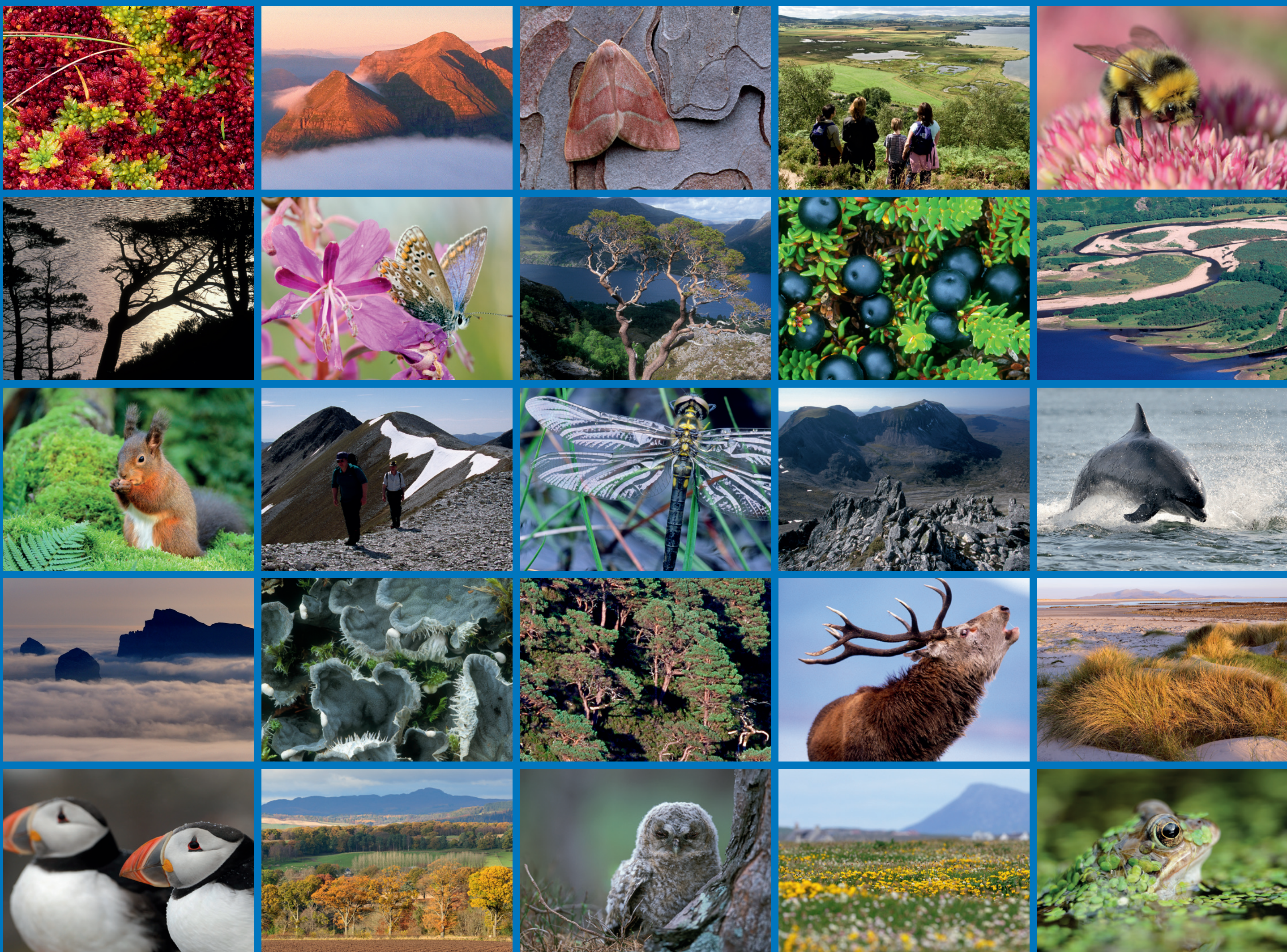
Scottish Natural Heritage
Research Report No. 1111

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

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RESEARCH REPORT
Summary

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

Research Report No. 1111
Contractor: OHES Environmental Ltd
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Keywords

nutrients; Kings Myre 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 Kings Myre, in order to assess the trophic status of the designated wetland and identify any likely sources of nutrient input.

Main findings

- Kings Myre SSSI is set within a relatively small catchment, with calcium rich spring water emerging on the north side of the myre and through the bed of the loch itself. The loch water is highly alkaline, with a recorded pH of 7.12 to 9.2, and is known to be nutrient rich. Both samples taken to the west of the loch (in S27) are within the higher category of Ellenberg Nitrogen Indicator values.
- Using the 2012 surface water samples and the SRBDD 2014 standards, the loch appears to exceed standards for Total Ammonia and also JNCC guidelines for Total Nitrogen (TN). However it is emphasised that this is from a single sample. Loch Phosphate levels appeared to be at borderline concentrations for Good Ecological Status.
- Two surface water points in particular showed high Phosphate levels, both of which occur at the western end of the SSSI where there is evidence of change in communities such as S27.
- As a result, given that Nitrogen levels are also above standards, this report concludes that <u>the trophic state of King's Myre surface water is Eutrophic.</u>
- Assessment of vulnerability showed Kings Myre SSSI was most at risk from agricultural practices, septic tank outfalls and possibly release of stored nutrient from loch sediments.
- Further investigations are recommended for the site (such as monthly water quality sampling, sediment sampling within the loch and a hydrological walkover to establish silt build-up and hydrological functioning). A range of remedial options are proposed for consideration, once additional data have been gathered.
- Groundwater samples taken at Kings Myre have been compared with the nutrient level requirements of the vegetation types known on site. This indicates that the groundwater

quality is consistent with the requirements of the vegetation currently found around the sample locations (and is consistent with the data recorded for Scotland (ER37) and for guideline/threshold levels for these habitats). However it should be noted that no groundwater samples were taken from the areas of most concern, such as the western area of S27. TN levels were higher at Kings Myre than generally recorded within the dataset from Scotland, but both Phosphate and Nitrate levels were reasonably low.

- Using the 1989, 1991 and 2010 NVC quadrat data, Ellenberg Indicator values for Nitrogen and Moisture have been calculated and are displayed. The scores suggest the M9 mire and S27 swamp communities have the lowest nutrient levels (although the range in S27 can be quite considerable). The 2010 data seems to indicate very low Nitrogen scores are still present on the northern and southern banks of the loch.

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Table of Contents **Page**

Acknowledgements

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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 Kings Myre, 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 Kings Myre.

2.1 Sampling 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 15 cm 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 near Perth 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

Kings Myre SSSI (Figure 1) is located in the Tay Valley, north of Stanley. The site (10.93 ha) is a small kettle hole and is important for open water transition fen, particularly the change in vegetation from open water to dry land.

Not part of the notified interest, the loch is used by a range of breeding and wintering wildfowl species, including coot and mute swan. Insects include two rare water beetle species, a rare fly and dragonflies. Otters have also been seen on the site.

The loch is thought to have been created by extraction of peat and clay and then through raising the water levels in 1990 by damming the eastern outflow. Historic maps from the 1800s show the presence of the loch (Figure 2). The site was once used as a water supply for neighbouring farms but is now stocked with rainbow trout a couple of times a year for boat fishing.

The Forestry Commission owns the plantations surrounding the loch, which are currently used by people for walking. Future woodland management is to include increasing the proportion of land allocated to broadleaved species and wetland.

Figure 1. Site Boundary – Kings Myre

Figure 2. Ordnance Survey Six Inch 1843 – 1882 map (Source: National Library of Scotland)

3.1.1 Site designation and specific targets

Kings Myre SSSI was designated in 1983. The features for which the SSSI is designated, as well as its pressures are detailed in Table 1. The emergent vegetation surrounding the myre is mainly sedge swamp and rich fen vegetation, with small areas of willow at the SE corner and at the west and east ends of the myre. Both the swamp and fen vegetation contain several plant species of restricted distribution in east Perth and Kinross. There are scattered areas of wet grassland, mainly on the north side of the myre. Adjacent to and surrounding the majority of the myre is coniferous woodland. The myre is nutrient rich, with abundant growth of macrophytes.

Table 1. Designated features and their pressures at Kings Myre SSSI

SSSI features	Feature Category	Summary Condition / Latest Condition	Pressure
Open water transition fen	Wetlands	Unfavourable Declining	a) Invasive species b) Water management

3.1.2 Site hydrology

Kings Myre SSSI is set within a relatively small surface water catchment, as shown in Figure 3. Calcium rich spring water emerges on the north side of the myre and through the bed of the loch itself. The loch water is highly alkaline, with a recorded pH of 7.12 to 9.2, and is known to be nutrient rich.

