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Research Report No. 1102

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

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RESEARCH REPORT

Summary

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

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Keywords

nutrients; diffuse pollution; wetland; Bogton Loch 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 Bogton Loch, in order to assess the trophic status of the designated wetland and identify any likely sources of nutrient input.

Main findings

- The 76.61 ha site contains a freshwater loch with an extensive range of associated wetland communities and is one of only two open water transition fens in Ayrshire.
- The loch, which is part of a larger hydrological unit which encompasses Dalmellington Moss SSSI, appears to be fed largely by surface water run-off but also potentially from groundwater inputs. Both the River Doon and the Dalcairnie Burn flow through the site and into the loch in the south-east corner.
- The open water transition fen is considered to be in unfavourable condition, partly due to the high occurrence of negative indicator species (indicative of nutrient enrichment).
- Site specific issues include several incidents of fire and possible drying out of the wetland in some areas. Also the expansion of Phalaris and Phragmites since 1990, particularly to the south of the loch.
- Groundwater samples taken at Bogton Loch have been compared with the nutrient level requirements of the vegetation types known on site. This indicates that the groundwater quality is generally 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 Total Nitrogen levels were elevated above those recorded for Scotland in fen communities across all three sampling locations.
- Analysis of surface water results was limited by the loss of some of the key data following sampling. However, it appears to indicate that Total Nitrogen and Total Phosphorus levels within the loch are above published standards and therefore that the loch would be classified as Eutrophic.

- Assessment of vulnerability showed Bogton Loch SSSI most at risk from agricultural practices and historic sewage input, with a risk that there may be a store of nutrients within the loch sediment. There may also be risk from oxidation of peat due to a lowering of water levels (though no data were available on water level change over time for this site).
- Further investigations are recommended for the site (such as monthly water quality sampling and seasonal water level recording. A range of remedial options are proposed for consideration, once additional data have been gathered.

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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 Bogton Loch, 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. METHODS

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

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

Bogton Loch SSSI is located less than 1km southwest of Dalmellington in East Ayrshire (Figure 1). The 76.61 ha site contains a freshwater loch with an extensive range of associated wetland communities. It is one of only two open water transition fens in Ayrshire. South of the loch itself there is a transition from swamp, tall-herb fen and mire communities, grading into marshy grassland and willow carr with occasional alder and birch (Site Management Statement, 2008). Figure 2 shows the extent of the loch in the 1800's.

The site supports a diverse breeding bird community, with song thrush, grasshopper warbler, spotted flycatcher, willow tit, reed bunting and occasionally a small colony of black-headed gulls.

The site is part of a larger hydrological unit which also encompasses Dalmellington Moss SSSI (Figure 1).

Also of interest (but not a notified feature) is the locally important numbers of wintering wildfowl and the passage of thrushes and finches that are attracted by the wet woodland and scrub. Otter also use the site and the diversity of habitats is important for invertebrates with several species of moth present.

In the past, the site has suffered from repeated burning, which has recently been a result of third-party fires, particularly in 2003. Burning releases nutrients locked up in the silt and peat (Site Management Statement, 2008). The incidents of fire have reduced due to sympathetic management by the landowner and the local community.

Fishing and game shooting occurs within the site, with hedges (using native species) being planted and fencing erected. Cattle and sheep grazing have occurred in the past but it is unclear if livestock still have access to the site. It is noted in the Site Management Statement that a small area adjacent to the western boundary and immediately south of the Dalcairnie Burn was cultivated to provide feed and cover for game birds.

