | <10 | <30 | 2.02 | 261 | 101.7 | 12.3 |
| Fedw Fawr Beach 1 | FF1.1 | 21/01/2014 | 7.1 | 539.4 | <0.2 | 1.36 | 5.99 | 1.16 | <0.0152 | 273 | 218 | 38.1 | <.02 | <0.05 | 15 | <.02 | 19.2 | 2.60 | 11.50 | 90.4 | 12.8 | 8.5 | 36 | 171 | <10 | <30 | 4.35 | 266 | 99.4 | 12.0 |
| Fedw Faw Beach 2 | FF2.1 | 21/01/2014 | 7.4 | 547.3 | <0.2 | 3.54 | 15.60 | 3.18 | <0.0152 | 260 | 212 | 37.0 | 0.021 | <0.05 | 16 | 0.044 | 17.3 | 5.69 | 7.77 | 91.2 | 12.7 | 8.3 | 37 | 219 | <10 | <30 | 2.06 | 259 | 100.4 | 12.0 |
| Fedw Faw Beach 3 | FF3.1 | 21/01/2014 | 8.5 | 482.0 | <0.2 | 2.09 | 9.23 | 1.92 | <0.0152 | 237 | 197 | 32.8 | <.02 | <0.05 | 15.1 | 0.026 | 18.8 | 0.93 | 13.80 | 72.0 | 15.7 | 8.4 | 15 | 164 | <10 | 164 | 2.33 | 240 | 98.0 | 11.4 |
| Ddol | D1.1 | 22/01/2014 | 9.8 | 668.3 | <0.2 | 5.98 | 26.40 | 5.76 | <0.0152 | 354 | 290 | 29.2 | <.02 | <0.05 | 25.7 | <.02 | 15.9 | 2.17 | 10.70 | 124.0 | 20.7 | 7.4 | <10 | <30 | <10 | <30 | 1.6 | 354 | 68.3 | 7.7 |
| McWalters Dingle | WD1.1 | 22/01/2014 | 8.8 | 886.0 | <0.2 | 3.54 | 15.60 | 2.9 | <0.0152 | 471 | 331 | 60.2 | 0.021 | <0.05 | 65.1 | <.02 | 28.5 | 6.94 | 31.90 | 136.0 | 1.2 | 7.8 | 16 | <30 | <10 | <30 | 4.59 | 404 | 84.3 | 9.8 |
| Nant Peris Spring 1 | NP1.1 | 23/01/2014 | 4.70 | 104.2 | <0.2 | 0.11 | 0.49 | 0.11 | <0.0152 | 46 | 43 | 5.60 | <0.02 | <0.05 | <10 | 0.05 | 3.80 | 0.26 | 1.90 | 15.10 | 31.3 | 7.2 | 27 | 209 | 10 | 30 | -6.55 | 15.1 | 94.80 | 11.20 |
| Nant Peris Spring 7 | NP7.1 | 23/01/2014 | 6.20 | 134.0 | <0.2 | 0.13 | 0.55 | 0.55 | <0.0152 | 74 | 55 | 6.30 | <0.02 | <0.05 | <10 | <0.05 | 4.06 | 0.43 | 2.28 | 26.00 | 37.1 | 7.0 | 184 | 2770 | <10 | <30 | 5.59 | 67.7 | 87.80 | 9.97 |
| Clydach Gourge | CG1.1 | 17/01/2014 | 6.90 | 319.6 | | | | | | 165 | | | | | <10 | 0.024 | 4.5 | 0.35 | 18.70 | 35.3 | 11.3 | 8.1 | <10 | <30 | <10 | <30 | | | 87.2 | 10.6 |

Water quality samples: Black text indicates analysis at NRW labs and red at Alcontrol labs. Grey boxes data not analyised and yellow boxes – sample lost

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