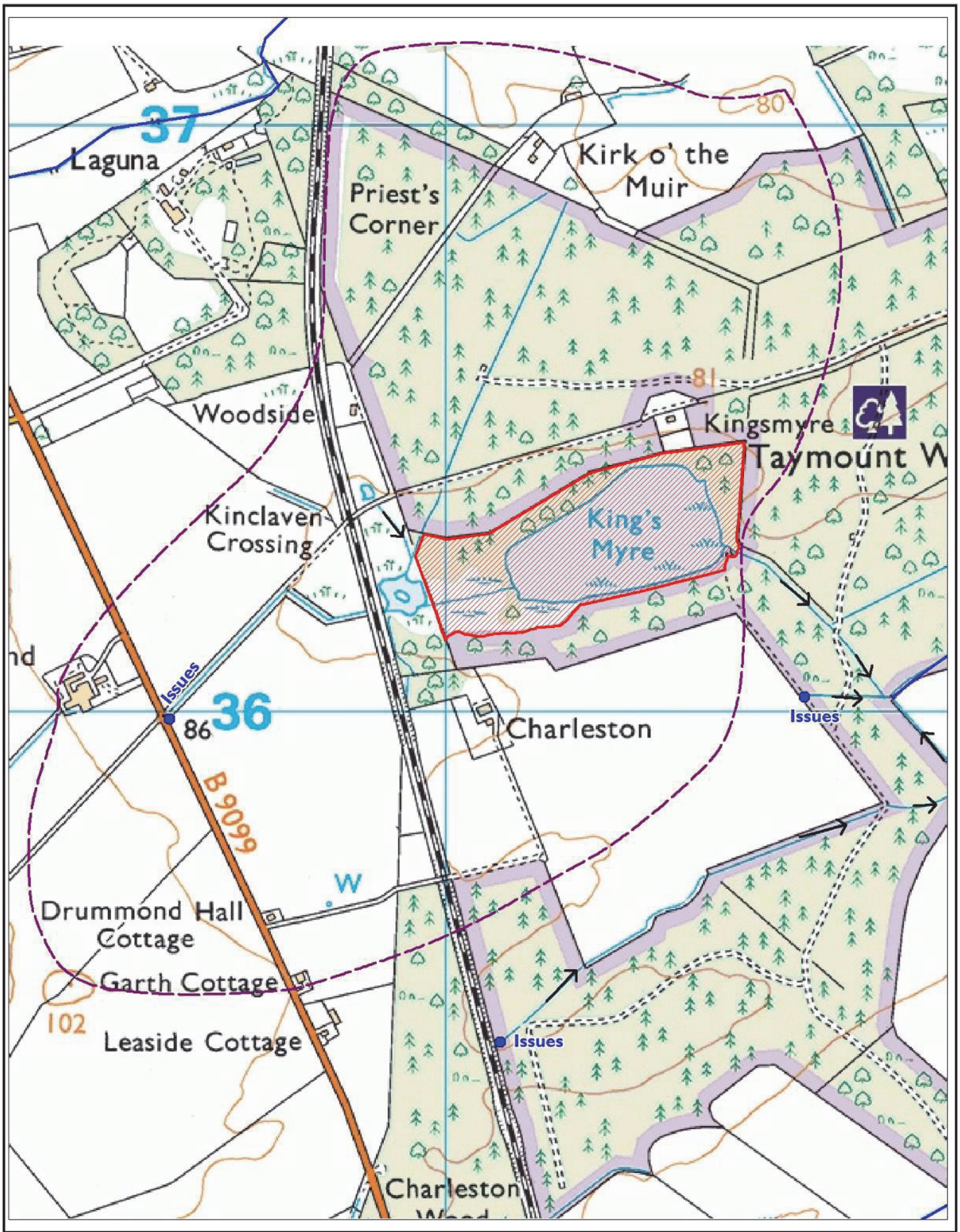
Surface water flows from west to east through ditches and the loch itself, with water flowing through a small pond in the west before entering Kings Myre (Figure 4). The outflow from King's Myre is in the south-east corner.

Kings Myre is underlain by Perth bedrock and localised sand and gravel aquifers. In 2008, the quality and quantity of the groundwater were classified as 'Good' with no trend for pollutants.

Evaluating the impact of nutrient sources on a wetland feature depends on a good understanding of how that wetland feature functions hydrologically and ecologically. One of the best systems to describe wetland functioning 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 the site (such as regular water quality sampling or water level data). However a detailed review of the nature of the catchment was conducted by Peter McPhail which provides useful information on its geology, soils, land use and vegetation. Given that the loch has formed within a kettle hole over what was previously peat and clay, but with a sandy layer and known presence of underground springs, it is likely that Kings Myre would be classified as either WetMec 13: Seepage Percolation Basins (groundwater-fed basins typically with a transmissive surface layer and a buoyant surface) or possibly WetMec 20: Percolation Basins (where some groundwater feed can occur but the status of the supply compared to surface water is unclear). Both of these classifications have sub-groups for "Water Fringe" situations and "Quag" surfaces, as is found at Kings Myre. Communities M9 mire and S27 swamps are both frequently recorded within WetMec 13 and occur here at Kings Myre.

Furthermore, groundwater flushed areas appear to be present on the northern side of the loch, which would be consistent with either WetMec 10: Permanent Seepage Slopes (summer wet surfaces usually on sloping, shallow peat), WetMec 11: Intermittent Seepage Slopes (as 10 but seasonal spring presence) or WetMec 17: Groundwater-Flushed Slopes (analogous to classes 10 and 11 but where the presence of a continuous aquitard forces groundwater to emerge at the top of the mire and flow downslope through WetMec 17). M10 mire in particular is associated with WetMec 17 as is found at Kings Myre.



Key:

= SSSI boundary

= Main watercourse

= Approximate surface water catchment

Figure 3. Kings Myre – approximate surface water catchment

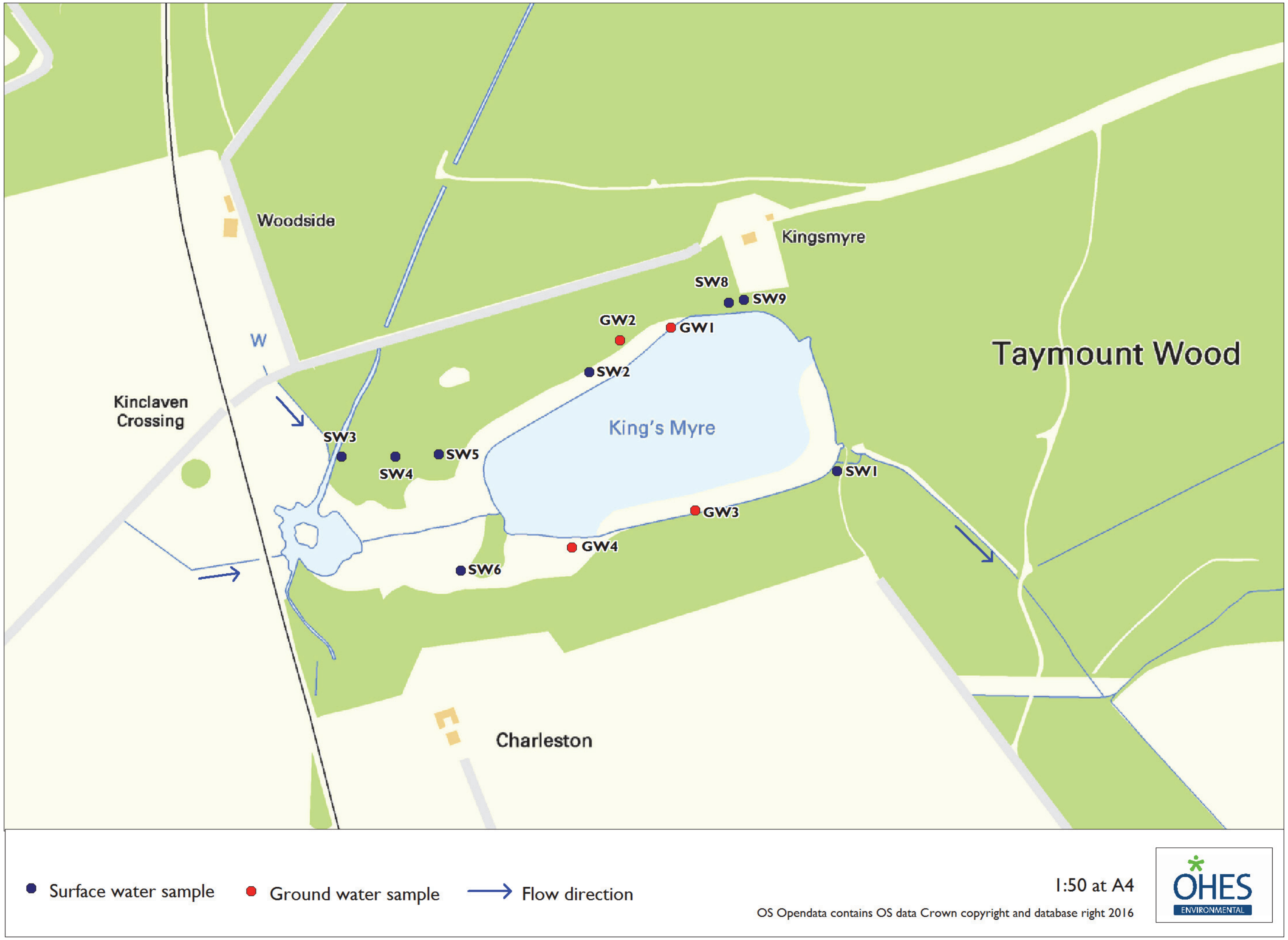


Figure 4. Kings Myre – Hydrology and Sample Locations

3.1.3 Site soils / sediments

Kings Myre is underlain by the Forfar Association, which develops mainly on water-sorted drifts and on colluvial material derived from Lower Old Red Sandstone sediments. The poorly drained drifts are believed to have been reworked and re-sorted in post-glacial times. Immediately underlying the loch and to the east is the Noncalcareous gleys Subgroup of the Forfar Association (shown in blue). The land to the north falls under the Humus-iron podzols Subgroup (shown in yellow).

To the south, west and eastern outskirts of the loch is the Balrownie Association (marked in brown on Figure 5), which are developed on drifts, often water modified, derived from Lower Old Red Sandstone sediments (containing both coarse-grained massive sandstones and fine-grained flaggy sandstones). The imperfectly drained drift is generally reddish brown and varies in texture from fine sandy loam to clay loam and has a moderate stone content of sandstones with occasional schist erratics. The soils frequently have partially sorted sandy clay loam or clay loam drift.

Observations made during the collection of water samples in 2012 record surface peat over sands and gravel to the north of the loch. On the southern edge is found unhumified and humified peat layers over dry blue sand or rock.

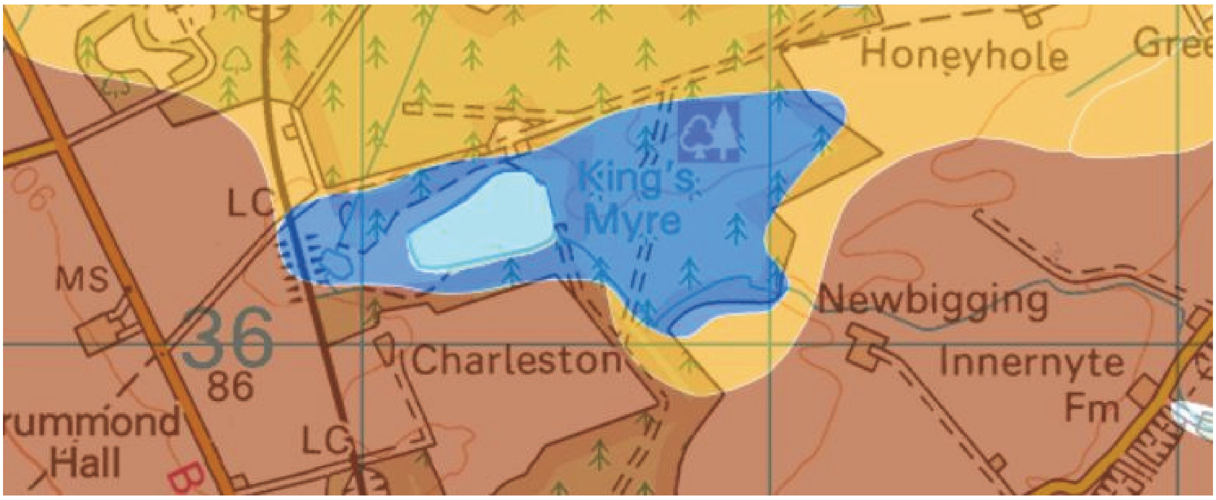


Figure 5. Kings Myre – Soil types (source: Soil Survey of Scotland Staff, 1987).