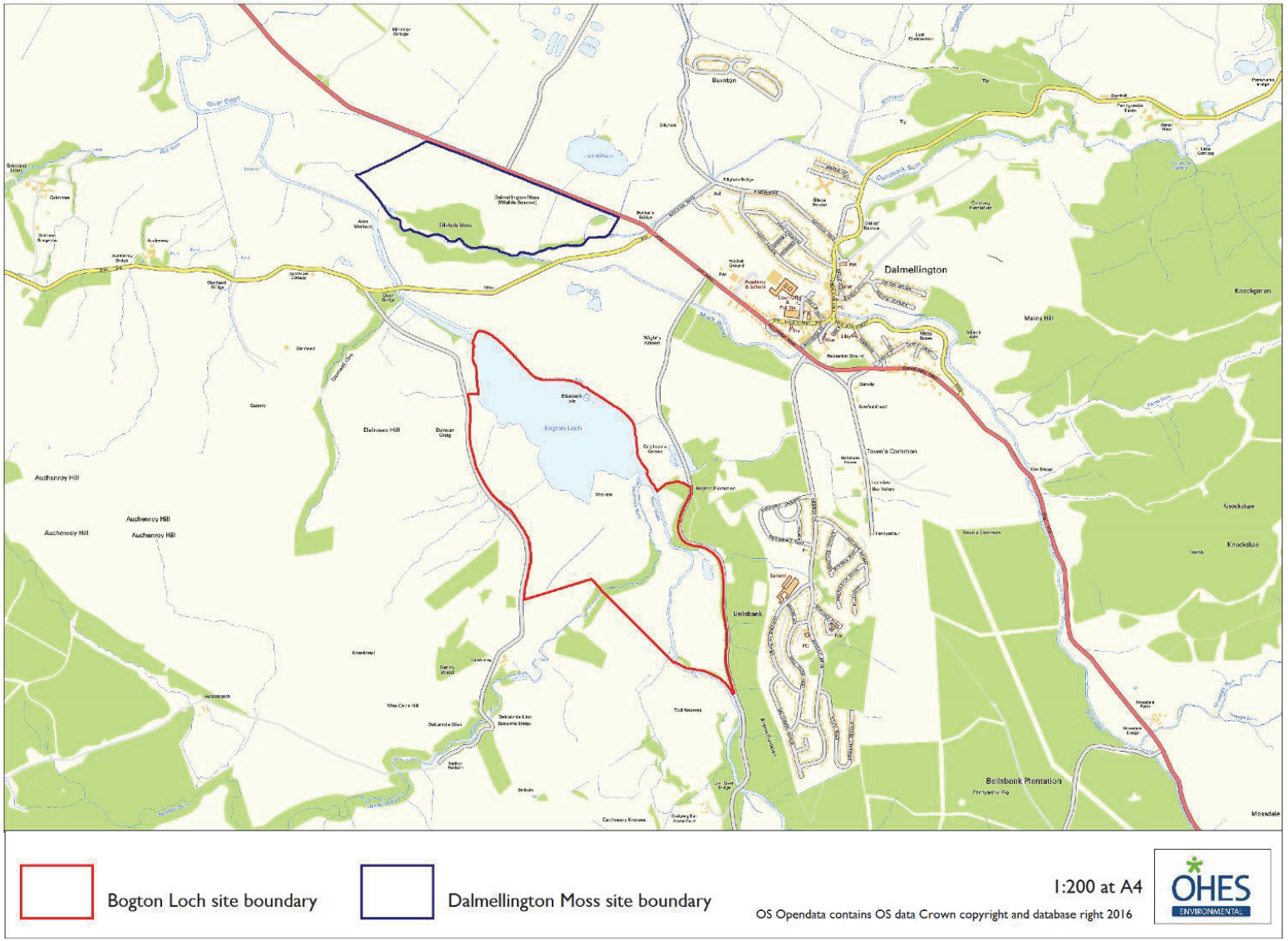

Figure 1. Site boundary and designation – Bogton Loch

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

3.1.1 Site designation and specific targets

Bogton Loch SSSI was first notified in 1975 and was re-notified in 1985 with an increase in area of 5 ha. The features for which the site is designated are detailed in Table 1. The wet woodland is generally situated along the eastern boundary of the site and adjacent to the banks for the River Doon.

The site contains a variety of plant species, including three notable plants: narrow small-reed (*Calamgrostis stricta)*, which is nationally rare, and purple small-reed (*Calamgrostis canescens*) and wood small-reed (*Calamgrostis epigejos*), which are both locally rare. The grey willow, birch and common reed community immediately south of the loch, referred to as 'The Isle', is regarded as a rare or highly localised community of fen woodland.

Table 1. Bogton Loch SSSI notified features and their pressures

SSSI features	Feature Category	Summary Condition / Latest Condition	Pressure
Breeding bird assemblage	Birds	Favourable Maintained (Jun 2000)	No negative pressures
Open water transition fen	Wetlands	Unfavourable Declining (Sept 2008)	a) Invasive species b) Natural event c) Water management

3.1.2 Site hydrology

The site lies within the floodplain of the River Doon and forms part of a larger hydrological unit, along with Dalmellington Moss SSSI. Both the River Doon and the Dalcairnie Burn flow through the site and into the loch in the south-east corner (Figure 3).

The surface water catchment for Bogton Loch is somewhat uncertain and is likely to cover a significant area. Much of the catchment is located to the west of the loch, as the Shalloch Burn/Dalcairnie Burn collects run-off from the uplands. Run-off from the residential area of Bellsbank is also probable (though the extent of this will depend on drainage routes within the estates).

Examination of the 1:10000 Ordnance Survey map also suggests that a bridge approximately 0.5 km south from the SSSI boundary is the point at which flow within the River Doon separates (i.e. north of this bridge the river flows north, and south of the bridge the river flows south). In the absence of any additional information on this structure, this report has assumed the OS map is correct. However, if water south of the bridge still enters the loch (even sporadically) this will expose the SSSI to a catchment area much greater than that shown in Figure 3 (in effect, including the surface water catchment for the entire River Doon south of Bogton Loch).

Several unnamed surface water drains are present in the south-west of the site, flowing directly into the loch. There also appears to be an inflow from the north-east, which originates in the east and flows through a small waterbody before crossing under a road, however this is not confirmed. Water exits the site as the River Doon from the loch itself, which flows in a north-west direction.

Drains within the site are no longer maintained and are largely vegetated. These terrestrialised ditches may still represent significant sub-surface flow lines into the loch depending on the permeability of the infill material. Some of the drains still known to carry surface water have been flagged as potential causes of the site becoming increasingly dry. However this was not considered to be having a significant effect on the site at the time of

the Site Condition Monitoring. If the drains were cleared it could have a detrimental impact by increasing the flow rate of water leaving the wetland into the loch.

The 2008 condition survey indicated that it is possible off-site factors could be contributing to adverse water levels in part of the site, and that further investigation was required.

Surface and ground water sampling locations are shown in Figure 7.1.2.2. Unfortunately three of the six surface water samples taken at Bogton Loch appear to have been lost following sampling. Furthermore, only 2 of these surface water samples have definitive locations provided in the field notes and both samples come from the same small ditch which enters the loch from the south-west. As a consequence, no water quality data exists on the main inflows, which make up the majority of the lochs water balance.

Bogton Loch is underlain by the Girvan bedrock and localised sand and gravel aquifers. In 2008, the groundwater quality and quantity were classified as 'Poor', with no trend for pollutants. Abstraction and diffuse source pollution were identified pressures.

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 or substrate for this site. However the presence of vegetation communities such as *Carex rostrata* swamp (S27) and *Carex rostrata – Calliergon cuspidatum/ giganteum* mire (M9) around the west and south of the loch suggest the presence of either WetMec 13: Seepage Percolation Basins or WetMec 20: Percolation Basins. These communities are typically fed by water discharging around the margins of topogenous hollows, either by groundwater outflow from a mineral aquifer or from surface water streams and run-off (Wheeler, Shaw & Tanner, 2009). It is therefore possible that water from the higher ground surrounding Bogton Loch percolates through the wetland margins (either near the surface or along sub-surface flow paths) to then flow into the loch (possibly beneath buoyant vegetation mats in some areas).

