UNITED UTILITIES
SUSTAINABLE CATCHMENT MANAGEMENT PROGRAMME

VOLUME 1
EXECUTIVE REPORT

United Utilities

Penny Anderson Associates Ltd
CONSULTANT ECOLOGISTS

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SUSTAINABLE CATCHMENT MANAGEMENT PROGRAMME

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EXECUTIVE REPORT

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This project has been undertaken in accordance with PAA policies and procedures on quality assurance.

Signed: Penny Anderson.

VOLUME 1 EXECUTIVE REPORT

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SUMMARY

The SCaMP Project

United Utilities' (UU) five year, innovative, large scale Sustainable Catchment Management Programme (SCaMP) set out to improve catchment quality whilst ensuring a sustainable future for tenants in Bowland Estate (Lancashire) and Southern Region (Peak District).

Key project drivers have been:

- to meet the Government's target of 95% of SSSIs being in favourable or favourable recovering condition by 2010;
- to support UU's Biodiversity Strategy;
- to improve water quality, particularly water colour; and
- to incorporate aims to reduce runoff rates, sediment load and downstream flooding.

As the project has progressed, climate change and carbon storage in peat have become more important and their relevant needs have been incorporated into the objectives.

Farm Plans and UU in hand works have included the following restoration/creation measures:

- re-wetting blanket bog through grip blocking (85.23km) in the Goyt and Bowland;
- re-vegetation of eroding bare peat (470ha) plus some gully blocking;
- reducing grazing pressure (12,322ha blanket bog and 7,564ha dwarf shrub heath) and restoration of dwarf shrub heath on selected sites,
- woodland enhancement in 111ha;
- planting new upland oak and wet woodland (516ha);
- hay meadow improvements (109ha); and
- management of 250ha of rush pastures for waders.

Penny Anderson Associates Ltd (PAA) was charged with designing, carrying out, evaluating and presenting monitoring data on selected botanical and hydrological parameters.

The Results

Restoring Drained, Burnt and Grazed Moorlands

Grip blocking as well as control of grazing and burning have been implemented on the Goyt (Southern Region), Brennand and Whitendale (Bowland Region).

Peat water table levels after grip blocking are being sustained at or near the surface for much longer in the Goyt. There are good indications of a similar change in Brennand, but the drought in 2010 has 'skewed' the data analysis for the automated dipwells in Brennand, preventing any long term trends in water table elevation being found. Such elevation of the water table is critical to enhancing blanket bog vegetation and functionality – a key objective of SCaMP.

Where grips have been blocked and grazing pressure reduced on Goyt and Brennand there has been a statistically significant reduction in Dissolved Organic Carbon (DOC) generation after two years following treatment. On Whitendale (blocked prior to the project starting) DOC production has stabilised or decreased five years after grip blocking. This is a key objective of the project as it reduces loss of stored peat and improves water quality entering treatment works.

A 45% reduction in streamflow DOC between the first and final years, falling from 8.9g C/m^2/year in 2006/7 to 4.9g C/m^2/year 2009/10 has been calculated for the Goyt. This is a very significant result for the project.

The hydrology of all sub-catchments monitored has maintained water yield characteristics, but with growing evidence of a hydrological response changing to a less flashy, more attenuated character.

Brennand and Whitendale meet the majority of the Higher Level Stewardship (HLS) indicators of success after only 3 years and should continue to move towards those that are currently not met. Goyt is also meeting its SSSI Objectives of moving the site towards favourable condition. All sites, therefore, can be considered as being in favourable recovering status. This success also meets a key objective of the project.

The initial reduction of grazing on the vegetation on Brennand and Goyt is reflected in an increased vegetation height and early increases in wavy hair-grass, heather and bilberry cover. As grip blocking takes effect, these early increases in dwarf shrub cover are possibly being checked in response to the re-wetting.

Sphagnum cover is beginning to increase in all plots after the reduction of grazing and elevation of water tables on both Brennand and Goyt. This is statistically significant for some plots, in particular where *Sphagnum* cover was already higher. On Goyt, the gripped but not blocked reference plot shows no trend towards increasing *Sphagnum,* indicating that the grip blocking is having an effect above that of the removal of grazing.

Where grazing was re-introduced after most of the grip blocking on Whitendale, vegetation height is reduced (as expected), but has not significantly altered the vegetation community type, although there is a trend towards lower dwarf shrub cover (largely bilberry) leading to a more grass/cottongrass/sedge dominated vegetation. This may be a response to the increased wetness following grip blocking, but the reintroduction of grazing may also be contributing.

Restoration of Highly Degraded Blanket Bog

Re-establishing vegetation on bare peat on the Longdendale Estates (Southern Region) has had a significant positive impact with substantial reduction in bare peat and establishment of vegetation that will develop into a form of blanket bog.

The bare peat gullies have a significant increase in vegetation cover, largely from the grass 'nurse crop' cover, which has established more effectively where heather brash and geojute were applied. The combination of all restoration measures was the most effective. Application of the 'nurse crop' without geojute and heather brash provided a good increase in vegetation cover, but only where the slopes were lower.

Heather cover is still low, but with an increased frequency compared to untreated areas and application of both brash and geojute appear to enhance its rate of establishment. An embryonic bryophyte layer is developing, with the establishment of *Hypnum* moss linked to brash material application possibly providing a source of propagules.

The use of coir rolls to stabilise bare 'peat pans' has helped reduce peat surface wash-off, but grazing stock removal appears to have had the greatest effect, enabling species like common cottongrasses and crowberry to spread vegetatively. The mobility of the bare peat in the pans still seems to be inhibiting seeding survival.

With the re-vegetation, sediment loss from Chew Clough sub-catchment into Chew Reservoir has reduced significantly. This is likely also to apply to the Longdendale and Greenfield Reservoirs, where the extent of bare peat restoration has been greater. Small Clough sub-catchment also shows a significant reduction in sediment load up to 2009, but owing to spikes of sediment and algal mats in the streams after the 2010 drought, this is now showing a long term slight increase in sediment discharge. This is not expected to be a long term trend as the new vegetation becomes better established.

Total carbon losses from two SCaMP catchments have been calculated based on developing a rating curve between Particulate Organic Carbon (POC) and turbidity (equivalent to suspended sediments). Although there are caveats for the calculations, they show that the Goyt sub-catchment, with its continuous vegetation cover and minimal area of eroding peat, has an annual sediment budget in the order of 39.31 tonnes C/ km^2/yr from a total catchment area of 7.53km^2. In contrast, the Ashway Gap Small Clough catchment, having an extensive bare and eroding peat area, albeit with a recently established vegetation cover, has an annual sediment budget of 50.77 tonnes C/ km^2/yr, from a total catchment area of 0.754km^2. These figures are within the range of those quoted elsewhere.

In response to the restoration works, Small Clough had some 14.35ha of bare peat (19%) of the catchment prior to restoration. The re-vegetating work reduced this to 10.3ha, representing a 28% reduction in bare peat across the sub-catchment as a whole. The sediment load into the Small Clough system reduced from 61 tonnes C/ km^2/yr (pre-treatment annual load to 50.7 tonnes C/ $km^{2/}$yr (post treatment), which is a significant result with multiple benefits.

These results are significant in meeting SCaMP objectives for enhancement of the condition of the SSSI. All three estates could now be assessed as being in favourable recovering condition against the Common Standards Monitoring (CSM) targets for SSSIs. In addition, the moorland is retaining more peat, thus also reducing its effect in the reservoir intakes. These results are also positive against the original targets.

Restoring Vegetation

Where grazing has been reduced on Lamb Hill and Sykes blanket bog sites (Bowland Region), progress towards favourable condition is good and the SSSI units are now achieving 'favourable recovering' status.

Reduced grazing levels resulted in significant increases in hare's-tail cottongrass and some trends towards increasing heather and bilberry on Lamb Hill. Bilberry showed a slightly stronger trend towards increasing cover where there was further winter stock removal, suggesting this regime is particularly important for its recovery. Moss cover and diversity, including *Sphagnum* mosses, were retained under these reduced stocking regimes.

Similar trends were recorded for Sykes with increases in both hare's-tail cottongrass and wavy hair-grass cover and some trends towards increasing heather. Again, moss cover and diversity was retained under the restoration measures.

The purple moor-grass reversion site (Pikenaze, North Longdendale, Southern Region) showed a significantly reduced cover of this grass following treatment, but the required cover and diversity of mosses and dwarf shrub species to meet favourable habitat condition have not yet developed. On-going management should enable the site to move towards these targets.

