

VIKING WIND FARM HABITAT MANAGEMENT PLAN



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EXECUTIVE SUMMARY

The Viking Energy Partnership is submitting an application for a 150 turbine, 540MW wind farm on northern Mainland Shetland (known simply as the 'Viking Wind Farm'). An Environmental Impact Assessment has been carried out to inform the planning process, part of which is known as an Environmental Statement (ES). Within the Viking ES, avian and non-avian ecology chapters assess the ecological effects and predicted impacts of the proposed Viking Wind Farm.

The purpose of this Habitat Management Plan (HMP) is to provide both the context and a statement of proposed actions to mitigate against and compensate for potential, adverse effects of the construction, operation and decommissioning of the Viking Wind Farm as well as past and present management activities upon blanket bog habitats and bird species using the area. The secondary objective of the HMP is to enhance other habitats and species present within the vicinity of the Viking Wind Farm, including wet grassland, native woodland restoration, lochs/lochans and streams/burns.

This document outlines the methods necessary to implement the planned actions, alongside an initial work programme that summarises the steps that need to be taken, appropriate partners and suitable funding and monitoring mechanisms for the life of the Viking Wind Farm. This HMP, which sets out a 25 year programme of action, has been developed as a living and evolving plan that will be responsive to changes in circumstance, best practice guidance and the results of its actions. It is planned that periodic progress reviews will be undertaken and that these will inform future work programmes and the techniques employed.

1. INTRODUCTION

1.1 Introduction

This Habitat Management Plan (HMP) forms an appendix to the Environmental Statement (ES) submitted by Viking Energy in support of its application for consent for the Viking Wind Farm situated across ca. 90 sq. km of northern Mainland, Shetland. The HMP is designed to (i) provide compensation for direct losses of habitats associated with the construction and operation of the Viking Wind farm, and (ii) alleviate the ecological impacts arising from past and present land management practices with the intention of conserving, enhancing and restoring the native habitats. The mitigation of impacts directly associated with the construction, operation and decommissioning of the windfarm are addressed in the Ecology Chapter within the Environmental Statement. However, in practical terms there will be links between defined mitigation works in the ES and the HMP, so integration will occur as and when necessary.

The HMP has been collated and developed by multiple authors and consultancies, including: EnviroCentre Ltd, Natural Research Ltd and University of Dundee.

1.2 Aim and objectives

The aim of this management plan is to outline methods to conserve, enhance and/or restore the degraded habitats in the vicinity of the Viking Wind Farm, in order to maintain or reinstate their full range of ecological functions and biodiversity. A particular focus throughout the HMP is the management of blanket bog which is the predominant habitat type throughout the area under consideration. All work outlined in this HMP will give due consideration to any localised features high of nature conservation value or cultural value. The HMP will:

- Introduce and describe the current nature of the habitats and the priority species associated with them;
- Identify the ecological impacts that are associated with past and present land management practices;
- Introduce and describe the management techniques that may be employed to reduce the negative effects and promote the positive effects of these impacts;
- Outline the criteria that should be used to determine the suitability of areas for management;
- Describe the proposed management of one area (as compensation for direct losses caused by the construction of the Viking Wind Farm); and
- Outline the monitoring necessary to determine the success or otherwise of the initial trials and other works.

1.3 Scope of the management plan

The geographical scope of the HMP is the habitats contained within the Viking 'study area', whose boundaries are taken to contain the four quadrants of the planning application boundary. Areas of terrestrial and freshwater habitat outside of this boundary may also be considered for management on account of their contiguity with habitat inside it, their potential role as buffer zones, or for their own inherent value. Marine habitats are excluded although some of the priority species identified within the plan, most notably the red-throated diver, salmon and sea trout are dependent upon such resources for feeding.

Management of the blanket bog habitat is especially prominent within the plan because it is so widespread within the application boundary, generally in poor condition in many areas and because it supports a high proportion of the priority bird species in Shetland. However, the HMP also considers the management and restoration of woodland, grassland and freshwater habitats in combination with the requirements of a range of priority species.

The HMP considers the restoration and conservation of the habitats and species over the expected, twenty-five year, minimum lifespan of the Viking Wind Farm.

2. SITE DESCRIPTION

2.1 Physical environment

The topography within the application boundary for the Viking Wind Farm is generally gentle and undulating. It ranges in altitude from sea level to 281m on Scalla Field. At Lerwick (approximately 10 km south of the application site boundary), monthly average temperatures vary from 3.3°C in February to 11.9°C in July and August and the mean rainfall ranges from 53 mm in June to 117 mm in November. These relatively benign but wet conditions are enlivened by the strength and persistence of the wind which averages 'Force 4' on the Beaufort scale and there are gales (\geq Force 8 on the Beaufort scale) on an average of 58 days per year. Hill and sea fogs are also frequent (Berry and Johnston, 1980).

As a result of the wet, oceanic climate, the Viking Wind Farm area is dominated by blanket peatland, which is drained by frequent small burns and it contains several hundred standing water bodies ranging in size from small pools of a few square metres to sizeable lochs over 1km² in area. These are important features within the habitat matrix and valuable habitats in their own right. The twenty-four largest water bodies (>3 ha) are referred to here as lochs, and all are flooded rock basins. These tend to have rocky shorelines and are up to several metres deep. The remainder are lochans and pools with water depth rarely more than 1.5 m, which are largely confined to approximately level summits and saddles within the peatland and usually have vegetated shorelines.

2.2 Vegetation

The information contained within this section of the HMP is summarised from the Phase 1 Habitat and Phase 2 National Vegetation Classification surveys in the Ecology Chapter which should be referred to for further details.

Blanket bog is the predominant vegetation type throughout the Viking area and the most frequent or constant vascular species are heather (*Calluna vulgaris*), cross-leaved heath (*Erica tetralix*), deer grass (*Trichophorum caespitosum*) and common and hare's tail bog-cotton (*Eriophorum angustifolium* and *E. vaginatum*). Bog moss (*Sphagnum*) species are frequently present and may form extensive carpets in the wettest areas but they are replaced by the woolly-fringe moss (*Racomitrium lanuginosum*) in more exposed and better-drained locations. Erosion of the blanket bog is widespread and it has resulted in the complete removal of peat to expose the mineral ground beneath in many areas. This is generally believed to be a consequence of over-grazing (Spence, 1979; Berry and Johnson, 1980).

Heath (vegetation dominated by sub-shrubs, especially heather) is present on well-drained, shallow peat and mineral soils. As well as forming extensive stands on the steeper slopes, it is commonly found as a mosaic within areas of eroding or fragmented blanket bog and on mineral or bedrock mounds protruding through the bog. As a consequence of historical and current grazing levels, the heath vegetation frequently includes a high proportion of grass species and may then form a mosaic with stands of acid grassland.

Acid grassland is widespread but sporadic in its occurrence when it typically forms a mosaic with dwarf shrub heath or, more rarely, within areas of eroding blanket bog. More continuous swards are occasionally present on steep, well-drained slopes that have been intensively grazed. It is also found in enclosed fields on lower-lying ground, where it has been modified by varying degrees of agricultural improvement.

Acid flushes, although limited in extent, are frequent throughout the area and have a relatively indistinctive flora of common blanket bog and semi-aquatic species. Base-rich flushes, which are much less common, have a more distinctive suite of species. Marshy grassland and calcareous grassland are rare habitats within the planning application boundary and trees and shrubs are also present but very rare.

2.3 Management

The whole area has been extensively grazed for at least four millennia and this has combined with the effect of the wind to create an open, generally treeless landscape. Within the application boundary, other land uses are limited to the enclosure and improvement of grassland for pasture around settlements. Hand cutting of peat for fuel is currently very limited in extent and restricted to accessible low-lying areas, where there is evidence of more widespread cutting in the past.

3. THE PRIORITY SPECIES AND HABITATS

This section of the report outlines the priority habitats and species and their relevant features, legislation and value.

3.1 Priority bird species

A number of priority species will benefit from the planned habitat management. Such species include red-throated diver, merlin, whimbrel, dunlin, golden plover and Arctic skua, in addition to the other bird species listed in Table 1. In addition to these, the Viking fish survey (see Appendix 10.6 of the Environmental Statement) identified two valuable species within the Viking study area: brown/sea trout and Atlantic salmon. Brown/sea trout are present in all eleven Viking catchments surveyed, whereas salmon were only recorded in two catchments (Burrafirth and Laxo).

A small number of rare plants species, primarily hawkweeds (in the genus *Hieracium*), are also resident within the boundary of the study area (in particular within the Burn of Lunklet SSSI). However, their location on steep slopes above water courses means that they are not directly affected by the proposed management. Some potential threat exists to their persistence with the restoration of woodland and this is considered in more detail below.

Table 1: Priority species, their conservation listing, significance of their populations within the application boundary, habitat and habitat management objectives.

Species	Conservation listings ¹	Viking population importance	Habitat	Habitat management objectives
Otter	EPS, UKBAP	Local – possibly regional	Low altitude streams & rivers, lochs & the coast.	Restore cover along riparian habitat & fish stocks.
Salmon & sea/brown trout	EPS, UKBAP	Regional	Low altitude streams & rivers, lochs & the coast.	Remove impasses & improve riparian habitat.
Red-throated diver	A1, S1	National	Peatland lochans & lochs.	Safeguard, restore & enhance lochans. Stabilise & restore erosion of surrounding peatlands.
Whooper Swan (breeding)	A1, S1	National	Lochs & wet grassland.	Safeguard suitable breeding lochs & shores.
Whooper Swan (wintering)	A1, S1	Regional	Lochs & wet grassland.	Safeguard suitable roosting & feeding habitat.
Merlin	A1, S1, LBAP	Regional	Rank heather for nesting, passerine-rich moorland & croftland for hunting.	Encourage rank heather. Manage moorland, blanket bog & pastures in ways that encourage passerines.
Red grouse	UKBAP	Regional	Heather moorland and blanket bog.	Appropriately grazed moorland. Stabilise & restore erosion of peatlands
Whimbrel	S1	National	Short sward moorland & bog.	Appropriately grazed moorland.

¹ Species conservation listings are as follows: A1, EU Birds Directive Annex 1; S1, Wildlife and Countryside Act Schedule 1; EPS, European Protected Species; LBAP, Local Biodiversity Action Plan; Red List, Birds of Conservation Concern UK red list; UKBAP, UK Biodiversity Action Plan.

Curlew	UKBAP	Regional	Moorland, blanket bog & pasture.	Stabilise & restore erosion of peatlands.
Golden plover	A1	Regional	Blanket bog.	Stabilise & restore erosion of peatlands.
Lapwing	UKBAP	Regional	Pasture and wet moorland.	Appropriately grazed pasture & moorland.
Dunlin	A1	National	Blanket bog with pools.	Stabilise & restore erosion of peatlands. Safeguard lochans & pool systems.
Snipe		Regional	Rank wet grassland & blanket bog.	Appropriately grazed wet grassland. Stabilise & restore erosion of peatlands.
Black-tailed godwit	S1, UKBAP, Red list	National (intermittent)	Rank wet grassland.	Appropriately grazed wet grassland.
Arctic skua	Red list	National	Blanket bog.	Stabilise & restore erosion of peatlands. Encourage Arctic tern.
Skylark	Red list	Regional	Blanket bog & pasture.	Stabilise & restore erosion of peatlands.
Twite	UK & LBAP, Red list	Low	Moorland & croftland & scrub.	Create deep heather & flower rich meadows. Create scrub habitat.
Fieldfare	S1	Irregularly breeding rare UK breeding species.	Scrub & pasture.	Create scrub habitat.

3.2 Blanket bog

Blanket bog is included in Annex I of the EC Habitats Directive (Habitat 7130 Blanket bogs), which highlights its international significance. Blanket bog characteristically has low floristic diversity, and its special biodiversity value lies in the way that its few plant species can interact with the relief to form a highly structured but richly varied mosaic of vegetated and open water surfaces that cloaks the landscape.

The cool, wet conditions that support blanket bog are globally limited, and as a consequence of this, blanket bog too has a limited global distribution. It has been estimated by Natural England that 10–15% (1.4 million ha) of the global resource occurs within Britain, and almost (1 million ha) of this is in Scotland (Lindsay, 1995). In Shetland, there are 56,645ha of active blanket bog² (Quarmby *et al*, 1999), representing *circa* 5.6% of the Scottish total (*circa* 3.8% of the UK total; *cf.* Quarmby *et al*, 1999).

3.2.1 Peatland function

Active blanket bog accumulates dead plant remains beneath the living vegetation because the ground is so wet that the decomposition process, which requires air, is limited. The partially decomposed organic material, or peat, gradually builds up as a waterlogged layer which continues to support blanket bog vegetation at the surface, transforming the landscape into peatland. As the name suggests, blanket peatland forms a continuous mantle over the whole landscape, apart from the steepest slopes. And remarkably, although it is made up of layers of vegetation and peat, more than 90% of its volume consists of water.

² Defined according to the EC Habitats Directive definition which is: "blanket bog still supporting a significant area of vegetation that is normally peat forming."

Certain characteristics of the peatland vegetation have a role to play in the accumulation of peat. For example, the litter of many of the flowering plant species (especially the deer- and cotton-grasses) is resistant to bacterial and fungal decomposers. However, one group of plants in particular stands out for its ability to engineer the conditions under which peat accumulates - the 'bog-mosses' or *Sphagnum* species. The bog-mosses are able to increase waterlogging because they store large amounts of water in special water-holding cells and because the spaces around the leaves, and between individual plants, both hold water and control its flow. In addition, their mode of nutrition reduces the nutrient supply and increases the acidity of the water (to a pH level approaching that of vinegar) which creates conditions that are conducive to the preservation (or 'pickling') of plant material and the accumulation of peat.

3.2.2 Peatland ecosystem services

The accumulation of peat results in the long-term storage of carbon captured from the greenhouse gas carbon dioxide in the atmosphere. The carbon is 'fixed' into the living tissues of the plants at the peatland surface and about 10–15% of the fixed carbon is eventually incorporated into the peat where most of it will be stored almost indefinitely if the peat remains waterlogged. This carbon capture by peatlands is of much greater significance than that undertaken by the more frequently publicised trees and forests (by around 50%: *cf.* Bohn, 1976; Botch *et al.*, 1995; Gorham, 1991 and Shvidenko *et al.* 2005).

As well as being important carbon stores, peatlands can also become sources of carbon dioxide and other greenhouse gas emissions when they dry out and/or lose their vegetation so that the rate of decomposition exceeds the rate at which new peat is being formed. If erosion then ensues, the peatland begins to release peat sediment which can be washed into lochs and streams to their detriment.

Peatlands also store water that is then available during periods of drought to sustain the bog vegetation and water supply to streams. When the water store has been depleted by drought, peatlands can also help to hold back heavy rainfall that may otherwise cause flooding. This role in water regulation can be drastically altered by drainage and/or erosion.

A number of more direct benefits to Shetland's socio-economic environment are provided by peatlands and the most prominent of these is the use of the blanket bog as grazing for sheep. However, the peatland pasture is generally poor in quality and the methods used to make it more productive (such as drainage or fertiliser application) are rarely sustainable in the long term because they degrade the habitat. Peat has also been an important source of fuel in the past.

The peat dominated landscape of Shetland also provides tourism opportunities because a significant number of tourists are interested in bird watching or 'getting-away-from-it-all' on the open hill. All of these experiences are dependent upon the maintenance of a 'wild' environment and the distinctive faunal and floral assemblages that have developed on Shetland over the past ten millennia.

The accumulation of peat within peatlands has also been utilised for the historical account of environmental changes that it has recorded. This historical account is very important because it provides us with a baseline for current environmental and climatic changes as well as the means to determine the nature of such changes by unravelling past natural 'experiments'. In so doing, we can better understand the environmental changes that are currently taking place around us.

3.3 Lochans

The lochs and lochans on the Viking site have particular importance for red-throated divers as they provide breeding sites for around approximately 6% of the UK population of this EU Birds Directive Annex 1 species. Some other priority breeding bird species are also associated with these water bodies, most notably whooper swans and dunlin. In addition, greylag geese use lochs, particularly those with islands, as a safe place for rearing goslings; and waders, terns,

gulls and skua species use shorelines for loafing and bathing. As perhaps the most sensitive loch species, if the habitat requirements of red-throated divers are addressed, it is likely that the requirements of these other species will be catered for too.