3.1.4 Site specific issues

The loch has a high nutrient status and there is often a thick ‘soup’ of algae, with Canadian pondweed also dominant (see Plate 1, courtesy of Peter McPhail). Concerns raised over the loch’s loss of condition are recorded from a number of sources in recent years. This has led to some remedial measures being taken, including the use of straw bales put across one inflow in an attempt to catch silt in 2006 and partial drainage of the loch in 2007 in an unsuccessful attempt to remove silt.

The main issue highlighted in the SCM management notes in 2010 are “the apparent nutrient enrichment leading to floristic impoverishment, changes in NVC communities and an increase in *Phalaris arundinacea,* a key indicator of increasing nutrient availability”. Farrell (2006) thought this is most likely due to run-off from the surrounding area, although enrichment from waterfowl could be contributing.

Other issues mentioned in this and other documents include:

- Excavation of a pond to the west of the SSSI in 2000 and the possible release of silt from the newly excavated pond into the loch.
- Uncertainty over whether the springs stop flowing in dry conditions, which could influence water supply and quality to the loch.
- Scrub development on the SSSI due to natural succession.
- pH levels are reportedly too high in the summer, according to fishing tenants.
- The existing buffer zone of emergent plants, marshy areas and scrub around the loch is an important element to maintain as these help absorb nutrient run-off from surrounding agricultural land. However, drainage from the surface water catchment to west of railway line is only filtered by the railway.
- Contributions from septic tanks and soakaway outfalls may also be a factor.

Plate 1. Algal blooms recorded in July 2005 at Kings Myre (courtesy of Peter McPhail).

Figure 6 shows the land use within the catchment, which is mainly agricultural and improved pasture to the west and south, and a plantation to the north and east.

Figure 6. Land use and potential nutrient sources at Kings Myre

3.2 Assessment of vegetation data

Kings Myre SSSI contains a range of open water transition fen, mire, swamp, grassland and woodland communities located around the margins of the loch and the terrestrialised margins of the site. Observations on the vegetation have been recorded on several occasions since the late 1970's; the most recent assessment took place in 2010 as part of the SCM (see Figure 7).

NVC community boundaries are most recently mapped for the whole site in 1991, but with a review undertaken in 2010.

The data suggests the presence of the following communities:

- M9 *Carex rostrata-Calliergon cuspidatum /giganteum* mire
- M10 *Carex dioica-Pinguicula vulgaris* mire
- M23 *Juncus effuses /acutiflorus-Galium palustre* rush-pasture
- M25 *Molinia caerulea-Potentilla erecta* mire
- S9 *Carex rostrata* swamp
- S12 *Typha latifolia* swamp
- S27 *Carex rostrata-Potentilla palustris* fen
- S28 *Phalaris arundinacea* fen
- MG9 *Holcus lanatus-Deschampsia cespitosa* grassland
- W3 *Salix pentandra-Carex rostrata* woodland

3.2.1 Historic evidence of community change

The earliest vegetation data available for this site, recorded in 1978 by R. Smith, describes the emergent vegetation surrounding the loch as mainly sedge swamp with dominant species of *C. rostrata, C. lasiocarpa* or *C.diandra* with abundant *Lysimachia nummularia* (indicating communities S9 or S27). The only reference made to S12 *Typha latifolia* swamp is an area in the east. Behind the emergent vegetation, on the northern side of the loch, an area of flushed grassland was recorded (consistent with M9 or M10 mire). At the western end the grassland is listed as more acidic in nature (probably M23 mire). These descriptions still broadly fit the current vegetation, but indicate considerable expansion of S12 swamp and recent appearance of S28 *Phalaris* swamp.

Vegetation data from the 1989 and 1991 surveys reflect fairly typical communities of fringing S12 swamp, followed by S27 tall herb fen (which is often relatively species-poor) and flushed grassland/mire communities on the northern and southern banks. A further loch inventory was taken in 1997 (author unknown) which still appears to be broadly consistent with previous vegetative classifications, with a few exceptions; firstly observations were made of M4 *Carex rostrata – Sphagnum recurvum* mire being present to the north of the loch in combination with S27/S9, secondly small areas of S11 *Carex vesicaria* swamp were recorded on the western loch edge.

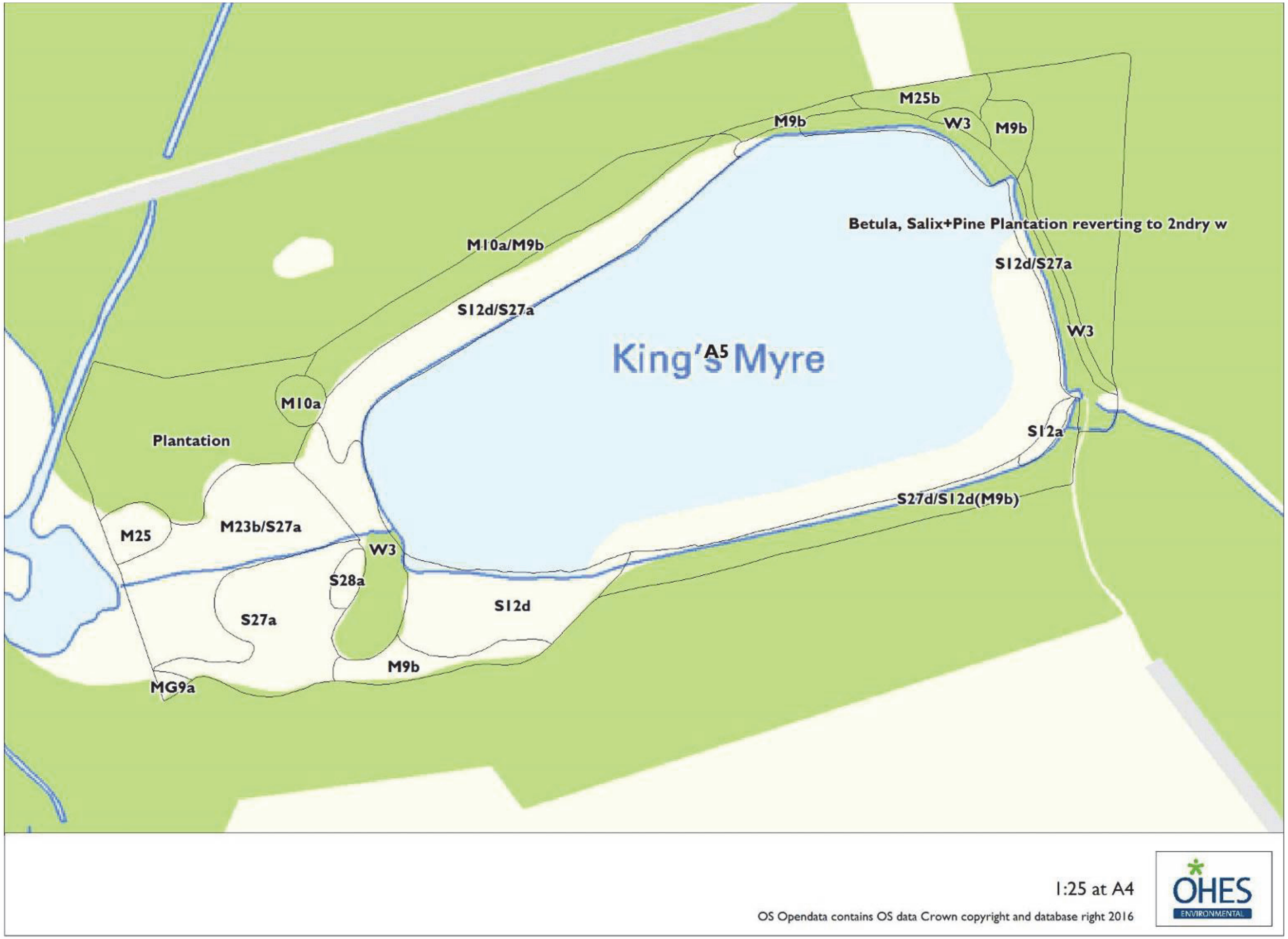


Figure 7. NVC communities recorded in 1991 (Source: SNH)

The 2010 SCM and analysis highlights a number of points regarding vegetation change. These include:

- There was a lack of locally characteristic species present at the site during the 2010 SCM. There was also a loss or degradation in S12 with an increase in *Juncus effussus* and a loss of *Carex rostrata*. M9 communities may have also declined to more of a grassy mire with a lack of bog bean on the south side. S27 at the western end appears to be severely degraded to a quaking grassy fen, which is species poor with signs of enrichment. A thick algal scum was also present on the water surface during the 2010 SCM.
- During the 2010 SCM there was evidence of clear zonation from M9 to S12 and open water was still present around the loch, resulting in a target failure. The M9/M10 flushed area was still present on the north side of the loch but it was thought it may have declined due to shading.
- A small area of *Phalaris arundinacea* (S28 tall-herb fen) mapped in 1991 at the western end of the loch has expanded and was about to encroach onto a previous area of S27, as well as in the north-west corner. *Phragmites australis* was more than rare, being classed as locally dominant and increasing, resulting in the target not being met.
- Some NVC polygons appeared to have changed from the baseline in 2010 with an increase in scrub cover.
- Change of S12 community from S12d to S12a or S12b with a perceived decline in *Carex rostrata* and increase in *Juncus effusus*. In one sample, *Juncus effusus* was co-dominant with *Typha.*
- Loss of *Carex rostrata* from S27 community at western end of the loch. A comparison of quadrat data taken at baseline in the S27 community was made with two samples taken in 2010. Samples indicate a total loss of *Carex rostrata* from relatively high DOMIN values in 1989/91 of 6-9 i.e. 26-90 % vegetation cover, to zero cover in 2010
- The area of S12 shown in Figure 7 to the south-west of the loch may in fact be a baseline error and should be classes as M9 mire.