Stock removal and herbicide and/or cutting followed by heather and bell heather seed addition to encourage dwarf shrub restoration on the acid grassland/dry heath sites on Goyt, were successful in opening up the sward and creating germination gaps. However, cover and diversity of dwarf shrubs remained low. The combination of cutting with herbicide appeared to be more effective at reducing existing vegetation cover than herbicide application alone. This treatment may be better suited to areas where there is already a low cover of desirable species in the existing vegetation.

The dry heath site at Ashway Gap (North Longdendale, Southern Region) also showed a promising change in vegetation composition from being largely grass-dominated with some bare ground to a more diverse mix of dwarf shrubs, sedges, grasses and bryophytes.

All these changes help these sites move towards their HLS or Conservation targets, and therefore indicate they are likely to be achieving favourable recovering status in terms of CSM targets.

Woodland Restoration

Nine upland oak woodlands and five wet woodlands located in Southern Region and Bowland have been used to follow progress before and after management works. The key management changes were removal of locally non-native broadleaved trees; removal of conifers; planting with native shrubs and additional locally native trees; removal of rhododendron and stock fencing.

Despite the short time scale in woodland growth terms, the structure and native species complement of the woods where management has been undertaken have improved, thus moving the woodland sites towards their BAP targets. The management measures have generally resulted in an enhanced structure to the woods, with less canopy dominance, opportunities for a new sub-canopy layer of shrubs, seedlings/saplings or brambles and re-establishment of a ground cover on bare ground previously shaded. Each woodland is individual and the nature of the changes tends to differ between each.

Hay Meadow and Rush Pasture Restoration

The grasslands studied have successfully maintained or increased their original diversity since the baseline collected in 2007. There are signs of positive improvement in the grasslands managed for hay with cattle aftermath grazing, with the diversity maintained or enhanced and grass dominance reduced. In general there are more species per quadrat (although the changes are not statistically significant yet) in most of the sites (including rough-grazed rush pasture areas) compared with the baseline in 2007. This is positive in such a short time period.

In the rush pastures, the enhancements for breeding birds do not generally also increase the botanical species richness, but some sites are already of value.

Achieving SSSI and BAP Targets

The restoration and management measures adopted have contributed significantly to improvements in the SSSI units and support their upgrading to favourable or favourable recovering condition. This is largely owing to the scale of the management measures as well as to their focus on enhancing features that contributed to the previously unfavourable status, such as drainage, gullying, eroding bare peat and over-grazing. All the SSSI units in Southern Region and nearly all of those in Bowland are now in favourable recovering or favourable condition after mostly less than five years since the management measures were implemented.

The works also contribute significantly to UU's Biodiversity Strategy targets and therefore a wide range of National BAP habitats and species that occur on the Estates. The habitat enhancements will be able to support better populations of BAP species and are at a landscape scale, thus supporting the rebuilding biodiversity approach being promoted by Defra and others.

Total Coliform Measurements

Sampling has shown expected results with increases downstream from inbye land and after muck spreading. Measures to reduce stock access to streams will have significant effects on total coliform levels and therefore also on water quality at the treatment works.

Conclusions

The restoration and management measures undertaken have resulted in significant improvements to nature conservation condition and water quality, as well as contributing to National and UU's BAP targets. The original SCaMP objectives have therefore largely been met, thus demonstrating the success of the approach and scale of the programme. An additional four years of monitoring on the blanket bog sites will provide an outstanding long-term data set and new opportunities to explore the relationships between restoration measures and their environmental responses.

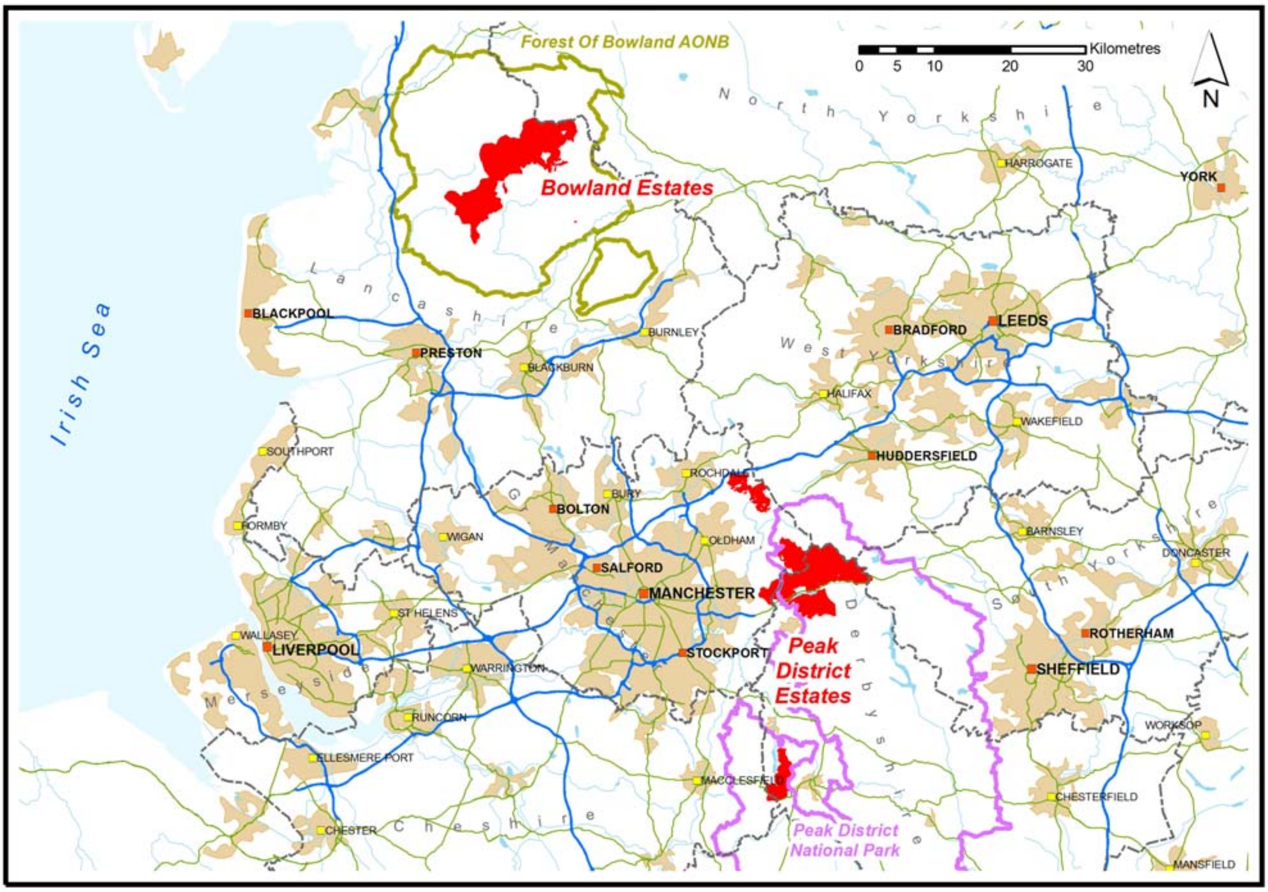
1 INTRODUCTION TO SCAMP

1.1 Background to the SCaMP Project

Overview

United Utilities' (UU) Sustainable Catchment Management Programme (SCaMP) has been an innovative and large scale project that aimed to improve catchment quality in terms principally of nature conservation condition, but with secondary aims of improving raw drinking water and ensuring a sustainable future for the company's agricultural tenants. It has been a five- year programme running from 2005 to 2010. The project has been undertaken principally in the Bowland Estate of UU's Central Region and much of its Southern Region in the Peak District (Figure 1 below).

Figure 1 *Overview of United Utilities SCaMP Monitoring Project Estates*



The project was funded through the Asset Management Programme (AMP4) and its broad aims were to:

- establish whether changes to land management practices that would benefit habitats and water quality can be achieved and, if so, by what means;
- establish the extent to which any changes:

- ◦ improve the condition of land based Sites of Special Scientific Interest (SSSIs) and the ecological status of valuable wildlife habitats and species; and
- ◦ reduce the cost of existing drinking water treatment and avoid the need for additional treatment by improving the quality of water that is abstracted from the catchment.

United Utilities' Estates

UU is the largest land owner of the water companies, with 57,000ha. Much of the upland element of these Estates has been designated as SSSIs for its dry dwarf shrub heath and blanket bog habitats and its upland breeding birds. Much of this area also lies in Special Areas of Conservation (SACs) and Special Protection Areas (SPAs). However 11,367ha of the SSSIs were in unfavourable condition at the commencement of SCaMP, as defined by the national Common Standards Monitoring (CSM) approach adopted by the UK's statutory nature conservation organisations.