Whether or not a water body is suitable for breeding divers is largely determined by its physical characteristics. The key requirements for nesting divers are a length of at least 15m, and ideally more than 25m (too short and the birds cannot take off), but less than 200m; a depth of at least 0.5m so that the birds can dive for cover; and vegetated shorelines close to the water level for nesting. Most of the water bodies that have these requirements are lochans that have formed within the peatland. Although the largest lochs on the site are all used by divers, they are mainly used by non-breeding birds and are seldom used for nesting. For this reason they merit lower priority within the HMP.

Widespread peat erosion is affecting a high proportion of the lochans in the Viking study area. Peat erosion has completely destroyed some lochans or at least, caused water levels to drop. As a result, many lochans that were once suitable for nesting divers are now less suitable or totally unsuitable. Furthermore, there is strong evidence to suggest that if peat erosion continues unchecked, the suitability of many lochans will continue to reduce. It is also likely that the water bodies damaged by peat erosion are of lower value to the other high priority bird species. For all these reasons, the main objective of HMP with regard to lochans is to address the problem of peat erosion.

Three types of action on lochans are proposed depending on the current condition status and extent of surrounding peat erosion. These are safeguarding lochans that are currently in a favourable condition, restoring lochans that are no longer in a favourable condition and enhancing lochans that irrespective of their condition do not have the appropriate characteristics for breeding divers.

A build up of organic sediment is apparent in many of the lochs and this is at least partly due to the loss of peat from eroding areas. This factor is also of relevance to the rivers and streams discussed in the next section but the scale and significance of this is not known.

3.4 Rivers and streams

Riparian habitats throughout the Viking study area have been significantly affected by centuries of grazing, mainly by sheep. In the few fenced areas where livestock are completely excluded e.g. the exclosures in lower reaches of Burn of Lunklet and Burn of Crookadale, the regeneration of riparian trees, shrubs and herbs is striking. Regeneration of riparian vegetation is of benefit to fish populations through the provision of food and cover in the form of draped vegetation, roots and debris. Stream productivity including invertebrate abundance may also increase through inputs of organic material originating from riparian vegetation. Regeneration of the riparian strip may be of greatest benefit to trout in the lower reaches of Shetland's streams, since cover in upper reaches is generally plentiful in the form of undercut peat turf. In contrast, the lower reaches of stream such as the Burn of Grunnafirth, South Burn of Burrafirth, Laxo, Seggie and Laxobigging are rather open and lacking in both cover and shade.

The removal/modification of artificial barriers to the movement of fish within these waters is also important, especially in relation to the migratory salmon and sea trout populations. This will benefit brown trout as well as the juvenile sea trout and salmon that form the basis of the sport-fishing in Shetland.

3.5 Woodland

Shetland is noted for the rarity of trees and shrubs in the contemporary landscape. However, the presence of such species in gardens and in isolated, natural settings demonstrates the potential for their growth in Shetland, from sea level up to a predicted altitude of around 200m (Spence, 1960). Studies of the Islands' ecological history based on pollen grains and wood recovered from peat and loch sediments also demonstrate the previous existence of widespread woodland

habitat on Shetland. However, this woodland would always have been naturally restricted in extent and altitude because of its exposure to high wind speeds.

The beginnings of woodland clearance on North Mainland have been dated to around 4,500 years ago with the arrival of an agricultural culture. The woodland at this time contained a diverse assemblage of species, some of which are currently locally extinct (see Table 2). Following clearance, woodland regeneration was largely prevented by livestock and burning and the habitat therefore became restricted to relatively inaccessible sites such as islands, ledges in gullies and cliffs.

At present there are very few sites where woodland vegetation persists. The Shetland Woodland Strategy (Shetland Amenity Trust, 2000), lists only seventeen 'selected' relict sites that are primarily located in the north-west of the Shetland Islands. These extant areas of woodland habitat (sometimes represented by only a few isolated shrubs or trees) are generally too small to support particularly distinctive floral or faunal communities.

Woodland habitat is therefore of relatively little importance to the priority bird species that currently occur on the Viking area but its restoration is likely to increase the numbers of small passerine species such as twite, starling and passage migrants; and in turn, the merlin, that preys on small birds. The restoration of woodland is also likely to result in additions to the breeding avifauna such as the nationally rare fieldfare, a species that has occasionally bred locally in the past, most recently in 2008.

Table 2: Native woodland species that have been known to occur in Shetland and their current status.

Vernacular name	Scientific name	Present occurrence in Shetland
Alder	<i>Alnus glutinosa</i>	Extinct. Known from sub-fossil pollen & the wood remains.
Aspen	<i>Populus tremula</i>	Rare, present at six sites.
Crab apple	<i>Malus sylvestris</i>	Very rare, present at one site, recently extirpated at another.
Downy birch	<i>Betula pubescens</i>	Rare, present at four sites. Its remains are commonly encountered beneath peat.
Downy willow	<i>Salix lapponum</i>	Very rare; present at one site.
Eared willow	<i>Salix aurita</i>	Relatively common & widespread.
Glaucous dog rose	<i>Rosa caesia</i> subsp. <i>glauca</i>	Widespread & common.
Grey willow	<i>Salix cinerea</i> subsp. <i>cinerea</i>	Rare; one sizeable population.
Hazel	<i>Corylus avellana</i>	Very rare; present at two sites.
Juniper	<i>Juniperus communis</i>	Very rare; present at two sites.
Rowan	<i>Sorbus aucuparia</i>	Uncommon but widespread.
Rusty willow	<i>Salix cinerea</i> subsp. <i>oleifolia</i>	Uncommon but widespread.
Sessile oak	<i>Quercus</i> sp.	Extinct. Known only from sub-fossil pollen. Presumably these remains are referable to sessile oak.

The woodland-associated herbs and ferns (see Table 3) that have been restricted to inaccessible ledges and islands by grazing pressure are relatively widespread but uncommon in Shetland, except for Royal Fern which is confined to five sites on islands in freshwater lochs in the west of Mainland. The original composition and distribution of the woodland on Shetland is not known definitively but it may be assumed that aspen, downy birch, hazel, rowan and the willows would

be present at higher altitudes (up to *ca.* 200m) where they would form a sub-alpine scrub extending close to sea level in the most exposed situations. More sheltered areas at the lower altitudes would be expected to support the formation of woodland including some of the foregoing species as well as alder, crab apple and oak.

Table 3: Herb and fern species which are associated with woodland habitat that have been restricted by grazing or habitat loss to inaccessible ledges and islands.

Vernacular Name	Scientific Name
Beech fern	<i>Phegopteris connectilis</i>
Broad buckler fern	<i>Dryopteris dilatata</i>
Greater woodrush	<i>Luzula sylvatica</i>
Honeysuckle	<i>Lonicera periclymenum</i>
Lady fern	<i>Athyrium filix-femina</i>
Male fern	<i>Dryopteris filix-mas</i>
Oak fern	<i>Gymnocarpium dryopteris</i>
Polypody	<i>Polypodium vulgare</i>
Primrose	<i>Primula vulgaris</i>
Red campion	<i>Silene dioica</i>
Royal fern	<i>Osmunda regalis</i>
Tufted hair-grass	<i>Deschampsia caespitosa</i>
Water avens	<i>Geum rivale</i>
Wavy hair-grass	<i>Deschampsia flexuosa</i>
Wild angelica	<i>Angelica sylvestris</i>

A number of relict woodland sites in the vicinity of the Viking area have already been identified by the Shetland Amenity Trust (2002): e.g. near Brae; on Fora Ness, and at Catfirth. The current resource at these three sites will be safeguarded and enhanced, where possible, in partnership with the relevant land managers and the Shetland Amenity Trust who have also established a monitoring programme and the cultivation of Shetland-sourced aspen, hazel, rowan and willow.

The current altitudinal limit of woodland growth in Shetland may alter in the near future as a consequence of climatic change with warming potentially driving this limit higher and increased wind speeds potentially driving it lower. The eventual balance between these two factors remains to be seen but a focus on woodland restoration at lower altitudes (up to 100m) where there is a higher chance of success in the establishment of a viable population is probably prudent. The woodland may then spread to its natural, upper climatic limit when assisted by appropriate grazing controls.

3.6 Wet grassland communities

The wet grassland habitats considered by the HMP are located in valley bottoms where they may be used continuously or intermittently as pasture or for silage production. As well as hosting a range of vegetation types and plant species they also provide nesting habitat for a number of wader species, potentially including black-tailed godwit, lapwing, redshank and snipe. In the past, this habitat would also have held corncrakes, a species that may return if sufficient areas were managed sympathetically.

The floristic variation of these grasslands is described by Roper-Lindsay and Say (1986) in relation to the soil moisture content. The drier areas support a tall herb community in which

black sedge (*Carex nigra*), meadow buttercup (*Ranunculus acris*), common sorrel (*Rumex acetosa*), sweet vernal grass (*Anthoxanthum odoratum*) and Yorkshire fog (*Holcus lanatus*) are abundant. In wetter situations, stands of yellow flag iris (*Iris pseudacorus*) predominate in association with a range of small grass and herb species such as creeping bent (*Agrostis stolonifera*), meadow grasses (*Poa* spp.) and white clover (*Trifolium repens*).

Grazing within these communities is usually light and they are often used only intermittently for pasture or hay production. Nonetheless, the grazing and mowing are important because they prevent perennial 'rough grasses' such as purple moor-grass (*Molinia caerulea*) and tufted hair-grass (*Deschampsia caespitosa*) from becoming dominant, thus maintaining biodiversity as well as the suitability of the vegetation cover for ground-nesting birds. Also, poaching of the ground by livestock creates small openings in which annual plant species may become established.

More heavily managed grasslands are uncommon within the application boundary of the windfarm and are restricted to altitudes below 30m a.s.l.. These grasslands have usually been re-seeded with perennial rye-grass (*Lolium perenne*), are fertilised with chemicals or manure, and are typically cut for silage. Given their economic importance, they are not included within the management plan although they could become important for nature conservation if they were managed in ways that benefit biodiversity.

4. MANAGEMENT TECHNIQUES

4.1 Overview

This section of the HMP considers the management techniques that are available to safeguard and enhance the priority species and habitats identified in previous sections. The techniques presented aim to:

- Prevent further damage to the habitats;
- Restore the natural functions of the habitats; and
- Manage human activity to ensure the long-term persistence of the targeted habitats and species populations.

The management of the blanket bog habitats is especially complex given the extent of the peatland within the area under consideration and the variety of impacts that have led to its degradation in recent centuries. In order to summarise the socio-economic benefits, functions, impacts, effects and alleviation of the latter, a summary table is included in Appendix B for the blanket bog and other habitats included within this section of the Habitat Management Plan.

4.2 Grazing

Grazing at low to moderate levels (the precise stocking rates are location-specific) is a sustainable practice which can maintain and enhance vegetation diversity and productivity. At higher levels of grazing, the regeneration or persistence of certain species is reduced to the point at which they may become locally extirpated, along with any associated and dependant organisms (such as insects or fungi). This is usually accompanied by the expansion of a limited range of species that are able to persist according to their unpalatability or other characteristics which reduce their sensitivity to grazing.

Grazing also affects vegetation structure which can be a key determinant of the value of the habitat to many species of breeding bird. Priority bird species on the Viking site that are known to be sensitive to grazing-induced changes to vegetation structure include merlin, whimbrel and golden plover. Furthermore all the high priority birds associated with blanket bog habitat are likely to be deleteriously affected by large scale peatland erosion precipitated by over-grazing.

At very high levels of grazing, serious damage may eventually ensue when the vegetation cover is broken by hooves or excessive vegetation removal, exposing the underlying peat. The combination of high wind speeds and rainfall in Shetland then results in the mobilisation of peat sediment so that the initial 'cut' into the blanket bog rapidly develops into a large 'scar' that is most evident in the gullies that further can proliferate up and down a slope, through the movement of water and sediment. Level plateau areas are also vulnerable to erosion caused by the wind when the protective vegetation layer is removed, although in this case, the removal of sediment is extensive over large areas, rather than intensive and localised, as in the case of gully formation.

Spontaneous recovery of blanket bog vegetation is occurring in some areas, and as sheep stocking levels are predicted to fall in the future, this may become more widespread. However, it is by no means clear that recovery of the blanket peatland as a fully functional and self-sustaining landscape system will automatically ensue because there is still active erosion downslope from re-vegetating patches, and grazing units that are still heavily used adjoin recovering ones. Moreover, in the case of some peat lochans, it appears that advancing erosion will cause water levels to fall (and thus reduce or destroy the suitability for breeding divers) before any spontaneous recovery of blanket mire will commence. Therefore, a co-ordinated landscape-level approach to grazing management, combined with active intervention at specific locations, will be needed. In order to reduce grazing, two mutually compatible and complementary approaches - stock exclusion and stock reduction - will be adopted with the objectives of:

- Reducing the influence of grazing on the vegetation;
- Preventing erosion;
- Restoring peatland vegetation and ecosystem functions (such as water regulation and peat formation); and
- Restoring woodland regeneration.

Fencing will be used to exclude stock and in some areas, hares and rabbits, for the purposes of:

- Restoring vegetation to reduce or prevent erosion;
- Enabling 'self-sown' woodland recruitment;
- Protection of specific areas of blanket bog to restore (or conserve) their natural, ungrazed state.

Where fencing is used to protect woodland regeneration it will enclose a larger area than initially planted. This will allow natural regeneration to occur away from the initial plantings and provide for 'soft' edges which have greater aesthetic appeal and value to biodiversity. In areas that are less sensitive to grazing, or where it will be required to maintain floristic diversity, stocking levels will be reduced in agreement with the relevant land manager. The reductions will be funded or compensated at a level agreed with involvement from a third party (such as the Shetland Crofting, Farming and Wildlife Advisory Group or an independent agricultural economist).

Due to the natural variability in the productivity of the common grazings it is not possible to define exact figures for the stocking density which should be adjusted according to the condition of the vegetation and substrate rather than to a rigid figure. However, as an *approximate* guideline, stock figures should not exceed 0.5 sheep per hectare during the summer months and 0.25 sheep per hectare during the winter months. In winter, complete removal of the sheep is a much more desirable option. Winter and summer are delimited by the time of tupping (in November, when the sheep should be taken off the hill) and lambing (in April, when the sheep can be returned to the hill).

Introduced rabbits and mountain hares are also present on Shetland and the former in particular pose a threat to the restoration of woodland. Their presence and their behaviour will be considered when constructing fences and regular monitoring of the fence integrity will be undertaken when hares and/or rabbits are established in the vicinity of a fenced area.

4.3 Hydrology

The management of drainage is integral to the success of the peatland-specific components of the management plan, in order to maintain or reinstate the waterlogged conditions that support the peat and vegetation. In eroding peatland, the management of peat sediment is closely related to the management of drainage. This involves the installation of structures to slow down the movement of water and sediment along ditches and erosion gullies, for which various techniques are described below. However, because of the way that water moves across and through the peat, not all of these techniques are suitable for all locations. An extreme example is that structures placed in the path of high-intensity storm flows are at risk of being washed away and may exacerbate the existing peat instability.

Because the summits of the hills are natural centres for peat formation, and the peatland develops a clear structure that radiates out from these centres, the effectiveness of remedial management on one side of a hill stands to be compromised if erosion continues on the other side. Although the EIA procedure separates 'mitigation' for infrastructure from habitat management, there are a number of hills where infrastructure will be present on only one side, making co-ordination of 'mitigation' with 'habitat management' beneficial. Therefore some brief comment on peatland management in areas with turbines is appropriate here.

The windfarm roads are potentially the most disruptive elements for the blanket peatland, but their routing for minimum disturbance to the natural flow pattern of water through the blanket

mire system (conditional on appropriate road design) can be advantageous for hydrological management on the Viking site. For further details of the road design principles please refer to Chapter 15, Roads and traffic. Many of the road sections will intercept water, and perhaps also sediment, moving across and through the peat blanket and erosion gullies, and it will therefore be beneficial to integrate their detailed design with management requirements for the surrounding blanket mire. A related issue is that the routes of streams ('blue lines') shown on published 1:50,000 Ordnance Survey maps do not accurately distinguish watercourses from erosion gullies everywhere on the Viking area, so that the 'rule of thumb' planning requirement to allow unimpeded water movement along these may be counter-productive for peatland restoration. In addition, the phase of peat excavation - and especially of turfs from the living surface of the peatland - to make way for infrastructure should be fully co-ordinated with blanket mire restoration work, so that all useful material excavated is immediately transferred to its new location and the deterioration that occurs within days of stockpiling is avoided.