Using the 1989, 1991 and 2010 NVC quadrat data, Ellenberg Indicator values[3] for Nitrogen and Moisture have been calculated and are displayed in Figures 8 and 9. Some adjustment was required to the 2010 data as species were recorded using the DAFOR scale rather than the previous DOMIN scale[4].

The Ellenberg Nitrogen Indicator scores suggest the M9 mire and S27 swamp communities have the lowest nutrient levels (although the range in S27 can be quite considerable). The 2010 data seem to indicate very low nitrogen scores (in this case green, but note yellow also represents *reasonably* low scores) are still present on the northern and southern banks of the loch, but that both samples taken to the west of the loch (in S27) are within the higher category of Ellenberg Nitrogen Indicator values (orange). This analysis cannot be considered conclusive because, as the samples were not taken in the exact same location each survey year, the differences in Ellenberg scores may be the result of different quadrat placement. However it does indicate that there is some cause for concern on the western loch edge.

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[3] 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 nitrogen, nutrient demanding species have a high nitrogen Ellenberg value, oligotrophic species a low one.

[4] DAFOR (Dominant, Abundant, Frequent, Occasional and Rare) were each assigned a comparative Domin class based on “Dominant” = 75% cover or more (i.e. class 9 & 10), “Abundant” = 35 to 74% cover (i.e. class 7 & 8), “Frequent” = 15 – 34% cover (i.e. class 5 & 6), “Occasional” = 3 to 14% cover (i.e. class 3 or 4) and “Rare” = 1-2% cover (i.e. class 1 or 2). For each species the lower of the two DOMIN classes were used.

The Ellenberg Moisture Indicator scores reflect that S12 swamp occupies the wettest end of the terrestrial open water transition, with the driest end occupied by M9/M10/S27 transitions on the northern and southern banks of the loch. Moisture Indicator scores from the western communities show only slight variations between years. If the data from the two 2010 samples are consistent with the trend within the western communities as a whole, this would suggest drying out is not the main cause of change in vegetative condition in the last decade. However, once again, it is emphasised that this is a very small dataset to base conclusions on.

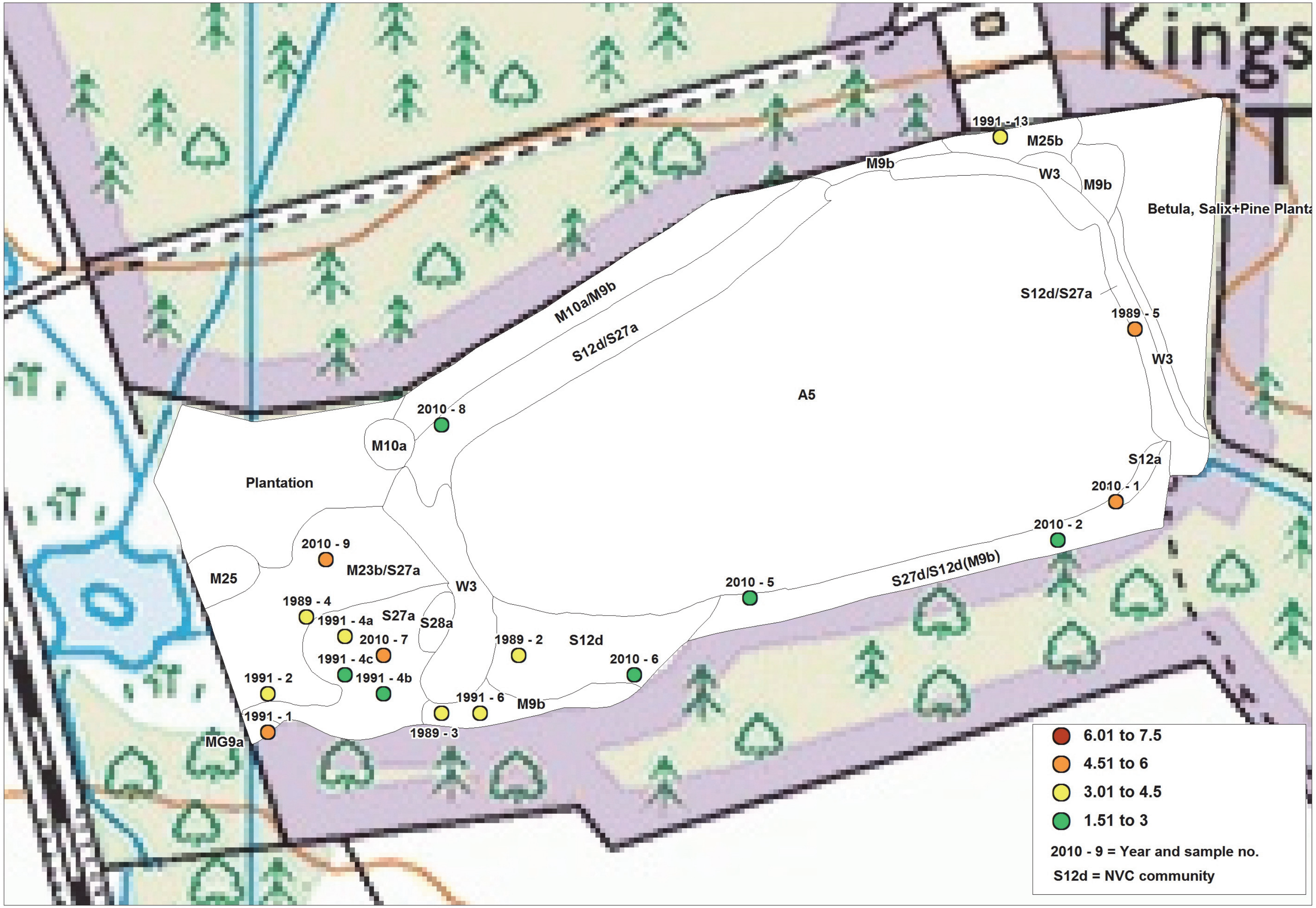

Figure 8. Ellenberg Indicator Values for Nitrogen at Kings Myre.

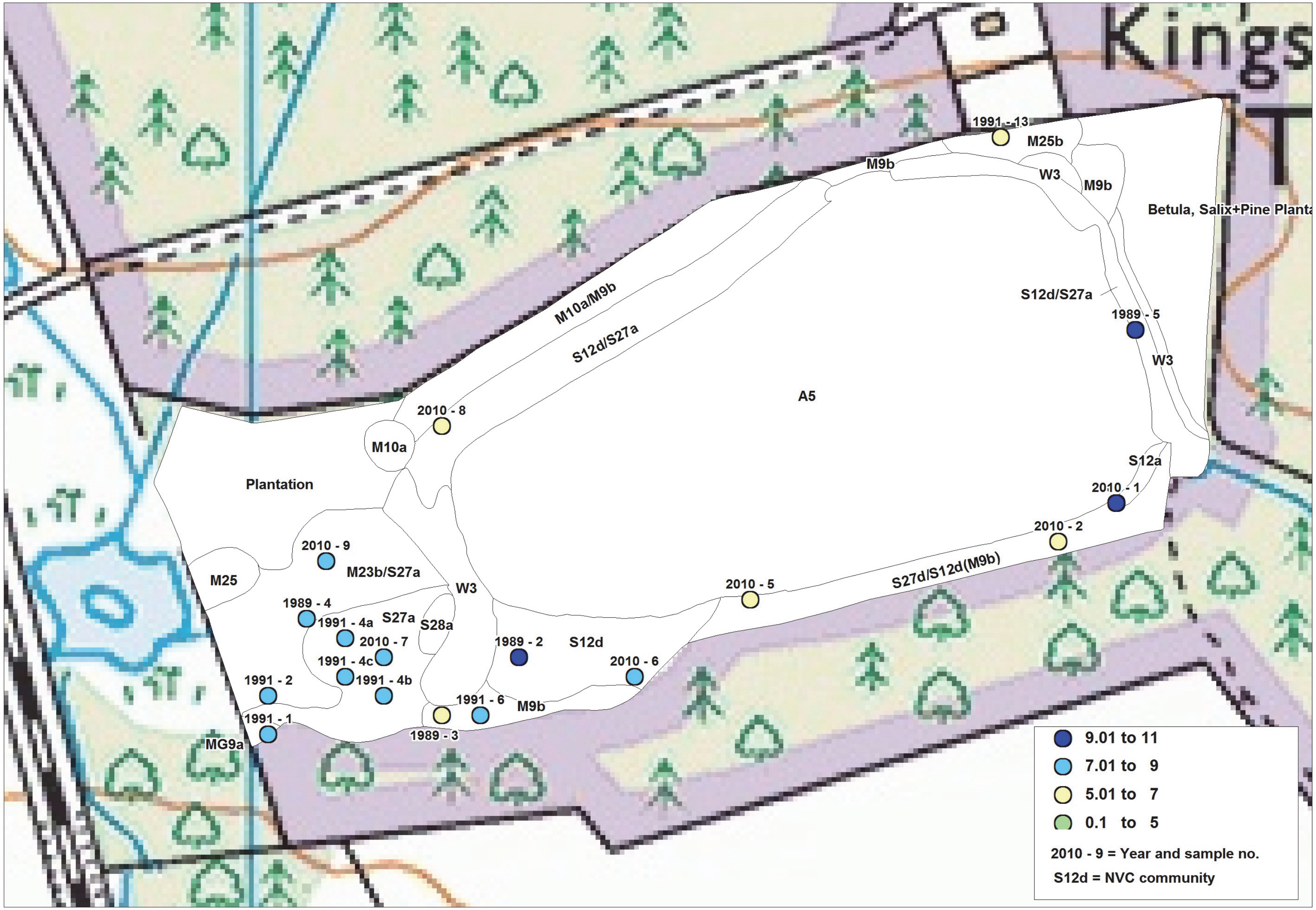

Figure 9. Ellenberg Indicator Values for Moisture at Kings Myre.