In addition to these upland habitats, the estates also support woodland of various types and a wide range of pastures and hay meadows. Some of these habitats contribute significantly to UU's Biodiversity Strategy targets which cascade down from the National Biodiversity Action Plan (BAP).

SCaMP covers 45 land holdings and 21 tenanted farms covering altogether 20,000ha in Bowland and the Peak District.

SCaMP Project Monitoring

In order to establish the extent to which the measures being adopted in the SCaMP project have been effective in achieving the objectives set, a monitoring programme was established to report on:

- the environmental effectiveness;
- the economic efficiency; and
- the wider lessons from the project.

Penny Anderson Associates Ltd (PAA) was charged with designing, carrying out, evaluating and presenting monitoring data on selected botanical and hydrological parameters for the SCaMP project. The RSPB carried out monitoring of the birds over selected areas of the Farm Plans.

The Project Drivers

From the ecological and hydrological point of view, the key driver for SCaMP was the enhancement of SSSI condition, but the combined drivers of the SCaMP project were:

- to meet the Government's Key Performance Indicator (KPI) target of having 95% of SSSIs in favourable or favourable recovering condition by 2010;
- to support UU's Biodiversity Strategy by delivering actions on their wet and upland oak woodlands, rush pastures and upland flower-rich meadows and pastures;
- to improve water quality, particularly water colour; and
- to incorporate aims to reduce runoff rates, sediment load and downstream flooding.

The issue of carbon retention and reduction of losses in peat degradation have increased in significance in relation to concern about climate change since the project commenced and are now seen as important drivers as well.

The monitoring programme that has been put in place has taken these drivers, applied them to the measures that are being implemented and set out to assess their effectiveness against the project's aims.

Project Implementation

The mechanisms for undertaking the restoration and management measures were largely dependent on Farm Plans, with the measures incorporated into agri-environment schemes, either through the Higher Level Stewardship (HLS) agreements, or through the existing Environmentally Sensitive Area (ESA) schemes in the Peak District.

The objectives of the Farm Plans were to:

- update the farm infrastructure to ensure that it was capable of supporting sustainable land management practice;
- implement low impact farming systems;
- restore catchment hydrology; and
- create habitats for a range of threatened wildlife.

As well as the agri-environment scheme approach to implementation, the former English Nature financed some works independently, particularly grip[1] blocking. In addition, UU has used Forestry Commission Woodland Management Grants for undertaking measures to support BAP upland oak and wet woodland targets.

The restoration measures applied included:

- re-wetting blanket bog (mostly through grip and gully blocking) to enhance its ecological condition and reduce the breakdown and subsequent loss of peat. 85.23km of grips have been blocked on selected estates in the Peak District (Goyt) and in Bowland (Brennand and Whitendale);
- re-vegetation of eroding bare peat to restore a blanket bog vegetation, reduce sediment loss and improve water quality. 470ha have been treated with some gully blocking also carried out;
- reducing grazing pressure through stock reduction, removal or seasonal changes in grazing regimes, and on some estates, through the addition of native dwarf shrub seed to enhance the vegetation in terms of its diversity and cover. These treatments cover 12,322ha of blanket bog and 7,564ha of dwarf shrub heath in Bowland and the Peak District;
- reversion of purple moor-grass-dominated moorland to a more diverse upland flora;
- woodland enhancement including removal of non native trees and shrubs or stock fencing in 111ha of existing woodlands;

[1] *grips are surface moorland drains, mostly established using grant aid in the mid 1900s.*

- planting of new upland oak and wet woodland. 516ha of new woodland has been established to link or buffer existing areas and protect stream water quality;
- hay meadow improvements over 109ha through changes in management such as reduced fertiliser use, hay cutting and subsequent grazing management; and
- management of 250ha of rush pastures by cutting to enhance the vegetation structure for breeding sites for waders.

1.2 SCaMP Hydrological and Vegetation Monitoring

The Monitoring Programme

The monitoring programme commenced in November 2005. The rationale was to monitor the effectiveness of most of the measures that had been implemented (as listed in para.1.1) over the last four years. The grip blocking in Whitendale (Bowland) and some in the Goyt (Peak District) and the stock removal on Ashway Gap (Peak District) pre-dated the start of the monitoring programme, but most other measures post-dated this, thus providing opportunities for collecting baseline information. In some areas, reference or comparative sites were found which were not treated, or where farm-wide measures were undertaken (eg. stock reduction) but no additional restoration treatments were carried out. This has permitted some comparison of treated and untreated areas. The following monitoring has been carried out at locations shown on Figures 2 and 3 (page 5):

- the hydrological effects of grip blocking in peat grips and streams on Whitendale and Brennand in Bowland and on the Goyt Estate in the Peak District;
- the botanical character of the same areas, including treated and untreated areas;
- the vegetation cover and water quality at sites on Ashway Gap, Quiet Shepherd and Arnfield Estates (Peak District) subjected to different bare peat re-vegetation treatments;
- the vegetation response to reduced or altered sheep stocking levels on Sykes and Lamb Hill Estates in Bowland;
- the vegetation response to the restoration of acid grassland dominated moorland on non-peaty soils to a more diverse, dwarf shrub-rich vegetation type, on two sites in the Goyt and one site on Ashway Gap, all in the Peak District;
- the vegetation response to the restoration of purple moor-grass dominated areas to a more diverse moorland vegetation on Pikenaze, Peak District;
- the progress in the restoration of upland oak and wet woodland at nine sites in Bowland and seven sites in the Peak District;
- the vegetation response to enhanced management of upland hay meadows and pastures at seven sites in Bowland;
- the vegetation response to structural and grazing pressure enhancements in rush pastures in Bowland (seven sites) and the Peak District (two sites); and
- total coliform levels in selected streams.

The hydrological monitoring has usually been largely continuous, but the botanical assessments have been annual or biennial and aligned with the generally slow change in vegetation after restoration measures have been implemented. Not all sites or vegetation types were therefore monitored in 2007 and 2009. The monitoring regime for each site is presented in more detail within the following sections of this report and in the detailed reports that accompany this volume.

Figure 2 *Overview of the Bowland SCaMP Monitoring Catchments*

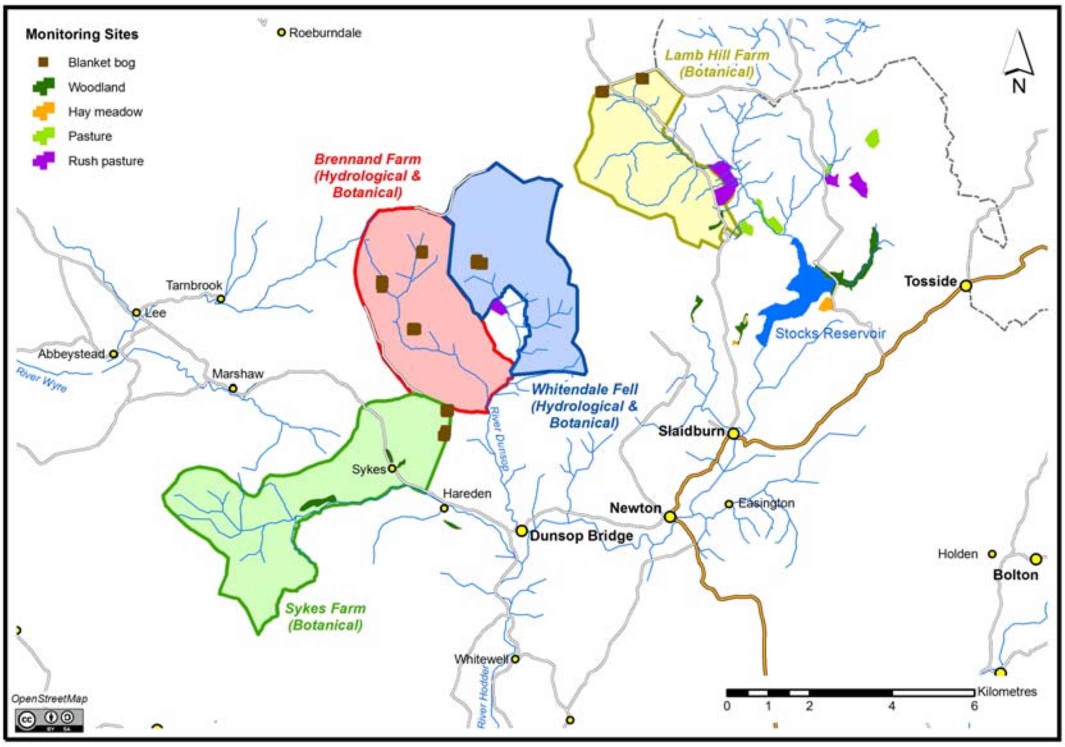
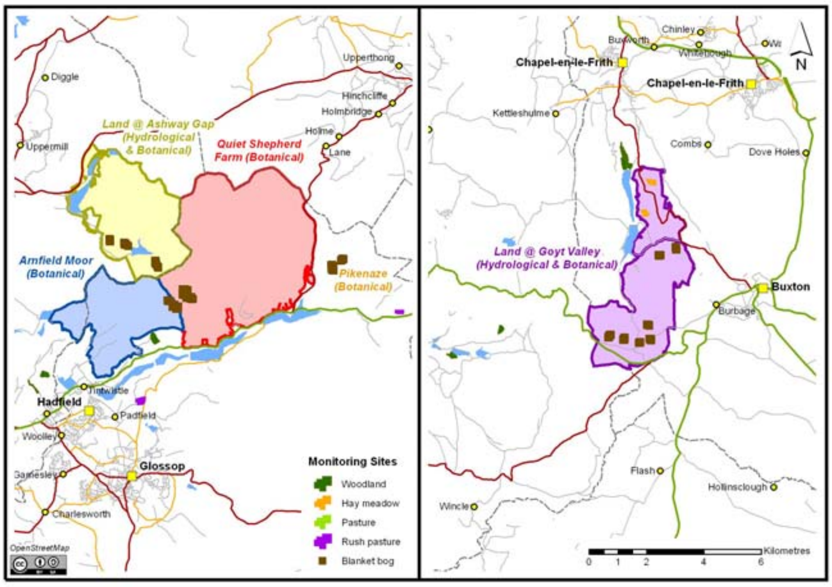


