Scottish Natural Heritage
Research Report No. 1104

An assessment of the results of soil and water samples from a range of wetland sites – Heart Moss SSSI

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RESEARCH REPORT

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An assessment of the results of soil and water samples from a range of wetland sites – Heart Moss SSSI

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This report should be quoted as:

Spencer, K.L. & Pitcher, A. 2019. An assessment of the results of soil and water samples from a range of wetland sites – Heart Moss SSSI. *Scottish Natural Heritage Research Report No. 1104.*

RESEARCH REPORT

Summary

An assessment of the results of soil and water samples from a range of wetland sites – Heart Moss SSSI

Research Report No. 1104
Contractor: OHES Environmental Ltd
Year of publication: 2019

Keywords

nutrients; Heart Moss SSSI, diffuse pollution; wetland; SSSI; water; soil

Background

In 2012, SNH conducted soil and water sampling from 17 designated wetland sites (Sites of Special Scientific Interest and Special Areas of Conservation). The samples were collected to establish whether the sites were subject to nutrient enrichment from either diffuse or point source pollution. The aim of this report is to analyse the data collected at Heart Moss SSSI, in order to assess the trophic status of the designated wetland and identify any likely sources of nutrient input.

Main findings

- Heart Moss SSSI has a small surface water catchment which includes several base-rich springs and issues. Groundwater input from outside the surface catchment can therefore not be discounted.
- Groundwater samples taken at Heart Moss have been compared with the nutrient level requirements of the vegetation types known on site. They indicate that the water quality currently found around the sample location GW1 exceeds guideline levels for Phosphate, Total Nitrogen (TN) and Nitrate. GW1 is the point at which water from the surrounding agricultural land issues onto the main body of the wetland. Enrichment from adjacent farming practises may be a significant risk to the existing vegetation.
- Of the other groundwater sampling points, GW4 also shows high Nitrate and TN levels, presumably due to its location downslope of GW1 and proximity to intensive grassland. GW2 and GW3 show less enriched conditions, which may be the result of slight topographic differences (i.e. raised ground with a higher proportion of rainwater contribution) or the filtering effect of the surrounding willow carr. However, even these samples show TN levels are above those generally recorded within the ER37 report for these wetland types.
- The surface water results are fairly similar to the nearby groundwater results, suggesting that there is considerable connectivity between the two.
- The site shows a progression of enrichment at SW1, followed by reduced Phosphate, TN and Nitrate at SW2 (after it has filtered through the wetland and has been collected into a channel again). Then at SW3 (the outfall) TN and Nitrate levels have reduced further, but are still more enriched (particularly in terms of Nitrate) than those groundwater samples taken away from the main flowpath of water through the site.

- Assessment of vulnerability showed Heart Moss SSSI was most at risk from agricultural practices.
- Further investigations are recommended for the site (such as monthly water quality sampling and a full NVC survey). A range of remedial options are proposed for consideration, once additional data have been gathered.

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Acknowledgements

OHES Environmental wish to thank Deborah Spray, Andrew McBride and the team of SNH Operations staff for their assistance in providing information on each site. We would also like to thank SNH, SEPA and SNIFFER for the release of the ER37 draft report on proposed eco-hydrological guidelines for Scottish wetlands before publication, in order to inform this report.

1. INTRODUCTION

1.1 Project background and aims

In 2012, SNH conducted soil and water sampling from 17 designated wetland sites (Sites of Special Scientific Interest and Special Areas of Conservation). The samples were collected to establish whether the sites were subject to nutrient enrichment from either diffuse or point source pollution. The aim of this report is to analyse the data collected at Heart Moss, in order to assess the trophic status of the designated wetland and identify any likely sources of nutrient input. The results will then be used to inform site management and also contribute to a wider project to develop eco-hydrological thresholds for wetland sites.

2. METHODOLOGY

The following methodology was used at all 17 sites studied under this project, including Heart Moss.

2.1 Sample methodology

The soil and water samples used in this report were collected by a team co-ordinated by SNH and were undertaken in two phases.

Soil samples were collected at specific sample locations at each site by hand augering holes into the peat. Soil samples were collected at two depths:

1. From the rooting zone.
2. From within the anoxic layer below the rooting zone.

The precise depth of the anoxic layer varied from site to site according to the vegetation that was present. Generally this was approximately 15cm depth for the root zone sample and 45-60cm depth for the sample below the root zone.

Groundwater samples were collected using plastic bailers from slotted pipes installed within hand augured holes.

Surface water samples were also collected from strategic locations within surface water courses at each site.

The two sampling rounds took place in the weeks commencing the 6th February 2012 and the 20th February 2012.

Samples were delivered to the EnviroCentre Glasgow Office and the SNH office at Battleby for dispatch to the project laboratory. Samples were packed in cool boxes with ice to ensure that the samples remained cool in transit to minimise sample deterioration. Unfortunately some samples from some sites were misplaced by the laboratory and could therefore not be processed. All samples were tested using accredited methods or where accreditation was not available, using in-house procedures with routine QA / QC checks in place to ensure data quality.

The soil sample analysis was undertaken on dry samples, which were analysed for the following suite:

- Soil type
- Bulk density
- Water content
- Organic carbon content
- Extractable N and P
- Total N and P
- Total Calcium, Magnesium, Sodium and Potassium

Water samples were analysed for the following suite:

- Calcium, Magnesium and Sodium
- N species – total N, nitrate and ammonium
- P species – orthophosphate and total P, low level P (LOD – 0.02 mg/l)
- Iron species – Fe^{2+} and Fe^{3+}

2.2 Analysis of results

The following data sets were used to assess the site, where available:

- Vegetation descriptions, varying in detail from observations within site condition monitoring assessments to full National Vegetation Classification surveys (NVC)
- Groundwater chemistry
- Surface water chemistry
- Soil chemistry
- Details of the designated site features, site management statements and condition monitoring assessments

Sufficient vegetation information was available for some sites to allow classification of the wetland communities that were (or could be) present at each of the sites and their water quality requirements. For those sites containing measured species data (for example NVC quadrat data) it was possible to apply Ellenberg's Indicator Values[1], weighted to species abundance, to achieve a score for each sample near to a sampling point. This method can indicate, for example, how nutrient-rich the conditions are where the sample was recorded. Mapping these scores then gives an indication of the distribution of eutrophic fen types. Such maps allow a geographical appreciation of distribution of habitat factors, always understanding these values are inferred from the vegetation and not measured directly.

Where NVC data was not available, assumptions were made based on i) vegetation described within the field notes when samples were collected[2] and ii) from the site condition monitoring reports and citation. Each site was split into 'wetland types' (as defined by the SNIFFER report (2009), such as marshy grassland, fen, springs and seepages, or swamp. Originally it was also intended to apply the Wetland Water Supply Mechanisms (WetMecs) framework to define the types of wetland present, as described in Wheeler, Shaw and Tanner (2009). However, in the majority of cases, there was insufficient data available on both the hydrological operation of the site and the substrate present to be able to assign WetMec types with confidence.

A number of published and unpublished sources were then used to define water quality guidelines for the wetland types. This included UKTAG reports on Water Framework Directive targets but was principally based on a draft report commissioned by SNH, SEPA and SNIFFER (known here as the ER37 report), which aims to define suitable targets for wetland types in Scotland. The ER37 report provides data on groundwater, surface water and soil based on the various wetland communities sampled throughout Scotland. These draft guidelines were used to classify the SNH data collected in 2012 and to establish if the results were within normal ranges observed in Scotland.

For sites with open water bodies, the surface water results were compared to Scotland River Basin District (Standards) Directive 2014, along with JNCC targets and Ecoframe targets (Moss *et al*., 2003). In order to apply the correct standards, in was necessary to classify the lochs in terms of their depth, altitude, alkalinity and bedrock, as well as whether they were freshwater or saline, coarse or salmonid. Very limited data on some of these variables meant that assumptions were necessary in the classification process (for example, alkalinity data was rarely available to aid classification).

[1] The Ellenberg values (Hill *et al.,* 1999) are a numerical rating given to each plant species according to its place on the spectrum of each determinant. So, for salinity, saltmarsh species have a high salinity value, freshwater marsh species a low one.

[2] Note that water samples were collected in February and this would necessarily limit the amount of species data able to be obtained.

Each site has been provided with an Assessment of Vulnerability to eutrophication, along with the relative importance of each nutrient source. Catchment nutrient modelling was beyond the scope of this project, and would not have been possible with the current data available. Instead, an 'interpretation' was made by eye of the available data of how each loch should be regarded in terms of trophic status. Any sites which would especially benefit from further more detailed study were flagged up within the report.

3. ASSESSMENT

3.1 Site review

Heart Moss is located 9 km east of Kirkcudbright and 15 km south of Castle Douglas (Figure 1). The fen habitats represent a tract of swamp, partly nutrient-poor, partly nutrient enriched and support a variety of peatland vegetation. Historic maps indicate the presence of a pond or lochan on the site (Figure 2). There may also have been peat cutting for domestic or industrial use in the past. The 23.08 ha site is a large basin fen which grades into grassland to the west and wet mixed broadleaved woodland in the east.