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 Kings Myre SSSI are:

- Type 2a: Marshy grassland
- Type 3:Spring, flush and seepage
- Type 4: Fen
- Type 5: Swamp

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 Kings Myre SSSI include:

- M23 *Juncus effuses/acutiflorus – Galium palustre* rush-pasture
- M25 *Molinia caerulea-Potentilla erecta* mire
- MG9 *Holcus lanatus-Deschampsia cespitosa* grassland

These communities range from relatively species-poor communities whose distribution is widespread across Scotland (such as MG9), to those which can contain considerable plant diversity (such as M23 and M25). 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 guideline 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 guideline 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: 6 (or 26 mg/l as NO_3) for <175 m AOD

3.2.2.2 Type 3 Springs, flushes and seepages

Type 3 wetlands are directly supplied by groundwater, with a water table typically maintained at or just below the ground surface for most of the year. They generally have a very localised distribution, where groundwater outflows from a mineral aquifer due to the presence of sloping ground or a low-permeability layer (aquitards). Springs refer to point-source outflows, seepages refer to strips of groundwater outflow and flushes are areas of low-permeability substrate located below springs and seepages, where the ground is kept wet by downslope flow (ER37).

The Type 3 wetlands relevant to Kings Myre SSSI include:

3c: Other Springs – Springs which occur at lower altitude than montane situations. Flows can be permanent or intermittent, consisting of varying mineral content. No tufa is present under this category (ER37).

3d: Seepages and flushes – Where diffuse water output occurs across both small and large areas. Vegetation can include extensive bryophyte coverage (such as Sphagnum species) and combinations of small sedges and rushes.

Types 3c and d include H7230 Alkaline fens and H7140 Transition mires and quaking bogs, both of which are Annex 1 habitats covered by the EC Habitats Directive.

The main NVC communities listed under Type 3c and d which have been recorded at Kings Myre SSSI include:

- M10 *Carex dioica–Pinguicula vulgaris* mire - usually associated with soligenous mires irrigated by base-rich, oligotrophic and highly calcareous waters (Rodwell, 1992). It is often found around suitable springs and seepages and can be seen as the northern counterpart of M13 mire. The community can be reasonably species-rich and can be transitional with communities such as M23 *Juncus effusus –Galium palustre* rush–pasture, M9 *Carex rostrata–Calliergon* mire and S27 *Carex rostrata–Potentilla palustris* tall-herb fen (Wheeler, Shaw and Tanner, 2009).

- M4 *Carex rostrata- Sphagnum recurvum* mire – occurs in pools and seepage areas across a range of mire situations, where waters are fairy acid and only slightly enriched (Rodwell, 1995). Calcium content in the source waters for M4 are believed to be less than those of M5 *C.rostrata-S.squarrosum* mire.

ER37 data and guidelines for springs and seepages are presented in Table 3. Under the 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 0.5 mg/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 Draft)

	Springs/seepages			
Parameter	**1st Quartile**	**Median**	**3rd Quartile**	**Guidelines**
pH (-)				
Dissolved Oxygen (%)				
Electric Conductivity (mS/cm)				
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 Kings Myre SSSI are:

- M9 *Carex rostrata–Calliergon cuspidatum / 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 are available for Scotland but quoted as always >5 and usually >6 for all of its range (Rodwell, 1991).

- M10 *Carex dioica-Pinguicula vulgaris* mire – see notes within Springs, flushes and seepages (3.2.2.2).
- M4 *Carex rostrata- Sphagnum recurvum* mire – see notes within Springs, flushes and seepages (3.2.2.2).
- S27 *Carex rostrata-Potentilla palustris* tall-herb fen - occurring in wet valley bottom/basin locations, where strongly sub-surface water levels are outside of normal conditions for the community. Despite containing a high number of total species, most stands are relatively species-poor (Wheeler, Shaw & Tanner, 2009). It is typically of moderate fertility, with transitions to M9 in mesotrophic conditions, and S9 in deeper, oligotrophic waters (ER37). Stands of S27 may be resistant to moderate nutrient inputs, but high levels of eutrophication lead to impoverishment, with an increased prominence of species like *Agrostis stolonifera, Juncus effusus* and *Phragmites australis* (Wheeler, Shaw & Tanner, 2009)

ER37 data and thresholds for Fens are presented in Table 4. UKTAG (2012 & 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 0.20 mg/l used in laboratory test for some of the samples”.

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

	Fen			
Parameter	**1st Quartile**	**Median**	**3rd Quartile**	**Threshold**
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 5 Swamp

Swamps occupy the transition between open water and dry land across a range of different trophic states. They typically occur where water levels are above the ground for most of the year, with the main water supply from surface waters (such as in floodplains and around loch shores). However, groundwater can be important in the absence of a surface water supply. They usually consist of species-poor, emergent vegetation but are still important as a UK BAP priority habitat.

The main NVC communities listed in WWF Consulting (2009) and which are found at Kings Myre SSSI are:

- S9 *Carex rostrata* swamp - occurring within shallow to moderately deep swamps within oligotrophic to mesotrophic waterbodies/wetlands. It can occur at variable altitudes on organic substrates, or more infrequently on silty or sandy substrates (Rodwell, 1995). It is widespread across the north and west of the UK in suitable situations.
- S12 *Typha latifolia* swamp - characteristic of mesotrophic to eutrophic waters within still or slow moving waters. S12 is highly tolerant of water level variations and prefers circumneutral to basic waters on silty substrates (Rodwell, 1995). It is generally rather species-poor and has a distribution throughout the UK, though it tends to be more uncommon in the north.
- S28 *Phalaris arundinacea* swamp – typically occurring on the margins of mesotrophic to eutrophic waters, with fluctuating water levels (though the community is not tolerant of permanent flooding). It tends to occur where summer water levels are consistently below the surface and is characteristic of mineral soils, but can be found on organic substrates also (Rodwell, 1995). S28 occurs across the UK within lowlands and on upland margins.

ER37 data and guidelines for Swamps are presented in Table 5. Mean nitrate levels for groundwater-fed swamp in good condition are reported in UKTAG 2012 as 4.9 and 3.5 mg/l $N\text{-}NO_3$ for mesotrophic and oligotrophic swamp respectively (ER37). Swamp groundwater sampled in Scotland was significantly lower than this (third quartile value of <0.25 mg/l $N\text{-}NO_3$). This suggests that all sampled Scottish swamps are in good condition.

Phosphate samples reported in the UKTAG (2012) show mean values for swamp in good condition of 0.050 and 0.034 mg/l $P\text{-}PO_4$ for mesotrophic and oligotrophic swamp respectively (ER37). However the results for poor condition suggest condition is not strongly related to groundwater phosphate levels in swamps. The UKTAG values for good condition are comparable with Scottish samples. However a threshold value has not been set at this stage due to inconclusive results.

Table 5. Groundwater guidelines for Swamp in Good Condition (Source: ER37)

	Swamp			
Parameter	**1st Quartile**	**Median**	**3rd Quartile**	**Guideline**
pH (-)	5.7	6.3	7.1	
Dissolved Oxygen (%)	15	24	36	
Electric Conductivity (mS/cm)	0.24	0.26	0.43	
Calcium (mg/l)	10	26	44	
Magnesium (mg/l)	3.6	5.4	16	
Sodium (mg/l)	5.5	9	18	
Phosphate (mg/l)	0.024	0.062	0.1	None set
Nitrogen (total) (mg/l)	2	3	7	
Nitrate (mg/l N-NO_3)	0.25	0.25	0.25	Guideline: Meso = 5 (or 22 mg/l as NO3) Olig = 4.1 (or 18 mg/l as NO3)

3.3 Assessment of ground water samples

Groundwater samples taken at Kings Myre have been compared with the levels recorded in vegetation types as shown in section 3.2. Groundwater concentrations were used as opposed to surface water concentrations for several reasons; firstly that almost all wetlands will have a component of groundwater influence, secondly that groundwater thresholds can often be more demanding than surface water thresholds and thirdly that the presence of a sandy base to the loch (as proved during the soil sampling) suggests some movement of water through the loch bed is possible.

Table 6 indicates that the vegetation currently found around the sample locations is typically consistent with the data recorded for Scotland (ER37) and for guideline/threshold values. However it should be noted that no groundwater samples were taken from the areas of most concern, such as the western area of S27. Total Nitrogen levels were higher at Kings Myre than generally recorded within the dataset from Scotland, but both Phosphate and Nitrate levels were reasonably low.

No groundwater samples were taken within/near to the marshy grassland habitat present on site and therefore no comparison could be made with published thresholds for this wetland type.

Table 6. Groundwater samples at Kings Myre compared to Wetland Type for Scotland. Red text denotes sample exceeds 3rd quartile.

	King's Myre	King's Myre	King's Myre	Swamp			King's Myre	King's Myre	King's Myre	Fen		
Sample	**GW1 (nr S12)**	**GW3 (nr S12)**	**GW4 (in S9)**	**1st Quartile**	**3rd Quartile**	**Guideline**	**GW1 (in M9)**	**GW2 (in M9)**	**GW3 (in M9)**	**1st Quartile**	**3rd Quartile**	**Threshold**
pH (-)				5.7	7.1					6.4	7.4	
Dissolved Oxygen (%)				15	36					18	28	
Conductivity (mS/cm)				0.24	0.43					0.37	0.69	
Calcium (mg/l)	33	21	23	10	44		33	46	21	12	55	
Magnesium (mg/l)	7.7	3.7	4.6	3.6	16		7.7	7.6	3.7	3.4	14	
Sodium (mg/l)	12	4.6	8.1	5.5	18		12	14	4.6	5.4	14	
Phosphate (mg/l)	<0.02	0.023	<0.02	0.024	0.1	None set	<0.02	0.02	0.023	0.064	0.1	None set
Nitrogen (total) (mg/l)	7	12	4.6	2	7		7	15.5	12	1	5.1	
Nitrate (mg/l N-NO_3)	<0.5	<0.5	<0.5	0.25	0.25	Guideline: Meso = 5 (or 22 mg/l as NO3) Olig = 4.1 (or 18 mg/l as NO3)	<0.5	0.98	<0.5	0.25	0.25	Threshold: <175 m Meso = 5 (or 22 mg/l as NO3) Olig = 4.5 (or 20 mg/l as NO3)

3.4 Assessment of surface water samples

3.4.1 Threshold levels

There are currently several relevant documents providing guidance on water quality standards for surface waters on Good Ecological Status (GES) or High Ecological Status (HES). The most up-to-date of these include the Scotland River Basin District (Standards) Directions 2014 (SRBDD, 2014) and JNCC Common Standards Monitoring for Freshwater Lakes (2015). However useful information is also available within the ECOFRAME report on implementation of the WFD by Brian Moss (2003).