Figure 3 *Overview of the Southern SCaMP Monitoring Catchments*



The SCaMP Monitoring Hypotheses

The drivers for the monitoring related to the blanket bog and dwarf shrub heath were derived from a series of hypotheses, as follows:

- blocking active grips would:
    - move degraded blanket bog vegetation towards favourable condition through enhanced cover and diversity of plant species indicative of a blanket bog habitat, in particular the cover and diversity of *Sphagnum*[2] in wetter peat;
    - raise and stabilise the water table within the peat for longer;
    - reduce colour (dissolved organic carbon – DOC) in raw water;
    - reduce suspended sediments (particulate organic compounds - POC) in raw water; and
    - hold water in the blanket peat for longer, thus affecting the character of downstream flows;
- blocking gullies and re-vegetating areas of bare, eroding peat would:
    - establish an initial vegetation cover on areas of bare peat allowing blanket bog species to colonise over time;
    - reduce colour in raw water;
    - raise and stabilise the water table for longer; and
    - reduce suspended sediments (POC) in stream flow raw water.
- reducing grazing and (on selected sites) introducing dwarf shrub seed would increase the diversity, cover and flowering of blanket bog and dwarf shrub vegetation, reduce damage levels to the vegetation and soils and, on peat soils, increase capacity to retain water on the moor.
- Introducing restoration measures on key BAP habitats would:
    - increase the structural diversity, decrease the presence of non-native flora and encourage natural regeneration in woodlands;
    - increase the floristic diversity and enhance the local character of the habitats of hay meadows and rush pastures.

These hypotheses have provided the project with a framework within which to specify the monitoring methodology for the moorland sites and to analyse the resulting data in order to assess the effectiveness of land management changes.

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[2] Sphagnum*, or bog-moss, is a key 'building block' of blanket bog systems being the main peat forming plant.*

The Scale of the SCaMP Monitoring

The SCaMP Monitoring Project is nationally significant in its scale of spatial and temporal operation. The hydrological monitoring is conducted across four separate geographical sites and nine different treatment plot types. Intensively monitored data are currently collected from over 40 monitoring installations, with the current data series spanning over four or more years. The vegetation monitoring is wider still, with numerous monitoring plots covering six key habitat types across a wide geographical area, with intensive monitoring being undertaken between two and four times over the course of the five-year monitoring period.

Armstrong *et al.* (2010) state that previous studies investigating the impact of drain-blocking on water colour and dissolved organic carbon have been restricted to a limited spatial and temporal research framework. Their study provides one of the only other known examples of monitoring work undertaken at the scale of the current SCaMP monitoring project, with their study combining an extensive, UK wide survey of blocked and unblocked drains across 32 study sites and intensive monitoring of a peat drain system that had been blocked for seven years. In this context, therefore, SCaMP is almost uniquely placed to provide intensively monitored, reliable data for water colour, hydrology and carbon flux studies, which crucially run over long sampling timescales.

In the context of landscape sensitivity and the sometimes slow rate of change due to anthropogenic inputs, it is critical that data are collected over longer timescales in order to observe, characterise and assess the magnitude and timescale of system response and recovery. To this end, key elements of the hydrological and blanket bog vegetation monitoring are to be continued for a further four years (2011 to 2014) under an extension of the SCaMP 1 monitoring. A key objective of continuing both aspects of the monitoring is to better understand the relationships between habitat condition, land management and hydrological function.

1.3 The Reports

This volume draws together the results of all the different aspects of the SCaMP monitoring which are individually presented in separate volumes to accompany this Executive Report. The methodologies and the rationale for their adoption, the analyses undertaken on additional data and further evaluation of the results are presented in volumes related to each subject area. A synopsis of the key results is presented here.

2 RESTORING DRAINED, BURNT AND GRAZED MOORLANDS

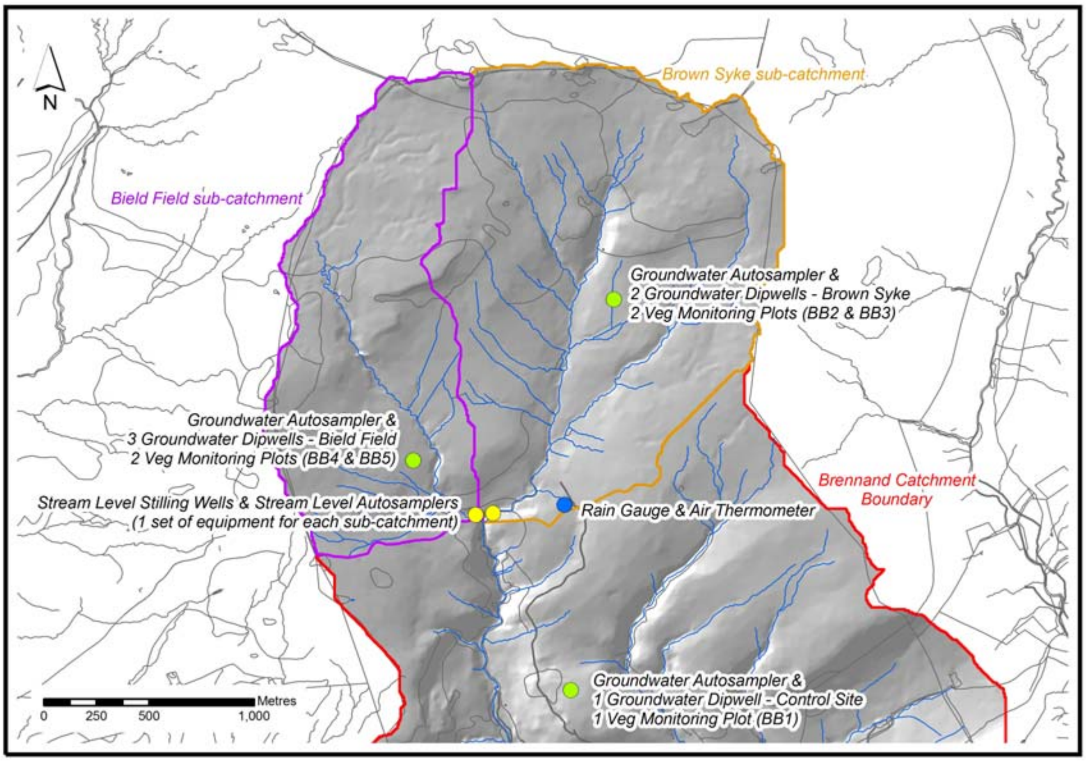
2.1 The Character of the Areas

Brennand

The River Brennand lies in the heart of the Forest of Bowland in Lancashire, serving as a tributary to the River Hodder and forming a significant part of the headwaters to the River Ribble. The Brennand catchment, rising to 527m, is some 1,100ha, with its headwaters divided into the two large sub-catchments of Brown Syke (277ha) and Bield Field (166ha). The area is characterised by deeply incised streams arising from blanket bog covered, gently sloping plateaux with peat depths varying from 0.5m to over 2m.