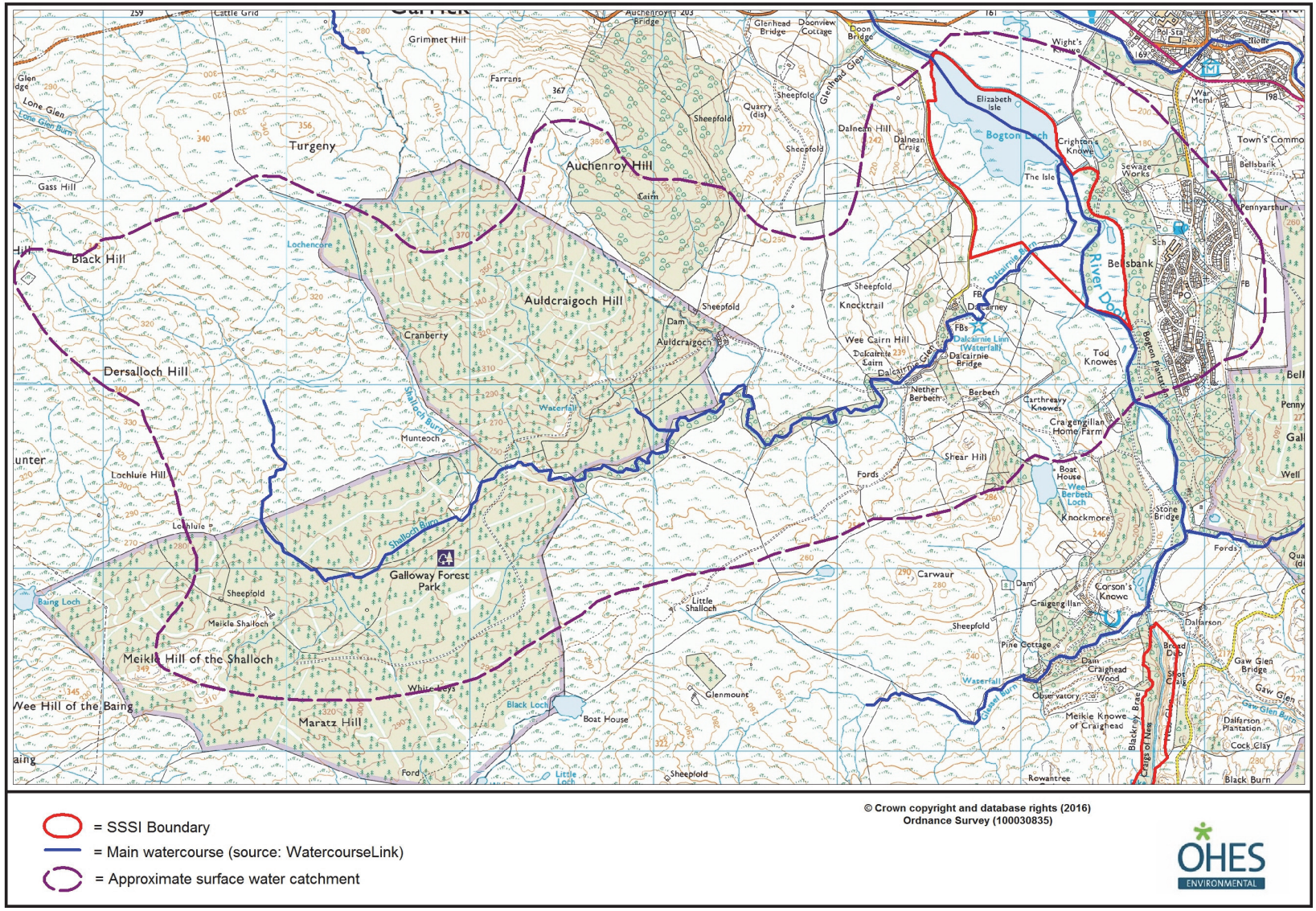

Figure 3. Bogton Loch – approximate surface water catchment

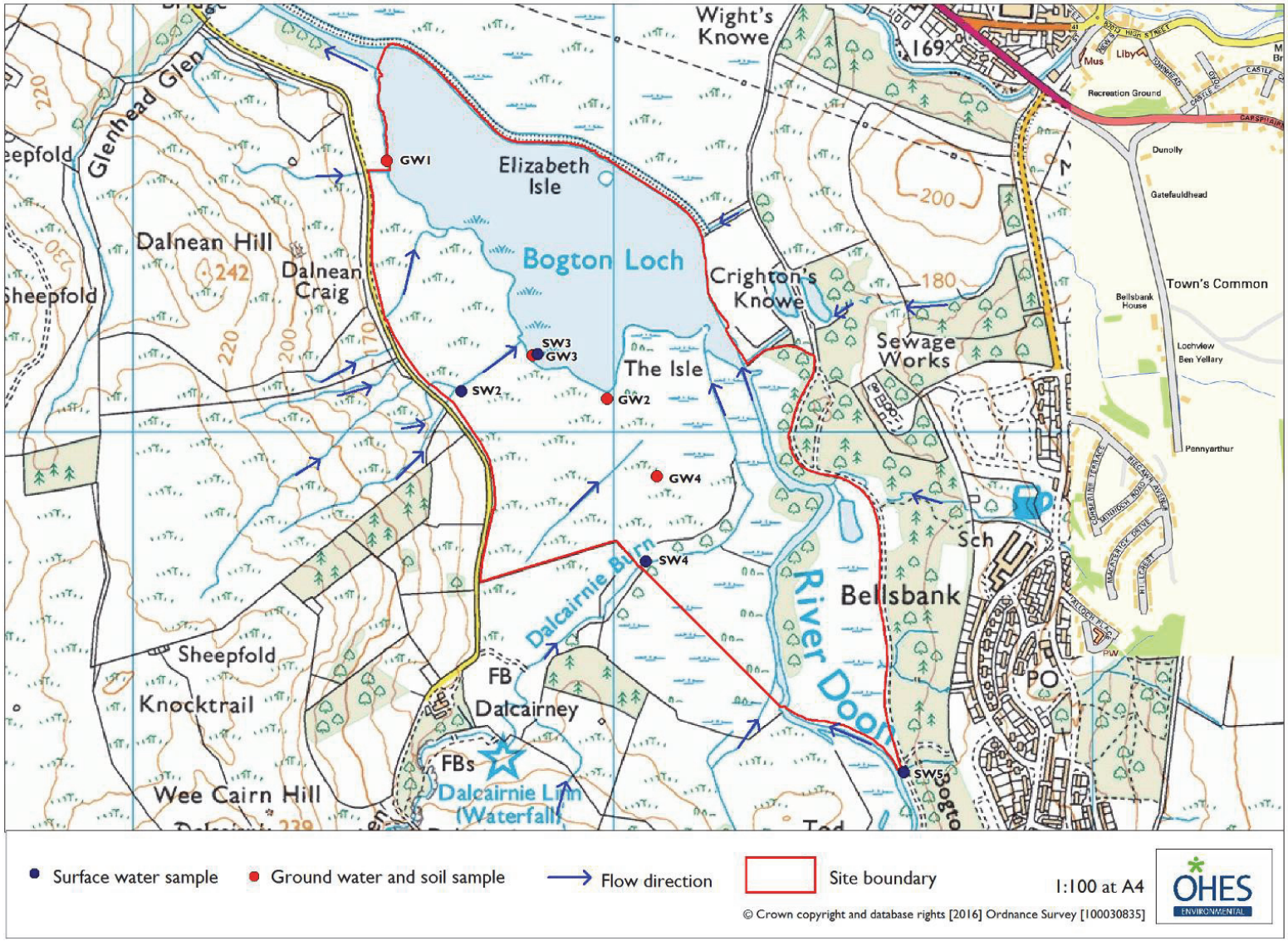

Figure 4. Bogton Loch – Hydrology and Sample Locations

3.1.3 Site soils / sediments

Bogton Loch is underlain by alluvial soils, derived from recent riverine and lacustrine alluvial deposits. To the south of the loch is a small deposit of basin peat. The remainder of the catchment is the Hindsward Association, which is a poorly drained till derived from sandstones and shales of Carboniferous age with basic igneous rocks. Figure 5 shows the distribution of soil types at Bogton Loch.