Another hydrological feature of the blanket peatland landscape is that the intensity of drainage (the volume of water draining through a unit area) is least on summits and flatter areas such as spurs, saddles and platforms protruding from the hillsides in the higher parts of the relief. These are the areas from which flow lines diverge, and the places where small 'blind' lochans' (those without connecting streams - many of which are attractive to red-throated divers) typically form (see Lindsay, 1995 for more information about blanket mire structure). Moving downslope, both the drainage intensity and the slope generally increase so that it becomes increasingly less practical to fully block up the erosion gullies and any other drainage lines.

The sediment load can be expected to increase until the draining water approaches the foot of the hill and begins to slow down, at which stage there is a tendency for sediment to be re-deposited. It has been shown that the quantity of particulate material entering watercourses is much reduced if there is a good cover of vegetation (notably common bog-cotton) to trap sediment in this part of the landscape; thus management intervention may be beneficial for denuded streamsides and in the lowermost parts of erosion gullies, as well as near the tops of the hills.

4.3.1 Damming small drainage channels

Drains that have been installed to facilitate the flow of water from areas of bog are relatively uncommon in the vicinity of the Viking Wind Farm. They generally serve to drain an area of bog for the purpose of improving pasture and they tend to be small (less than 1m x 1m in cross-section) and simple in structure (typically forming a single, linear feature or a localised 'herringbone' pattern, rather than an extensive network). Much more frequent are small (<2m x 2m) erosion gullies and the early treatment of these will hopefully prevent their development into a larger and more complex gully system that will prove considerably more difficult to repair.

A range of established techniques will be used to reduce and reverse the impacts of small drainage channels (ditches and small erosion gullies). Where these involve installing a series of dams to retard flow and hold water within the channel, the intention is to promote the development of pool vegetation in the open water areas between the dams which, over time, will accrue peat that itself reduces the flow of water and reverses the impact of the drain in the medium to long term.

The placement of the dams will be determined by a levelling survey prior to the commencement of works. This is to ensure that the water table is restored to as close to the vegetation surface as possible and that water flow is effectively reduced to prevent erosion and to promote the colonisation of plants that would otherwise be flushed from the drain.

The dams will be constructed from a variety of materials depending upon the size of the drain, access, labour and availability (with some potential for the recycling of waste materials). These materials will be discussed in turn below and they include:

- Peat;
- Composite dams of peat combined with other impervious materials such as plastic sheeting;
- Plywood, plastic and metal sheeting; and
- Plastic piling.

4.3.1.1 Peat

Peat is the most widely available material in the vicinity of the drains and it is suitable for use on its own only over low gradients because of its propensity to erode when subjected to water flows and its inability to provide a reliable spillway. It is also suitable only where permanent waterlogging is expected because peat dams are not completely impervious to water (unless used in association with a membrane) and they disintegrate if they dry out.

The best result is obtained by completely filling relatively level ditches with re-located peat and surface turfs so that the original arrangement of peat and vegetation layers in the surroundings is reinstated. Unusually for peatland restoration projects, this may be a feasible option for the Viking site during installation of wind farm infrastructure, which can be expected to generate large quantities of 'waste' peat and turves. However, it will be necessary to strike a balance between potential benefit from using this technique and the disturbance that will be caused by transporting large quantities of material across the site to locations that are remote from construction areas.

Where less peat is available, dams will be built from well-humified cohesive peat (classified as H6–H8 on the von Post humification scale; see Appendix C) as this is relatively impervious to water flow. This peat will be removed in large blocks and handled as little as possible in order to maintain its cohesiveness. At the site of the proposed dam, the sides of the drain will be cut back to leave a clean face that will form a good seal with the peat blocks and vegetated turfs will be placed on the top of the dam in order to protect it from erosion. Drains larger than *ca.* 1m x 1m will require the peat to be cut by machine and potentially, the use of additional strengthening materials (as specified below) to form a composite dam. The completed peat dams will stand proud of the adjacent surface (by around 30cm; Brooks and Stoneman, 1997) in order to compensate for slumping and shrinkage.

Where suitably cohesive peat is not available, erosion-resistant dams will be constructed from stacks of sand bags filled with the non-cohesive peat available at the site. Where suitable access is possible, this method could also make use of the peat excavated during the construction of the windfarm, thereby reducing the need to locally remove intact peat. If large quantities of 'peatbags' can be produced and transported, they may also be used, topped with turves, to completely fill ditches and/or the spaces between other types of dams.

4.3.1.2 Plywood, plastic and metal sheeting or panels

Sheeting made of suitable plastic or plywood (usually marine ply) will be used as a means of damming the smaller drains and gullies. Metal sheeting might be considered if readily available, but alloys and coatings likely to leach metal ions that are toxic to bog plants will be avoided (e.g. galvanised metal leaches zinc, which is highly toxic to bog moss), and if mild steel is used it will be coated with waterproof paint to prevent corrosion where medium-term serviceability is required. Panels of these materials will block the width of the drain allowing for additional width to anchor them into the adjacent peat at the sides and bottom of the drain (*ca.* 20–50% of the drain width or depth). Sheets of the appropriate dimensions will be hammered into vertical slits cut into the base and the sides of the drain until they are just proud (2–3cm) of the adjacent vegetation surface. A shallow spillway will be cut into the mid-point of the dam face with the lowest point just below the level of the vegetation surface. Some form of strengthening (horizontal struts or supporting wall of turfs) may be required if upstream water pressure causes sheets to bow.

4.3.1.3 Plastic piling

Plastic piling is very strong, lightweight and long-lasting (up to 150 years). The piles are normally 30cm wide, come in lengths of up to 8m, and they join together using integral interlocking edges that are designed to be water-tight. Their installation will be undertaken in a manner similar to that described above for the sheeting dams but each pile is installed separately, from the centre of the gully, towards the edges. Plastic piling should not be strengthened by rigid cross braces as it must bend in order to maintain its strength and water-tightness.

4.3.2 Damming large erosion gullies

In comparison to the approaches described above, which completely block the cross-section of the drain, the methods adopted for the larger and/or unstable gullies will focus only on the lowermost part of the cross-section in which any water and eroded materials are transported. The materials used here will be both resistant to erosion and securely anchored in order to resist the energetic water flows that may occur during or following storm events, slowing it down to encourage re-deposition of sediment as high as possible in the gully system. Should revegetation and peat accumulation prove to be successful, the gullies might be re-dammed to raise the water level further if appropriate. However, in many instances, the intention will be to reproduce and assist the process of sediment accumulation and re-stabilisation that is occurring naturally in gullies across the site (Crowe *et al.* 2008), any artificial obstructions being designed for compatibility with natural blocks upslope and downslope.

Materials that have been used successfully in the pioneering work already undertaken by the Moors for the Future Partnership and other groups in the English Peak District³ include:

- Stones;
- Sand bags filled with peat;
- 'Sausages' of rolled coir matting anchored with metal pins;
- Conifer brash;
- 'Hay bales' that may be formed from rushes; and
- Corrugated plastic piling.

The potential also exists to use other materials naturally present on the site or generated by the construction of the windfarm. These include:

- Vegetated turfs; and
- Excavated peat *en masse* where its retention can be assured, e.g. upstream of windfarm road crossings.

The creation of the dams will aim to retard water and sediment flow and achieve as much storage as possible within the confines of the gully in order to help support the associated water table in the adjacent, upstanding areas of peat. However, the height and extent to which water and sediment may be stored is dependent upon:

- Steepness of the slope;
- Complexity of the surrounding topography;
- Nature of the upslope catchment;
- Hydrological interconnections;
- Relative widths of gullies and upstanding peat; and
- Conformation and complexity of the gullies' 'drainage network'.

³ See <http://www.moorsforthefuture.org.uk> for further details. Accessed November, 2008.

The feasibility of the action and the desired height, location and number of dams will be determined by survey work beforehand because an *ad hoc* approach that does not take account these factors is likely into result in failure.

In the case of gently sloping gullies, the use of natural, readily accessible materials (such as peat, stones or dislodged turfs) to form low dams may be appropriate. In the case of steeper gullies where complete damming is required, it will be necessary to use stronger, erosion resistant structures such as the sheeting and plastic piling methods described above (Section 4.3.1). In many cases, fully restoring the water table in the larger gullies to the level of the surrounding vegetation surface will not be feasible or advisable, especially where this will involve impounding substantial depths of water between banks of degraded peat on sloping ground. In such cases, the intention will be to promote the natural recovery process, in which peat sediment is captured, retained and re-vegetated in the gullies so that their floors gradually rise towards the level of the surrounding peatland surface. For this, the same materials may be used to create low dams and/or baffles (not extending across the full width of the gully).

Capture of the water and sediment flow behind the dams will create small pockets of stabilised peat which will act as nuclei for the re-establishment of plants such as common bog-cotton and heath rush (*Juncus squarrosus*) that will spread and consolidate the peat with their rhizomes and roots. This process will be facilitated by introducing individual plants or turfs of these species that have:

- Become detached from the bank of the gully;
- Been cut selectively from small, discontinuous areas of the neighbouring, undisturbed vegetation; or
- Been specifically grown for the purpose within a nursery.

It is also possible to introduce species to bind the peat such as wavy hair-grass (*Deschampsia flexuosa*) and bents (*Agrostis* spp.). These grasses are introduced to the bare peat as turf or as seed and they rapidly grow to form a sward that resists erosion. Seed collection of the native grasses that are likely to persist can be undertaken locally and this will require the purchase and hire of machinery and the training and seasonal employment of suitable locally based staff.

Given the especially nutritious nature of these grasses, especially if their establishment is accompanied by fertilisation and/or liming, the success of this approach is dependent upon the exclusion or severe reduction of the number of stock in the area. This is because the sheep will concentrate their attentions on the consumption of these 'grasslands' that are more palatable than the surrounding blanket bog vegetation.

Where it is necessary to stabilise peat as rapidly as possible, biodegradable erosion and sediment control textiles (e.g. coir mesh) will be used to assist the process of revegetation. These will be rolled out over areas subject to erosion (i.e. where the dominant process is sediment removal rather than re-deposition), e.g. on level plateau areas and at the *tops* of eroding gully sections, and may be seeded or planted with appropriate species where these are not expected to colonise naturally.

4.4 Lochan restoration

A range of techniques will be required to achieve the three objectives (safeguarding, restoration and enhancement) of the HMP aimed at lochans. The probability of achieving enduring success with these management objectives is crucially dependent on the hydrology of the surrounding peatland. The lochan management objectives therefore require a two-pronged approach, indirect measures aimed at the wider hydrology and direct measures aimed at the lochans and their banks. If the hydrology is not properly taken into account then it is unlikely that lochans subject to management will be sustainable in the long term or possess the special characteristics required by breeding divers, in particular water levels close to the bog surface. Indeed, to a very large extent, the challenge of tackling the consequences and threats posed by peat erosion to lochans

is primarily a question of managing the surrounding part of the blanket peatland, possibly up to several hundred metres from a lochan. For this reason, the major part of the work associated with managing lochans would involve the various techniques aimed at promoting a healthy peatland system that have already been discussed (in Sections 4.2 and 4.3).

A lochan that has developed in a summit position, and so has no upslope catchment, is full of water because the surrounding blanket peat slows the rate at which water is lost by seepage to below the rate at which new water arrives as rain (minus evaporation and overflow). Lochans of this type on the Viking site are vulnerable to erosion in two ways. Firstly, when erosion gullies develop on the surrounding slopes, they begin to drain the peat layer around the lochan. The result on some summits is that the peat has disappeared (through a combination of shrinkage, vegetation loss, drying-out, decomposition and wind erosion) from around the shoulder of the hill, leaving the lochan in a separate, hydrologically unstable 'upstanding' block of peat that continues to erode at its outer edges. Secondly, once formed on the slopes, one or more of the gullies can cut back through the peat blanket towards the summit, and eventually breach the bank of the lochan itself. The lochan can then drain into the gully system. The water level in the lochan may only be lowered initially but once a gully has connected with it, there is a tendency for the connection to grow in width and depth through continued erosion until the lochan is completely empty. Once such a process has begun, observations indicate that there does not appear to be any natural mechanism to arrest it.

Accordingly, appropriate measures to safeguard a summit lochan or to reinstate a recently drained one will include damming techniques – essentially blocking up a breach in the bank of the lochan or an erosion gully that is approaching it. However, the approach of a gully is a sign that the ability of the peat blanket to sustain the hydrological equilibrium of the lochan is becoming marginal, so that artificially restoring the water level may actually destabilise the system further. Therefore, simultaneous action should be taken to re-establish vegetation and peat formation on the surrounding areas. This would involve working outwards from the lochan, applying appropriate measures to stabilise and re-vegetate with appropriate plant species any halos of bare peat, mineral ground and/or gullies. Ideally, the area treated should extend to the next stream, reversal of slope or other line of hydrological discontinuity in the landscape. In some cases, however, the distance may be so large or the boundary so indistinct that a closer range for intensive remedial work might be set following a detailed assessment of the individual situation.

Lochans and larger bodies of open water in valley locations receive water from upslope and discharge it *via* a distinct outlet. Here, the principal adverse effect of erosion is the delivery of peat sediment which tends to fill up the basin, displacing the stored water. The two effects are combined in lochans that have so far survived on 'islands' of bog vegetation in saddles between eroding summits, which can be simultaneously receiving sediment from two upslope directions and under threat of drainage by gullies advancing from downslope. Where lochans of this type are to be safeguarded or restored, the peatland on both of the flanking summits will need to be returned to 'healthier' condition as part of the management prescription, in order to curtail the sediment supply.

4.4.1 Lochan stabilisation and repair techniques

The direct measures necessary to address the objectives of safeguarding lochans and restoring the damage already caused by erosion described in this section are concerned with the lochan banks. These aim to arrest the advance of erosion gullies towards vulnerable lochans, and to rebuild and strengthen banks where gullies have already been penetrated; in both cases promoting the development of peat forming vegetation around the lochan where this has been lost. Depending upon the nature of the problems at a particular lochan, measures could range from large scale blocking up of gullies (which can be up to 2m deep and several metres wide) with a mix of hard (rock or timber) and soft defences (compacted peat) to small scale surface measures aimed at raising the water table and promoting colonisation by *Sphagnum* moss, e.g. infilling or damming small gullies. The depth of water to be retained is typically 0.5 to 1m so the

potential pressure on the banks is not especially high. However it is essential that the repairs do not leak significantly more than the remainder of the bank, which is likely to consist of fairly well humified (i.e. low permeability) peat. Whereas the use of membrane liners (e.g. 'butly' rubber) would undoubtedly produce a watertight basin, their use is probably not necessary and would in any case be very expensive. Nevertheless, there may be merit in incorporating some form of membrane patch across severe bank breaches to simulate the function of the impervious, well-humified peat that forms the remainder of the bank, since peat that is formed from recently established vegetation will probably take a very long time to reach the same degree of humification. The upper edge of the patch should, however, be level with the base of any vegetation layer on the bank and new vegetation should be re-established above to complete the surrounding, more-permeable living surface layer that is important in regulating the water level of the lochan.

Where the restoration of former water levels is an objective, the works may need to be phased over several years so that vegetation can recolonise and reinforce banks as they are gradually built up and strengthened. Restoring 'empty' lochans that retain most of their original shorelines is an attractive option for creating new water bodies because there is a ready-made basin and so relatively little if any excavation is required. However it remains to be seen if large sections of destroyed bank can be economically repaired to successfully impound water. These measures would also need complementing by measures to tackle erosion of the surrounding peatland, which is often particularly severe around empty lochans.