Brennand Farm includes just over 400ha of blanket bog, almost all of which is identified as degraded, and 300ha of upland dwarf shrub heath with some 15% classified as degraded. The study sub-catchments, Brown Syke and Bield Field, were extensively gripped in the 1950s with over 25km of grips representing 15% and 37% of the sub-catchment areas respectively. Bield Field has a proportionately greater area of its catchment surface gripped at the same density as that of Brown Syke. In addition, the upper catchment zone of Brown Syke is highly degraded with substantial areas of exposed peat and bed rock, whereas Bield Field has an intact blanket bog/dwarf shrub heath cover throughout. Figure 4 (below) provides an overview of the sub-catchment and SCaMP monitoring installations.

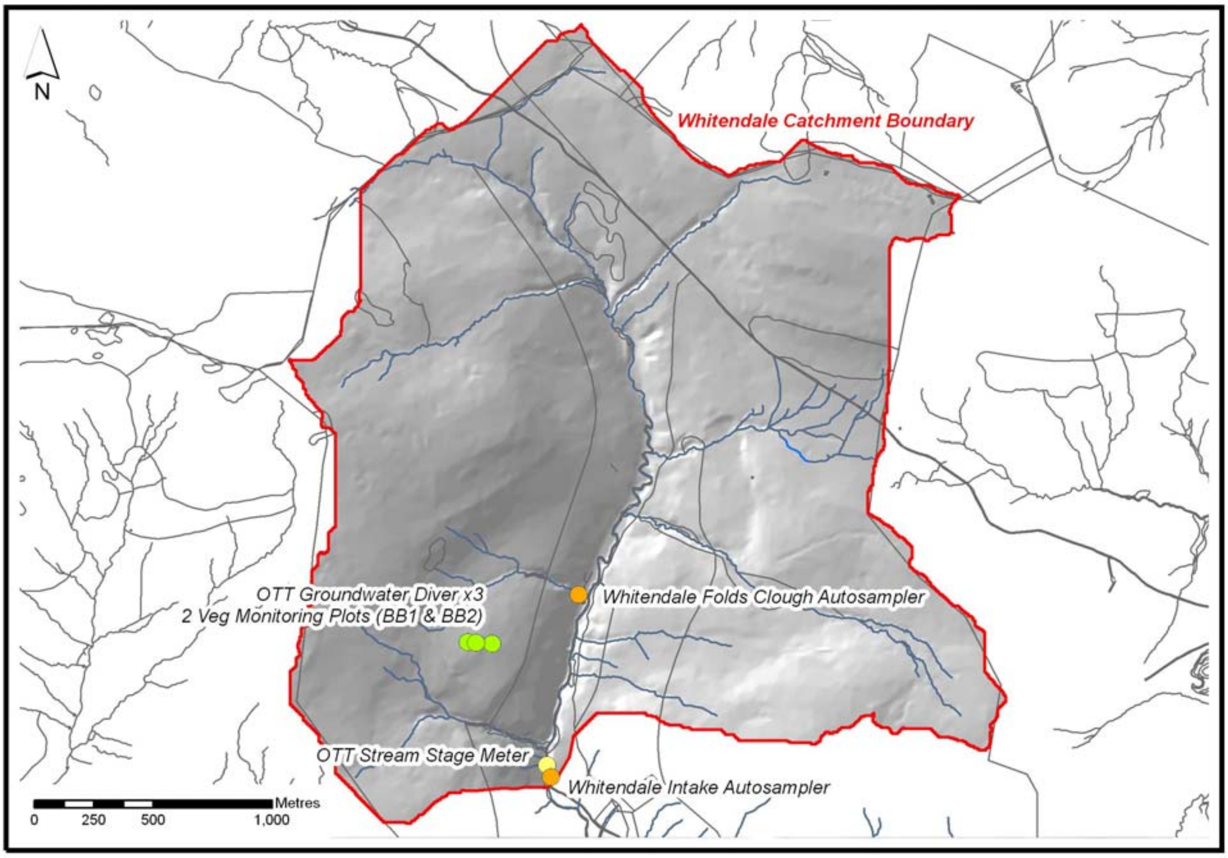
Figure 4 *The Division of the Brennand Catchment and Monitoring Locations*



Whitendale

The Whitendale sub-catchment lies immediately east of the Brennand sub-catchment catchment. The waters also drain into the River Hodder. The sub-catchment rises to over 500m and covers 673ha in total area. The vegetation monitoring sites are located in blanket bog vegetation with a mix of typical species, including a range of key indicator species for blanket bog vegetation and frequent *Sphagnum* on the reference site. In addition, approximately 34% of the sub-catchment is under burning management for grouse. Figure 5 below provides an overview of the sub-catchment and SCaMP monitoring installations.

Figure 5 *Location of SCaMP Monitoring Sites Across the Whitendale Catchment*

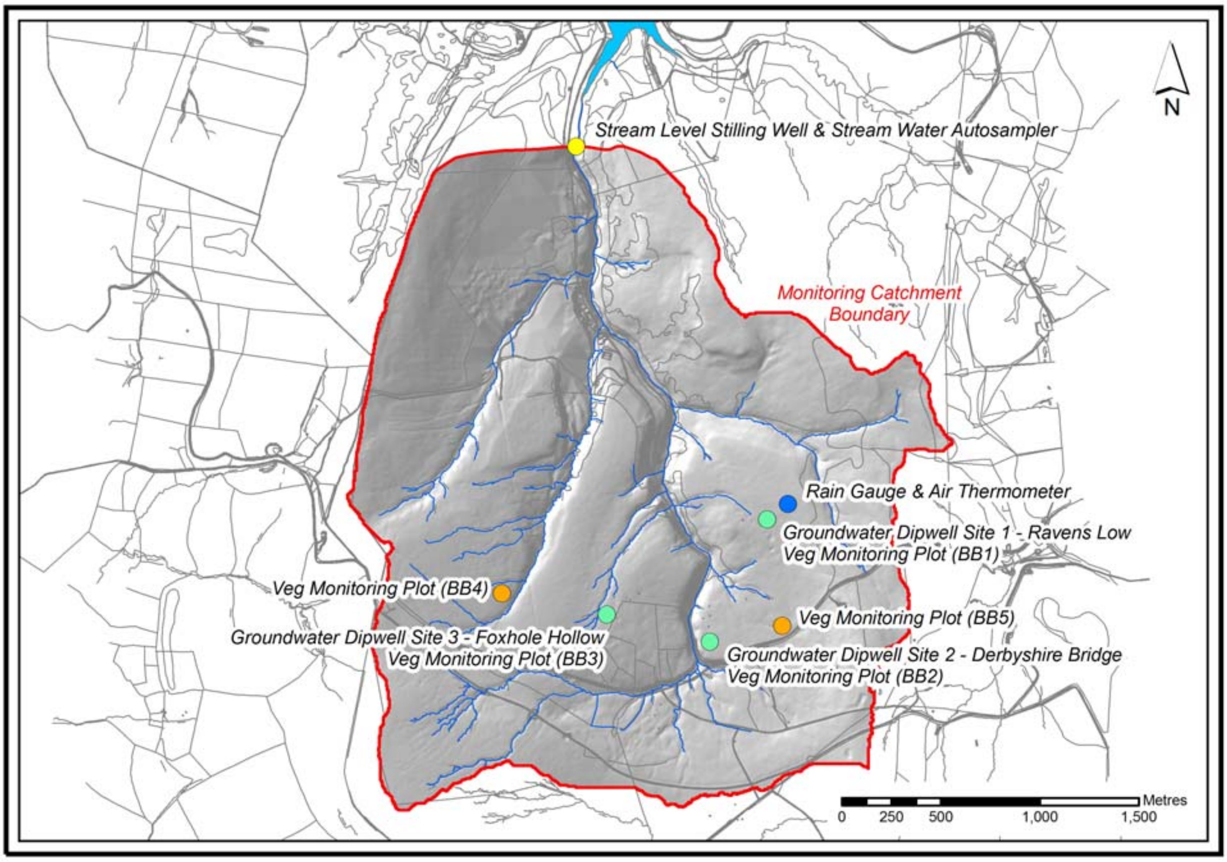


Several periods of grip blocking have historically taken place on the Whitendale catchments, the last of which was completed in 2005, prior to the start of SCaMP monitoring. The Folds Clough sub-catchment was included in the SCaMP monitoring primarily to monitor the water quality and hydrological response to earlier grip blocking.