A number of rare and localised plants are present, as well as an extensive undisturbed willow carr along the eastern side, with a rich flora of bryophytes and vascular plants. Acid loving vegetation such as herb-rich fen and grazed fen meadow are on the western side.

Although not a notified feature, the site is also important for invertebrates, with a total of 29 species of water beetle, including 4 nationally scarce species, an uncommon caddis fly and the variable damselfly.

Poaching of the ground where the fen or moss area merges with the cattle grazed western edge of the site makes it difficult to define the fen area on its western edge. The poached area is threatened by overgrazing. A livestock fence keeps cattle out of most of the fen, which has resulted in the potential for scrub encroachment (currently occupying 60 % of the fen area).

The plantation on the eastern boundary was felled and replanted with native broadland trees. This woodland is managed for timber and part of a shooting enterprise, with up to 1000 pheasants being released around the site and straw feed areas being established within the woodland.

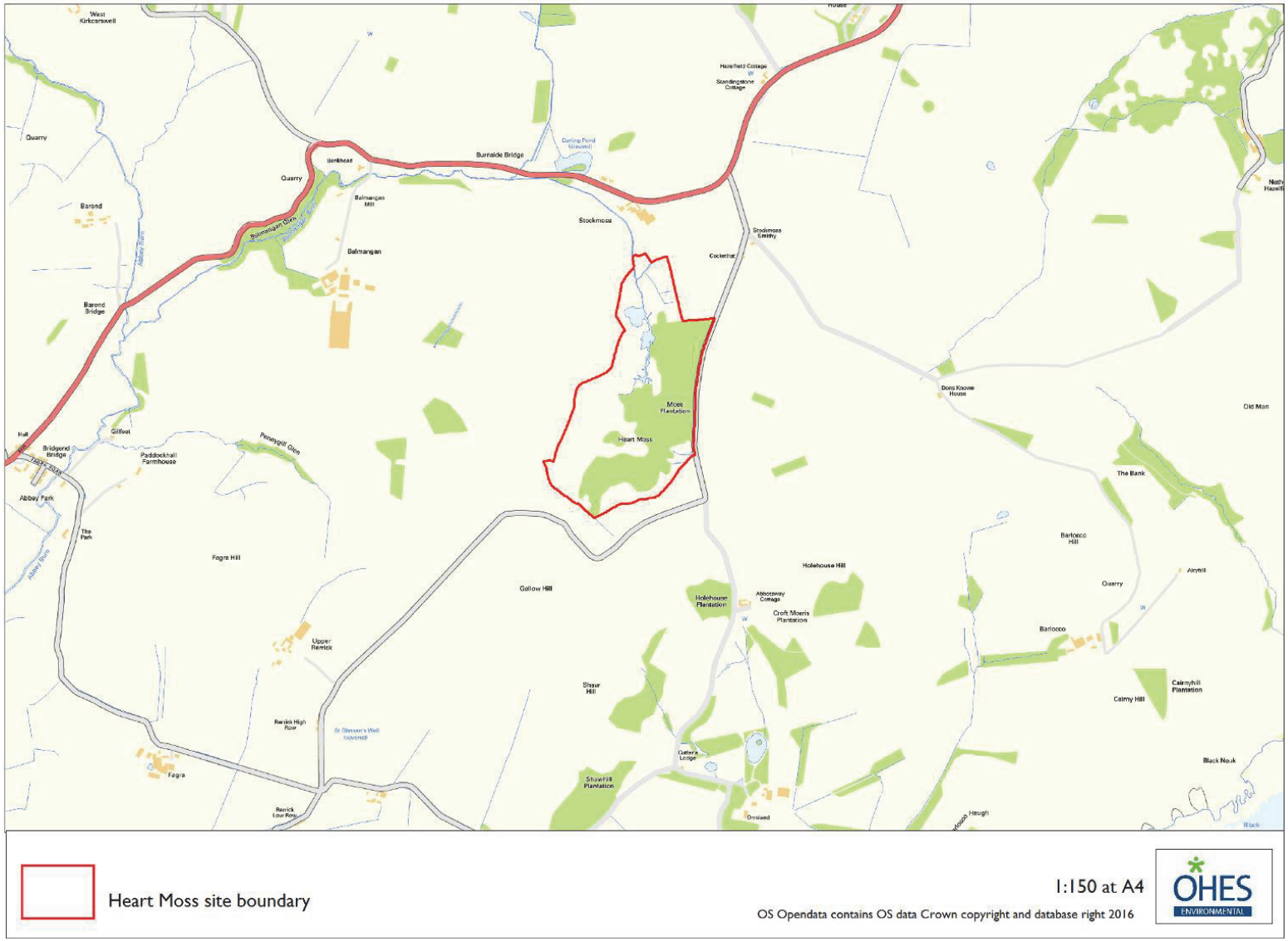

Figure 1. Site Boundary – Heart Moss

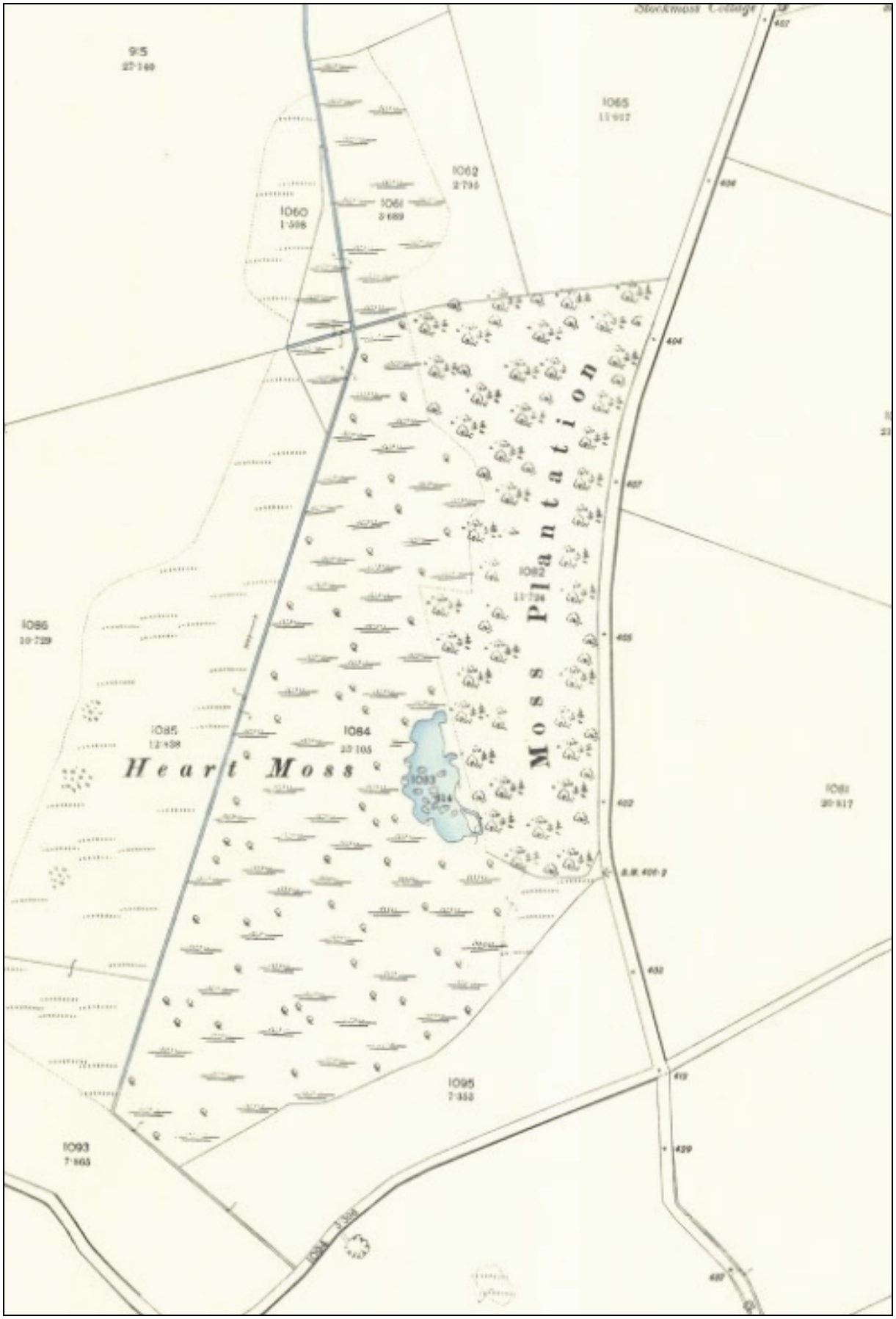

Figure 2. Ordnance Survey Six Inch 1895 map (Source: National Library of Scotland)

3.1.1 Site designation and specific targets

The site was first notified in 1967 and was re-notified in 1984 with a small increase in area. The features for which the site is notified are detailed in table 1, along with their associated pressures.

Table 1. Heart Moss SSSI notified features and associated pressures.