4.4.2 Lochan enhancement techniques

Lochan enhancement is distinct from restoration, though some lochs may benefit from a combination of both. The aim of enhancement would be to change the characteristics of an existing lochan or pool that, irrespective of any erosion, does not meet the requirements of nesting divers into those of a lochan that does. In addition, it may be possible to create lochans in places with no existing water body by digging out a completely new basin, though this has the obvious disadvantage that the amount of work involved is potentially greater. The aim of the lochan enhancement work would be to create lochans that comfortably exceed the minimum dimensions required by nesting divers. In practice, to be reasonably attractive to divers, a lochan should measure at least 20m x 15m and have a depth of at least 0.5m, though a lochan of twice this size may be more than twice as likely to be occupied and would still be well below the optimum dimensions for divers.

New potential diver breeding lochans could be created in several ways. Existing lochans that are either too small or too shallow could be enlarged or deepened. In some cases it may be possible to amalgamate two small existing pools. It may also be possible to impound water in certain existing erosion features (such as large horizontal gullies) to form suitable pools using small dams of mineral till, peat or plastic piling. Lastly, completely new water bodies could be dug in either deep peat (i.e. excavate a basin in the peat), or mineral till.

Each of these approaches has pros and cons. Enlargement of existing deep-peat lochans that are currently too small for divers is attractive as a watertight basin clearly already exists and in some cases relatively little excavation would be needed to create a water body that would meet the requirements of breeding divers. However any excavation in such areas runs the risk of upsetting the local hydrology and will therefore need to be subject to expert hydrological scrutiny. In practice, this method will work best at sites surrounded by extensive level ground, as these are most likely to have the hydrological capacity to successfully impound relatively large lochans. Excavating a basin into the mineral drift (either creating a completely new lochan or deepening a shallow-peat lochan) may be a particularly effective and relatively easy to achieve because the resultant lochan would not be dependent on the hydrological integrity of the surrounding blanket bog to impound water. However the practicalities of this approach will depend on the proximity of bedrock. Summits and/or spurs that have completely lost their peat cover may be potential sites for this type of intervention since, if a suitable waterproof basin could be created by excavation and new peat formation initiated on the surrounding area, diver breeding habitat

would be created in the short term whilst the long-term result could closely resemble a natural summit.

The amount of material that would need to be excavated to achieve such lochan enhancement works is likely to range from about 25m³ to 250m³ of peat and/or mineral drift per lochan. There should be no difficulty in 'losing' the material locally - for example, it could be used as part of the wider blanket bog restoration programme. It maybe necessary to have SEPA's support and this would only be progressed once such discussions and agreements had been reached. The work would probably require the use of a tracked excavator. However, as the amounts of material involved are modest it may be most practical and economic to helicopter in a mini-digger and 4WD mini-dumper. This would also prevent vegetation damage caused by driving machinery over blanket bog. The vegetation from any excavated areas would be carefully saved as turfs and re-used to help stabilise banks and treat any nearby erosion.

4.5 Rivers and streams

Man made barriers to the passage of migratory fish are present on three rivers and streams within or close to the Viking study area. These may be removed in some instances or alternatively, modified in order to facilitate the passage of fish. The habitat for these fish species will be enhanced further by the restoration of riparian vegetation which will provide cover and an additional source of food.

Where streams and rivers are responsible for the conduction of large quantities of eroding peat, sediment traps may be employed to reduce the impact of this on the lochs and lochans receiving the sediment and potentially, on the spawning areas within the streams and rivers used by migratory and resident fish species. The sediment traps should be situated where they will not block passage to the spawning grounds and where they are accessible to the means necessary to empty them.

4.6 Woodland regeneration and management

Two complementary approaches will be adopted in the restoration of woodland:

- The facilitation of natural regeneration from extant woodland stands; and
- The recreation of woodland from local seed or cuttings.

In both cases, grazing control will be necessary to prevent the loss of reproductive structures, individuals and whole areas of regeneration. In these cases it will be necessary to protect (with fencing) and then supplement the existing vegetation with the transplantation of saplings (as listed in Table 2) and once a mature canopy has started to develop, appropriate herb species (as listed in Table 3) will also be introduced as seed or transplants. The restoration of the woodland ground flora will also benefit bumble bees (LBAP priority) and other insects through the provision of a range of nectar-bearing flowers, as well as a broad range of other species.

In certain instances, it may be possible to incorporate a degree of grazing within the restoration areas. This can be achieved by protecting specific areas of regeneration with mobile or re-usable fencing, or well-supported growth tubes, which can be removed once the trees have established to a size where they will not be affected by grazing. Such fencing can then be relocated to encourage regeneration within an adjacent area. This is a long-term approach that should be supplemented by the creation of core areas in which only very limited grazing at most is permitted.

The support and expansion of existing local nursery facilities will be required to facilitate the woodland regeneration and preferably, locally-sourced and prepared seeds and/or cuttings will be used to establish the required species. Appropriate seed and spores for the establishment of the herbaceous species will also be gathered by hand, or by machine, depending upon the nature and size of the sources. Alternatively, and much less desirably, appropriately sourced material may be brought in.

An important consideration in the restoration of the woodland is its potential to spread onto adjacent areas of blanket bog that are in poor condition because this will result in further degradation of the latter habitat. For this reason, it will be necessary to initiate the establishment of woodland in some areas only when the adjacent areas of blanket bog are or have been brought into a wetter, healthier condition that is resistant to colonisation by shrubs and trees.

4.7 Wet grassland habitats

Due to the variation in their vegetation, substrates, past and present management and in some cases, the selectivity of the stock that will be used to graze them, it is not possible to prescribe a specific management regime to satisfy all requirements at all grassland sites. However, the management of the sites should ensure that the vegetation does not all become overgrown or rank or be so heavily utilised that it becomes a short, homogenous sward.

The management of the grassland habitats will be undertaken by grazing or through their usage as hay meadows. The latter is especially appropriate where this land use has been practised previously (or continues to be so) because a significant proportion of the fauna and flora will be adapted to the pressures that this land management imposes. Leaving a proportion of the field uncut (such as its margins) will promote the creation of greater structural diversity that will benefit insects, amongst other species, and supply cover when the hay is mown. If corncrakes should colonise hay meadows, then corncrake-friendly management techniques would be adopted.

Management by light and/or seasonal grazing will be adopted where appropriate. Cattle will be favoured rather than sheep because they create a less even sward and break up the ground more effectively, thereby increasing the range of niches available for plants and invertebrates. Cow pats also create a valuable habitat for fungi and invertebrates and the latter will then supply foraging birds with a food resource.

Seasonal grazing is preferred to a continuous regime as this allows flowering species to set seed and is generally preferable for ground-nesting birds as well.

A number of implementation options are available, these include:

- Crofters will be encouraged to adopt the grazing and/or mowing regimes described above through fiscal or material incentives;
- The fields may be purchased or rented by the project and the grazing or hay-making rights let; and
- The project can purchase or rent the fields and undertake appropriate management with its own stock or machinery.

4.8 Trials

Some of the techniques described in this section are relatively novel and totally unproven in the Shetland environment. This applies especially to the methods proposed for stabilising and re-vegetating bare peat surfaces, and for safeguarding and restoring/enhancing lochans. For these techniques in particular, trials are needed in order to determine the most satisfactory techniques across the Viking area as a whole and potentially for other degraded sites in Shetland.

The approach suggested for bare peat surfaces (and possibly also for bare mineral ground) is for a trial to be carried out on an extensive area of bare peat from which sheep are excluded. The trial would be designed to test the following factors:

- Colonising vascular species – initially heath rush and/or common bog cotton, resorting to 'exotic' nurse grasses only if the bog species cannot be persuaded to grow;
- Planting method – sowing seed or planting nursery-grown seedlings;
- With or without fertiliser application;
- With or without coir matting or other textile laid over surface;

- With or without the addition of bog moss propagules (e.g. macerated material); and
- No treatment apart from exclusion of grazing.

All of the techniques proposed for lochan management are completely new and thus require trialling, preferably in a relatively confined area that is readily accessible from public roads. The techniques are:

- Safeguarding, which involves arresting erosion that is specifically threatening an existing valuable lochan, using peatland restoration techniques that are appropriate to the individual situation;
- Excavating a basin in exposed mineral ground, e.g. on a bare summit, and re-establishing blanket bog vegetation on the surrounding area; and
- Damming up the banks of a drained lochan.

5. SELECTION OF HABITAT MANAGEMENT AREAS

This section outlines the ecological selection criteria to be used in the identification and prioritisation of areas for conservation management.

An important consideration in realising the habitat management objectives in practice is the question of how to replace any crofting revenue lost in conjunction with habitat management, e.g. due to any requirements for reductions in stocking levels. EU agri-environmental instruments offer one potential source of alternative revenue. Also, establishment of a Viking Habitat Management grant programme to support positive habitat management work by land users and financed by Viking Energy, perhaps modelled on SNH's Peatland Management Scheme for the Caithness and Sutherland Flow Country, might be considered. A dialogue with local stakeholders has been opened with a view to identifying ways for taking forward these suggestions in respect of the pilot management area.

5.1 Selection criteria

5.1.1 Criteria for blanket bog

Blanket bog vegetation is widespread across the Viking study area, and much of it has been classified as 'active' according to the EU Habitats Directive definition. The principal attribute that is lacking is its landscape-level continuity, which is severely compromised by peatland erosion. The HMP aims to promote the recovery of active blanket peatland across each of the four quadrants. However, given the size of the site and the extent of the peatland, it will be impractical to apply this type of management everywhere at once, and it will be necessary to prioritise between candidate areas for active intervention. Criteria that are relevant to determining priorities and practicalities are listed below.

1. Each area to be managed (compartment) should be chosen with consideration for its ability to support a self-sustaining section of blanket peatland, and its management should take into account any functional connections to adjacent sections.
2. Priority might then be afforded to:
 - Compartments which are actively eroding (e.g. have extensive areas of bare peat and mineral ground and/or actively eroding gully systems) as opposed to those which have begun to re-vegetate, and thus apparently to recover spontaneously;
 - Compartments where there are signs of direct human disturbance such as ditches, grazing lines, ploughing, tracks etc., especially where impacts could be reversed by active intervention;
 - Compartments that support additional important peatland habitats and species;
 - Compartments where specific and imminent threats to the additional important habitats and species have been identified;
 - Compartments where opportunities have been identified for enhancing specific habitat features (e.g. increasing the number of lochans suitable for red-throated diver breeding); and
 - Compartments where continued erosion would detract from the quality of the stream and loch habitats receiving water from them (e.g. the silting up of salmonid spawning gravels with fine-grained, organic sediment).
3. Two principal logistical constraints on management can be identified:
 - Planned windfarm infrastructure which, although designed for minimal interruption of the hydrological continuity of the recovering peat blanket, may nonetheless restrict the range of habitat elements that it would be appropriate to create during the projected lifetime of the windfarm (e.g. it would be unwise to create areas of open water that may attract breeding red-throated divers close to turbines); and

- Practical and financial compatibility of habitat management work with existing land use, especially in view of the complex pattern of land ownership and occupancy associated with the long-established crofting economy, combined with recent and continuing changes in agri-environment subsidy mechanisms.

5.1.2 Criteria for lochans

The large number of candidate lochans and pools within the Viking area makes it unlikely that all those that would benefit from practical management could be treated, at least to begin with. A two-stage selection process has been devised that uses the information on the approximately two hundred water bodies examined in the Viking lochs and lochans survey (ES Chapter 11, Birds) together with other information to prioritise sites for habitat management. The aim of this process is to maximise the conservation benefit of whatever level of habitat management work is agreed.

The first stage considers each lochan as a candidate for each of the three management objectives, namely safeguarding, restoration and enhancement. Matrices were used to classify lochans as 'very high', 'high', 'medium' or 'low' priority for each of these management objectives on the basis of measures of current and potential suitability for nesting divers and the apparent threat from future erosion (Table 4 to Table 6). The prioritisation matrix for safeguarding lochans from erosion (Table 4) is based on a combination of apparent erosion threat and the likely medium-term change in suitability for breeding divers. The prioritisation matrix for restoration work to reverse the impacts of existing erosion (Table 5) is based on a combination of current and estimated pre-erosion suitability. The prioritisation scoring for work to enhance lochans for divers, irrespective of any erosion, was restricted to small lochans (less than *ca.* 25m long) and pools, i.e. those that are currently below or close to the minimum acceptable size. Clearly the potential increase in suitability of a particular lochan will depend on the amount of enhancement work undertaken. Therefore, the prioritisation matrix (Table 6) is based on the expected change in suitability for divers that would result from a defined level of enhancement effort. This was arbitrarily set at increasing length by 10m and depth by 0.3m. The measures of lochan condition and erosion threat; and the current, potential and expected future changes in suitability are all based on value to divers.

Table 4: Matrix for prioritising lochans for management aimed at safeguarding them from future erosion, according to the apparent risk of future peat erosion and the likely change in suitability for breeding red-throated divers.

Apparent erosion risk	Medium term future change in suitability			
	High>Unsuit.	High>Low Med.>Unsuit.	High>Med. Med.>Low	Low>Unsuit.
High - severe	very high	high	medium	low
Medium	high	medium	low	low
Low	medium	low	low	low

Table 5: Matrix for prioritising lochans for habitat restoration measures according to their pre-erosion and current suitability for breeding red-throated divers.

Pre-erosion suitability	Current suitability			
	High	Medium	Low	Unsuitable
High	low	medium	high	high
Medium	N/A	low	medium	high
Low	N/A	N/A	low	medium

Table 6: Matrix for prioritising small and pools for habitat enhancement measures according to their current and predicted post-enhancement suitability for breeding red-throated divers.

Current suitability	Potential post-enhancement suitability			
	High	Medium	Low	Unsuitable
Medium	medium	low	N/A	N/A
Low	high	medium	low	N/A
Unsuitable	high	medium	low	N/A

The second stage takes the 'very high' and 'high' priority sites identified in stage one and examines them against potential constraints that would affect the practicality and desirability of management work at that site. The potential constraints that need to be considered are local hydrology, distance from vehicular access, predicted amount of work involved (equates to likely costs) and the proximity to any proposed wind turbines. It is suggested that these factors are each scored on a nominal 0, 1, 2, 3, 4 scale and that the product of the scores is used as a single practicality score to consider alongside the priority ratings from stage one. The zero score would be reserved for what are considered to be absolute constraints. Thus a site that scores zero for any constraint would also achieve an overall practicality score of zero, indicating that management work at that site was impractical.

5.1.2 Criteria for rivers and streams

The need for criteria to be developed in relation to riverine habitat is negated to some extent by the ready identification of a series of clearly defined impediments to the passage of migratory fish species. The potential for restoring the riparian vegetation is discussed below in relation to woodland restoration.

The dam on the Burn of Laxobigging at HU417727 apparently serves no purpose. Its removal, or the installation of a fish pass, would open up approximately 1km of habitat upstream, most of which is good juvenile salmonid habitat with spawning potential. Should the waterfalls at HU411720 be passable by sea trout, the removal of the dam would permit access all the way into the upper reaches of the catchment.

The fish pass on the lower Kirkhouse Burn where the stream flows below the B9071 (HU402627) could be modified in agreement with the current landowner. The drop from the lower pool of the fish pass is onto shallow rock, with no suitable pool from which fish can make the jump to the pass. Access would be improved by deepening the pool below the fish pass.

A further man-made obstacle, the weir at Weisdale Mill (HU396531) should be fully assessed. While the weir is passable, it clearly impedes fish passage at certain flows and fish trapped below the weir may be vulnerable to predation. Indeed, this was a favoured poaching area in past years (Paul Featherstone, *pers. comm.*). The weir is an integral part of the hatchery operation at Weisdale so any modification to water flows or the structure of the weir will be undertaken with the full consultation, agreement and co-operation of all stakeholders.

The fish pass on the lower Sandwater (HU408511) was not inspected during Viking ES surveys. However concerns were expressed by members of the Shetland Angling Association, who felt that its efficacy should be assessed.

5.1.3 Criteria for woodland

Although an occasional, natural component of blanket bog vegetation, the widespread regeneration of woodland has the potential to further degrade the blanket bog vegetation and function. This would be as a result of the shade and increased water loss and nutrient cycling that is associated with the presence of woodland. In order to ensure that such negative impacts

do not arise, the site selection for woodland regeneration will therefore avoid areas adjacent to poor quality blanket bog habitat where the relatively dry conditions will encourage shrub colonisation and further blanket bog habitat degradation.