For the purposes of this study, the primary standards used for variables are sourced from the SRBDD 2014 because they are the latest interpretation of the WFD for Scotland and are therefore highly relevant. The standards referred to in the other documents (such as JNCC standards) are referred to in some circumstances. Where SRBDD standards are not provided a range of published documents are used to define standards.

Under the SRBDD (2014), King's Myre is classified as shallow (3 to 15 m depth), freshwater, salmonid, lowland (less than 200 mAOD) loch of high alkalinity (>100 mg/l). This equates to Ecotype 14 (small temperate lake, with a catchment geology of rock and a conductivity between 100 – 800 uScm) within the ECOFRAME document (Moss, 2003). Table 7 presents the SRBDD 2014 standards compared to those recorded from Kings Myre.

Table 7. In-loch water quality standards for Kings Myre. Red text indicates site exceeds standard.

Variable	SRBDD (2014)		JNCC	ECOFRAME		King's Myre
	GES	HES		Good	High	(Sample SW1)
Total Ammonia as N	0.6 mg/l	0.3 mg/l	-	-	-	1.6 mg/l (Ammonium only)
Total Nitrogen	-	-	<1.5 mg/l	0.6 – 1.0 mg/l	<0.6 mg/l	4.6 mg/l
Acid Neutralising Capacity	>20 µeq/l	>40 µeq/l	>40µeq/l	-	-	?
Dissolved Oxygen	7 mg/l	9 mg/l	As SRBDD	-	-	?
Salinity/Conductivity	<1000 µScm		-	100 – 800 µScm		270 µScm
Total Phosphorus	23 µg/l	16 µg/l	35 µg/l	30-50 µg/l	<30 µg/l	26 µg/l (Phosphate only)
pH	-	-	7 - 9	6 - 9		7.12-9.1

3.4.2 Current surface water quality status

Eight surface water sampling points were monitored by SNH during the single sampling round (conducted in February 2012). These included several input channels (SW2, 3, 4, 6 and 8), surface water adjacent to the loch (SW5 and 9) and the outlet channel (SW1), see appendix 1 for raw data.

Figure 10 shows the results of Ammonium recording at Kings Myre against SRBDD 2014 standards. It indicates that at the time of survey, the loch was above threshold values, with the majority of inflows bringing in consistent concentrations of Ammonium, with the exception of a substantial peak in SW9 (taken within ochreous silty flow opposite Kingsmyre Cottage). The outflow shows the accumulation of the various inflow sources, with an Ammonium concentration of 1.6 mg/l.

Total Nitrogen levels (as shown in Figure 11) indicate that other forms of Nitrogen may also be problematic, with TN recorded in all surface samples exceeding JNCC threshold levels. Again it appears that there is a source of Nitrogen near SW9, which could be the septic tank at Kingsmyre Cottage. It also appears that the northern catchment may contain more nitrogen than the southern catchment as readings were higher at the northern monitoring points (SW4, SW5, SW2, SW8 and SW9) than the south (SW6). SW4 in particular shows high TN levels and was taken from an inflow into the SSSI from a pond which showed a strong flow.

Total Phosphorus levels were recorded at Kings Myre but the levels of determination were below those useful in assessment against threshold values (i.e. all samples were marked as <0.2 mg/l). Instead, Phosphate Low Levels ranged between Poor and Good, with the exception of SW9, which again may be being influenced by any septic tanks at Kingsmyre Cottage (Figure 12). Given that these values do not take into account the full TP concentration, it can therefore be assumed that TP levels exceed SRBDD 2014 standards.

Surface water points SW4 and SW6 in particular show high Phosphate levels, both of which occur at the western end of the SSSI where there is evidence of communities (such as S27) loosing condition. Interestingly, these higher Phosphate levels are not reflected in the main inflow from the north (SW3), which could indicate either; i) the main source of Phosphate enrichment (apart from Kingsmyre cottage) is coming from the other inflows which reach the western edge of the loch but which were not sampled, or ii) enrichment from the main northern inflow (SW3) is sporadic (such as would occur if the Total Phosphorus concentrations were high in suspended sediments and were only brought down the channel in high flow conditions).

The sample point at the outflow (SW1), which is also the closest approximation we have to in-loch conditions, showed some of the lowest surface water Phosphate concentrations recorded on the site and were similar to groundwater phosphate concentrations. It is therefore probable that some of the spring inputs into the loch are, to some degree, compensating for enriched input from surface waters. As a consequence, if these spring inputs are intermittent or seasonal in nature, there would be a tendency for nutrient concentrations to build up during the drier months, exacerbating algal blooms.

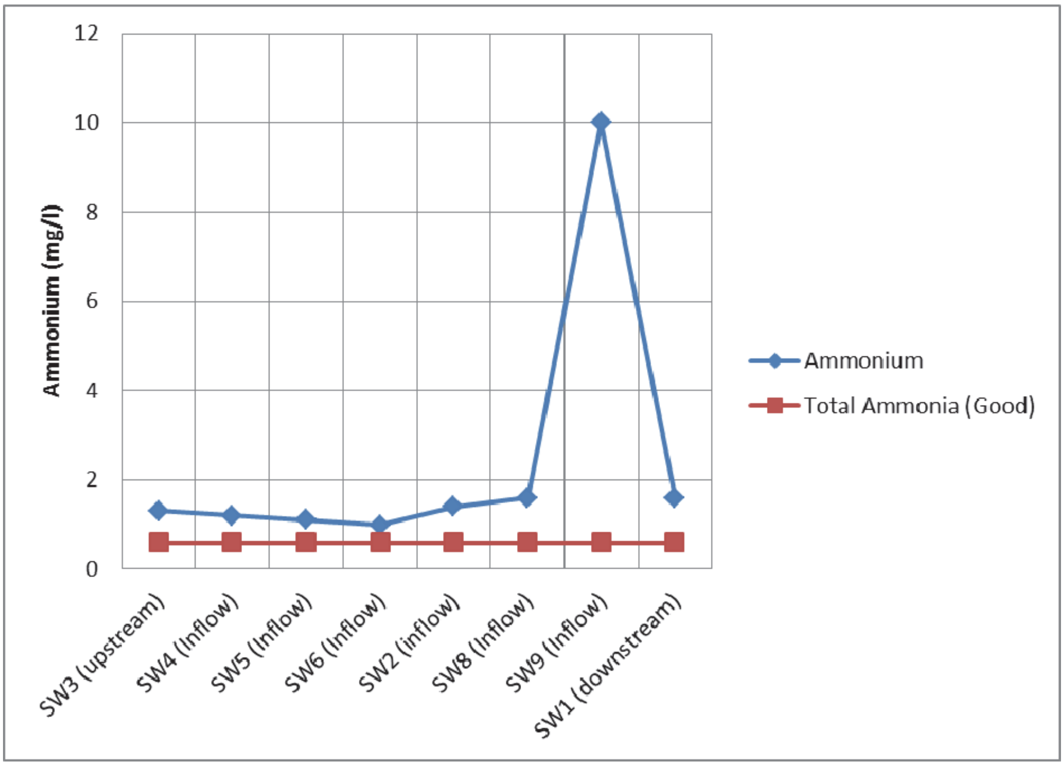

Figure 10. Ammonium recording at Kings Myre (blue line) against SRBDD 2014 standards for Total Ammonia

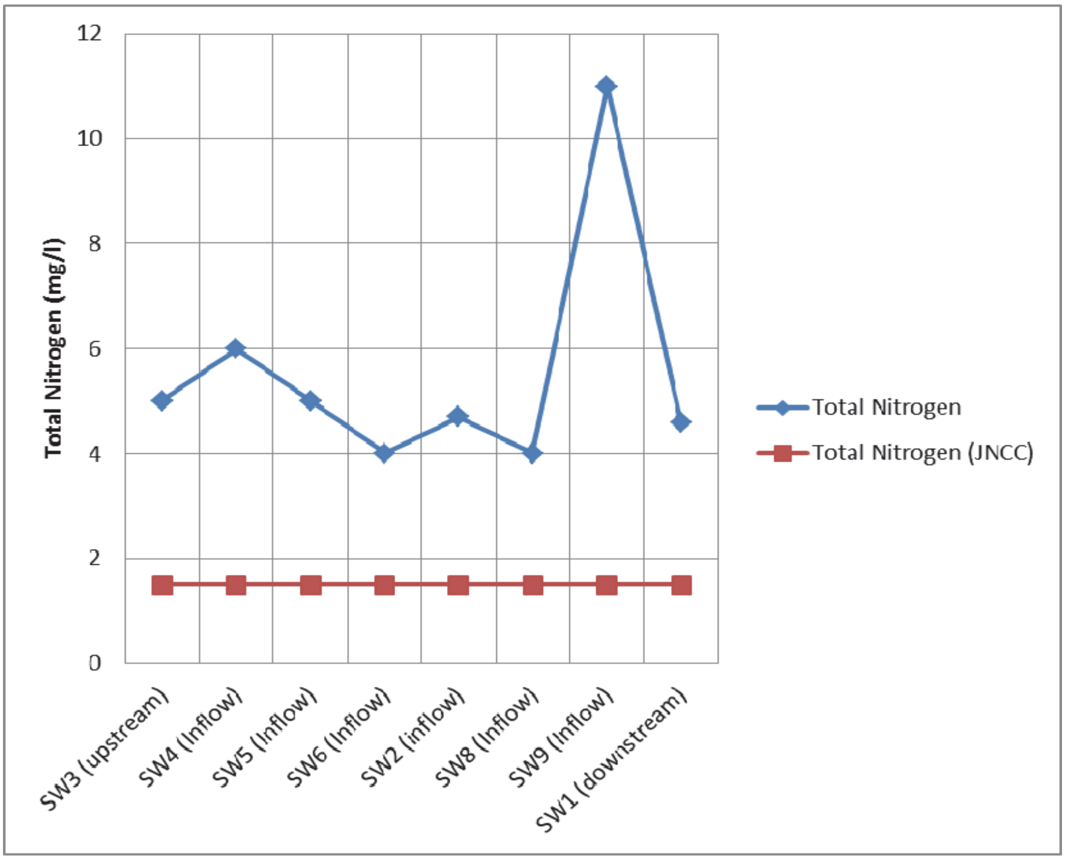

Figure 11. Total Nitrogen recording at Kings Myre (blue line) against JNCC standards.