The Goyt

The River Goyt is a major tributary and significant headwater of the River Mersey. Rising to 525m, the sub-catchment studied within SCaMP consists of around 600ha of predominately blanket bog over deep peats (averaging 1.5m) and around 250ha of dwarf shrub heath. The vegetation is a mix of cottongrasses and dwarf shrubs typical of drier blanket bog habitat, with little *Sphagnum* cover except in the wettest areas. Figure 6 (next page) provides an overview of the sub-catchment and SCaMP monitoring installations.

Figure 6 *Location of Monitoring Sites Across the Goyt Estate*



2.2 The Restoration Programme

Grip blocking has been carried out on Brennand, Whitendale and the Goyt on a large scale. At the same time, sheep stocking levels were reduced (Brennand and Goyt) or sheep grazing was re-introduced (Whitendale) and burning for grouse moor management ceased, at least for a period (Goyt). The objectives for these activities were:

- to raise the water table in the peat, thus establishing wetter and therefore better condition blanket bog, thus also increasing the possibility of maintenance and enhancement of carbon sequestration;
- to encourage, through this re-wetting, a more diverse blanket bog vegetation with more characteristic plant species, including a greater cover and diversity of *Sphagnum*; and
- to reduce the production and loss of dissolved organic carbon (DOC), thus contributing to improved water quality for UU's treatment works, but also reducing carbon loss from the peat store on the moorlands.

Hydrological Monitoring

The framework for hydrological monitoring is logically set out in three main themes, which encompass the key objectives of SCaMP restoration objectives:

- determining the appropriate scale and nature of baseline characterisation of catchments from a hydrological, hydrochemical and ecological perspective;
- determining the early responses to land management changes; and
- determining how highly degraded blanket bog catchment responds to extensive habitat restoration.

The baseline characterisation prior to large scale grip blocking has been achieved on the Brennand catchment. This has been followed by assessment of the early responses to the grip blocking, together with stock reductions. The effects of grip blocking, stock reduction and cessation of burning have also been studied on the Goyt and Brennand sub-catchments, following completion of the land management works. In addition, monitoring work on the Whitendale catchment has allowed the investigation of long-term responses to past and recent grip blocking and stock re-introduction.

Crucially, on the Brennand sub-catchments, there was an opportunity to carry out baseline data collection prior to the works being carried out. To this end, a detailed monitoring programme was implemented over five years for Brennand, Goyt and Whitendale in terms of:

- vegetation;
- water table depth and temperature;
- DOC and POC in stream flow and in the peat itself;
- discharge and temperature of streams; and
- various climatic parameters.

2.3 The Monitoring Sites and Their Objectives

Vegetation Monitoring Plots

The vegetation monitoring plots (Table 1 page 12) are closely tied with the hydrological monitoring regime and are all within SSSIs units that were reported as being in unfavourable condition in terms of CSM targets in 2005 (prior to restoration treatments). Brennand and Whitendale sites are also within the Higher Level Stewardship (HLS) agreement for each farm and therefore have ‘indicators of success’ attached to the moorland areas. The Goyt sites are within Tier 2E Moorland Management option of the South West Peak Environmentally Sensitive Area (ESA) agreement.

Table 1 *Summary of the Restoration Treatments and Objectives for Vegetation Monitoring Sites Across Brennand, Whitendale and the Goyt*

Farm	Monitoring Plot	Treatment	Monitoring Objectives
Brennand	BB1	*Reference plot:* Reduced sheep grazing from 1.2 to 0.485 ewes/ha April to Sept, and to 0.257/ha in winter	1. to assess if changes in the vegetation move the sites towards favourable condition status, in terms of SSSI CSM targets 2. to assess performance against the indicators of success identified within the relevant HLS agreement
	BB2	*Treated plots on eroding catchment:* Reduced grazing as above. Selected grips blocked	
	BB3		
	BB4	*Treated plots on non-eroding catchment:* Reduced grazing as above. Selected grips blocked	
	BB5		
Whitendale	BB1	*Reference plot:* Re-introduction of sheep as summer only grazing @ 0.47ewes/ha 2007. No active grips (old grips present but completely in-filled and no longer functioning)	
	BB2	*Treated plot*: Re-introduction of sheep as above and active grips blocked	
Goyt	BB1	*Treated plots:* Reduced summer grazing from 0.72 to 0.2 ewes/ha plus off-wintering, heather burning removed, grips blocked with peat dams	1. to assess if changes in the vegetation move the sites towards favourable condition status, in terms of SSSI CSM targets and ESA targets
	BB2		
	BB3	*Reference plot:* As for BB1 but retention of open grips and grazing reduced to 0.5 ewes/ha plus off wintering	
	BB4	*Reference plot:* As for BB1 but ungripped site therefore no grip blocking required and grazing reduced to 0.5 ewes/ha plus off wintering	
	BB5	*Treated plots:* As for BB1 but additional grip blocking with plastic piling and grazing reduced to 0.5 ewes/ha plus off wintering	

2.4 Results and Discussion

The Hydrological Response

Effectiveness of Grip Blocking

The study sub-catchments in Brennand: Brown Syke and Bield Field, were extensively gripped in the 1950s with over 25km of grips representing 15% and 37% of the sub-catchment areas respectively. Many of these grips were relatively shallow and narrow but within both sub-catchments several grips have enlarged and eroded into the mineral layer beneath, forming significant 'storm drains' across the catchments.

Despite the extent of grip blocking over the two sub-catchments and, particularly the blocking of large, highly eroded grips on Brown Syke (see Photograph 1 below), this simple, cost-effective grip blocking method has proven to be highly effective at achieving the objective of raising and sustaining water levels in the peat body and are proving to be a robust, reliable solution to the blocking of major grip features.

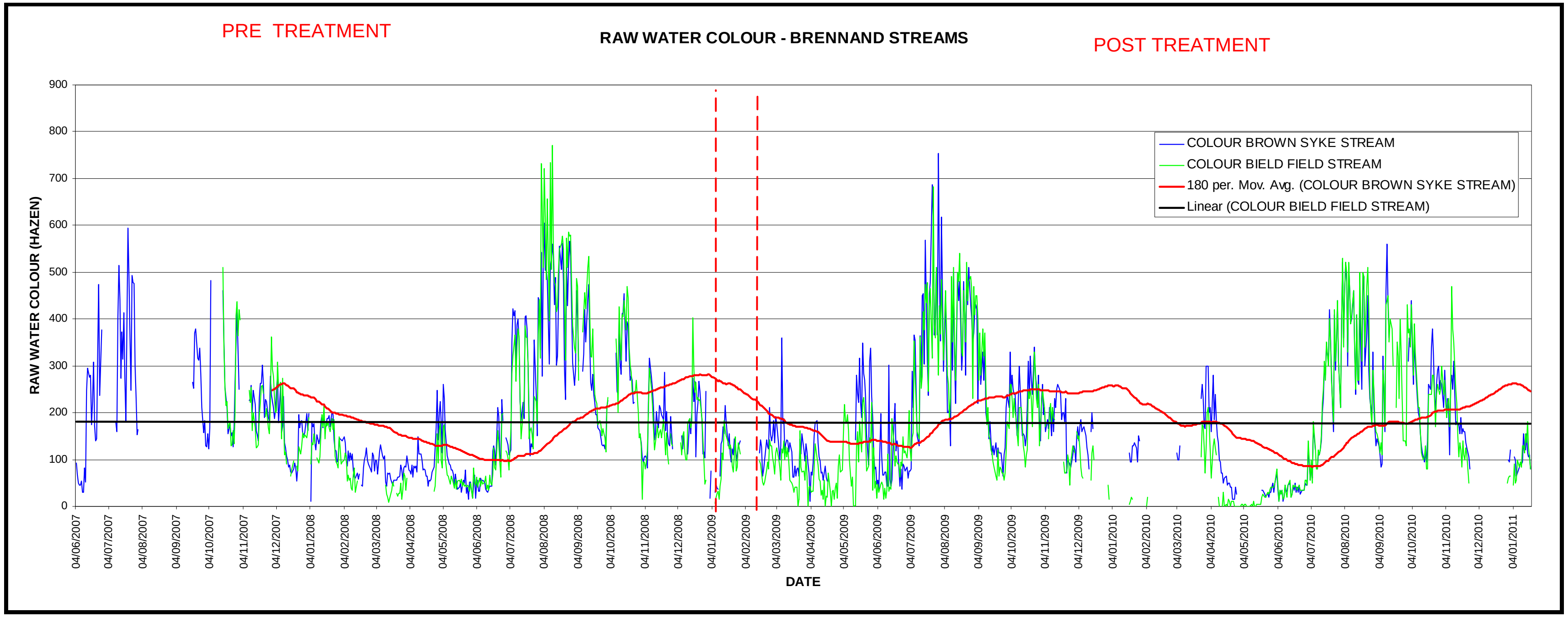
Colour

On all the sub-catchments monitored, there has now been a decrease in raw water colour generated in the peat and measured in the streams, although they vary between the different catchments studied. At Brennand, both the Bield Field and Brown Syke SCaMP monitoring sub-catchments now show declining trends in raw water colour. Observed trends on both sub-catchments are slight, but statistically significant (Bield Field stream: $p<0.001$; Brown Syke stream: $p<0.001$). Colour trends are indicated in Figure 7 (page 14). (NB: Both moving average and linear trend lines are added to each of the graphs to demonstrate the underlying trends more clearly).