SSSI features	Feature Category	Summary Condition / Latest Condition	Pressure
Basin fen	Wetlands	Unfavourable Declining (Jul 2010)	a) Agricultural operations b) Invasive species c) No proactive management d) Under-grazing

The SNH management objectives are:

1. To maintain suitable water level management of a high water table with occasional flooding and subsequent drying of pools through management of the drainage system.
2. To maintain suitable water quality by creating buffer zones around the site to intercept water from the surrounding arable land.
3. To maintain the fen / grassland structure through light grazing over accessible areas. Cutting in areas of dense scrub growth should also be considered. Maintenance of the wetland transition from open water to rushy pasture, grassland and woodland for diversity of invertebrates and plants should also be undertaken.

3.1.2 Site hydrology

Heart Moss SSSI has a small surface water catchment which includes several base-rich springs and issues (Figure 3). Groundwater input from outside of the surface catchment can therefore not be discounted. Water enters the basin fen from a ditch at the southern tip of the site (Figure 4). This ditch goes beneath ground surface under the minor road to the south of the SSSI and therefore its start point is currently unknown (though it is likely to be somewhere near Orroland Farm).

The site drains in a northerly direction via a drainage ditch which was dug through the basin prior to 1854 (as part of wide scale agricultural improvements). This ditch is cleared occasionally. There is no obvious ditch within the southern half of the SSSI, but instead the water appears to filter into and across the site especially to the east. The ditch becomes more defined in the centre of the site and flows towards the outlet in the north, which is probably an artificial cut through into the exposed bedrock.

There is no SEPA standing water, sediment or water monitoring points at Heart Moss. The closest monitoring point is c.350 m north-west, which is a standing water sample point. Heart Moss is underlain by Castle Douglas bedrock and localised sand and gravel aquifers. In 2008 the quality and quantity of the groundwater were classified as ‘Good’ with no trends for pollutants. There are no historic rainfall data available for Heart Moss SSSI.

Evaluating the impact of nutrient sources on a wetland feature depends on a good understanding of how that wetland feature functions hydrologically and ecologically. The best system to describe wetland functioning developed so far is the WetMec system (short for Wetland Mechanism) developed by Wheeler *et al* (2009). Each WetMec describes an assemblage of hydrological characteristics that determine functioning, and this is usually linked to a characteristic ecology. Crucially, wetland sites are not viewed as a single type (such as floodplain fen or groundwater fed valley fen), but are understood as inter-linked hydrologies composed of more than one WetMec type.

One of the limitations to this study is that little data were available to define detailed hydrological functioning for this site. Similarly, little information is available on the substrate present at Heart Moss (other than the apparent presence of clay and silt at the base of the slopes, over which peat has developed). Application of systems such as the WetMecs framework requires detailed information on both these factors before it can be accurately applied. As a consequence, all that can currently be stated is that the site is likely to contain either WetMec 10: Permanent Seepage Slopes or WetMec 11: Intermittent Seepage Slopes on the higher ground within the site, where springs and seepages occur. Within the lower areas, water supply will be determined by the extent and nature of the clay/silt infill (or presence of low permeability peat). If the substrate is permeable, this area would seem most likely to fall within WetMec 13: Seepage Percolation Basins (typically groundwater fed, with a buoyant surface and transmissive surface layer). If the permeability is low, this area would tend towards WetMec 20: Percolation Basin (where the status of groundwater supply is uncertain due to the extent/nature of the aquitard).