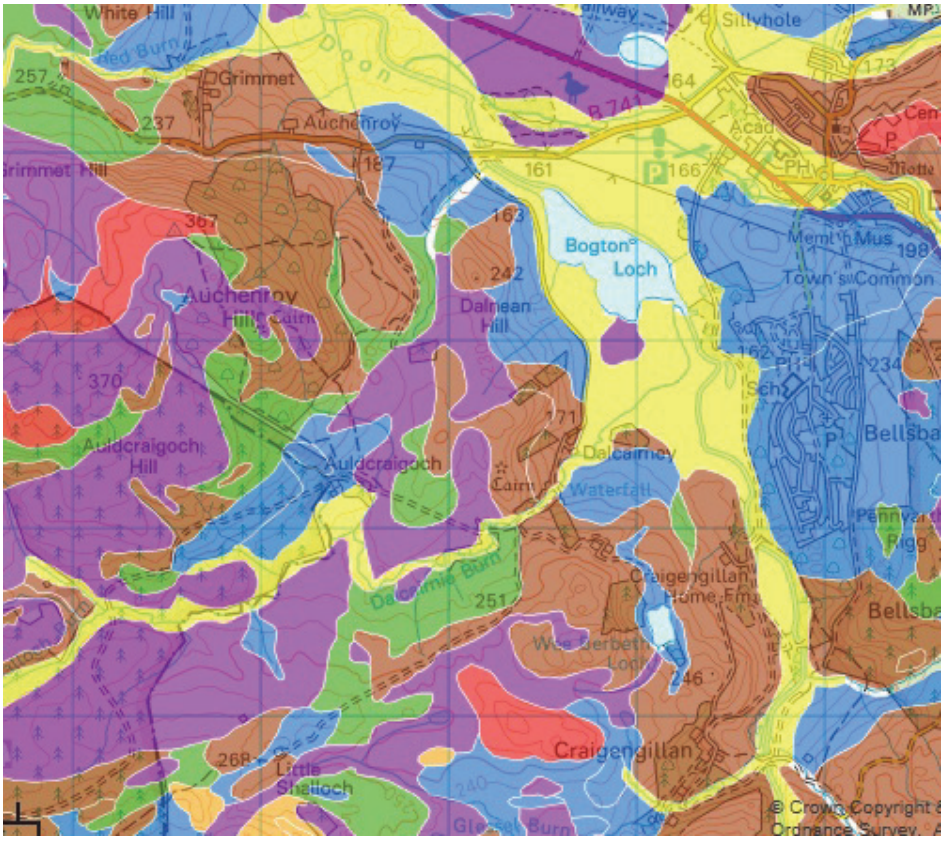

Figure 5. Bogton Loch – Soil types (source: Soil Survey of Scotland Staff. 1987). Yellow = Alluvial Soils, Purple = Organic Soils, Blue = Hindsward Association (non-calcareous gleys), Brown = Darleith (brown earths), Green = Glaisnock (peaty gleys).

3.1.4 Site specific issues

Nutrients may be entering the water supply to the wetland through runoff from the surrounding farmland and roads. The water quality of the River Doon is being affected upstream which may also be a possible source of nutrients.

The Ordnance Survey maps show a sewage treatment works just south of the Bogton Plantation (Figure 5), which may have historically added nutrients to the system. The site has been subject to a number of fires, which cause nutrients to be released from the silt and peat, which could have impacted upon the nutrient status of the site. Any supplementary stock feeding, which may have been undertaken in the past, adds nutrients and foreign seed, which may be damaging. The underlying reason for nutrient enrichment however has not yet been determined and needs further investigation.