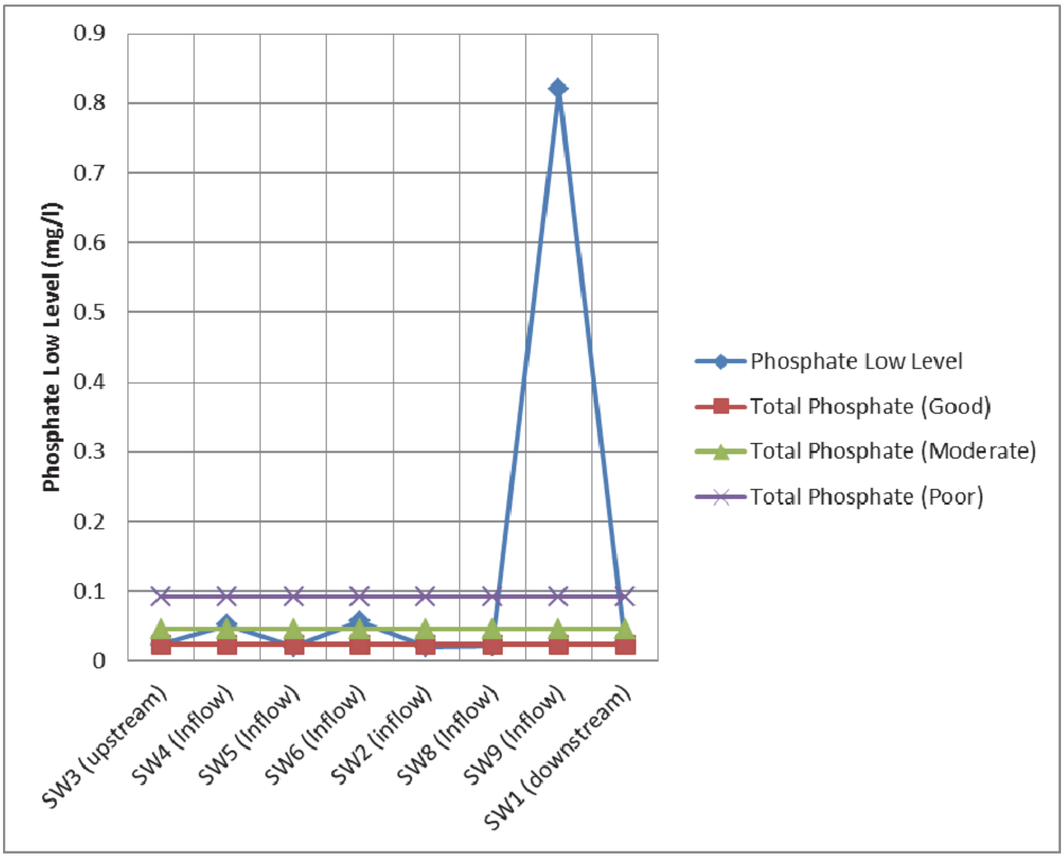

Figure 12. Total Phosphorus/Phosphate recording at Kings Myre (blue line) against WFD threshold values

3.4.3 Summary of tropic state and site vulnerability

Trophic state:

The categories of trophic state used within this report are as follows:

- **Dystrophic:** referring to those waterbodies with brownish waters as a result of high concentrations of humic substances and organic acids suspended in the water (also referred to as Humic lakes). They are typically acidic and nutrient-poor (though this is not always the case).
- **Oligotrophic:** those waterbodies with low productivity as a result of low nutrient content. As a consequence, algal production is low and the waterbody retains very clear waters.
- **Mesotrophic:** namely lakes with an intermediate level of productivity, usually with clear waters and moderate cover of submerged plants.
- **Eutrophic:** referring to those waters with high biological productivity due to high levels of Nitrogen and Phosphorus. The water body may be dominated by either aquatic plants or algae.
- **Hypereutrophic:** those very nutrient-rich waterbodies which are characterized by frequent algal blooms and low visibility in the water column (less than 3 feet).

In addition to the definitions of trophic state provided in the JNCC CSM for freshwater lakes and the SRBDD 2014, the relationships between Trophic State/class and variables such as Phosphorus and Chlorophyll are shown in Table 8.

Table 8. Nutrient status classification scheme (SEPA).

Description	Biological Factors	Chemical Factors
Oligotrophic (surrogate mean [TP] value; 8 $\mu g\ l^{-1}$)	High diversity, low biomass of biota. Phytoplankton blooms rare, macrophytes may be rare or adapted to low nutrient levels. Profundal benthos and plankton typical of nutrient poor lakes.	Mean total phosphorus ≤ 10 $\mu g\ l^{-1}$. Mean chlorophyll-<u>a</u> ≤ 2.5 $\mu g\ l^{-1}$. Max. chlorophyll-<u>a</u> ≤ 8.0 $\mu g\ l^{-1}$. Mean Secchi transparency ≥ 6.0 m. High oxygen concentration in hypolimnion.
Mesotrophic (surrogate mean [TP] value; 25 $\mu g\ l^{-1}$)	High diversity, variable biomass of biota. Phytoplankton blooms occur, macrophytes often diverse and abundant. Profundal benthos and plankton often intermediate between oligotrophic and eutrophic types.	Mean total phosphorus 10-35 $\mu g\ l^{-1}$. Mean chlorophyll-<u>a</u> 2.5-8 $\mu g\ l^{-1}$. Max. chlorophyll-<u>a</u> 8-25 $\mu g\ l^{-1}$. Mean Secchi transparency 6-3 m. Oxygen concentration may show some depletion in hypolimnion.
Eutrophic (surrogate mean [TP] value; 80 $\mu g\ l^{-1}$)	Lower diversity, high biomass of biota. Phytoplankton blooms occur regularly, macrophytes may be limited in diversity and abundance. Profundal benthos and plankton typical of nutrient rich lakes.	Mean total phosphorus 35-100 $\mu g\ l^{-1}$. Mean chlorophyll-<u>a</u> 8-25 $\mu g\ l^{-1}$. Max. chlorophyll-<u>a</u> 25-75 $\mu g\ l^{-1}$. Mean Secchi transparency 3-1.5 m. Oxygen concentration frequently depleted in hypolimnion.
Hypertrophic	Low diversity of tolerant biota, biomass may be very high. Severe phytoplankton blooms may be almost continuous, macrophytes may be limited to tolerant taxa or absent. Profundal benthos and plankton dominated by tolerant forms.	Mean total phosphorus ≥ 100 $\mu g\ l^{-1}$. Mean chlorophyll-<u>a</u> ≥ 25 $\mu g\ l^{-1}$. Max. chlorophyll-<u>a</u> ≥ 75 $\mu g\ l^{-1}$. Mean Secchi transparency ≤ 1.5 m. Severe oxygen concentration depletion in hypolimnion.

Using SW1 data, this would probably equate to a borderline Meso-Eutrophic class for the loch in terms of Phosphorus levels. However, given that Nitrogen levels are also above standards this report concludes that <u>the trophic state of Kings Myre surface water is Eutrophic.</u>

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

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

Source	**King's Myre**	
	Vulnerability	**Details of Factors**
EXTERNAL SOURCES		
1. Agriculture	Moderate	- Improved pasture and arable land are present particularly to the west and south of the loch, which will be generating a supply of nutrients. - Drainage of the catchment permits the flushing of fertiliser and nutrients into nearby watercourses which will eventually lead into the loch. - There is some indication that spring input into the loch may be partially compensating for enriched surface water sources within the loch itself.
2. Human population	Moderate - High	-Run off and potential septic tank outfalls at Kingsmyre Cottage are likely to be contributing to the enrichment of the site.
3. Aerial deposition	Low-Moderate	- Deposition rates within this part of the UK are lower than recorded in the south. Thus atmospheric Total Phosphorus input into the catchment is small, although Total Nitrogen remains a major contributor.
4. Regional Groundwater	Low	- The site is partially spring fed so regional groundwater contributes to the water balance within the catchment. Regional groundwater quality is reported to be "Good".
INTERNAL SOURCES		
1. Wildlife	Low	- Several bird species are recorded in large numbers on the reserve, which may represent a source of nutrient input, depending on the species. For example, species such as coots (which feed within the waterbody) will not represent an input of nutrients, whereas species such as geese (which often feed outside of a catchment but roost within it) can contribute significantly to Phosphorus and Nitrogen levels. - However, Total Phosphorus coefficients for individual birds are very small so that, even when occurring in large numbers, overall contribution to the nutrient budget is likely to be small.
2. Site Management	Unknown	- The site is stocked annually with rainbow trout, which if fed artificially could be contributing nutrients to the system. - It is unclear how much of the mire and tall-herb communities are currently being grazed or mown, but the absence of such management will inevitably lead to a build up of plant litter and add to the nutrient store within the site.
3. Lake sediment	Unknown	- A considerable store of nutrient may be present within the loch in sediment form. The seasonal release of stored nutrients within the loch sediments will occur naturally under certain conditions. - If excess nutrients continue to be generated from other practises within the catchment, the subsequent store of nutrients available for release within the reserve will continue to build up.

3.5 Assessment of soil samples

Soil chemistry was sampled at four locations within Kings Myre (three of which were in M9 *Carex rostrata-Calliergon cuspidatum /giganteum* mire and one was in S9 *Carex rostrata* swamp. 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

Table 10 presents the soil chemistry data for King's Myre samples against the ER37 data. The results show that levels of Magnesium, Calcium, Sodium and Nitrogen in the soil are all at the lower end of the range observed in Scottish samples (though it should be noted that the 3rd Quartile range presented for Nitrogen is relatively high and probably reflects enriched sites within the dataset). However, in all four samples from Kings Myre, Phosphate concentrations were above those typically recorded in swamp or fen. Soil sample 3 (GW3) was particularly high in Phosphate both within the root layer and below. This is likely to be due to its location within a "silt fan" at the southern edge of the loch, on fibrous peat, underlain by "watery slop" at c.50 and then rock at c60 cm.