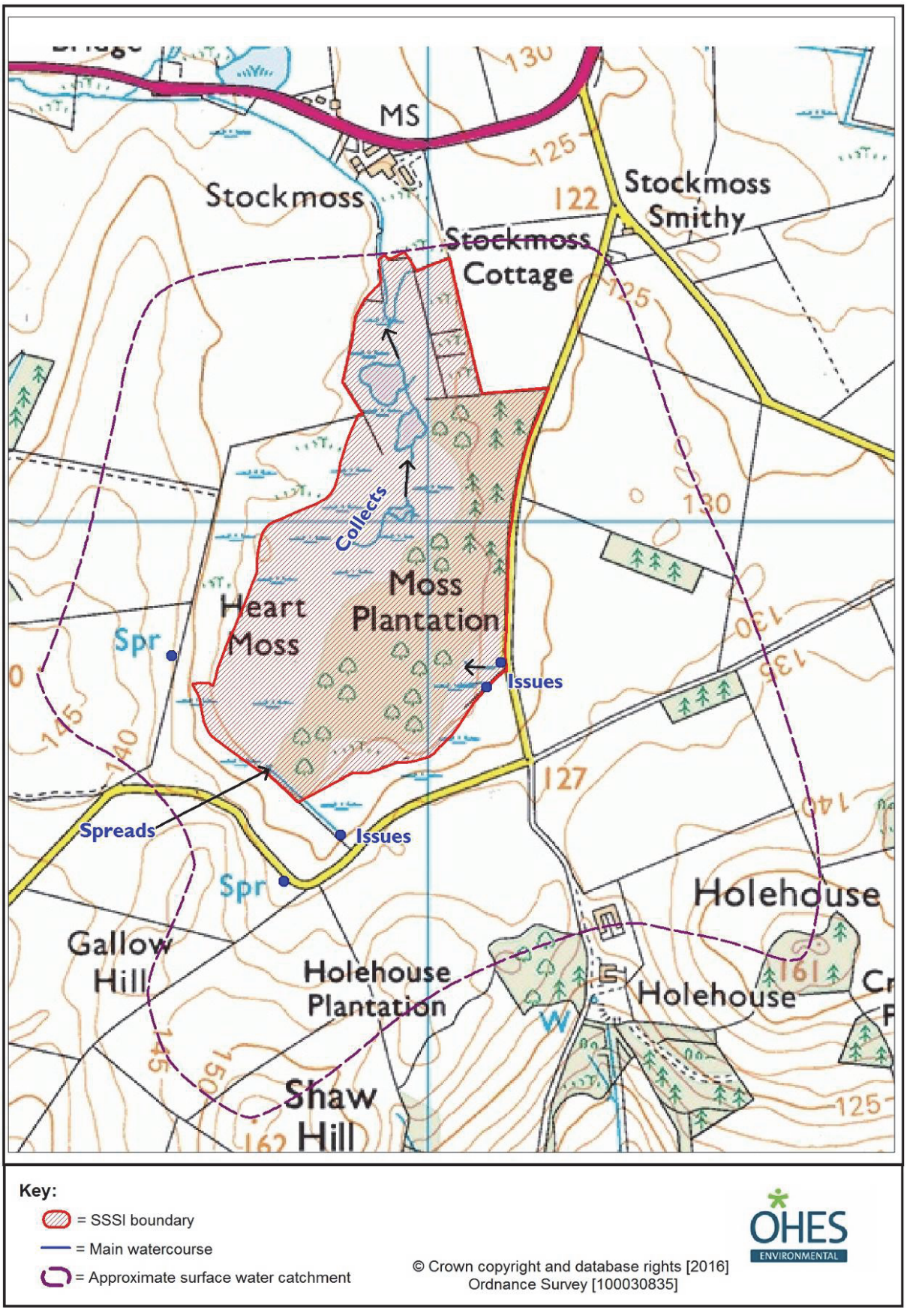

Figure 3. Heart Moss – approximate surface water catchment

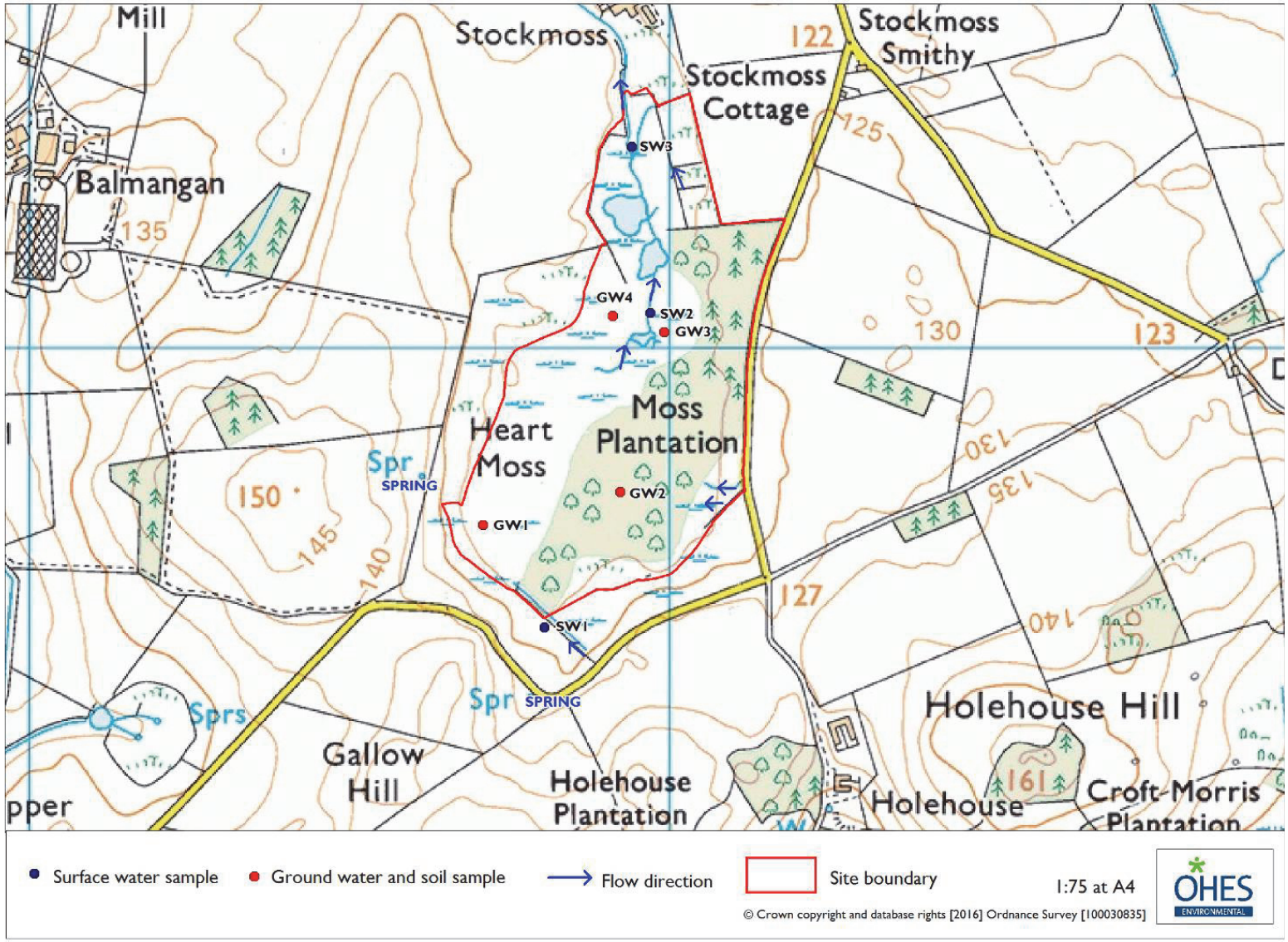

Figure 4. Heart Moss – Hydrology and Sample Locations

3.1.3 Site soils / sediments

Heart Moss is underlain by the Ettrick Association, which developed on drifts derived from Lower Palaeozonic greywackes and shales. The greywackes have been described as 'a form of sandstone, with a variety of mineral and rock fragments and a paste like matrix of the same material' and are interbedded with finder grained siltstones and shales. The valley tills are mainly grey-brown clay loams which are widespread in valleys and on the lower slopes of hills. The SSSI marks an area of peat deposits, consisting of mixtures of solid, fibrous peat and sloppy peat layers, with the water level at the surface throughout. Figure 5 shows the distribution of soil types at Heart Moss.

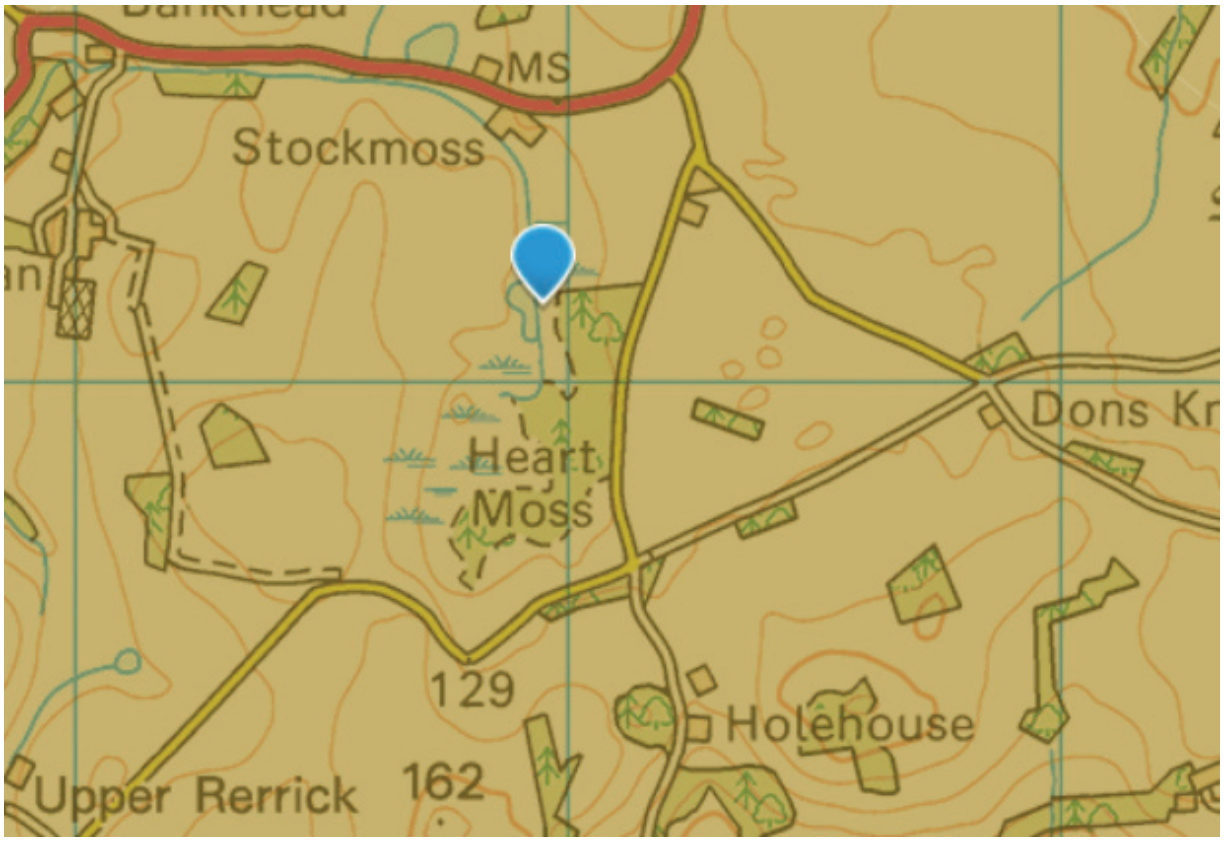

Figure 5. Heart Moss – Soil types (Source: Soil Survey of Scotland Staff, 1981).

3.1.4 Site specific issues

There is concern that agricultural activities within the catchment are resulting in nutrients being transported onto site during rainfall events. Pollution sources along the tributary watercourses also input nutrients to the basin fen. The site is surrounded by dairy farming, which could result in problems due to air pollution and nutrient runoff. The presence of *Phragmites* at the inlet suggests possible nutrient enrichment. The south west boundary of the site is also currently influenced by nutrient enrichment from adjacent fields. Figure 6 shows the locations of these possible sources of nutrients.

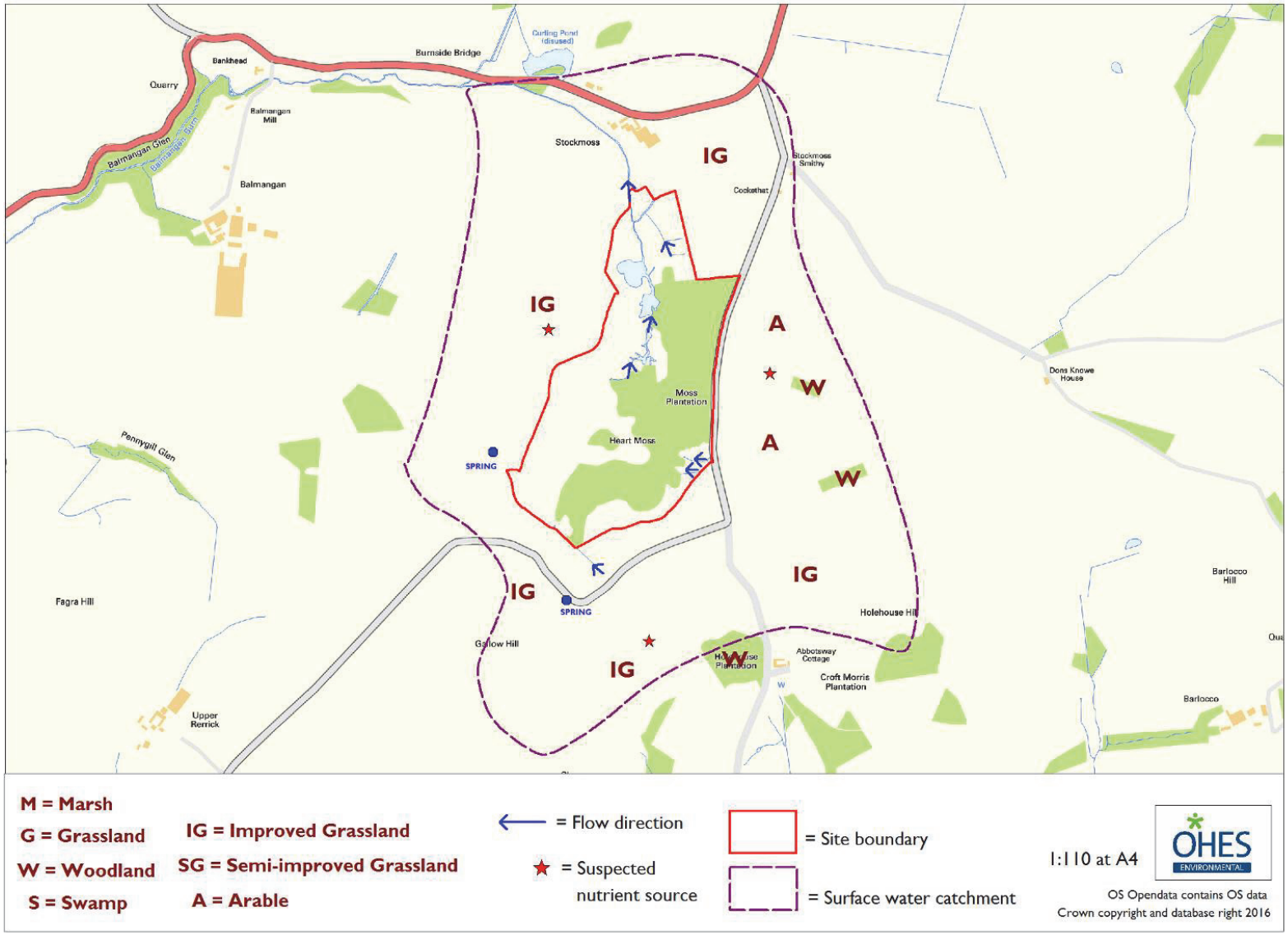

Figure 6. Land use and potential nutrient sources at Heart Moss

3.2 Assessment of vegetation data

Heart Moss SSSI contains a number of swamp, grassland and mire vegetation types. Observations on the vegetation have been recorded in the early 1980's, 1982, 2000 and 2010. NVC community maps and quadrat data are not available for the site.