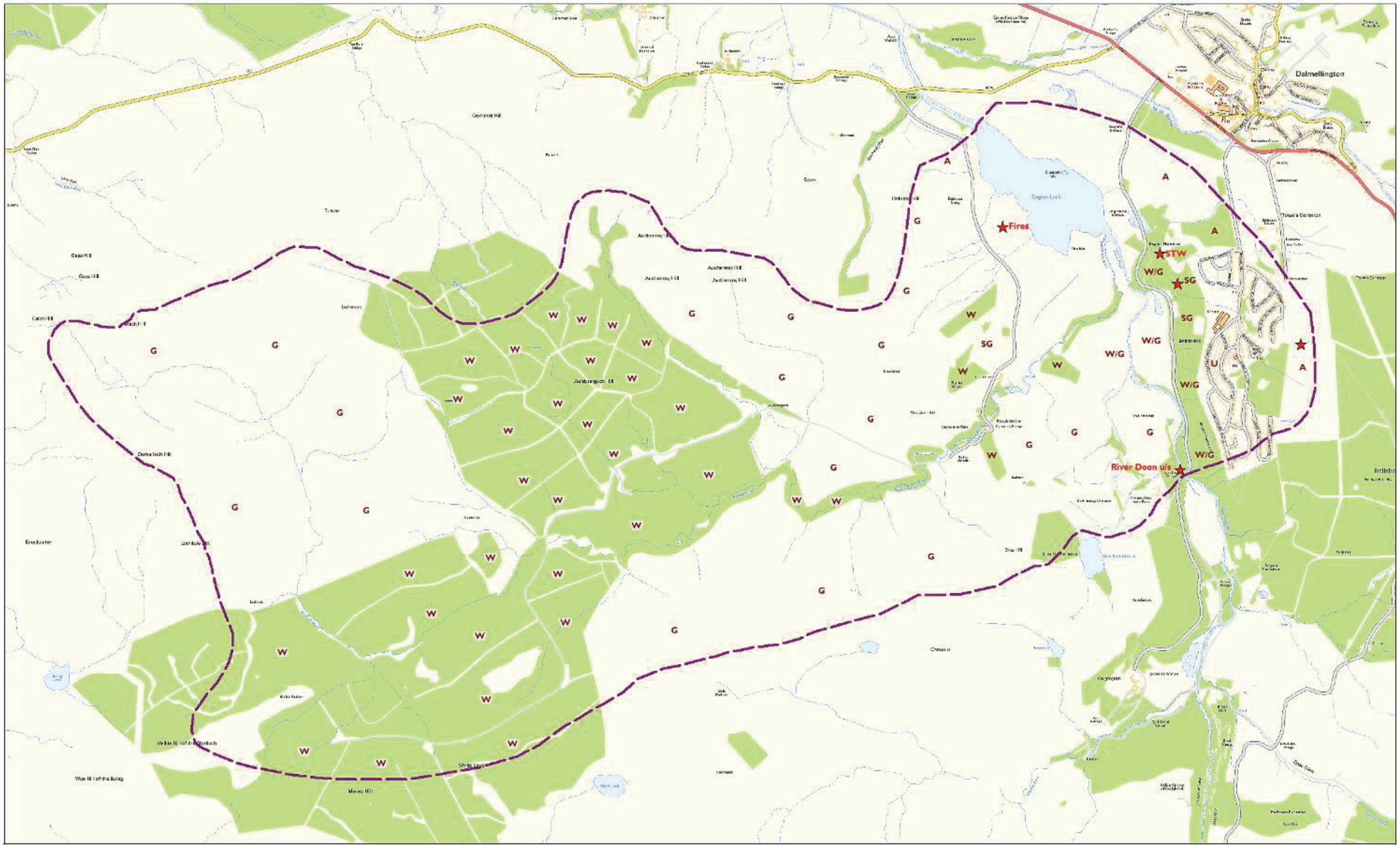

Figure 6. Land use and potential nutrient sources at Bogton Loch

3.2 Assessment of vegetation data

Bogton Loch SSSI contains a range of open water transitional fen, swamp and marshy grassland communities. Observations on the vegetation have been mapped for the whole site in 1990 (with some quadrat data) and 2000 (with no quadrat data available). Figure 7 shows the NVC communities recorded in 2000. It shows communities such as S9 and S27 are located on former areas of the loch that are in the process of terrestrialisation. Communities indicative of more enriched environments (such as MG1, M27 and S28) are located in areas around the Dalcairnie Burn and River Doon.

The NVC data (2000) recorded the presence of the following communities:

- S4 *Phragmites australis* swamp
- M27 *Filipendula ulmaria – Angelica sylvestris* mire
- S9 *Carex rostrata* swamp
- S10 *Equisetum fluviatile* swamp
- S11 *Carex vesicaria* swamp
- S27 *Carex rostrata – Potentilla palustris* tall-herb fen
- S28 *Phalaris arundinacea* tall-herb fen
- M23 *Juncus acutiflorus – Galium palustre* rush-pasture
- M9 *Carex rostrata-Calligeron cuspidatum /giganteum* mire
- M25 *Molinia caerulea-Potentilla erecta* mire
- M18 *Erica tetralix-Sphagnum papillosum* raised and blanket mire
- MG1 *Arrhenatherum elatius* grassland
- MG9 *Holcus lanatus-Deschampsia cespitosa* grassland
- M15 *Scirpus cespitosus-Erica tetralix* wet heath

There are also additional recordings of:

- W3 *Salix pentandra-Carex rostrata* woodland
- W6 *Alnus glutinosa-Urtica dioica* woodland
- W10 *Quercus robur-Pteridium aquilinum-Rubus fruticosus* woodland
- A7 *Nymphaea alba* community

3.2.1 Historic evidence of community change

When the 1990 and 2000 NVC maps are directly compared, there is little apparent change in the distribution and extent of S4, S9 or S27 communities around the loch edge (though there was some evidence of an increase in *Phragmites* in places during the 2008 survey). Interestingly, of the 8 quadrats taken in 1990, none of them contained *Phragmites* or *Phalaris*. In contrast, the land to the south of the loch shows some clearer changes. Most obvious is the expansion of S28 swamp on land between the Dalcairnie burn and River Doon from 2000 onwards, into what was formerly M23 in 1990. Also within this same area, the extent of S27 on the western side of the River Doon appears to have reduced due to encroachment of W3 woodland. This suggests land to the south of the loch (around the two main inputs into the loch) is reducing condition and requires remedial measures.

Finally, one of the fields immediately to the west of Dalcairnie Burn appears to show a shift from S27 / S10 to M27 / S28 in the 2000 survey, but this is not borne out by the 2008 Site Condition Monitoring, which again showed the field as a S27 and S10 mixture.

Figure 7. NVC communities recorded in 2000 (Source: SNH Site Management Statement)

Other key vegetation changes noted in the condition assessments include;

- The 2008 Site Condition Assessment noted that key communities were still well-represented in the locations where they have previously been mapped, however there was some replacement of sedge swards (S9, S10, S11) by *Phragmites* going towards S4.
- The drying of the surface and reduction of the water table was noticeable in some areas during the 2008 Site Condition Monitoring assessment. This may have been compounded by the presence of scrub which is present along the margins of the feature.
- In the sampled area of S11 towards the west of the loch, the surface was drying and there was clear evidence of a shift in vegetation towards more terrestrial forms during the Condition Monitoring Assessment in 2008.
- Many stands were in transition to open water or in small pools in the floating rafts where *Equisetum fluviatile* was dominant but the vegetation cover was overall sparse. Associated species were constant but of low cover, resulting in a target failure in 2008 Condition Monitoring Assessment.
- Cyperaceous cover was generally quite prominent in the S27 stands at the site during the 2008 Site Condition Assessment. *Carex rostrata, Carex aquatilis* and *Carex nigra* were frequent. With higher cover of sedges, there was a reduced cover of *Potentilla, Menyanthes and Equisetum*, resulting in a target failure for vegetative composition.
- *Phragmites* and *Phalaris* were seriously encroaching on many stands of S27 in the 2008 Site Condition Monitoring assessment, resulting in target failure for vegetative composition.

3.2.2 Community requirements and targets

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 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, February 2016). The ER37 document presents guidance on the eco-hydrological requirements of the different Scottish wetland types as described in SNIFFER (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 Bogton Loch SSSI are:

- Type 2a:Marshy grassland
- Type 4: Fen
- Type 5: Swamp
- Type 6: Reedbed

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 Bogton Loch 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). 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: 6 (or 26 mg/l as N-NO3) for <175 m AOD

3.2.2.2 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 *Caricion mariscus).*

The main NVC communities listed in ER37 and which are found at Bogton Loch are:

- M9 *Carex rostrata-Calligeron cuspidatum /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 800m). 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.

- 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, B.D., Shaw, S., & Tanner, K, 2009)

ER37 data and thresholds for Fens are presented in Table 3. Under the UKTAG report (2012 and 2014), mean nitrate levels in groundwater fed fens in good condition are 3.4 and 2.9 mg/l $N\text{-}NO_3$ for mesotrophic and oligotrophic fen respectively, and the 3rd quartile values are 5.7 and 5.0 mg/l $N\text{-}NO_3$. However, ER37 reports that Nitrate levels in Scotland are significantly lower, with a 3rd quartile value of 0.25 mg/l $N\text{-}NO_3$ 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 $P\text{-}PO_4$ for mesotrophic and oligotrophic fen respectively (ER37). Mean values for fen in poor conditions are 0.034 mg/l $P\text{-}PO_4$ and 0.064 mg/l $P\text{-}PO_4$ for mesotrophic and oligotrophic groups. ER37 reports that median Phosphate concentrations in Scottish fens are 0.10 mg/l $P\text{-}PO_4$ (for groundwater) and 0.046 mg/l $P\text{-}PO_4$ (for surface water). These figures exceed the mean values given for good condition under UKTAG, 2012. No guidance 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 tests for some of the samples”.