Soil sample 1 (GW1) was taken within M9 mire, with a loose fibrous root mat overlying a layer of humified peat over sands and gravels. The soil moisture content was extremely low at the root layer, but much higher at depth (within the sands and gravels). Soil sample 2 (GW2) was also taken from M9 mire to the north of the loch, which once again had a much lower moisture content in the root layer when compared to below. The floating vegetation mat at this location was noted to be creating an elevated water table which was above that of the loch itself.

Soil sample 4 (GW4) was taken at the south of the loch in a rootmat, underlain by peat and sand. Once again, the below root sample had a much higher moisture content than the root layer, suggesting the water table generally sits slightly below the surface within several of these mire stands.

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

	Kings Myre		Kings Myre		Kings Myre		Swamp		Kings Myre		Kings Myre		Kings Myre		Fen	
Sample	**Soil1 Root (nr S12)**	**Soil1 below (nr S12)**	**Soil 3 Root (nr S12)**	**Soil 3 below (nr S12)**	**Soil 4 Root (in S9)**	**Soil 4 below (in S9)**	**1st Quartile**	**3rd Quartile**	**Soil 1 Root (in M9)**	**Soil 1 below (in M9)**	**Soil 2 Root (in M9)**	**Soil 2 below (in M9)**	**Soil 3 Root (in M9)**	**Soil 3 below (in M9)**	**1st Quartile**	**3rd Quartile**
Calcium (mg/kg)	590	<100	3,000	<100	<100	<100	140	5,800	590	<100	<100	<100	3,000	<100	960	12,000
Magnesium (mg/kg)	1,300	370	420	75	540	75	410	3,400	1,300	370	2,800	1,300	420	75	1,500	3,800
Sodium (mg/kg)	16	49	18	<0.2	14	16	17	140	16	49	49	27	18	<0.2	74	280
Phosphate (available) (mg/l)	8.7	30	32	16	4	26	2.9	12	8.7	30	16	18	32	16	2.7	9.5
Nitrogen (total) (%)	0.14	0.23	0.5	0.56	0.5	0.5	0.17	1.2	0.14	0.23	0.06	0.85	0.5	0.56	0.25	1.4
Nitrogen (extractable) (mg/kg)	0.15	0.19	<1.0	<0.1	<0.1	<0.1	0.43	0.9	0.15	0.19	0.19	0.14	<1.0	<0.1	0.4	1.4
Total organic carbon (%)	1.4	38	6.9	15	6.2	19	4.1	25	1.4	38	0.29	13	6.9	15	3.7	12
Potassium (total)	110	-	85	19	60	75	-	-	110	-	1,000	95	85	19	-	-
Soil Moisture Content %	22	1,727	1,103	1,736	372	1,519	-	-	22	1,727	27	480	1,103	1,736	-	-

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.
- 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 sampling did not include measurements from all of the inflow channels, or include a within-loch sample. Therefore it cannot be determined which source is the main contributor of nutrients into the loch.
- 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.
- As stated in the ER37 report, insufficient numbers of samples within certain wetland types have limited the possibility of defining target thresholds, and therefore certain wetland types will need to be revisited once additional data has been gathered. In the short term, this means that wetland types such as Fens, which currently contains a wide range of NVC communities, may appear to be more tolerant of nutrient-rich situations than is actually the case. For example, assessment of lowland wetland communities across England and Wales (by Wheeler, Shaw and Tanner, 2009), states that M5 has a mean substrate fertility[5] (mg phytometer) of 13.8 (and a range of 4 to 29), whereas M10 has a mean substrate fertility of 6.5 (and a range of 3 to 18). Both of these communities are currently placed within the same wetland type of "Fen" and are given the same threshold/guidance levels.
- There were insufficient data for any statistical analysis.
- Conclusive evidence of vegetative change is limited due to the absence of permanent vegetation monitoring plots.

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.

Other remedial measures, such as re-routing water supplies, de-silting 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

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[5] Wheeler, Shaw and Tanner state that "Experience has shown that N and P data derived from soil analysis has only limited use in assessing fertility of wetlands. Consequently the technique of phytometry (measuring the biomass of test species grown on soil samples) was developed. Typical phytometer yields (dry wt.); low fertility = <8mg, high fertility>18mg.

options identified below are merely put forward for further consideration based on the characteristics of each site.

The initial assessment of Kings Myre SSSI, based on a single sampling round, suggests enriched water is present within the SSSI, and that the main source of this enrichment is likely to be surface water input. Confirmation would need to be obtained by the following data input:

- Ideally, monthly surface water sampling within all inflow and outflow channels 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.
- At least three sediment samples within the waterbody to identify possible internal store of nutrients, as well as the average depth of sediment present.
- A basic hydrological walkover of the site/catchment to confirm the extent of silt within the ditches and the condition of the peat.

Once these data have 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:

- ***<u>Reducing nutrient input</u>*** - This is the most effective means of addressing eutrophication of the site. The primary exporters of nutrients appear to be a combination of agriculture to the south and west, as well as localised enrichment in the north (Kingsmyre cottage). 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.

- ***<u>Redirecting problematic water sources</u>*** – It may be possible to redirect one or more of the feeder ditches to the site if it represents a particular problem to loch water quality.

- ***<u>Removing nutrient-rich sediments from the loch</u>*** – This would be an expensive option and would need careful consideration to ensure such action did not risk damage to the bed of the loch, any geological or archaeological features or alter the water level regime. Consideration would also need to be given to suitable receiver sites and to whether long term measures (such as a change in landuse upstream of the SSSI) may also be required to prevent future build up of sediment. It is understood that one attempt to desilt the loch has already taken place, though the reason for its limited success is not known.

- ***<u>Soft engineering options</u>*** - 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:

  <u>Buffer Zones</u>; 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 within some parts of the surface water catchment of Kings Myre, but that the proximity of point sources such as Kingsmyre cottage may not allow for sufficient width of buffer strip to filter water effectively before it reaches the 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. Such ditch management is already likely to take place within the SSSI but could be extended into neighbouring agricultural land for additional benefit,

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.

Use of constructed wetland features; This includes the creation of new waterbodies as settling ponds to filter out nutrients and suspended sediment before they reach the SSSI. For example, the pond to the west of the loch will already be acting as a settling pond to some degree. However, this can be a costly measure and consideration will need to be given to future maintenance of such features (which require silt removal periodically to remain operational). However, they can be very effective at improving water quality and creating new habitat.

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ANNEX 1: WATER AND SOIL SAMPLES

Water samples

			Sample ID	GW1	GW2	GW3	GW4	SW1	SW2	SW3	SW4	SW5	SW6	SW8	SW9
Parameter	**Unit**	**Detection Limit**	**Sample Date**	23/02/2012	23/02/2012	23/02/2012	23/02/2012	23/02/2012	23/02/2012	23/02/2012	23/02/2012	23/02/2012	23/02/2012	23/02/2012	23/02/2012
Phosphorus (total)	mg l^{-1}	0.2	Water	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.27
Ammonium	mg l^{-1}	0.01	Water	0.7	0.89	0.92	0.92	1.6	1.4	1.3	1.2	1.1	0.98	1.6	10
Nitrate	mg l^{-1}	0.5	Water	<0.5	0.98	<0.5	<0.5	<0.5	1.4	<0.5	11	1.3	4.6	1	1.7
Phosphate Low Level	mg l^{-1}	0.02	Water	<0.20	0.02	0.023	<0.02	0.026	<0.02	0.023	0.052	<0.02	0.057	0.022	0.82
Nitrogen (total)	mg l^{-1}	1	Water	7	15.5	12	4.6	4.6	4.7	5	6	5	4	4	11
Calcium	mg l^{-1}	5	Water	33	46	21	23	32	22	38	44	29	39	13	25
Magnesium	mg l^{-1}	0.5	Water	7.7	7.6	3.7	4.6	5.3	3.5	4.3	6.8	3.6	6.5	2.5	5.8
Sodium	mg l^{-1}	0.5	Water	12	14	4.6	8.1	8.7	6.2	8.5	18	5.7	17	5.7	14
Iron (II)	µg l^{-1}	20	Water	290	270	20	<20	<20	<20	<20	40	<20	40	300	160
Iron (III)	µg l^{-1}	20	Water	<20	<20	380	760	210	190	330	260	430	210	90	210
Iron (total)	µg l^{-1}	20	Water	290	270	400	760	210	190	330	300	430	250	390	370

Soil samples

			Sample ID	S1	S1	S2	S2	S3	S3	S4	S4
			Other ID	Below	Root	Below	Root	Below	Root	Below	Root
			Sample Date	23/02/2012	23/02/2012	23/02/2012	23/02/2012	23/02/2012	23/02/2012	23/02/2012	23/02/2012
Parameter	**Unit**	**Detection Limit**	**Type**								
Moisture	%	0.02	Soil	91.9	38.2	79.9	22.3	80.5	70	81	47.3
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	30	8.7	18	16	16	32	26	4
Phosphorus (total)	mg kg^{-1}	-	Soil	6100	1800	980	4000	2500	2000	1100	550
Nitrogen (total)	%	0.02	Soil	0.23	0.14	0.85	0.06	0.56	0.5	0.5	0.5
Nitrite (extractable)	mg kg^{-1}	0.1	Soil	0.19	0.15	0.14	0.19	<0.1	<1.0	<0.1	<0.1
Nitrate (extractable)	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	<100	590	<100	<100	<100	3000	<100	<100
Potassium (total)	mg kg^{-1}	0.2	Soil	-	110	95	1000	19	85	75	60
Sodium (total)	mg kg^{-1}	0.2	Soil	49	16	27	49	<0.2	18	16	14
Magnesium (total)	mg kg^{-1}	0.5	Soil	370	1300	1300	2800	75	420	75	540
Total Organic Carbon	%	0.2	Soil	38	1.4	13	0.29	15	6.9	19	6.2
Moisture content	%	-	Soil	1727	22	480	27	1736	1103	1519	372
Bulk density	Mg/m3	-	Soil	1.02	2.07	1.09	1.88	1.01	1.03	0.97	1.09
Dry density	Mg/m3	-	Soil	0.06	1.7	0.19	1.49	0.06	0.09	0.06	0.23

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