The following NVC communities have been noted at the site (the locations of which are unknown):

- S9 *Carex rostrata* swamp
- M9 *Carex rostrata-Calliergon cuspidatum /giganteum* mire
- M15 *Scirpus cespitosus-Erica tetralix* wet heath
- M18 *Erica tetralix-Sphagnum papillosum* raised and blanket mire
- M23 *Juncus effusus/acutiflorus-Galium palustre* rush-pasture
- M27 *Filipendula ulmaria-Angelica sylvestris* mire
- M35 *Ranunculus omniophyllus-Montia fontana* rill

The absence of detailed vegetation data (particularly an NVC survey) makes any vegetation analysis extremely difficult at this site. In the north of the SSSI, an area of *Eriophorum* spp. over *Sphagnum* bog historically occurred (which could have either been bog pool communities (such as M1, M2 or M3) or mire communities (such as M5 and M6). This northern area is now dominated by *Molinia caerulea* in the east (which in a transitional context could equate to M27 if enrichment has occurred) and *Carex sp*. in the centre (which could equate to M5, M6 or M9 mire). The closest water sample taken was at TS4, which is recorded to contain *Carex lasiocarpa* and *Myrica gale*. These species would be consistent with M5 or M9. Reference is also made to seepage or waterlogged communities, often forming a floating or unstable raft of vegetation, which would be consistent with M9 or S9.

In the central section, east of the north-south fence line, the vegetation is recorded as dominated by *Molinia, Juncus* and *Phragmites* (M23 rush-pasture, M27 mire or S4 swamp). This area was sampled by TS2 and TS3. TS3 records species of *Molinia, Myrica, Calluna* and an unidentified moss (possibly referring to M15 wet heath). TS2 records *Carex lasiocarpa, Phragmites* and *Myrica* and may therefore be something akin to S4c swamp if reed is dominant or M9 if *Carex rostrata* is dominant).

At the western edge of the site and south-eastern corner, the vegetation increasingly becomes acidic marshy grassland. TS1 was taken from an area that lies somewhere between this marshy grassland and *Molinia/Juncus* dominated mire. It lists *Juncus acutiflorus, Filipendula ulmaria, Calliergon cupsidatum* and *Potentilla palustris* over sloppy peat (examples of which occur in M23 or M27).

It has also been observed that:

- *Phragmites australis* is confined to a belt at the southern end of the site around the willow carr.
- Inundated grassland with *Glyceria fluitans, Alopecurus geniculatus* and *Agrostis stolonifera* is present on site.
- Neutral grassland along the NE boundary much of which had been destroyed by drainage operations at the time of survey.

3.2.1 Historic evidence of community change

There are unfortunately insufficient data to quantify changes in the communities recorded at Heart Moss SSSI and it is proposed that a baseline NVC survey is a priority for this site so that any future changes can be identified accurately. It is noted however, that:

- During the 2000 SCM the swamp, mire and grassland habitats to the west of the central drain were split by a central fence with the vegetation degraded on the western side due to severe overgrazing.
- During the 2010 SCM the Salix carr in the north had spread at the expense of valley bog habitat *Carex rostrata – Juncus effusus-Equisetum fluviatile* swamp with *Carex* communities being restricted to the wettest area close to the central ditch. *Molinia caerulea, Juncus* species and *Phragmites* species appeared to have spread westwards from the central ditch across the site since re-notification. Sphagnum carpets and *Calluna* hummocks appeared much reduced from that recorded in the 2000 survey. Overall it appeared that west of the central ditch the ground was wetter than in 1982 when much of it was described as dry pasture.

3.2.2 Community requirements

The requirements of wetland communities have been discussed in several publications over the past decade, some of which are specifically aimed at providing guidance on the implementation of WFD regulations. Considerable advances have also recently been made in determining the environmental conditions under which particular vegetation types can be found in Scotland, through a collaboration of SNH, SEPA and SNIFFER (Draft report: ER37). The ER37 document presents guidelines on the eco-hydrological requirements of the different Scottish wetland types as described by WWF Consulting (2009). The report emphasises that "they are meant to be adequate for broad-scale appraisal but site specific data is likely to be required for more detailed assessments". Therefore, further sampling is needed for many habitats before definitive thresholds can be set, with the draft ER37 report referring to thresholds, guidelines or indicators, depending on the level of sampling that has so far been conducted for that habitat. The three confidence levels used throughout the ER37 report are described as:

Indicator: Reflects best professional judgement based upon limited data
Guideline: Reflects adequate data for risk screening but not to establish a hydroecological standard
Threshold: Represents a wide range of consistent data with confidence to set a standard.

Where there has been insufficient sampling of a particular habitat in Scotland, the tables refer back to the UK TAG figures.

The wetland types potentially relevant to Heart Moss SSSI are:

- Type 2a: Marshy grassland
- Type 3: Spring, flush and seepage
- Type 4: Fen
- Type 6: Reedbed
- Type 7: Wet heath

The guidance below is therefore based primarily on the ER37 report findings, but with additional information on individual community types where known.

3.2.2.1 Type 2a Marshy grassland

Marshy grassland communities are present across a wide range of environmental situations with several different potential water supply mechanisms. Three types are recognised within ER37.

- Type 1: water supply by rainfall, local snow-melt, overland flow and interflow
- Type 2: groundwater seepages or springs

- Type 3: surface and groundwater flooding (characteristic of floodplains and other localities such as ground adjacent to loch shores)

The equivalent NVC types contained within these types are considerable, but those relevant to Heart Moss SSSI include:

- M23 *Juncus effuses/acutiflorus – Galium palustre* rush-pasture - this community has a fairly widespread distribution across Scotland and can contain considerable plant diversity. The hydrology is typically one of a high water table close to the surface for most of the year (ER37), with periodic flooding.

SNIFFER data and guidelines for marshy grassland are presented in Table 2. Mean nitrate results for wet grassland in good condition are given in UKTAG (2014) as 6 mg/l N. The UK third quartile value is 5.9 mg/l N-NO_3. The SNIFFER values in groundwater for Scotland are significantly lower, with a third quartile value of 0.25 mg/l N-NO_3 (ER37).

Mean Phosphate values indicated by the UKTAG (2012) for the UK in wet grassland are 0.045 mg/l for good condition and 0.024 mg/l for bad condition. However the UKTAG 2014 states "there is no clear distinction in phosphate concentrations between wetlands in good condition and those in poor condition or with a likely nutrient risk." Thus no targets are given.

Table 2. Groundwater guidelines for Marshy Grassland in Good Condition (Source: ER37 – DRAFT)

	Marshy grassland			
Parameter	**1st Quartile**	**Median**	**3rd Quartile**	**Indicator/guideline**
pH (-)	6.3	6.6	7.1	5 to 8
Dissolved Oxygen (%)	32	35	40	
Electric Conductivity (mS/cm)	0.093	0.13	0.18	
Calcium (mg/l)	8	18	24	
Magnesium (mg/l)	2.5	4.5	8.7	
Sodium (mg/l)	6.2	9.2	12	
Phosphate (mg/l)	0.041	0.06	0.065	Indicator: 0.065
Nitrogen (total) (mg/l)	2.5	4	7	
Nitrate (mg/l N-NO_3)	0.25	0.25	0.25	Guideline: 5.9 (or 26 mg/l as N-NO3)

3.2.2.2 Type 3 Spring, flushes and seepages

This is another broad category, defined by direct irrigation from groundwater at near-surface water levels for much of the year. SNIFFER record 30 NVC communities which may occur in spring, flush and seepage wetlands in Scotland. No direct evidence of these spring/seepage communities were recorded from Heart Moss SSSI but the conditions would suggest that M5 *Carex rostrata-Sphagnum squarrosum* mire would not be out of place here (and may be recorded if an NVC were conducted). M5 occurs on soft, spongy peats or as a floating raft within topogenous and soligenous sites. It is typically supplied by mildly acidic to moderately calcareous waters, which can be oligotrophic to moderately fertile in nature. It can be found in base-poor catchments where slates and shales predominate, but is also sometimes associated with more calcareous rocks.