Table 3. 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)

3.2.2.3 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 which are found at Bogton Loch 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.

- S10 *Equisetum fluviatile* swamp - occurs in shallow to moderately deep, standing waters with substrate ranging from fine inorganic material (such as silt or sand) to peaty soils. It can occupy both eutrophic and oligotrophic waters and has a wide distribution across the UK.

- S11 *Carex vesicaria* swamp - a community of both inorganic and peaty substrates over which mesotrophic conditions exist. S11 occurs within slow moving or standing water, with some sub-communities characteristic of deep waters more than 40 cm depth, and some of drier situations where the water table can be 10 cm below ground level (Rodwell, 1995).

- S28 *Phalaris arundinacea* tall-herb fen - 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 4. 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 4. 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 $N\text{-}NO_3$)	0.25	0.25	0.25	Guideline: Meso = 5 (or 22 mg/l as NO3) Olig = 4.1 (or 18 mg/l as NO3)

3.2.2.4 Type 6 Reedbed

Equivalent NVC types covered:

- S4a *Phragmites australis* sub-community (present at Bishops Loch)
- 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 5. Nitrate guidelines under UK TAG for groundwater are 22 mg/l but this value is significantly higher than was observed in Scottish reedbed. Thus ER37 state values between observed 1 mg/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**	**Threshold**
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)

3.3 Assessment of ground water samples

Groundwater samples taken at Bogton Loch 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.

Table 6 indicates that the vegetation found around the sample locations is typically consistent with guideline levels for marshy grassland and swamp. However, the Total Nitrogen levels are a cause for concern for fen communities such as S27 and M9. This would suggest that the condition of these fen communities is likely to deteriorate over time.

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

	Bogton Loch	Marshy Grassland			Bogton Loch	Bogton Loch	Swamp		
Sample	**GW1 (in M23)**	**1st Quartile**	**3rd Quartile**	**Indicator/ guideline**	**GW3 (in S9)**	**GW4 (in S9)**	**1st Quartile**	**3rd Quartile**	**Indicator**
pH (-)		6.3	7.1	5 to 8			5.7	7.1	
Dissolved Oxygen (%)		32	40				15	36	
Conductivity (mS/cm)		0.093	0.18				0.24	0.43	
Calcium (mg/l)	5.3	8	24		<5.0	<5.0	10	44	
Magnesium (mg/l)	2.6	2.5	8.7		1	3	3.6	16	
Sodium (mg/l)	6.3	6.2	12		5.9	6.5	5.5	18	
Phosphate (mg/l)	0.056	0.041	0.065	Indicator: 0.065	0.056	0.051	0.024	0.1	None set
Nitrogen (total) (mg/l)	5.73	2.5	7		7.58	6.91	2	7	
Nitrate (mg/l N-NO_3)	<0.5	0.25	0.25	Guideline: 6 (or 26 mg/l as N-NO3) for <175 m AOD	<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)

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

	Bogton Loch	Bogton Loch	Bogton Loch	Fen		
Sample	**GW3 (nr S27)**	**GW2 (in S27)**	**GW4 (in S27)**	**1st Quartile**	**3rd Quartile**	**Indicator**
pH (-)				6.4	7.4	
Dissolved Oxygen (%)				18	28	
Conductivity (mS/cm)				0.37	0.69	
Calcium (mg/l)	<5.0	<5.0	<5.0	12	55	
Magnesium (mg/l)	1	2.8	3	3.4	14	
Sodium (mg/l)	5.9	5.7	6.5	5.4	14	
Phosphate (mg/l)	0.056	0.048	0.051	0.064	0.1	None set
Nitrogen (total) (mg/l)	7.58	8.14	6.91	1	5.1	
Nitrate (mg/l N-NO_3)	<0.5	<0.5	<0.5	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)

3.4 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 in order to achieve Good Ecological Status (GES) or High Ecological Status (HES). The most up-to-date of these include the Scotland River Basin District Directions 2014 (SRBDD, 2014) and The 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 European WFD for Scotland and are therefore highly relevant. The standards referred to in the other documents (such as JNCC targets) are referred to in some circumstances but it should be noted that, where they exist, the SRBDD standards are more stringent than CSM targets and therefore GES standards should be used for Favourable Condition targets of SSSI's. Where SRBDD standards are not provided a range of published documents are used to define those standards.

Under the SRBDD 2014, Bogton Loch is classified as shallow (3 to 15 m depth), freshwater, salmonid, mid altitude (over 80 mAOD) lake of low alkalinity (<10 mg/l) and >90 % calcareous bedrock. This equates to Ecotype 14 (Small temperate lake, with a catchment geology of rock and conductivity between 100 – 800 uScm) within the ECOFRAME document (Moss, 2003). Table 7 presents the SRBDD 2014 standards compared to those recorded from Bogton Loch, but owing to the fluid nature of the research and advice, represent a starting point.

Table 7. Water Quality standards for Bogton Loch (using SW3 sampling point to indicate in-loch conditions)

Variable	SRBDD 2014		JNCC	ECOFRAME		Bogton Loch
	GES	HES		Good	High	
Total Ammonia as N	0.3 mg/l	0.2 mg/l	-	-	-	0.14 mg/l (Ammonium only)
Total Nitrogen	-	-	<1.5 mg/l	0.6 – 1.0 mg/l	<0.6 mg/l	6.09 mg/l
Acid Neutralising Capacity	>20 µeq/l	>40 µeq/l	>40 µeq/l	-	-	?
Dissolved oxygen	7 mg/l	9 mg/l	As SRBDD	-	-	?
Salinity/Conductivity	<1000 µScm		-	100 – 800 µScm		?
Total Phosphorus	10 µg/l	7 µg/l	35 µg/l	30-50 µg/l	<30 µg/l	46 µg/l (Phosphate only)
pH	-	-	7 - 9	6 - 9		?

3.4.2 Current surface water quality status

Data from three surface water sampling points monitored by SNH during the single sampling round, were available for analysis. These include: an input channel (SW2), surface water within the loch (SW3) and a third unknown location (SW1). There are three other identified monitoring locations where water quality data was lost in transit to the laboratory. As a result, no meaningful conclusions can be drawn on which inflows represent major contributors to loch enrichment, or whether the loch is acting as a source of nutrients. However, the inflows with no data did show other evidence that they may be bringing in significant concentrations of nutrients and suspended sediment (see Plate 1).