Extensive survey will be required to establish the areas most suitable for the regeneration of woodland. It is expected that this will take place primarily along stream valley sides where the steepness of the ground will facilitate natural drainage and relict woodland vegetation may already be present that will provide a natural seed source. In such circumstances however, cognisance must be paid the potential presence of rare or otherwise notable plant species whose persistence may be threatened by the exclusion of grazing animals and/or the establishment of woodland.

Islands in lochs, isolated rock outcrops and mineral mounds protruding through areas of high quality blanket peat may also be targeted to enhance the connectivity between valleys (subject to the provisos above). The borrow pits created during the construction of the windfarm also hold potential for the establishment of woodland within a sheltered, well drained situation. The following criteria will be used to determine the suitability of areas for woodland regeneration:

- Altitude less than 100m a.s.l.;
- The presence of relict trees or shrubs that may be capable of naturally regenerating woodland habitat with the exclusion of grazing;
- A wind exposure that is compatible with tree establishment (wind exposure has been modelled and mapped across the site for the purposes of turbine location);
- The presence of a mineral soil suitable for shrub/tree establishment;
- The absence of adjacent, blanket peatland in poor condition that will be susceptible to widespread woodland regeneration to its detriment;
- The absence of high densities of priority bird species that require open ground (such as whimbrel, golden plover, dunlin and Arctic skua); and
- The potential for stock management (through stock reductions or the erection of enclosures).

5.1.4 Criteria for grassland

Appropriate sites will be identified by survey and agreement with the relevant land owner/manager and prominence will be given to:

- The enhancement and/or conservation of those sites that are already especially rich in distinctive faunal or floral species; and
- The restoration of those grasslands that have fallen into dereliction.

6. PILOT HABITAT MANAGEMENT AREA

It is anticipated that habitat management will be undertaken in stages over a large part of the Viking site during the lifetime of the windfarm, and that the criteria developed will be applied at a range of levels during this time. In order to illustrate how they may be applied, an example for Nesting quadrant is summarised here. The following section then describes in detail, the application of the techniques in Section 4 to a proposed pilot management area.

Nesting quadrant is chosen because a qualitative assessment of peatland condition based on available field observations and air photographs indicates that this is the quadrant with the most widespread, active erosion at the present time. In other quadrants, post-erosion bog moss carpets have developed on at least some summits, whereas in Nesting all of the summits appear still to be losing peat. This is reflected by the presence of six lochans prioritised for safeguarding and thirteen candidates for restoration/enhancement.

The principal convex and concave landform units (hills and valleys) in the Nesting Quadrant are distinguished in Figure 1, as indicative management compartments. Table 7 summarises, for each landform unit, the available information relating to peatland condition, nature conservation features requiring safeguarding, opportunities for habitat enhancement, and the constraints. For windfarm constraints, the approximate fraction of the unit that will lie within turbine clusters (i.e. the approximate area from which birds may be displaced) is estimated. For land use constraints, the approximate fraction that lies on common grazings (as opposed to enclosed parcels) is given, as a first indication of the number of land users involved.

An outline of management considerations and potential indicated by this exercise for each of the Nesting hills is given below.

Riven Hill is the closest of the Nesting hills to being separate from the remaining convex landforms, although it is connected by a low saddle to Muckle Hill. It is completely covered by peatland and its two eroding summits appear to be re-vegetating with heath rush and heather, with limited recolonisation by bog moss. A nationally rare moth has been recorded and there is a non-priority saddle lochan (seldom used by red-throated divers). There is also some degraded spur peatland which appears to retain elements of what may be typical blanket bog patterning for Shetland. The small areas of croft apportionments (possibly three land users) and planned windfarm construction, and its proximity to a public road make this a strong candidate area for peatland restoration including the establishment of trials (re-vegetation, hydrology and lochans).

Muckle Hill has some old ditches and its principal summit is eroding quite severely. Two apportionments occupy around half of the compartment, and windfarm infrastructure is confined to one corner of the hill. There are three lochans, two of which have been identified as priorities, with potential for enhancement at three more (all on the priority list) for safeguarding. Access to these will be improved when the windfarm tracks are in place.

Skellister breeding sites for red-throated diver are mostly medium-sized lochs and none of these needs urgent safeguarding. Some twenty crofting apportionments account for around half of the compartment, and windfarm construction will be confined to one corner of the hill. The southern and south-eastern parts of the hill are potential areas for wet meadow and woodland management sites, and a small roadside borrow pit that will be required for windfarm construction offers an additional site for eventual woodland planting.

Table 7: Summary of peatland condition, safeguarding requirements, opportunities for habitat enhancement, and management constraints identified for each indicative landform unit within Nesting quadrant. Attributes are grouped according to:

(a) condition of peatland in terms of erosion (E: eroding summits, R: revegetating summits, S: sediment issues apparent, C: erosion in catchment) and signs of human impacts (D: ditches, P: plough lines, G: grazing lines, T: tracks, M: improved pasture, Q: quarry, S: shelter belt;

(b) nature conservation features requiring safeguarding (number of lochans and *priority lochans for safeguarding, record of nationally rare or other priority species e.g. moths, vascular plants, fungi, 's' indicates important for salmonid spawning);

(c) opportunities for habitat enhancement (RTD: number of restorable or enhanceable lochans and * priority lochans, W: woodland, WP: wet pasture); and

(d) constraints (estimated fraction of compartment occupied by windfarm infrastructure and thus potentially unavailable to birds; estimated fraction of compartment on common grazing as a first indication of types of land use constraints).

Unit	Condition		Safeguard		Opportunities			Constraints	
	Erosion	Human Impacts	RTD lochans	Rare or priority species	RTD	W	WP	Wind farm (%)	Common grazing (%)
Sae Water/ Laxo Burn	C	D				✓	✓	0	ca. 60
Riven Hill	E (R?)	G	1	✓	✓			ca. 25	ca. 75
Atler Burn	C	D		✓				0	0
Gossa Water and burns	S			✓ s				<1	100
Muckle Hill	E	DG	3*	✓	2*+1			ca. 30	ca. 50
Burn of Grunnafirth	C	DGM		✓ s		?	?	ca. 30	ca. 60
Skellister	E	GTPMS	4	✓		?	?	ca. 25	ca. 50
Burns of Quoys and Flamister	C	DGM		s		?	?	ca. 40	<20
Flamister	E	GTMS		✓			?	ca. 60	ca. 80
Burn of Crookadale	C	D		s	3*+1			ca. 10	ca. 90
East Kame	E	Q	1		1*	?		ca. 10	ca. 50
Hoo Kame / Mossy Hill	E	M	3*+1		3*+2		?	ca. 60	ca. 95
Wester Filla Burn	C							<1	100

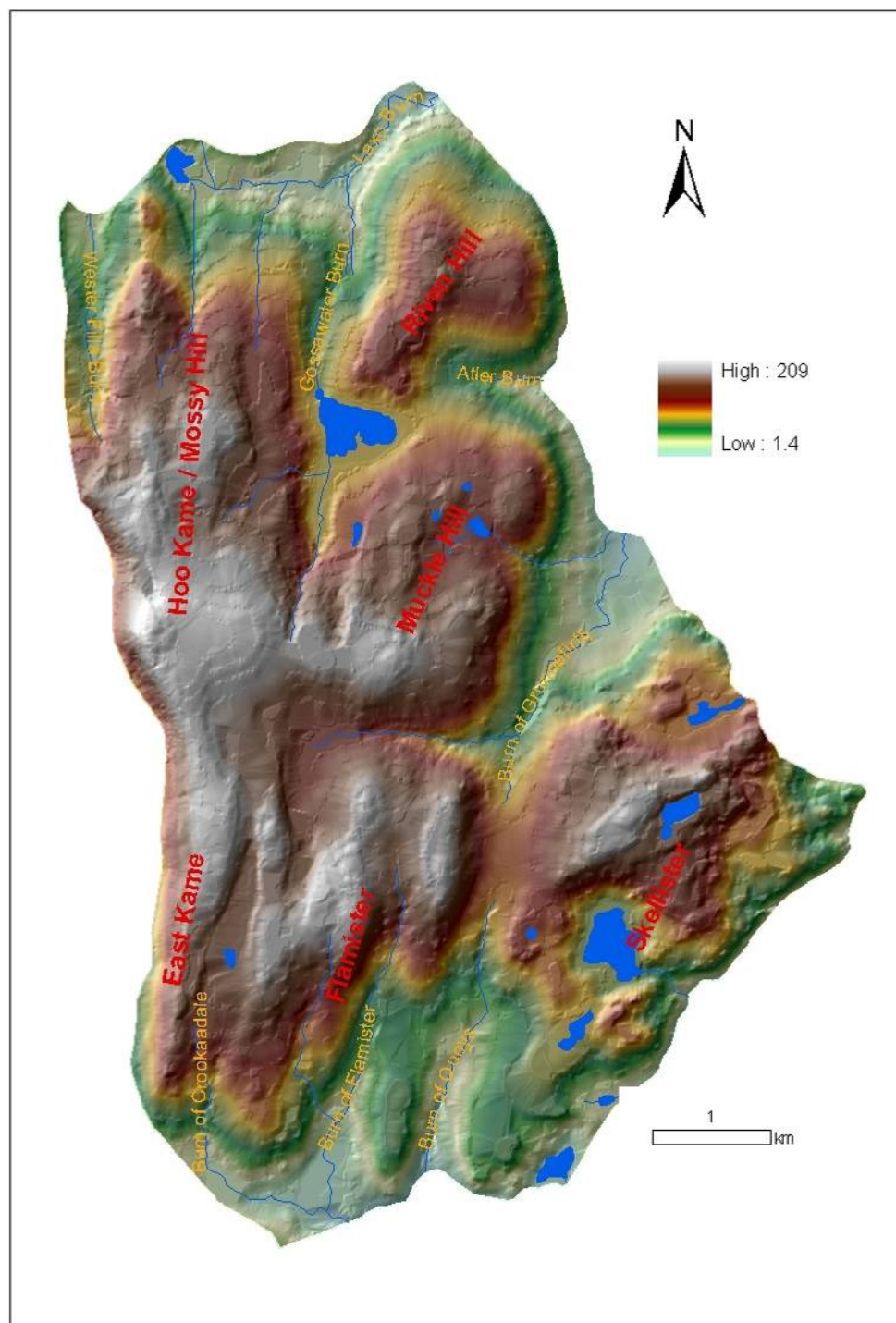


Figure 1: Relief map of Nesting quadrant, indicating the major landform units (convex with red labels, concave with orange labels) listed in Table 7. Altitude scale is in metres above Ordnance Datum. Derived from © Ordnance Survey data, licence no. EL273236.

Flamister has no special interest for rare or priority species, but some flush vegetation has been noted and the number and extent of the turbines on the summit makes it a non-favoured area for lochan creation. There is a borrow pit search area on the boundary between the catchments of the Burns of Flamister and Quoys, for which sediment issues will be important as these burns contain important salmonid spawning habitat. The house at Flamister will be surrounded by turbines and, if unoccupied, the improved pasture around it may offer potential for management as wet meadow (although the possibility of re-integrating this land into the main expanse of blanket bog should be eliminated first).

East Kame is close to a public road, although separated from it by a steep ascent. The principal interest lies in two lochans, one of which requires (non-priority) safeguarding and the other of which is a priority site for enhancement; both are on land apportioned to a single user. Existing and proposed borrow pits along the A970 public road offer sites for woodland patches which would contribute to the connectivity of this habitat.

Hoo Kame/Mossy Hill. One very high value diver lochan is situated here that merits highest priority for safeguarding. Unless conditions at this lochan deteriorate further, any management work is probably best postponed until practical experience is gained at other lochans of lower value. There is also a second diver lochan that would benefit from safeguarding measures but the relatively close proximity of several of the proposed turbines lowers might lower the priority for management. Two large borrow pit search areas offer potential for creating woodland.

In general, peatland management on the hills has implications for the valleys and burns that separate them, and parts of more than one hill typically make up the catchment of a single stream. Thus peatland management on two or more adjacent hills will normally be required to achieve maximum benefit for an individual stream (*i.e.* a catchment-based approach).

One of the valleys (that contains the Burn of Crookadale) warrants special mention because its upper reaches contain some potentially restorable lochans. As this is one of the important salmonid spawning streams, peatland management here will potentially benefit both red-throated divers and fisheries. This is also an area where management to restore stands of deep heather would benefit breeding merlins.

6.1 Selection and management of the pilot area

At the planning stage, the need to demonstrate that tangible arrangements were in place to develop and trial both the practical restoration methods themselves and a robust mechanism for integrating habitat management work into the Shetland crofting economy was identified. For this, a pilot area is required with the following attributes:

- A high-priority area for active management intervention;
- Potential for restoration of a self-sustaining section of blanket peatland incorporating a representative range of landforms;
- Area at least sufficient to compensate for the direct impact (footprint) on peatland of infrastructure associated with the whole Viking windfarm, which is 314ha reducing to 252ha after recovery of disturbed vegetation;
- Presents opportunities to trial most or all of the management techniques proposed;
- Avoids risk to the highest quality habitat elements (e.g. lochans where divers breed with consistent success) until techniques are proven;
- Accessible from public roads; and
- Location enabling management work to commence and proceed largely independently of windfarm construction work.

The area identified for this purpose is assembled from the first five of the landscape units listed in Table 7. The pilot area for peatland is bounded to the east by the B9075 public road, to the north by the Laxo Burn, to the west by the Gossawater Burn, Gossa Water itself, Burn of the Dale and the Stour Burn, probably with a functional connection in this area to the Hoo Kame

peat blanket; and by the Burns of Forse and Gunnafrith to the south and south-east. Its total area is 1051ha (see Figure 2). This area could be increased slightly so that boundaries would be set back from burns, to allow both banks on streams to re-establish and for practical reasons to allow stock exclusion fencing if necessary.

There is potentially continuous peatland over the whole of this area, but 51 ha of peripheral improved pasture which may prove impractical to re-integrate into the peat blanket (subject to inspection and landowner preferences) are deducted from the area calculation. Thus the total area of potentially restored blanket peatland is 1000 ha (10km²). Wind farm infrastructure in this area consists of 14 turbines (N96, N97, N98, N99, N122, N123, N124, N125, N126, N127, N128, N138, N139, N140), one anemometer and a total of 7.62km of track (5.53km single width, 1.77 km double width and 0.32km operational), whose footprint should also be deducted from the peatland area. The area of improved-quality habitat is estimated as 10km². Some bird species may not fully benefit from all parts of the pilot area due to displacement effects close to turbines and roads (as described in the ES). Nevertheless, at worst, the species concerned are unlikely to be displaced from more than approximately 25% of managed pilot area.

Figure 3 summarises the condition of peatland within the pilot area. The map of blanket bog 'activity' prepared in conjunction with the ground-based Phase 1 habitat/vegetation survey indicates that more than half (*ca.* 500ha) of the pilot area peatland has an activity score less than 5 and thus could potentially be improved as compensation for the calculated 252–314 ha 'direct take' of blanket bog at all activity levels beneath the entire footprint of the windfarm.

Air photography broadly confirms the relative proportions of vegetated and bare ground in different parts of the pilot area, although peat thickness is obviously not taken into account. Both maps show abrupt discontinuities in peatland condition coinciding with some of the fence lines in Figure 2, which can be attributed to differences in historical and/or current management between land holdings (grazing lines). Thus co-ordination of management across the different land holdings is needed in order to recover the peatland's landscape-level continuity. The presence of securely fenced areas offers potential for conducting comparative manipulations of grazing regimes. Figures 4 to 7 illustrate some examples of locations where management intervention involving combinations of the techniques described in Section 4 could be applied.

The peatland pilot area offers limited opportunities for introducing the other 'biodiversity' habitats (woodland and wet grassland). Nevertheless, along the burns forming the West boundary appears potentially suitable for woodland, and the croft field on the mid East boundary seems to have grassland opportunities e.g. the 'peripheral 51ha of grassland'. As previously suggested, boundaries would be best set back from burns, to allow both banks to re-establish and for practical reasons to allow stock exclusion fencing if necessary.