In successional terms, M5 can form part of a sequence from open water through to drier mineral soils, or represent localised areas of oligotrophic conditions within stands of S27 *Carex rostrata–Potentilla palustris* tall herb fen, M9 *Carex rostrata–Calliergon*

cuspidatum/giganteum mire or swamps such as S9 *Carex rostrata* swamp (Wheeler, Shaw & Tanner, 2009). The community has been found to show increases in species-richness associated with base enrichment, but decreases in the number of principal fen species where P enrichment occurs.

ER37 data and guidelines for springs and seepages are presented in Table 3. Under the WFD UKTAG report (2012), mean nitrate levels in springs and seepages (excluding tufa-forming springs) is 1.8 mg/l N-NO3 for good condition and 6.4 mg/l N-NO3 for poor condition. Clearly the data from wetlands in Scotland of this type is very low compared to these targets, and below the detection limit of 0.5mg/l N-NO3. Phosphate levels are also typically below the detection limit of 0.2 mg/l PO4 and the UKTAG report suggests there is no statistical difference between phosphate concentrations in good and poor condition. Therefore no guidelines are available for this determinand.

Table 3. Groundwater guidelines for Springs and seepages in Good Condition (Source: ER37)

	Springs/seepages			
Parameter	**1st Quartile**	**Median**	**3rd Quartile**	**Indicator/guidelines**
Calcium (mg/l)	5.7	42	76	
Magnesium (mg/l)	3.2	12	19	
Sodium (mg/l)	8.4	14	26	
Phosphate (mg/l)	0.09	0.1	0.1	None set
Nitrogen (total) (mg/l)	0.5	1.5	4.2	
Nitrate (mg/l N-NO_3)	0.25	0.25	0.25	Guideline: 2.05 (or 9 mg/l as NO3)

3.2.2.3 Type 4 Fen

Type 4 Fens contain a wide range of vegetation communities, which may be fed by either surface water (topogenous) or ground water (soligenous). The group includes 7230 Alkaline fens (an Annex 1 habitat covered by the EC Habitats Directive) such as M24, and 7210 Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae* (including vegetation types which can support great fen-sedge *C. mariscus).*

The main NVC communities listed in ER37 and which are found at Heart Moss SSSI are:

- M9 *Carex rostrata–Calliergon cuspidatum (Calliergonella cuspidata)/ Calliergon giganteum* mire – occurs on slopes, stream-sides, lochsides and valley bottoms/basins which are fed by oligotrophic to mesotrophic waters, typically at lower altitudes (up to 800 m). The vegetation (a type of slender sedge fen) can form a soft mat of quaking or semi-floating material, with variable depths of peat/fluid underneath it. It typically occurs in transition with S9 *Carex rostrata* swamp, S10 *Equisetum fluviatile* swamp and M5 *Carex rostrata-Sphagnum squarrosum* mire. No pH data available for Scotland but quoted as always >5 and usually >6 for all of its range (Rodwell, 1991).

- M27 *Filipendula ulmaria-Angelica sylvestris* mire - occurs on slopes, floodplains, stream-sides, lochsides and valley bottoms and is associated with high water level fluctuation (ER37). It is generally associated with moderate to high fertility.

ER37 data and thresholds for Fens are presented in Table 4. UKTAG (2012 and 2014) states that mean nitrate levels in groundwater fed fens in good condition are 3.4 and 2.9 mg/l N-NO_3 for mesotrophic and oligotrophic fen respectively, and the 3rd quartile values are 5.7 and 5.0 mg/l N-NO_3. However, ER37 reports that Nitrate levels in Scotland are significantly

lower, with a 3rd quartile value of 0.25 mg/l N-NO_3 for groundwater, suggesting that most fen samples for Scotland are in good condition.

Mean Phosphate values for the UK (UKTAG, 2012) for fens in good condition are 0.033 and 0.021 mg/l P-PO_4 for mesotrophic and oligotrophic fen respectively (ER37). Mean values for fen in poor conditions are 0.034 mg/l P-PO_4 and 0.064 mg/l P-PO_4 for mesotrophic and oligotrophic groups. ER37 reports that median Phosphate concentrations in Scottish fens are 0.10 mg/l P-PO_4 (for groundwater) and 0.046 mg/l P-PO_4 (for surface water). These figures exceed mean values given for good condition under UKTAG, 2012. No guideline value has currently been set for Phosphate. ER37 reports however that "groundwater results are skewed by the analytical level of detection of 0.2 mg/l used in laboratory tests for some of the samples".

Table 4. Groundwater thresholds for Fen in Good Condition (Source: ER37)

	Fen			
Parameter	**1st Quartile**	**Median**	**3rd Quartile**	**Indicator**
pH (-)	6.4	7.1	7.4	
Dissolved Oxygen (%)	18	21	28	
Electric Conductivity (mS/cm)	0.37	0.55	0.69	
Calcium (mg/l)	12	25	55	
Magnesium (mg/l)	3.4	6.4	14	
Sodium (mg/l)	5.4	9.7	14	
Phosphate (mg/l)	0.064	0.1	0.1	None set
Nitrogen (total) (mg/l)	1	3	5.1	
Nitrate (mg/l N-NO_3)	0.25	0.25	0.25	Threshold: <175 m AOD Meso = 5 (or 22 mg/l as NO3) Olig = 4.5 (or 20 mg/l as NO3)

3.2.2.4 Type 6 Reedbed

Equivalent NVC types covered:

- S4a *Phragmites australis* sub-community
- S4b *Galium palustre* sub-community
- S4c *Menyanthes trifoliata* sub-community

These are generally species-poor stands, heavily dominated by *Phragmites australis* with few associate species. They are however, valuable in their own right, particularly for bird and invertebrate species and consequently are a UK Biodiversity Action Plan (BAP) Priority Habitat under the fen, marsh and swamp UK BAP broad habitat. S4 can occur across a wide range of wetland conditions, with hydrological inputs including surface water, ground water or often combinations of the two. Water levels are typically above the surface for several months of the year, and can reach significant depths. ER37 notes that "Although reedbed grows best in wet, eutrophic habitats (Rodwell, 1995), it also occurs in oligotrophic or hypertrophic conditions which are more frequently found in Scotland (Mountford, 2004)".

ER37 data and thresholds for Reedbed are presented in Table 6. Nitrate guidelines under UKTAG for groundwater are 4.9 mg/l N-NO_3 for groundwater feeding mesotrophic swamp and reedbed in good condition and 5.1 mg/l N-NO_3 for poor conditions, but this value is significantly higher than was observed in Scottish reedbed. ER37 reports that "site specific investigations indicate mean concentrations of Welsh and Scottish swamp and reedbed of 0.3 and 0.5 mg/l N-NO_3 (16 wetlands in good condition) and 6.2 mg and 5.6 mg/l N-NO_3 (9

wetlands poor condition). On this basis a threshold value of 5.0mg/l N-NO_3 has been adopted by UKTAG (2012)". However, ER37 concludes values between observed 1mg/l and UKTAG threshold of 22 mg/l should be viewed as an increasing risk.

Table 5. Groundwater thresholds for Reedbed in Good Condition (Source: ER37)

	Reedbed			
Parameter	**1st Quartile**	**Median**	**3rd Quartile**	**UKTAG (2014)**
pH (-)	5.7	6.1	6.5	
Dissolved Oxygen (%)	18	20	22	
Electric Conductivity (mS/cm)	0.13	0.2	0.28	
Calcium (mg/l)	36	48	59	
Magnesium (mg/l)	5.8	12	18	
Sodium (mg/l)	12	13	19	
Phosphate (mg/l)	0.043	0.1	0.1	None set
Nitrogen (total) (mg/l)	1.1	3	6.9	
Nitrate (mg/l N-NO_3)	0.25	0.25	0.25	Threshold: 5 (or 22 mg/l as NO_3)

3.2.2.5 Type 7 Wet heath

Wet heath occurs in a range of situations varying from relatively dry to permanently waterlogged sites. It corresponds to H4010 Northern Atlantic wet heaths with *Erica tetralix* which is listed in Annex 1 of the EU Habitats Directive. The SNIFFER account excludes wet heath occurrences on deep peat (>0.5 m) as these are covered by peat bog (wetland typology 8).

Two models can be distinguished within wet heath habitats

- Wet heath on moderate slopes with impeded drainage and high rainfall
- Wet heath in small depressions or basins (as is found at Heart Moss)

The NVC community listed in ER37 and found at Heart Moss is:

- M15 *Scirpus cespitosus-Erica tetralix* wet heath – characteristic of acidic and oligotrophic, moist peats and peaty mineral soils (Rodwell, 1995). Distributed mainly across the north and west of Britain, it can be moderately species-rich depending on management such as burning and grazing history.

The ER37 draft report has not captured data from wet heath habitats to develop new Scottish guidelines. Therefore UKTAG thresholds for nitrate (9 mg/l as NO3) are utilised for this assessment, alongside guidelines for flush and seepage habitats. No guidelines are provided for Phosphate levels.