This result is particularly encouraging as prior to land management works (ie. before January 2009) the trend in raw water colour was increasing on both sub-catchments. After land management changes were completed (primarily grip blocking and reduction in sheep stocking levels), declining trends have taken two years to become apparent in the time series data.

Photograph 1 *Brennand Brown Syke Sub-Catchment 2007 Before (left) and 2009 After (right) Major Grip Blocking Work was Completed*

Figure 7 *Raw Water Colour – Brennand Brown Syke and Bield Field Streams*



This response pattern is consistent with that observed on the Goyt study catchment where a slight, statistically significant, decline in streamflow colour levels ($p<0.001$) is also demonstrated. This decline became apparent two years after the completion of the major phases of grip blocking and other land management changes including the cessation of burning and reduced sheep stocking levels. Colour trends are illustrated in Figure 8 (page 16)

The restoration and land management changes on Whitendale have occurred over a protracted period of time, prior to and including the period of SCaMP monitoring. Initial results on colour indicated an increasing directional trend in streamflow colour production in the Folds Clough sub-catchment, (where historical grip blocking works had taken place until recently), whilst the whole sub-catchment showed no overall trend in colour production (as recorded at the Whitendale Intake monitoring site).

The latest results (Figure 9 page 17), for Folds Clough sub-catchment now displays a stable, stationary state of colour generation, whilst for the catchments as a whole, colour trends have changed from a stationary trend to a slight, statistically significant decreasing trend in colour ($p<0.001$); a trend detected at the catchment outlet (Whitendale Intake monitoring site). Again, this finding represents a highly significant result, demonstrating the potential positive long term effects of land management changes on colour generation from upland catchments.

These key results indicate that in response to land management changes, these three sub-catchments are either showing a slight statistically significant decline or stabilisation in colour generation and delivery in streamflow. This was a key objective of SCaMP.

The difference between the three sub-catchments investigated appears to be the response time between the completion of land management works and the effect on colour generation and delivery. This is likely to be related to variations in physical catchment characteristics, but in all cases the response time itself appears to be relatively rapid.

Many previous studies indicate that gripping is reflected in increasing levels of water colour and that following grip blocking, the level of colour can in fact increase further (Worrall *et al.* 2007). However, a recent wide ranging review by Armstrong *et al*. (2009, 2010) has found the majority of sites they studied showed a reduction in DOC after a significant time period. Therefore, this finding in both Brennand sub-catchments (and the Goyt) is indicative of a catchment response seldom previously observed in short-term data sets.

Turbidity

Turbidity levels have remained constant (with no overall directional trends) on both the Bield Field and Brown Syke streams in Brennand. This is again the case on the Upper Goyt and Whitendale, suggesting that grip blocking causes no long term disturbance to sediment losses from the catchment. The sediment losses are fairly low in all cases.

Streamflow

Over the five year period of SCaMP monitoring, Brennand, Goyt and Whitendale catchments show no overall changes in streamflow water yield and hydrograph response, with all time series trend tests reporting stationary data series. However, it is likely that the blocking of grips has enabled the re-establishment of a more 'natural' hydrological regime in the upper areas of the sub-catchments where runoff is no longer dominated by the surface, storm flow characteristic of a highly gripped catchment. These changes should be reflected in changes in the form of the runoff hydrograph, which is to be constructed.

Figure 8 *Raw Water Colour – Goyt*

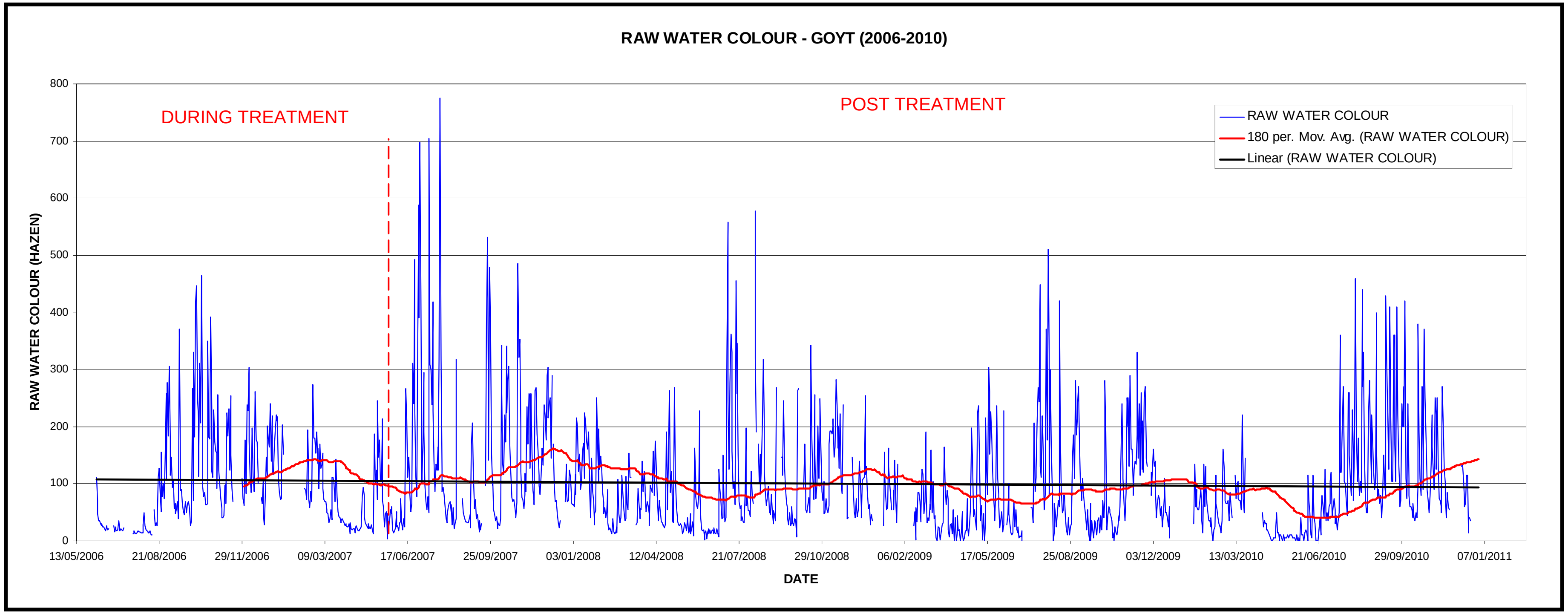
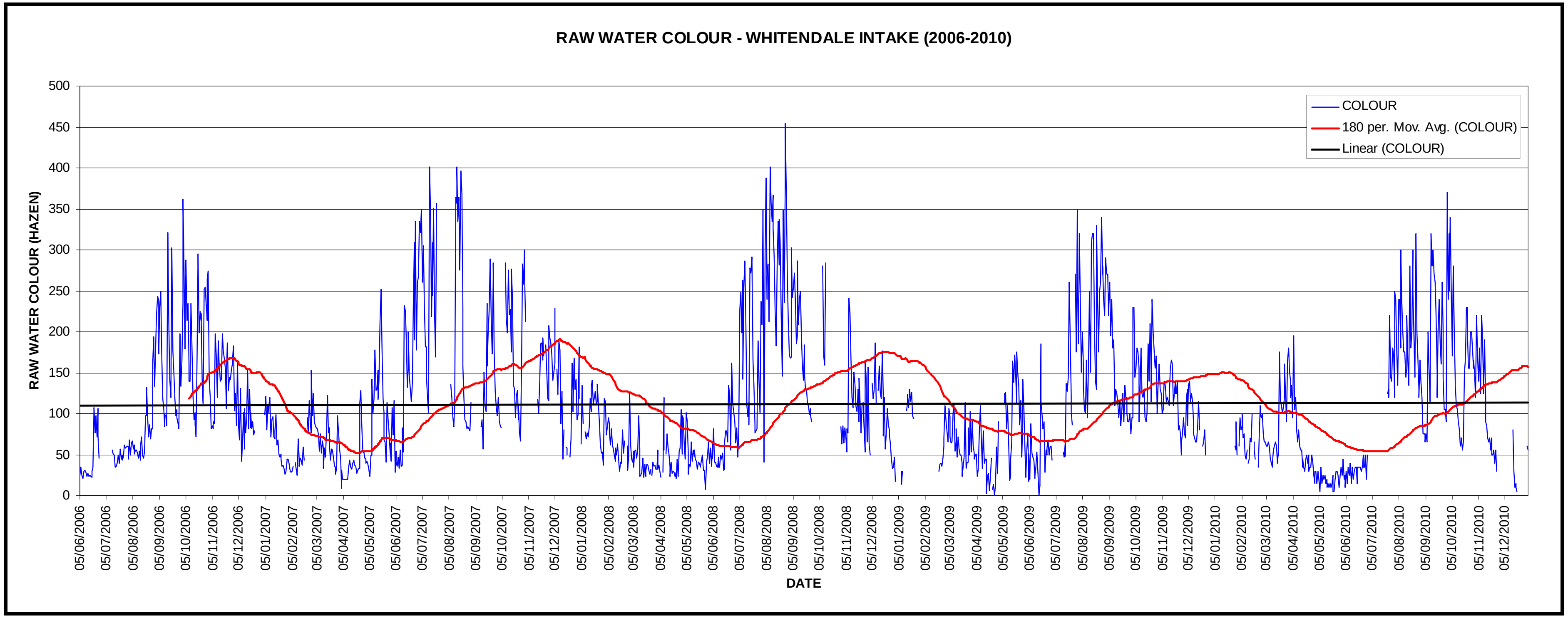