In the area north of the Laxo Burn, the B9071 road has permanently isolated a strip of the edge of the Collafirth peatland which could potentially be developed as a 'biodiversity corridor' connecting the coast at Voe with that at Laxo (Figure 2). Here, a series of woodland and wet pasture patches might be introduced to facilitate movement of birds, *Lepidoptera etc.* between the two sides of the island. The drained land around the eastern side of Sae Water may be suitable for management as wet grassland, and an early adjacent planting of woodland could be helpful in determining whether there is any danger of tree invasion onto the edge of the Nesting blanket peatland. Including this northern part expands the pilot area, allowing significant opportunities for woodland and wet grassland habitats that are not readily available elsewhere in the pilot area.

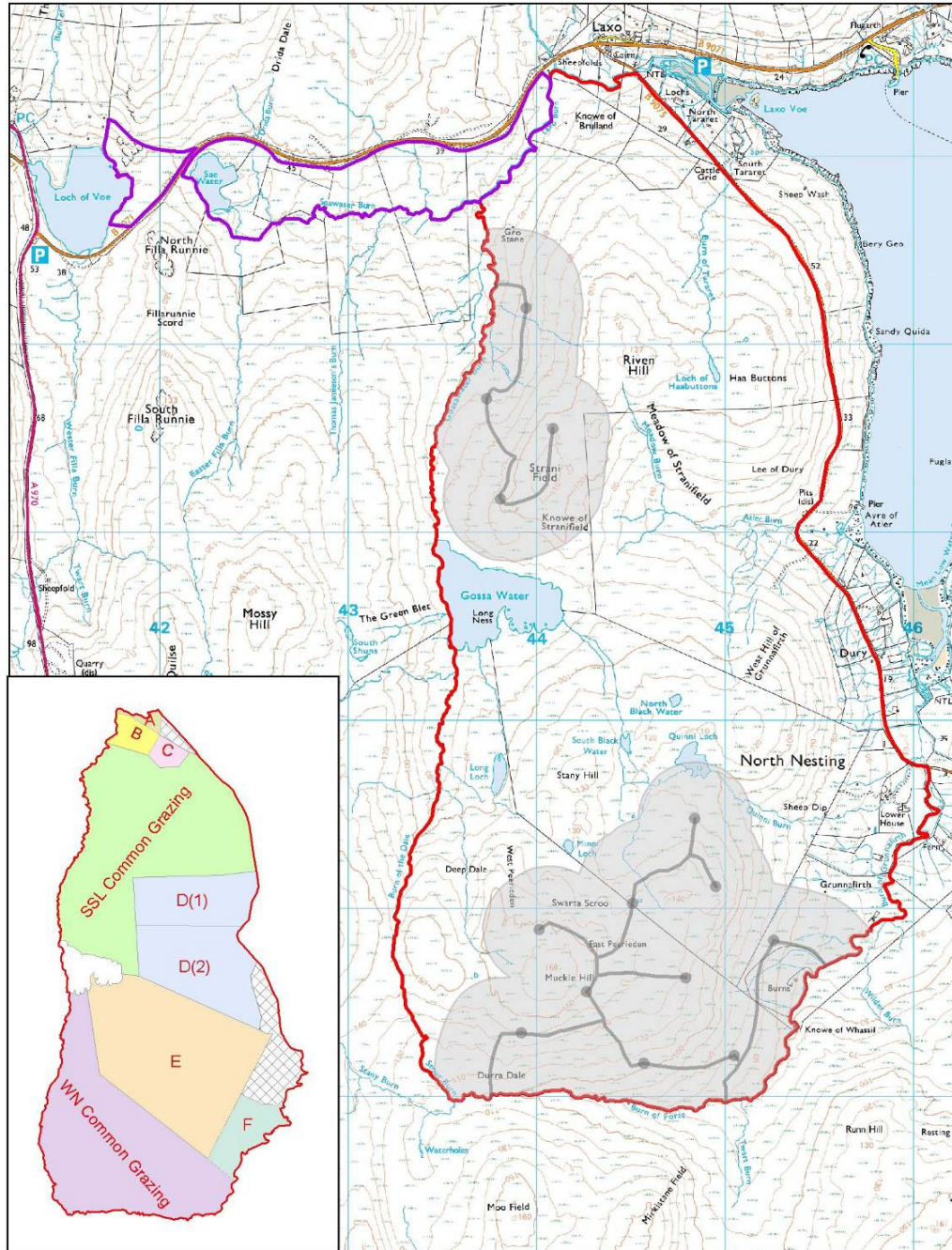


Figure 2: Map showing outlines of the proposed pilot areas for peatland management (red) and development of woodland and wet grassland habitats (purple). The positions of proposed turbines and tracks are also shown, surrounded by a 300 m 'bird exclusion' buffer (grey). The inset shows, for the peatland area only, fenced land holdings (A-F), areas of improved pasture (cross-hatched), and the areas that lie within common grazings (SSL: Sandwick, Sweening & Laxo; WN: West Nesting). There may be no fence separating holdings D(1) and D(2). Base map © Ordnance Survey, licence no. EL273236.

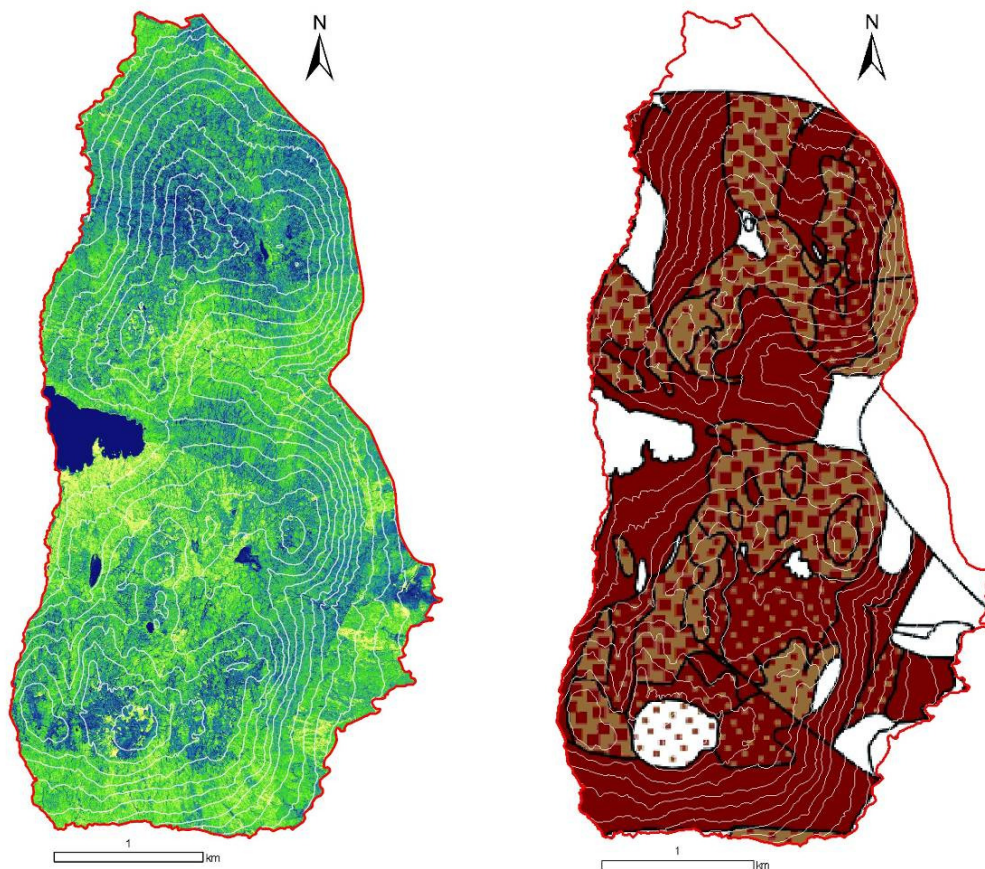
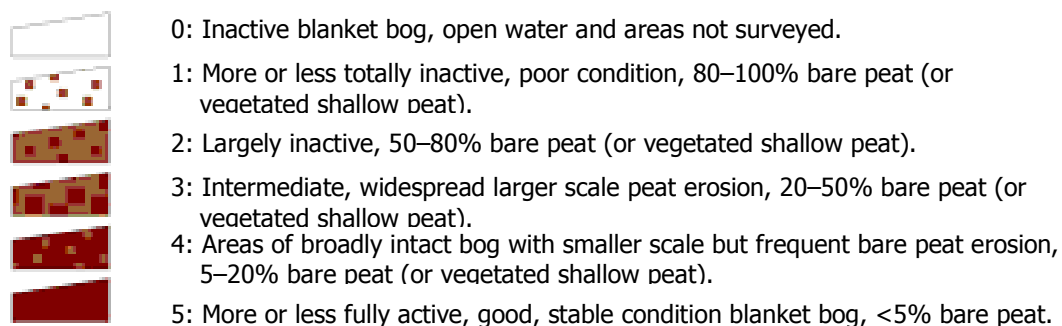


Figure 3: Left: false-colour air photograph of the peatland pilot area with contours (10 m interval) superposed. The lightest tones from the air photograph are coloured yellow, and the darkest navy blue; thus, bare mineral ground appears yellow and open water lochs/lochans as solid dark blue shapes. Between these extremes, blue generally indicates bare peat and green tones vegetated areas. **Right: map showing different levels of blanket bog activity,** estimated during the Phase 1 vegetation survey (key below), for the same area.

Key to assessments of blanket bog activity (from ground-based Phase 1 survey).



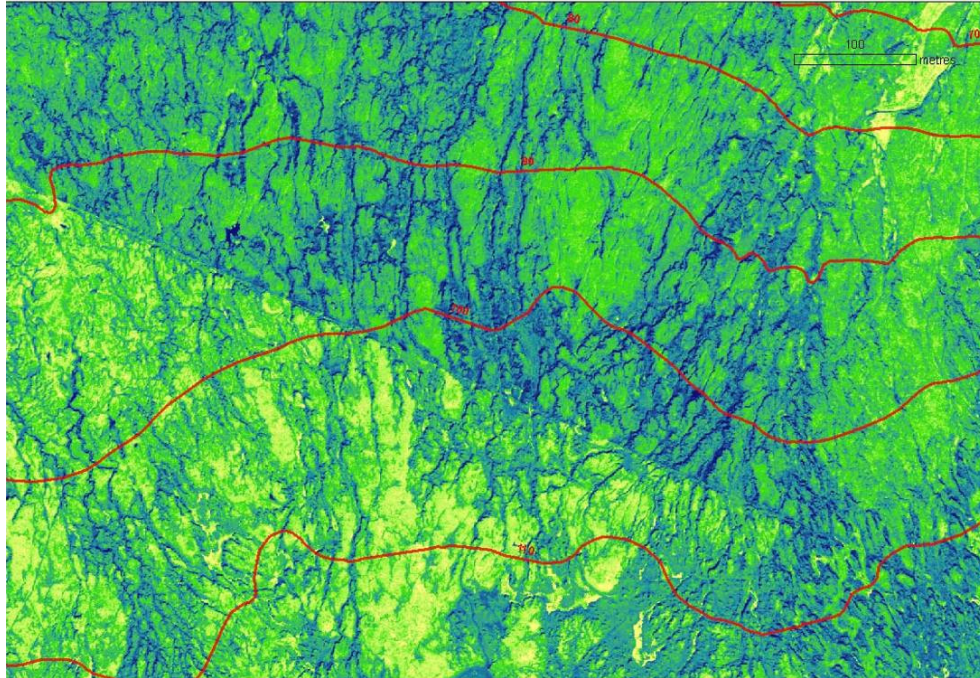


Figure 4: Example of the apparent effect of differences in grazing intensity on the two sides of a sheep-proof fence separating a pair of adjacent land holdings. Contours (red) are at 10m intervals and labelled with altitude in metres a.s.l.

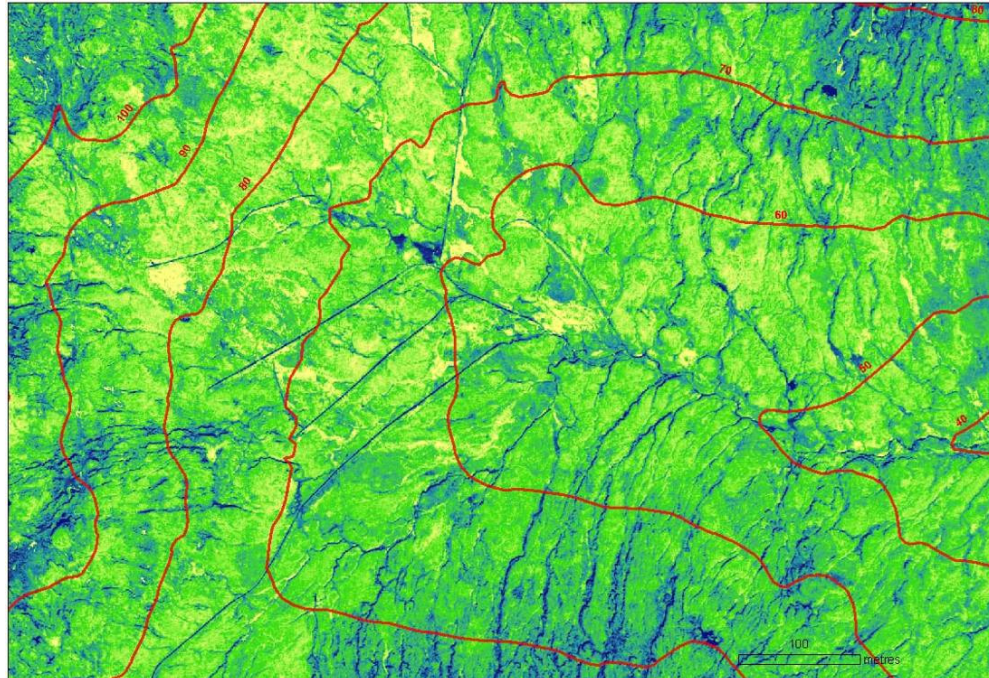


Figure 5: Head of the Atler Burn, showing ditches running at an angle to erosion gullies through 'level 5 active blanket bog'. There are associated areas of altered vegetation or possible bare mineral ground (yellow). Contours as in Figure 4.

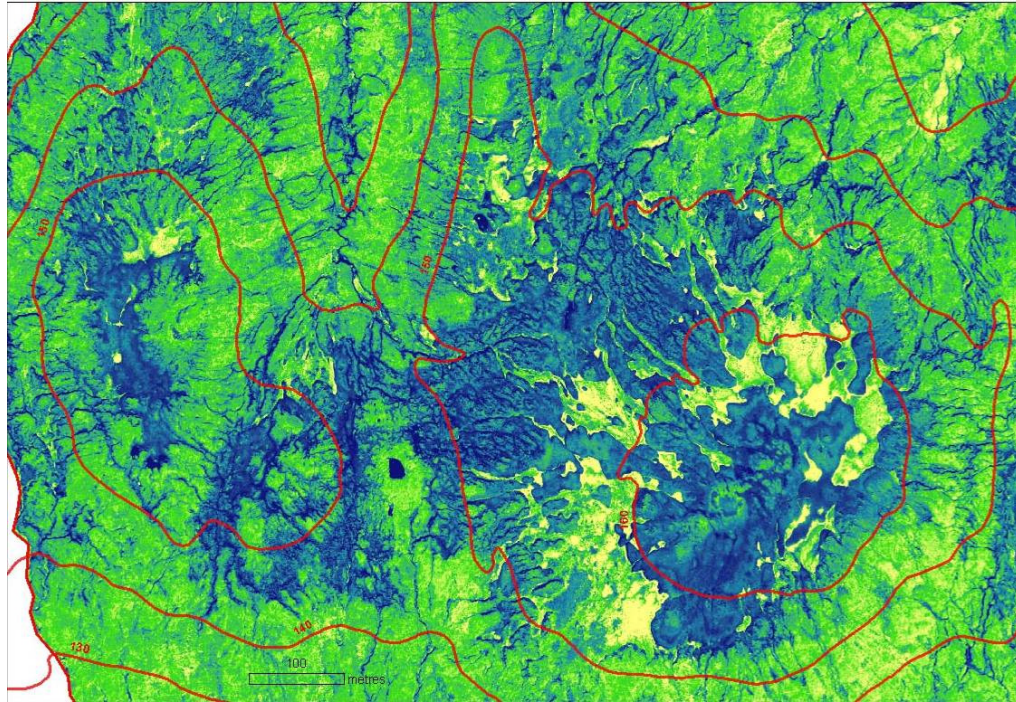


Figure 6: Poor condition (activity class 1) blanket bog on the main summit of Muckle Hill, showing extensive bare peat - a candidate area for re-vegetation trials - eroding to mineral (yellow) and re-vegetating, probably with heath rush. The small dark patch in the saddle slightly below and to the left of centre frame is the lochan that features in Figure 7. Contours as in Figure 4.