3.3 Assessment of ground water samples

Groundwater samples taken at Heart Moss have been compared with the targets given for vegetation types as shown in section 3.2. Groundwater targets were used as opposed to surface water targets for several reasons. Firstly that almost all wetlands will have a component of groundwater influence, and secondly that groundwater targets can often be more demanding than surface water targets.

Due to the unavailability of NVC data it was only possible to categorise the vegetation types at the sampling location based on the site notes.

Table 6 indicates that the vegetation currently found around the sample location GW1 exceeds indicator levels for Phosphate, TN and Nitrate. This is the point at which water sourced from the surrounding agricultural land issues onto the main body of the wetland and therefore suggests enrichment from adjacent farming practises is a significant risk to the existing vegetation. Of the other ground water sampling points, GW4 also shows high Nitrate and TN levels, presumably due to its location downslope of GW1 and proximity to intensive grassland. GW2 and GW3 show less enriched conditions, which may be the result of slight topographic differences (i.e. raised ground with a higher proportion of rainwater contributions) or the filtering effect of the surrounding willow carr. However, even these samples still show TN levels are above those generally recorded within the ER37 report for these wetland types.

Table 6. Groundwater samples at Heart Moss and Wetland Type for Scotland. Red text denotes sample exceeds 3rd quartile.

	Heart Moss	Heart Moss	Heart Moss	Fen			Heart Moss	Springs/seepages/wet heath		
Sample	**GW1 (in M27 / 9)**	**GW2 (in M9)**	**GW4 (in M9 / 27)**	**1st Quartile**	**3rd Quartile**	**Indicator**	**GW3 (in M15)**	**1st Quartile**	**3rd Quartile**	**Indicator**
pH (-)				6.4	7.4					
Dissolved Oxygen (%)				18	28					
Conductivity (mS/cm)				0.37	0.69					
Calcium (mg/l)	20	12	13	12	55		12	5.7	76	
Magnesium (mg/l)	6.2	4.5	3.1	3.4	14		3.8	3.2	19	
Sodium (mg/l)	12	14	9.6	5.4	14		12	8.4	26	
Phosphate (mg/l)	0.08	0.062	0.06	0.064	0.1	None set	0.057	0.09	0.1	None set
Nitrogen (total) (mg/l)	8.45	6.51	9.85	1	5.1		7.75	0.5	4.2	
Nitrate (mg/l N-NO_3)	11	<0.5	0.55	0.25	0.25	Threshold: <175 m Meso = 5 (or 22 mg/l as NO3) Olig = 4.5 (or 20 mg/l as NO3)	<0.5	0.25	0.25	Guideline: 2.05 (or 9 mg/l as NO3)

3.4 Assessment of surface water samples

3.4.1 Current surface water quality status

Three surface water samples were taken from Heart Moss. Due to the likely interaction of groundwater and surface water, the two sets of results were compared to assess their similarities. The surface and groundwater results can be found in Table 7. The surface water results are fairly similar to the nearby groundwater results in terms of Calcium, Magnesium, Sodium and Phosphate, suggesting that there is some interaction between the two.

GW1 is supplied in part by water from SW1 and therefore reflects the high nutrient conditions found there. It is noted however that Phosphate and TN are higher in GW1 than SW1, presumably because GW1 is also receiving enriched water from the spring to the west of the SSSI.

By the time water reaches SW2, after it has filtered through the wetland and has been collected into a channel again, Phosphate, TN and Nitrate have all reduced noticeably. Then at SW3 (the outfall) TN and Nitrate levels have reduced further, but are still more enriched (particularly in terms of Nitrate) than those groundwater samples taken away from the main flowpath of water through the site.

Table 7. Comparison of Surface water and Groundwater at Heart Moss

	SW1	GW1	SW2	GW3	GW4	SW3
Calcium (mg/l)	16	20	16	12	13	17
Magnesium (mg/l)	6.4	6.2	6.3	3.8	3.1	6.3
Sodium (mg/l)	11	12	11	12	9.6	11
Phosphate (mg/l)	0.073	0.08	0.061	0.057	0.06	0.061
Nitrogen (total) (mg/l)	7.4	8.45	6.27	7.75	9.85	5.35
Nitrate (mg/l $N\text{-}NO_3$)	15	11	7.7	<0.5	0.55	6.4

Surface water results were compared to SNIFFER data (ER37 report) for fen communities at Heart Moss SSSI, as these are the principle communities found within the main flowpath through the site. Water chemistry guidelines generally refer to groundwater rather than surface water and therefore comparison can only typically be made between Heart Moss SSSI and the SNIFFER dataset for wetlands in Scotland. Table 8 indicates that the surface water within the central channel is not consistent with the general requirements for fen communities such as M9 and M27 mire. The current condition of this water supply is therefore likely to be detrimental to the SSSI feature.

Table 8. Surface water samples at Heart Moss and Wetland Type for Scotland (ER37).

	Heart Moss			Fen		
Parameter	**SW1**	**SW2**	**SW3**	**1st Quartile**	**3rd Quartile**	**UKTAG 2012**
pH (-)	-	-	-	6.7	7.4	
Dissolved Oxygen (%)	-	-	-	53	57	
Electric Conductivity (mS/cm)	-	-	-	0.25	0.62	
Calcium (mg/l)	16	16	17	13	38	
Magnesium (mg/l)	6.4	6.3	6.3	5	8	
Sodium (mg/l)	11	11	11	7	12	
Phosphate (mg/l)	0.073	0.061	0.061	0.02	0.084	None set
Nitrogen (total) (mg/l)	7.4	6.27	5.35	1.8	5	
Nitrate (mg/l N-NO_3)	15	7.7	6.4	0.25	5.2	Meso = 5 (or 22 mg/l as NO3) Olig = 4.5 (or 20 mg/l as NO3)

3.4.2 Summary of site vulnerability

The site is believed to be fed by a combination of surface and groundwater (sourced from the springs off-site). The feeder ditches to the west and south appear to be bringing in some forms of Nitrogen at detrimental levels to the fen communities present. Phosphate levels also appear to be high when compared to the UKTAG mean phosphate levels for Fen communities. This is particularly so in the south of the SSSI.

An assessment of vulnerability of the site to enrichment is given in Table 9 below.

Table 9. Assessment of the vulnerability of Heart Moss SSSI to eutrophication from catchment sources and their relative importance. Negative factors are shown in black, positive factors in blue.

Source	Heart Moss	
	Vulnerability	**Details of Factors**
EXTERNAL SOURCES		
1. Agriculture	High	- A significant proportion of the land within the catchment is used as improved grassland or arable, some of which appears to be providing enriched water directly into the SSSI.
2. Human population	Low	- Very few residential properties are present within the catchment. - If residential properties utilise septic tanks, there may be some enrichment of groundwater.
3. Aerial deposition	Low-Moderate	- Deposition rates within this part of the UK are lower than recorded in England. Thus atmospheric Total Phosphorus input into the catchment is small, although Total Nitrogen remains a contributor.
4. Regional groundwater	Low	- Regional groundwater may be contributing to the site's water balance and is understood to be of good water quality.
INTERNAL SOURCES		
1. Wildlife	Low	- The site does not contain large numbers of bird species which would significantly contribute to the nutrient balance.
2. Site management	Moderate	- The site is not grazed and therefore will be accumulating nutrients slowly over time.

3.5 Assessment of soil samples

Soil chemistry was sampled at four locations within Heart Moss (three of which were in M27 / M9 mire combinations, the other was in M15 wet heath).

Very little has been published about soil chemistry targets in terms of wetland types or NVC communities. However, the ER37 report presents summaries of the soil chemistry recorded across a number of sample locations in Scotland, which are used here as an indicator of any site abnormalities.

The ER37 data is based on: 20 samples across 8 sites for Reedbeds
49 samples across 13 sites for Marshy Grassland
60 samples across 19 sites for Fens
87 samples across 23 sites for Swamps
2 samples across 1 site for Wet heath

Table 10 presents the soil chemistry data for Heart Moss samples against the ER37 data. The results show that calcium, magnesium and sodium are at the lower end of the range observed in Scottish samples. Total nitrogen readings (and in some cases Phosphate readings) are above those typically recorded in fen, both within the root layer and below.

Table 10. Soil samples at Heart Moss and soil chemistry recorded by Wetland Type in Scotland (ER37). Red text denotes sample exceeds typical range.