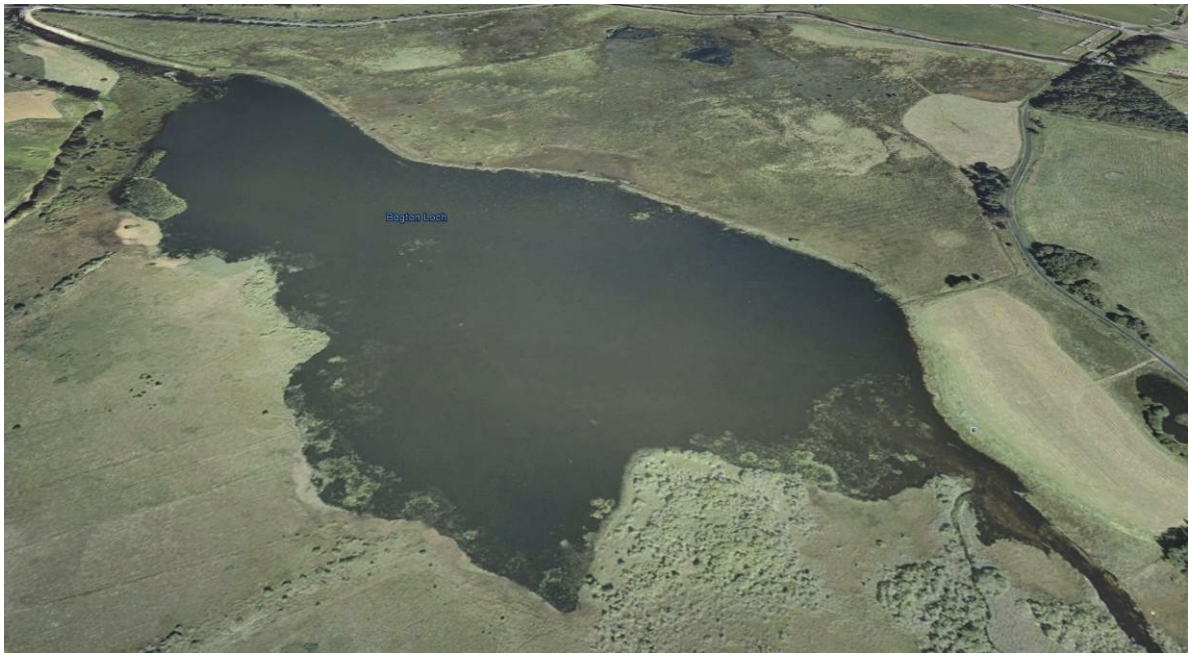

Plate 1. Aerial photograph of Bogton Loch (Source: Google Earth, 2004)

3.4.3 Summary of trophic 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 characterised 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-*a* ≤ 2.5 $\mu g\ l^{-1}$. Max. chlorophyll-*a* ≤ 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-*a* 2.5-8 $\mu g\ l^{-1}$. Max. chlorophyll-*a* 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-*a* 8-25 $\mu g\ l^{-1}$. Max. chlorophyll-*a* 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-*a* ≥ 25 $\mu g\ l^{-1}$. Max. chlorophyll-*a* ≥ 75 $\mu g\ l^{-1}$. Mean Secchi transparency ≤ 1.5 m. Severe oxygen concentration depletion in hypolimnion.

Given that only Total Nitrogen and Phosphorus levels are significantly above standards for GES, this report concludes that the trophic state of Bogton Loch surface water is Eutrophic.

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

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

Source	Bogton Loch SSSI	
	Vulnerability	**Details of Factors**
EXTERNAL SOURCES		
1. Agriculture	Moderate	- Though much of the catchment appears to be under extensive grassland management, there are still collections of fields which appear to be heavily improved and may support significant numbers of livestock. - Drainage of the catchment permits the flushing of fertiliser and nutrients into nearby watercourses which will eventually lead into the loch. - Any stock feeding will increase nutrients into the system.
2. Human population	Moderate-High	- Historic input of sewage from the nearby sewage treatment works, linked to substantial residential areas to the east of the site. - Fires are believed to have released nutrients from the peat on-site. - Potential run-off from the surrounding roads to the east and west of the loch. - Upstream pollution influences on the River Doon may be a factor but require further investigation. - Flushing of historic nutrient loads (such as those from the STW) may have been achieved over time as a result of the River Doon passing through the loch (though this would need further investigation).
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 extent to which regional groundwater contributes to the water balance of the loch is not fully understood, but is unlikely to be as significant as surface water inputs.
INTERNAL SOURCES		
1. Wildlife	Low – Moderate	- Several bird species are recorded in large numbers on the reserve, which may represent a significant 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. 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 loch may continue to build up if there is insufficient flushing of the waterbody.
3. Oxidation of peat due to lower water levels	Unknown	- There is some concern that the site is becoming drier and, if this is the case, it is possible that there may be a release of nutrient from certain kinds of substrate (such as peat).
4. Release of nutrients through activities such as burning	Low – Moderate	- Historically activities such as burning will have released stores of nutrients within the site, but such activities are now believed to have ceased.

3.5 Assessment of soil samples

Soil chemistry was samples at four locations within Bogton Loch (1 in M23 *Juncus effuses /acutiflorus-Galium palustre* rush-pasture, 1 in S9 *Carex rostrata* swamp, 1 in S27 *Carex rostrate - Potentilla palustris* fen and 1 in S9/S27. 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 Bogton Loch samples against the ER37 data. The results show that nearly all of the parameters are within normal ranges observed in Scottish samples. However, Total Nitrogen levels in the root zone were above the upper ranges typically observed in swamp and marshy grassland, for Soil samples 1, 3 and 4. Two of these samples were taken where significant depths of silty material were present, either sourced from suspended sediment from the catchment or as part of the natural territorialisation of the loch edges. All three of the soil samples surrounding the loch had high soil moisture content; both at the root layer and below, due to their connectivity with the loch. Soil sample 4 showed lower moisture content, particularly at depth, as it was not directly connected to a waterbody/channel.

Available Phosphate exceeded ranges typically observed for fen in Soil 4 below the root layer. Total Phosphate levels were also shown to be higher in those samples where significant depths of silt occurred.