Figure 7: Saddle lochan due west of the principal summit of Muckle Hill. Although this diver nesting lochan has so far survived, it is threatened by erosion advancing from both upslope and downslope. Re-vegetation of the hill behind would contribute to safeguarding the lochan, and also improve the quality of grazing for stock.

6.1.1 Outline of management approach for pilot area

Although the ultimate objective of peatland management is to reinstate its landscape-level continuity, management will in practice be applied at the level of individual land holdings. The individual holdings within the pilot area are shown in the inset map in Figure 2. Table 8 gives a preliminary list of management objectives and techniques for each holding, derived from currently available information. Ground inspection will, however, be required before details can be finalised.

Table 8: Preliminary list of management objectives and techniques for each of the land holdings within the Nesting pilot area.

Land holding (Fig. 5.2)	Peatland area (ha) within pilot area		Specific objectives & techniques
	holding	cumulative	
A	4.7	4.7	Reduce fragmentation of peatland; re-incorporate marginal areas into peat blanket.
B	14.6	19.3	
C	9.4	28.7	
SSL CG	289.6	318.3	Relate peatland condition to grazing history. Safeguard (1) lochan. Excavate lochan & re-establish peat formation in an area where mineral ground has been exposed by erosion. Improve <i>Sphagnum</i> recolonisation on summits. Encourage recovery of patterned spur peatland. Encourage re-vegetation of gullies on slopes. Reduce fragmentation of peatland. Integrate windfarm infrastructure into peatland system (minimise hydrological discontinuity). Optimise stocking regime. Monitoring of vegetation & surface patterns.
D(1)	70.3	388.6	Ditch & gully repair. Relate peatland condition to grazing history. Encourage re-vegetation of gullies on slopes. Reduce fragmentation of peatland. Comparative stocking manipulations (e.g. sheep density, sheep plus cattle) to determine optimal grazing regime(s). Monitoring of vegetation & surface patterns. Construct pilot catchment carbon budget.
D(2)	101.1	489.7	
E	227.1	716.8	Rehabilitate (2) saddle lochans & 1 loch subject to sedimentation. Safeguard 1 lochan (only part of relevant peatland lies within this holding). Stabilise bare peat (factorial trials?). Re-vegetation of bare mineral. Ditch (and possibly gully) repair. Reduce fragmentation of peatland. Relate peatland condition to grazing history. Encourage re-vegetation of gullies on slopes. Integrate windfarm infrastructure into peatland system (minimise hydrological discontinuity). Optimise stocking regime. Monitoring of vegetation & surface patterns.
F	36.4	753.2	Reduce fragmentation of peatland; re-incorporate marginal area into peat blanket.
WN CG	247.1	1000.3	Safeguard (2.5) lochans. Stabilise bare peat (factorial trials?). Re-vegetation of bare mineral ground. Gully repair? Reduce fragmentation of peatland. Relate peatland condition to grazing history. Encourage re-vegetation of gullies on slopes.

			Integrate windfarm infrastructure into peatland system (minimise hydrological discontinuity). Optimise stocking regime. Monitoring of vegetation & surface patterns.
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6.1.2 Monitoring of the blanket peatland habitat

For the peatland, management will aim to:

- Reduce the extent of bare peat;
- Reinstall continuous 'active' blanket bog vegetation;
- Replace erosion patterns with the typical surface patterning for healthy blanket bog in Shetland;
- Achieve a more or less neutral carbon budget; and ultimately
- Establish grazing at a level that is compatible with maintenance of these features of the peatland.

In order to monitor progress towards the first three of these targets, it will be necessary to make repeat assessments, perhaps at intervals of five years, of the surface condition of the peatland. There are drawbacks to both of the methods illustrated in Figure 3. Ground-based vegetation survey of such a large area is time consuming and inevitably involves scanning substantial areas of ground obliquely from a low viewpoint, which prevents accurate assessment of the extent of erosion gullies. High-resolution vertical air photographs sample the whole surface and give a much clearer indication of surface patterns; but tonal inconsistencies between frames mean that automated analysis of the data (e.g. to calculate the extent of bare peat) is problematic. Satellite imagery captures the whole scene almost instantaneously so that tonal variations do not cause problems, but resolution is relatively low (pixels typically some tens of metres across). On the other hand, sophisticated analysis techniques are available and archive images can be obtained so that it would be possible to make retrospective condition assessments for comparison with trends emerging in the future. Thus it is proposed that the possibility of basing repeat monitoring of peatland condition primarily on satellite imagery (supported by vegetation survey for ground-truthing purposes) should be explored.

The response to peat restoration measures by most of the priority breeding bird species will be measured periodically (approximately every three years) using standard moorland bird survey methods. It is likely that this survey work will be instigated as part of the wider programme of ornithological monitoring across the windfarm site, however it will be important that it is integrated (though careful design) with the specific needs of monitoring the habitat restoration work. Stands of heather managed for nesting merlin will be monitored by annually measuring vegetation height and density. These areas will also be incorporated into areas checked during routine annual breeding merlin surveys.

Given the condition of the Viking peatland, it is probable that, overall, it is losing carbon at present. If the carbon balance of the peatland can be brought closer to neutrality through management stimulated by windfarm development, the additional carbon saving could be added to that achieved by wind power generation alone. Thus, an early, full evaluation of the carbon balance for a couple of the stream catchments within the site would provide valuable baseline information, and evaluation of carbon budgets should continue for the life of the windfarm.

Finally, in order to determine sustainable long-term stocking levels for the Viking peatland, accurate measures of grazing management will be made.

6.1.3 Monitoring red-throated diver lochans

The condition of diver lochans will be assessed periodically in terms of the extent and nature of nearby peat erosion, water levels, shoreline vegetation and hydrological integrity. This would be

done at both lochs subject to habitat management measures and a control sample of those that were not. Information will also be available from the programme of monitoring the occupancy and breeding success of divers recommended as part of the wide measures of ornithological monitoring across the windfarm site.

6.1.4 Monitoring of fish populations

Fish surveys above dams that have been removed or modified will be undertaken for the first three-five years following their removal to assess whether fish are now able to pass previous obstacles. Suitable baseline data, pre-removal or modification will also be necessary.

6.1.5 Monitoring of woodland restoration

Plant and bird species are the two groups that are expected to benefit directly from the restoration of woodland. The success of the former will be monitored by the following means every five years:

- Counts of trees and shrubs >1 m in height on a systematic or stratified basis;
- Quadrat samples of the ground vegetation within permanent plots;
- Monitoring of herbivore impacts through assessment of tree/shrub mortality and/or dung counts; and
- Fixed point photography from one or more vantage points.

Bird species will be monitored every five years using standard methods such as point counts.

6.1.6 Monitoring of wet grassland communities

Monitoring of the impact of the grazing levels will be undertaken on an annual basis for the first five years or until a suitable grazing density and seasonal regime has been established. Monitoring will include the sampling of permanent vegetation plants and fixed-point photography. After the first five years, or once an appropriate regime has been established, further monitoring will then take place every five years.

Bird species will be monitored approximately every three years using standard methods such as transect surveys.

7. INTERPRETATION

The unique culture of Shetland and its distinctive land forms, flora and fauna already attract a wide range of visitors to the islands including: archaeologists, botanists, geologists and ornithologists who visit on private or organised holidays and as researchers and students associated with academic institutes. These visitor groups may be curious about the implementation and outcomes of the HMP in terms of:

- Changes in the composition and diversity of the native flora and fauna;
- The restoration of degraded habitats;
- The sustainability of wind farms, farming and other land management practices; and
- The potential recreation of an extinct landscape.

A number of opportunities for interpretation are consequently available to inform and educate widely and to encourage local involvement. The most desirable approach is the restoration and conservation of all of the habitats in one demonstration area wherein the full range of approaches to managing blanket bog, woodland and freshwater bodies can be demonstrated in combination with sustainable farming practices, or in their absence, in order to demonstrate how the pre-agricultural landscape of Shetland may have looked. This could be taken forward through an interpretation programme linked to panels, leaflets, guided walks etc.

Opportunities also exist for local groups (such as schools and youth groups) to become involved through the adoption of a specific area and helping with some of the management and monitoring. This may include damming gullies, propagating (at home or at school) and transplanting plants, and survey work.

8. IMPLEMENTATION

8.1 Management

Implementation of the management plan will be the responsibility of the proposed Shetland Wind Farm Environmental Advisory Group (SWEAG) and Monitoring Committee modelled on but distinct from the Shetland Oil Terminal Environmental Advisory Group (SOTEAG).

Implementation will be a complex process requiring the commitment and dedication of a full time project manager. The project manager will be responsible to SWEAG, the Monitoring Committee and VEP for day-to-day implementation of the HMP, and will be supported in this role by additional staff as necessary. Relevant organisations and consultants will also be employed to assist as necessary.

An initial work programme that outlines the necessary steps to be taken and that summarises the management prescriptions above is include in Appendix A.

8.2 Partnership working

The implementation of the management plan will draw upon a diverse range of expertise, knowledge and facilities. To meet this need, it is envisaged that the potential partners listed in Table 9, together with their potential roles, will be involved from the earliest stages in order to ensure the effective delivery of the plan.

Table 9: Potential partners identified as relevant to the delivery of the HMP.

Partner	Roles
Academic institutes and environmental consultancies.	<ul style="list-style-type: none">• Research & monitoring of the HMP outcomes.• Independent peer review.
Highland Birchwoods/Shetland Amenity Trust	<ul style="list-style-type: none">• Advice, information & technical input on woodland regeneration.
Moors for the Future Partnership	<ul style="list-style-type: none">• Advice, information & technical input on blanket bog restoration.
Royal Society for the Protection of Birds	<ul style="list-style-type: none">• Advice, information & technical input on habitat restoration & species requirements.
Scottish Environment Protection Agency	<ul style="list-style-type: none">• Advice, information, monitoring & technical input. Licensing.
Scotland's Environmental and Rural Services	<ul style="list-style-type: none">• Assistance developing a scheme to fund the modifications to agricultural practice.
Scottish Natural Heritage	<ul style="list-style-type: none">• Advice, information, monitoring & technical input. Licensing.
Shetland Amenity Trust	<ul style="list-style-type: none">• Provision of nursery facilities.• Advice, information & technical input.
Shetland Crofting, Farming & Wildlife Advisory Group	<ul style="list-style-type: none">• Assessment of grazing levels.• Negotiations with crofters.• Production of grazing management plans.
Shetland Islands Council	<ul style="list-style-type: none">• Advice, information & technical input.• Integration of management plan outputs with LBAP.
Shetland Oil Terminal Environmental Advisory Group	<ul style="list-style-type: none">• Advice, information & technical input in developing SWEAG.

8.3 Funding

The implementation of the management plan will be funded by Viking Energy Ltd. with supplementary or match funding being sought where available. The funding commitment by Viking Energy Ltd. will span the twenty-five year operation of the HMP and will include:

- The salary and other expenses associated with the project manager (including office space and equipment);
- Consultancy, research and labour fees;
- Stock reduction compensation;
- Materials, (fencing, matting, dam materials, etc);
- The collection and propagation of plant species for blanket bog and woodland regeneration;
- The hire or purchase and maintenance of necessary equipment and premises; and
- Development and delivery of the interpretive programme.

8.4 Duration

The HMP will only be instigated once the construction of the windfarm is agreed and it will incorporate two phases. Phase 1 will extend over the first five years and it includes the establishment of the necessary survey and monitoring programmes; instigation of the blanket bog restoration trials; and restoration/conservation of the other habitats in the proposed Nesting Pilot Area. Phase 2 will extend over the following twenty years and will incorporate the wider application of the blanket bog restoration techniques and management of the other habitats across the Viking study area.

8.5 Monitoring and review

The work undertaken to fulfil the habitat management plan will be monitored periodically to ensure it delivers the aims. This will be achieved by a programme of survey work that quantifies the changes to the extent and condition of priority habitats and changes in the abundance and distribution of priority species. For those aspects of the management plan where field trials will determine the most efficacious methods, a further aim of the monitoring will be to provide timely quantitative assessment of various alternative methods and combination of methods tested. For example, the results of trials undertaken in the Pilot Area in Phase I of the HMP will be needed within 5 years to inform the works to be undertaken in Phase II. Phase II will be monitored in a similar manner to Phase I and this will feedback into the process of review and implementation.

In all cases it will be necessary to have adequate measures of baseline conditions made before management work commences. In some cases data already collected for the purposes of the Ecological Impact Assessment of the windfarm may be adequate for this, in other cases new survey work will be required to establish baseline conditions.

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APPENDIX A
WORK PROGRAMME

No.	Proposed area of activity	Timescale	Expected Actions or Outcomes
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Section 4.2: Grazing

	Identify the most severely eroded blanket bog habitat in relation to the stock density on management/ownership units.	2009 – 2010	Identification of land management units where stocking densities are excessive & have resulted in the erosion of peatland vegetation & substrates.
	Negotiation with land owners & managers to manage stock in a way that ensures the sustainability of both the practice & the habitats upon which it is dependent.	2009 – 2011	<p>a) Agreement with willing land owners &/or managers to reduce the stock levels to sustainable levels through appropriate compensation where this cannot or has not been achieved by changes to the national funding mechanisms; and/or</p> <p>b) Provision of the necessary infrastructure to exclude stock or over-winter them away from the blanket bog habitat.</p>

Section 4.3: Hydrology

	Negotiation with land owners & managers to obtain permission for the establishment of trials to assess the efficacy of the restorative measures outlined in Section 4.3.	2009 – 2010	<p>a) Identify suitably eroded areas for the establishment of the trials.</p> <p>b) Agreement with willing land owners and/or managers to establish the trials on their land and to manage stock levels accordingly.</p>
	Establishment of trials over 100ha of eroded blanket bog habitat to assess the efficacy of the restorative measures outlined in Section 4.3.	2010 – 2015	Identification of the most appropriate methods to prevent &/or reverse the effects of erosion.
	Establishment of the most successful methods over the areas of the Viking area for which permission may be achieved.	2015 - 2035	Restore as much of the site as possible within reasonable financial & pragmatic constraints.

Section 4.4: Lochan restoration

	Protection or restoration of red-throated diver lochans.	2009 – 2010	Identify red-throated diver lochans within the area selected for hydrological management of the blanket peatland & agree the necessary works with the relevant land owners &/or managers.
		2010 – 2015	Implement the necessary works to protect or safeguard the lochans with appropriate monitoring of the outcome(s).

Section 4.5: Rivers and streams

	Identify & agree with stakeholders a minimum of 3-5 large-scale areas where general catchment management to favour fish habitats & populations will be undertaken within Viking study area.	2009 – 2035	<p>a) 3-5 potentially suitable areas for 'fish friendly' management will be identified, defined & agreed with stakeholders – 2009.</p> <p>b) Based on further site specific studies, agree a series of 'fish friendly' management practices to take place over duration of windfarm – 2009.</p> <p>c) Implement agreed 'fish friendly' catchment management practices over life of windfarm in defined areas – 2010-2035.</p>
	Investigate, assess & implement measures with partners to ease fish passage at a series of man-made barriers within Viking study area.	2009 – 2011	<p>a) Assess & implement removal or installation of fish pass on Burn of Laxobigging dam with stakeholders</p> <p>b) Assess & implement modification of Kirkhouse Burn fish pass with stakeholders – 2009.</p> <p>c) Assess & implement modification of Weisdale Mill Burn fish pass with stakeholders – 2010.</p> <p>d) Assess & implement modification of Sandwater fish pass with stakeholders – 2010</p>

Section 4.6: Woodland restoration

	Establish the appropriate opportunities & support for woodland restoration.	2009 - 2010	Undertake survey of any Viking areas not included within the Shetland Amenity Trust woodland scheme that may contain relict woodland or trees/shrubs & ascertain their viability for restoration (i.e. species & numbers present, sexual ratio; distance from poor condition blanket bog prone to undesirable scrub encroachment)
			Identify non-relict areas suitable for woodland restoration according to: shelter/exposure, aspect, altitude & the potential for agreement from land owners &/or managers.
		2010 – 2011	Agreement with willing land owners &/or managers to establish the woodland restoration on their land & to exclude stock from the restoration areas with fencing.
		2011 – 2015	Establish <i>de novo</i> &/or assist the Shetland Amenity Trust's nursery facilities to produce sufficient, locally-sourced stock for planting.
	Establish the woodland planting	2011 – 2015	Establish the necessary fencing & planting regime to respectively restore or enhance new or relict areas of woodland.
	Establish monitoring scheme & appropriate management.	2015 - 2035	Monitor the success of the woodland plantings & take appropriate actions as highlighted by the monitoring to ensure the eventual establishment of a self-sustaining area of habitat.