	Heart Moss		Heart Moss		Heart Moss		Fen		Heart Moss		Wet heath (2 samples only)	
Sample	**Soil 1 Root (in M27 / 9)**	**Soil 1 below (in M27 / 9)**	**Soil 2 Root (M9)**	**Soil 2 below (M9)**	**Soil 4 Root (M9/27)**	**Soil 4 below (M9/27)**	**1st Quartile**	**3rd Quartile**	**Soil 3 Root (M15)**	**Soil 3 below (M15)**	**1st Quartile**	**3rd Quartile**
Calcium (mg/kg)	1,300	2,100	490	330	400	1,100	960	12,000	550	750	520	520
Magnesium (mg/kg)	240	390	90	55	55	160	1,500	3,800	100	160	840	8400
Sodium (mg/kg)	41	26	21	16	17	16	74	280	20	22	-	-
Phosphate (available) (mg/l)	10	3.9	4.1	3.5	5.1	3.8	2.7	9.5	4.9	4.0	7.3	8.9
Nitrogen (total) (%)	2.5	2.1	1.8	1.6	1.9	1.4	0.25	1.4	1.6	1.6	0.16	0.27
Nitrogen (extractable) (mg/kg)	<0.1	0.27	0.18	0.15	<0.1	0.1	0.4	1.4	0.17	0.16	0.55	0.9
Total organic carbon (%)	4.4	8.5	2.2	4.6	2.7	4.9	3.7	12	3.5	3.1	-	-
Potassium (total)	<5.0	<5.0	<5.0	<5.0	47	<5.0	-	-	<5.0	<5.0	-	-
Soil Moisture Content %	846	628	1,161	1,183	1,445	802	-	-	1,161	829	-	-

3.6 Limitations

A number of factors will limit the possibility of drawing reliable conclusions relating to the potential eutrophication of this site. They include:

- No site visit was possible as part of the analysis within this report and therefore there has been no opportunity to gain first-hand knowledge of the site.
- There was no NVC data available for Heart Moss, therefore the NVC type at the various sampling locations was inferred using descriptions from SCM and field notes taken during the sampling.
- Data was collected from a single sampling round which, though providing consistency of timing could be very misleading if for example weather conditions were atypical. Clearly a single sample round will also not reflect conditions experienced through the various seasons (such as those times of the year when fertiliser may be added or heavy rain may increase the amount of suspended solids and therefore nutrient loadings).
- The relationship between wetland types and Phosphorus targets is still under review and therefore levels which may appear to be acceptable now may change status if Phosphorus targets are more clearly defined.
- There were insufficient data for any statistical analysis.

3.7 Recommendations on future measures and / or data requirements

There are a wide range of options for remedial measures within wetland systems. Some, such as the implementation of buffer zones, represent very little risk of negative impact and therefore can be implemented without the need for more detailed study. The risk with such early implementation is mainly that the measures may be placed in sub-optimal locations and therefore may result in an ineffective use of resources. However, in the case of Heart Moss SSSI, it seems highly likely that the two spring feeds to the west and south are sources of enriched water and therefore should be the main focus for measures such as buffer strips. It is also noted that the willow carr to the east of the site may already be acting as a filter strip to groundwater issues and therefore any plans for removal of scrub should take this role of the carr into account.

Other remedial measures, such as re-routing water supplies or addition of water control structures, require a minimum level of supporting data in order to accurately assess their potential impact and effectiveness. These measures are not advisable without further investigation.

The recommendations for further investigation presented below are based on ensuring sufficient understanding exists so that any remedial measures focus on the area of greatest concern and can undergo risk/benefit assessment prior to implementation. The remedial options identified below are merely put forward for further consideration based on the characteristics of the site.

The initial assessment of Heart Moss SSSI, based on a single sampling round, strongly suggests enriched water is entering the SSSI particularly from the springs to the west and south, as well as diffusely from the adjacent field boundaries in general. This indication would be reinforced by the following datasets:

- Ideally, monthly surface water sampling within existing points SW1, SW2 and SW3 (but also an additional point SW4 on the issues at the eastern boundary of the SSSI) for a full year to ascertain the patterns of enriched water movement across the site and whether it is acting as a sink for nutrients generated off-site.
- Rainfall data in the region for the period when surface water sampling takes place.

- A baseline NVC survey so that direct comparisons of future conditions can be made, as well as remedial measures tailored to the full suite of vegetation communities currently present.

Once these data has been gathered and analysed it will be possible to assess the best means of protecting the ecological value of the site. Such measures could include:

- ***Implementation of a grazing plan*** – with livestock ideally removed from site at night (thus ensuring a net loss of nutrient from the site as well as providing greater opportunities to increase plant diversity).

- ***Reducing nutrient input*** - This is the most effective means of addressing eutrophication of the site. The primary exporters of nutrients appear to be the dairy farm within adjacent fields. Reduction of nutrient would require the support of neighbouring landowners prepared to reduce the application of fertiliser and slurry to their land, or to change their land use to semi-improved grassland in addition to reducing their livestock units per hectare. The advantage of this approach is the long-term sustainability of the wetland interest in the catchment. There are also likely to be benefits to other habitats such as dry grassland through reduction in nutrients.

- ***Redirecting problematic water sources*** – It may be possible to redirect one of the spring feeds to the site, but as there is evidence to suggest that all spring sources are bringing in enriched waters this may not be a productive method of remediation.

- ***Soft engineering options*** - There are several generally accepted soft engineering options available, all of which work on the principle of protecting wetland through a combination of chemical, physical and biological processes. These might include:

  Buffer Zones; Buffer zones of various kinds can be used to remove nutrients before they can enter the wetland (such as reedbeds, grass strips and woodland buffers). Nitrate in particular is removed both by bacterial processes (such as denitrification) and plant uptake. However the effectiveness of the buffer zone will depend on its size, condition of the vegetation, flow rate of water through the buffer and the underlying substrate. Hence buffer strips are generally more effective when they are 30-40 m wide, with vegetation a few years old, on flat or gently sloping ground consisting of clay or humified organic material. Initial review of the available data would suggest that suitable substrate and topography is present at Heart Moss SSSI.

  Ditch management; Ditches can be profiled to permit marginal wetland vegetation to establish, thus acting as a buffer strip. In addition, ditch clearance is only undertaken over short sections at a time and only when absolutely necessary, in order to maximise plant uptake, reduce velocity and increase residence time.

  Vegetated filter strips and earth banks; Filter strips are thin lines of vegetation (often only 2 m wide) which are located within field or at field edges and are generally used to reduce run-off and soil erosion (e.g. “contour grass strips”). Earth banks provide a similar role but both methods are ineffective when on free-draining soils and so are not recommended within this catchment.

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ANNEX 1: WATER AND SOIL SAMPLES

Water samples

			Sample ID	GW1	GW2	GW3	GW4	SW1	SW2	SW3
Parameter	**Unit**	**Detection Limit**	**Sample Date**	21/02/2012	21/02/2012	21/02/2012	21/02/2012	21/02/2012	21/02/2012	21/02/2012
Phosphorus (total)	mg l^{-1}	0.2	Water	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ammonium	mg l^{-1}	0.01	Water	2.3	2.4	1.9	4.3	7.3	8.7	10
Nitrate	mg l^{-1}	0.5	Water	<0.5	<0.5	<0.5	0.84	5.6	12	<0.5
Phosphate Low Level	mg l^{-1}	0.02	Water	0.071	0.056	0.062	0.06	0.059	0.059	0.063
Nitrogen (total)	mg l^{-1}	1	Water	15	6	7.5	4	2	4.5	2
Calcium	mg l^{-1}	5	Water	770	26	14	21	27	12	31
Magnesium	mg l^{-1}	0.5	Water	63	6.7	3.6	4.5	6.1	4.2	7.6
Sodium	mg l^{-1}	0.5	Water	16	15	10	7.8	25	11	31
Iron (II)	µg l^{-1}	20	Water	<20	300	1000	850	<20	<20	500
Iron (III)	µg l^{-1}	20	Water	640	140	<20	<20	150	210	<20
Iron (total)	µg l^{-1}	20	Water	640	440	1000	850	150	210	500

Soil samples

			Sample ID	S1	S1	S2	S2	S3	S3	S4	S4
			Other ID	Below	Root	Below	Root	Below	Root	Below	Root
			Sample Date	21/02/2012	21/02/2012	21/02/2012	21/02/2012	21/02/2012	21/02/2012	21/02/2012	21/02/2012
Parameter	**Unit**	**Detection Limit**	**Type**								
Moisture	%	0.02	Soil	61	66	86	76.9	68.5	61.7	77.4	70.5
Stones content (>50mm)	%	0.02	Soil	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Phosphorus (available)	mg l^{-1}	10	Soil	8.1	13	4.7	8.5	10	10	5.9	8.9
Phosphorus (total)	mg kg^{-1}	-	Soil	1100	1900	2100	2200	1500	1800	1100	1300
Nitrogen (total)	%	0.02	Soil	0.72	0.78	0.09	1.2	0.96	0.8	0.39	0.97
Nitrite (extractable)	mg kg^{-1}	0.1	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate (exctractable)	g l^{-1}	0	Soil	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Calcium (total)	mg kg^{-1}	100	Soil	760	850	2200	2300	1500	1100	1800	1500
Potassium (total)	mg kg^{-1}	0.2	Soil	160	300	85	380	1100	980	170	530
Sodium (total)	mg kg^{-1}	0.2	Soil	300	400	70	300	500	530	210	430
Magnesium (total)	mg kg^{-1}	0.5	Soil	1500	2200	2300	1600	2200	2300	2100	150
Total Organic Carbon	%	0.2	Soil	6.5	7.7	24	16	12	11	18	10
Moisture content	%	-	Soil	130	486	810	363	195	468	160	431
Bulk density	Mg/m3	-	Soil	1.31	1.08	1.04	1.08	1.13	1.08	1.21	1.02
Dry density	Mg/m3	-	Soil	0.57	0.18	0.11	0.23	0.38	0.19	0.47	0.19

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