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

	Bogton Loch		Marshy Grassland		Bogton Loch		Bogton Loch		Swamp		Bogton Loch		Bogton Loch		Fen	
Sample	**Soil 1 Root (in M23)**	**Soil 1 below (in M23)**	**1st Quartile**	**3rd Quartile**	**Soil 3 Root (in S9)**	**Soil 3 below (in S9)**	**Soil 4 Root (in S9)**	**Soil 4 below (in S9)**	**1st Quartile**	**3rd Quartile**	**Soil 2 Root (in S27)**	**Soil 2 below (in S27)**	**Soil 4 Root (in S27)**	**Soil 4 below (in S27)**	**1st Quartile**	**3rd Quartile**
Calcium (mg/kg)	220	220	160	4200	120	150	140	240	140	5,800	150	250	140	240	960	12,000
Magnesium (mg/kg)	55	55	1100	2700	26	33	44	80	410	3,400	32	47	44	80	1,500	3,800
Sodium (mg/kg)	14	9.5	43	200	7.5	7	16	9.5	17	140	7	7	16	9.5	74	280
Phosphate (available) (mg/l)	6	2.9	3.4	9.5	2.9	3	5.2	11	2.9	12	4.2	<2.0	5.2	11	2.7	9.5
Nitrogen (total) (%)	1.7	1.4	0.05	0.78	1.5	1.2	1.4	0.56	0.17	1.2	1.2	0.66	1.4	0.56	0.25	1.4
Nitrogen (extractable) (mg/kg)	0.2	0.29	0.35	0.93	0.14	0.16	0.12	0.2	0.43	0.9	0.18	0.26	0.12	0.2	0.4	1.4
Total organic carbon (%)	4	4.7	2.1	2.0	2.9	4	3.7	3.2	4.1	25	3.1	4.1	3.7	3.2	3.7	12
Potassium (total)	<5.0	<5.0	-	-	<5.0	<5.0	<5.0	<5.0	-	-	<5.0	<5.9	<5.0	<5.0	-	-
Soil Moisture Content %	479	361	-	-	1249	1009	325	128	-	-	451	369	325	128	-	-

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:

- Several key surface water samples were lost before analysis could take place. Without this information it is not possible to gauge which are the primary sources of nutrient into the site and whether the loch is acting as a source or sink of nutrient.
- 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 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.
- No data were available on the nutrient context and extent of loch sediment, which could represent a significant source of enrichment.

3.7 Recommendations on future measures and / or data requirement

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

The initial assessment of Bogton Loch SSSI, based on a single sampling round, suggests enriched water is present within the SSSI, though the main source of this enrichment is unconfirmed. 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 four sediment samples within the waterbody to identify possible internal store of nutrients, as well as the average depth of sediment present. This could be combined with sampling of macrophytes presence (in order to better gauge the condition of the water body).
- Installation of a simple dipwell or gauge board in order to build up a series of monthly water levels from this point forward.

- A basic hydrological walkover of the site/catchment to confirm whether the SSSI is connected to upstream waterbodies, the extent of silt within the ditches and the condition of the peat.

Once this 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:

- ***Installation of a control structure downstream of the loch to restore appropriate water levels*** – This would increase the control of water levels within the site but allow flushing of nutrients at certain periods. However, flows would need to be carefully managed to ensure no increased risk of flooding upstream of the loch and therefore this option would require careful design and considerable supporting information.

- ***Reducing nutrient input*** – 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. 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 or more of the feeder ditches to the site if it represents a particular problem to loch water quality. However, as there is superficial evidence that the site is becoming drier this is not a recommended course of action. Particularly as further sampling may show that the main source of nutrients is the River Doon.

- ***Removing nutrient-rich sediments from the loch*** – 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.

- ***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 Bogton Loch and that some buffer zone establishment through hedge planting has already taken place.

  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 some of 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 and so are not recommended within this catchment.

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. Once again, this can be a costly measure and consideration will need to be given to future maintenance of such features. 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
Parameter	**Unit**	**Detection Limit**	**Sample Date**	09/02/2012	09/02/2012	09/02/2012	09/02/2012	09/02/2012	09/02/2012	09/02/2012
Phosphorus (total)	mg l-¹	0.2	Water	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.20
Ammonium	mg l-¹	0.01	Water	0.28	0.24	0.31	0.14	0.07	0.06	0.14
Nitrate	mg l-¹	0.5	Water	<0.5	<0.5	<0.5	<0.5	<0.5	<0.50	<0.5
Phosphate Low Level	mg l-¹	0.02	Water	0.056	0.048	0.056	0.051	0.078	0.06	0.046
Nitrogen (total)	mg l-¹	1	Water	5.73	8.14	7.58	6.91	4.71	5.13	6.09
Calcium	mg l-¹	5	Water	5.3	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Magnesium	mg l-¹	0.5	Water	2.6	2.8	1	3	1.2	1.3	1.1
Sodium	mg l-¹	0.5	Water	6.3	5.7	5.90	6.5	5.9	5.1	5.5
Iron (II)	µg l-¹	20	Water	510	360	200	50	20	30	40
Iron (III)	µg l-¹	20	Water	690	1200	1300	430	290	220	710
Iron (total)	µg l-¹	20	Water	1200	1600	1500	480	310	250	750

Soil samples

			Sample ID	S1	S1	S2	S2	S3	S3	S4	S4
			Other ID	Root	Below	Root	Below	Root	Below	Root	Below
Parameter	**Unit**	**Detection Limit**	**Sample Date**	09/02/2012	09/02/2012	09/02/2012	09/02/2012	09/02/2012	09/02/2012	09/02/2012	09/02/2012
Moisture	%	0.02	Soil	84.6	78.1	82.2	71.8	90.7	91.3	76.7	59.4
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	6	2.9	4.2	<2.0	2.9	3	5.2	11
Phosphorus (total)	mg kg^{-1}	-	Soil	930	940	850	300	160	310	1500	33
Nitrogen (total)	%	0.02	Soil	1.7	1.4	1.2	0.66	1.5	1.2	1.4	0.56
Nitrite (extractable)	mg kg^{-1}	0.1	Soil	0.2	0.29	0.18	0.26	0.14	0.16	0.12	0.2
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	220	220	150	250	120	150	140	240
Potassium (total)	mg kg^{-1}	0.2	Soil	<5.0	<5.0	<5.0	<5.9	<5.0	<5.0	<5.0	<0.50
Sodium (total)	mg kg^{-1}	0.2	Soil	14	9.5	7	7	7.5	7	16	9.5
Magnesium (total)	mg kg^{-1}	0.5	Soil	55	55	32	47	26	33	44	80
Total Organic Carbon	%	0.2	Soil	4	4.7	3.1	4.1	2.9	4	3.7	3.2
Moisture content	%	-	Soil	479	361	451	369	1249	1009	325	128
Bulk density	Mg/m3	-	Soil	1.03	1.03	1.02	1.05	1.01	0.98	1.05	1.18
Dry density	Mg/m3	-	Soil	0.18	0.22	0.18	0.22	0.08	0.09	0.25	0.52

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