Section 4.7: Wet grassland habitats

	Identification of suitable grasslands for management.	2009 – 2010	Identify areas suitable habitat on the basis of existing interest that is in danger of lost through inappropriate management & the willingness of land owners &/or managers to co-operate.
	Management & monitoring of the grazing regimes established to improve the grassland value for biodiversity.	2010 – 2015	Implement appropriate grazing regime(s).
		2010 – 2035	Monitor the success of the management regime & alter the stock levels & seasonality accordingly.

**APPENDIX B:
OPTIONS FOR MITIGATING THE EFFECTS OF
DETRIMENTAL HUMAN IMPACTS UPON VIKING AREA ECOSYSTEMS.**

1. Peatlands

Ecosystem Services	Function(s) producing the Service	Impacts that effect Function	Effects of Impacts on Function	Mitigation of Effects	Management Options
Sequestration	The capture & storage of CO ₂ & other nutrients &/or pollutants as biomass & peat.	• Drainage.	<ul style="list-style-type: none"> • Loss of vegetation. • Loss of productivity. • Mineralisation of dewatered peat layers. • Vegetation changes associated with the dewatering & associated mineralisation of the peat releasing plant nutrients. • Erosion may be initiated by cutting or drainage. 	<ul style="list-style-type: none"> • Prevent or reduce the opportunities for peat extraction or agricultural conversion & associated drainage. • Damming to reduce drainage efficiency. 	• Damming.
		• Erosion.	<ul style="list-style-type: none"> • As above. • Loss of peatland area & volume. • Sediment release into adjacent water bodies & courses. 	<ul style="list-style-type: none"> • Damming. • Storage of erosive water flows. • Matting or planting to consolidate exposed peat. • Reduce grazing. 	<ul style="list-style-type: none"> • Damming. • Matting. • Reseeding, plugging or planting. • Rewetting. • Stock reduction.
		• Overgrazing	<ul style="list-style-type: none"> • Changes in species composition & <i>Sphagnum</i> loss as: <ul style="list-style-type: none"> ○ grazing & trampling insensitive species proliferate; & ○ nutrient turnover increases to favour the dominance of competitive species. • Erosion through trampling & loss of vegetation. 	<ul style="list-style-type: none"> • Reduce grazing. 	• More appropriate grazing management.

Ecosystem Services	Function(s) producing the Service	Impacts that effect Function	Effects of Impacts on Function	Mitigation of Effects	Management Options
Catchment Management	<p>Maintenance of a base flow & buffering of runoff water chemistry. Enhanced water storage under certain circumstances (reducing the scale of flood events).</p> <p>Provision of clean water suitable for salmonid fish & other aquatic life.</p>	<ul style="list-style-type: none"> • Drainage. • Erosion. 	<ul style="list-style-type: none"> • Variations to water quantity through the: <ul style="list-style-type: none"> ◦ loss of peatland volume for water storage & flow moderation; & ◦ creation of conduits for rapid discharge. • Variations in water quality through the: <ul style="list-style-type: none"> ◦ mobilisation of peat sediment; ◦ exposure of underlying mineral substrates; & ◦ release of nutrients from the peat as a result of mineralisation. • Reduction in water quality & seasonal water quantity buffering through the loss of the sequestration & drainage properties of the peat &/or the <i>Sphagnum</i>-dominated vegetation & potentially fish populations in affected catchments. 	<ul style="list-style-type: none"> • Reduce negative anthropogenic effects as outlined above. 	<ul style="list-style-type: none"> • As above • Sediment traps on water courses.
Biodiversity	<p>The maintenance of economic activity & a range of specialist &/or distinctive species, communities & processes.</p>	<ul style="list-style-type: none"> • Drainage. • Erosion. • Overgrazing • Disturbance 	<ul style="list-style-type: none"> • The loss of specialist &/or distinctive species, communities or processes as a consequence of changes to the habitat's: natural range; connectivity; nutrient dynamics; hydrology; structure; stability; & disturbance. • The loss of ecosystem functions & associated ecosystem services. • A reduction in long-term blanket bog persistence because the loss of biodiversity can result in an impaired ability to adapt to environmental (e.g. climatic) changes & therefore fail to sustain economic activity into the medium to long-term.. 	<ul style="list-style-type: none"> • Maintain a network of active (self-sustaining) exemplars of the semi-natural blanket bog ecosystem. • Restore marginal areas to form a part of this habitat network. • Implement & demonstrate appropriate management regimes. 	<ul style="list-style-type: none"> • Conserve & restore areas of active blanket bog. • Influence the management of connecting areas of active blanket bog. • Conserve or restore isolated or marginal areas of blanket bog to increase the extent & connectivity of the habitat.

Ecosystem Services	Function(s) producing the Service	Impacts that effect Function	Effects of Impacts on Function	Mitigation of Effects	Management Options
Environmental History	The upward growth of the vegetation has captured & preserved as peat a range of environmental materials (such as volcanic ash or biological remains) in sequential layers that can be analysed to reveal past environmental events & conditions.	<ul style="list-style-type: none"> • Drainage. • Erosion. 	<ul style="list-style-type: none"> • The removal, dewatering or disturbance of peat layers. Those layers from the most recent past (near the surface) are especially threatened & the most important for understanding the baseline conditions & historical context of contemporary environmental issues. 	<ul style="list-style-type: none"> • Take measures to reduce erosion. • Prevent or reduce the opportunities for peat extraction or agricultural conversion & associated drainage. • Prevention of peat stripping to leave exposed, open surfaces. 	<ul style="list-style-type: none"> • Influence the management of areas of intact, active blanket bog. • Purchase & conserve areas of intact, active blanket bog. • Erosion control measures as outlined above.
Economy & Society	The maintenance & enhancement of local pride of place & the aesthetic value of the area to locals & visitors; the maintenance & long term sustainability of grazing, angling, potable water supplies & of the peatland landscape in terms of its attraction to tourists.	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • The loss of opportunities for grazing, small scale peat-cutting & tourism. 	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • As above.
Research & Education	Demonstration & study of ecosystem function.	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • The loss of opportunity to: <ul style="list-style-type: none"> ◦ demonstrate & study natural ecosystem function & biodiversity; ◦ monitor environmental changes. 	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • As above.
Recreation	The opportunity to undertake recreation in a semi-natural, harmonious & wildlife rich landscape.	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • The loss of opportunity to: <ul style="list-style-type: none"> ◦ undertake recreation in a harmonious environment; & ◦ experience distinctive, blanket bog species. 	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • As above.

2. Peatland-based, red-throated diver lochans

Ecosystem Services	Function(s) producing the Service	Impacts that effect Function	Effects of Impacts on Function	Mitigation of Effects	Management Options
Catchment Management	Maintenance of a base flow & water storage.	<ul style="list-style-type: none"> • Drainage. • Erosion. 	<ul style="list-style-type: none"> • Variations in water quality through the: <ul style="list-style-type: none"> ○ mobilisation of peat sediment; ○ exposure of underlying mineral substrates; & ○ release of sediment from the lochan as a result of erosion. 	<ul style="list-style-type: none"> • Reduce erosion of the surrounding peatland. 	<ul style="list-style-type: none"> • Influence the management of areas of intact, active blanket bog. • Purchase & conserve areas of intact, active blanket bog. • Erosion control • Sediment traps.
Biodiversity	The maintenance of a distinctive species.	<ul style="list-style-type: none"> • Drainage. • Erosion. • Disturbance 	<ul style="list-style-type: none"> • The loss of individuals of a specialist & distinctive species. 	<ul style="list-style-type: none"> • Maintenance of a sufficient number of lochans to ensure the persistence of the population. 	<ul style="list-style-type: none"> • As above.
Economy & Society	The maintenance & enhancement of local pride of place & the aesthetic value of the area to locals & visitors. The maintenance & sustainability of grazing, small -scale peat cutting.	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • The loss of an iconic & charismatic species of interest to tourists. 	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • As above.
Research & Education	Demonstration & study of the ecology & behaviour of a distinctive & iconic species.	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • The loss of opportunity to demonstrate & study the behaviour of a distinctive & iconic species. 	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • As above.
Recreation	The opportunity to enjoy watching a distinctive & iconic species.	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • The loss of opportunity to: <ul style="list-style-type: none"> ○ undertake recreation in a harmonious environment; & ○ experience distinctive& iconic species. 	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • As above.

3. Rivers and streams

Ecosystem Services	Function(s) producing the Service	Impacts that effect Function	Effects of Impacts on Function	Mitigation of Effects	Management Options
Catchment Management	Maintenance of natural river functions & associated biological processes (see also below).	<ul style="list-style-type: none"> • Dams. • Loss of riparian vegetation. 	<ul style="list-style-type: none"> • Changes in the nature & quantity of sediment & alteration of the original geomorphological processes. 	<ul style="list-style-type: none"> • Removal of dams. • Restoration of riparian vegetation. 	<ul style="list-style-type: none"> • Remove dams. • Restore riparian vegetation.
Biodiversity	<p>The free passage of migratory fish species to areas of spawning habitat.</p> <p>Organic inputs to the system that maintain its productivity & provide habitat or cover for species.</p>	As above.	<ul style="list-style-type: none"> • Loss of passage to spawning grounds for migratory fish species. • Loss of organic inputs to the water course that maintain productivity, & provide habitat or cover. • Widening of the river course (by erosion) in the absence of trees to maintain its width & depth at a suitable level for the passage & spawning of migratory fish. 	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • As above.
Economy & Society	The maintenance of viable fish populations.	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • The loss of viable, migratory fish populations at a density & average size that is attractive to anglers. 	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • As above.
Research & Education	Demonstration & study of ecosystem function.	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • The loss of opportunity to demonstrate natural ecosystem function & biodiversity. 	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • As above.
Recreation	The presence of viable, migratory fish populations at a density & average size that is attractive to anglers; & the opportunity to undertake recreation in a semi-natural, harmonious & wildlife rich landscape.	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • The loss of opportunity to: <ul style="list-style-type: none"> ○ catch fish at a rate & size attractive to anglers; & ○ undertake recreation in a semi-natural environment. 	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • As above.

4. Woodland

Ecosystem Services	Function(s) producing the Service	Impacts that effect Function	Effects of Impacts on Function	Mitigation of Effects	Management Options
Catchment Management	Nutrient & water cycling, defence of river banks; & inputs of woody debris to the water course.	<ul style="list-style-type: none"> • Historic loss of woodland. • Current overgrazing. 	<ul style="list-style-type: none"> • Modification of nutrient & water cycling; • Widening & 'shallowing' of rivers as erosion cuts into sections of bank; • Loss of woody debris as habitat, nutrient source & for its role in geomorphological processes. 	<ul style="list-style-type: none"> • Preservation of the few remaining woodland areas; • Regeneration/recreation of woodland. 	<ul style="list-style-type: none"> • Woodland planting; • Woodland protection through fencing & adjustments of the stock levels.
Biodiversity	The existence of woodland resources which are now very rare in Shetland.	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • The loss of extant woodland regeneration 	<ul style="list-style-type: none"> • As above. • Establishment of a woodland network that permits: <ul style="list-style-type: none"> ◦ the natural spread of woodland species; & ◦ the maintenance of viable populations of woodland species. 	<ul style="list-style-type: none"> • As above • The consideration of connectivity between plantings.
Economy & Society	The maintenance of a diverse landscape of aesthetic & potentially, economic value.	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • The loss of opportunity to experience woodland habitats & to derive economic benefit from its resources. 	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • As above.
Research & Education	Demonstration & study of ecosystem function.	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • The loss of opportunity to demonstrate & study natural ecosystem function & biodiversity. 	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • As above.
Recreation	The opportunity to undertake recreation in a semi-natural, harmonious & wildlife rich landscape.	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • The loss of opportunity to: <ul style="list-style-type: none"> ◦ undertake recreation in a semi-natural environment; & ◦ experience distinctive woodland species. 	<ul style="list-style-type: none"> • As above. 	<ul style="list-style-type: none"> • As above.

5. Wet grassland

Ecosystem Services	Function(s) producing the Service	Impacts that effect Function	Effects of Impacts on Function	Mitigation of Effects	Management Options
Catchment Management	Nutrient & sediment capture &/or retention.	Inappropriate grazing density &/or timing.	<ul style="list-style-type: none"> Excessive grazing resulting in erosion of the vegetation layer & root mat. Little or no grazing resulting in the establishment of rank vegetation. 	<ul style="list-style-type: none"> Establishment of an appropriate grazing regime that is responsive to the condition of the grassland on a seasonal basis. 	<ul style="list-style-type: none"> Adjustment of the density & timing of stock levels.
Biodiversity	The existence of wet grassland/meadow resources which are relatively rare in Shetland.	<ul style="list-style-type: none"> As above. 	<ul style="list-style-type: none"> Inappropriate grazing resulting in the loss of floral diversity & vegetation structure. 	<ul style="list-style-type: none"> As above. 	<ul style="list-style-type: none"> As above The consideration of connectivity between plantings.
Economy & Society	The establishment & maintenance of a more diverse landscape of aesthetic & potentially, economic value.	<ul style="list-style-type: none"> As above. 	<ul style="list-style-type: none"> The loss of opportunity to experience wet grassland habitats & to derive economic benefit from its resources. 	<ul style="list-style-type: none"> As above. 	<ul style="list-style-type: none"> As above.
Research & Education	Demonstration & study of ecosystem function.	<ul style="list-style-type: none"> As above. 	<ul style="list-style-type: none"> The loss of opportunity to demonstrate & study natural ecosystem function & biodiversity. 	<ul style="list-style-type: none"> As above. 	<ul style="list-style-type: none"> As above.
Recreation	The opportunity to undertake recreation in a semi-natural, harmonious & wildlife rich landscape.	<ul style="list-style-type: none"> As above. 	<ul style="list-style-type: none"> The loss of opportunity to: <ul style="list-style-type: none"> undertake recreation in a semi-natural environment; & experience distinctive wet grassland species. 	<ul style="list-style-type: none"> As above. 	<ul style="list-style-type: none"> As above.

APPENDIX C
VON POST HUMIFICATION SCALE

H	Description	Proportion of dy*	Plant structure	Expressed fluid	Peat lost through fingers	Peat retained in the hand
H1	Completely unhumified	None	Evident	Colourless, clear	None	Not porridgey
H2	Virtually unhumified	None	Evident	Yellow-brown, clear	None	Not porridgey
H3	Little humified	Small	Evident	Noticeably turbid	None	Not porridgey
H4	Poorly humified	Modest	Evident	Very turbid	None	Somewhat porridgey
H5	Fairly humified, structure distinct	Fair	Evident but somewhat obscured	Strongly turbid	Some	Very porridgey
H6	Fairly humified, structure less distinct	Fair	Indistinct but still clear	Strongly turbid	Up to 1/3	Very porridgey
H7	Quite well humified	Considerable	Much still visible	Strongly turbid	Up to 1/2	Gruel-like
H8	Well-humified	Large	Vague	Strongly turbid	2/3	Only fibrous matter & roots remain
H9	Almost completely humified	Most	Almost none visible	Very strongly turbid	Almost all	Homogeneous
H10	Completely humified	All	None visible	Very strongly turbid	All	Porridge

* Highly decomposed organic matter.