Figure 9 *Raw Water Colour – Whitendale Intake*



Peat Water Table Levels

The Upper Goyt monitoring sub-catchment demonstrates the most definitive evidence to date for the recovery and stabilisation of peat water table levels as a result of SCaMP land management changes, principally in the form of grip blocking.

All three automatic dipwell instruments on the Goyt (their location is shown in Figure 6 page 10) show statistically significant increasing monotonic trends in water table levels, with a corresponding reduction in variability (as reflected by decreasing standard deviations in the running daily mean water table level). The Mann-Kendall trend tests indicate slight (though statistically insignificant) directional trends in a rising daily mean water table levels at all three sites. These are backed up by regression analyses which again indicate very slight, statistically significant ($p<0.001$) trends in elevated water table levels over time. Both results are consistent with the water table trends observed in the time series plots illustrated in Figure 10 (page 19). All results are consistent with a general recovery of water table levels to a higher position in the peat profile, post grip blocking, closer to the ground surface.

The differences in the levels of the water table between the three dipwells probably relates to their locations, just behind (Goyt White Post) or just in front (Goyt 2) of a dam, or in an unblocked section of grip downstream from a blocked section (Bird Cage dipwell). Also apparent are the large draw-down 'spikes', observed in 2010 as a response to the particularly dry spring and summer weather conditions. The White Post, wetter site had a consistently higher water table than the Bird Cage dipwell on the partly blocked site. This is a good sign.

Crucially, these hydrological results are supported by results from the vegetation surveys (see below) which are indicative of a change in vegetation community composition from dry heath and grassland to more of a blanket bog-type habitat and species assemblage, with enhanced levels of *Sphagnum* in particular.

Figures 11a and 11b (page 20) illustrate the mean peat water table profile from fields of dipwells on Brennand recorded manually approximately monthly in the pre-damming period (November 2007 to June 2008) and the early post blocking period (spring and summer 2009). The dipwells at the same distance from the grip are amalgamated and averaged. As the recording is much less frequent than the automated dipwells achieve, many of the spikes owing to the antecedent weather conditions are missed.

The graphs demonstrate a general elevation of the water table after blocking, with a reduced drawdown effect of the grip in both cases. The more intact peatland on Bield Field seems to have responded to the damming more effectively than on the more eroded side of the catchment on Brown Syke in the period immediately after blocking was implemented. The graphs also show that the effect extends out to some 1-1.5m of the grip on either side and demonstrates a fairly consistent trend in rising water tables across the grip blocked site. There will be local variations across the sites which will produce differences on the local scale. These results tally with the obvious increases in wetness reported by field surveyors over repeated visits.

However, with the exception of the Bield Field 2 dipwell instrument (see Figure 4, page 8, for the location), analysis of all the detailed data from the automated dipwells across Brennand, including the reference site, show either stationary or declining long-term trends in mean daily water table level in the peat. This could be explained by the short run of data post grip blocking and the significant spikes resulting from the 2010 drought at the end of the data run, which skews the statistical tests. This analysis has not demonstrated, therefore, any significant increase in the water table in the peat at this stage. The declining trend at the control site suggests that the slight drying is a climatic phenomenon and not a consequence of any land management works on the catchment.

Figure 10 *Daily Mean Water Table Levels – Goyt, all Three Dipwell Sites*

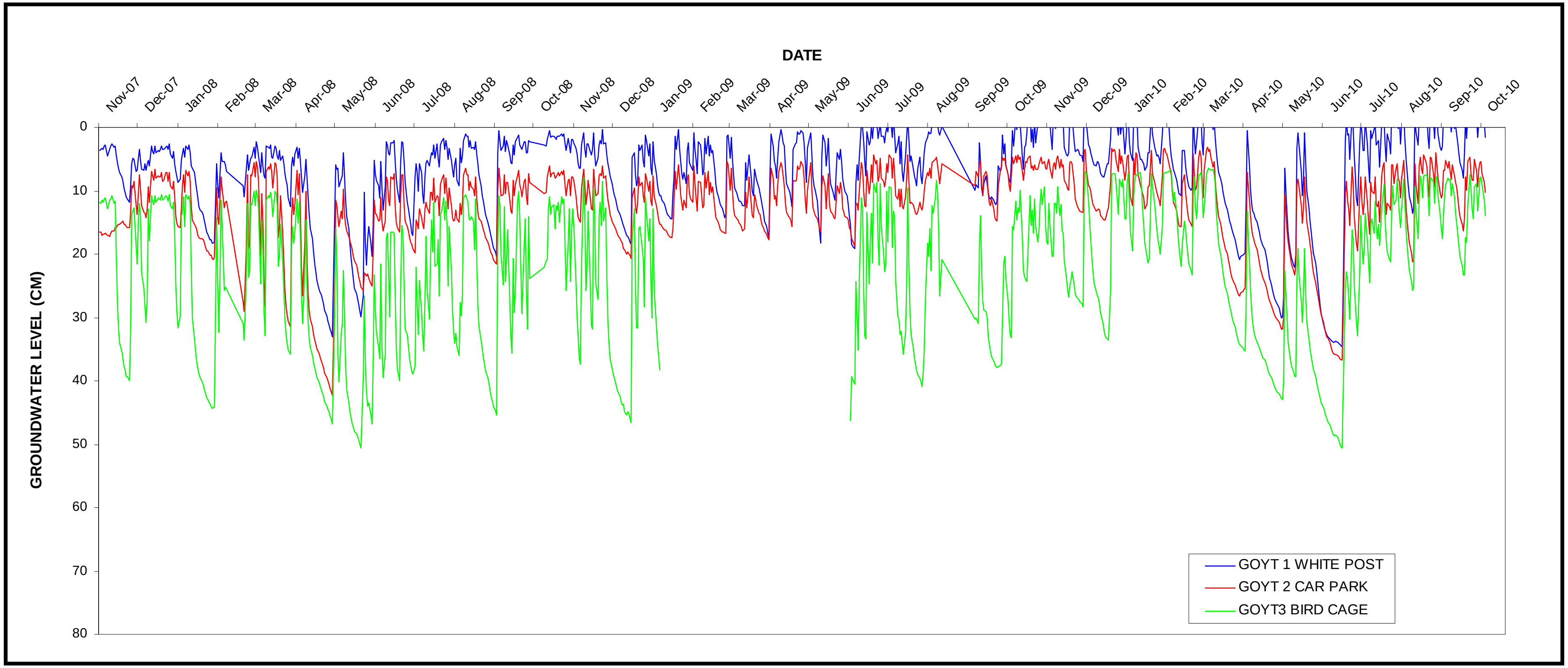
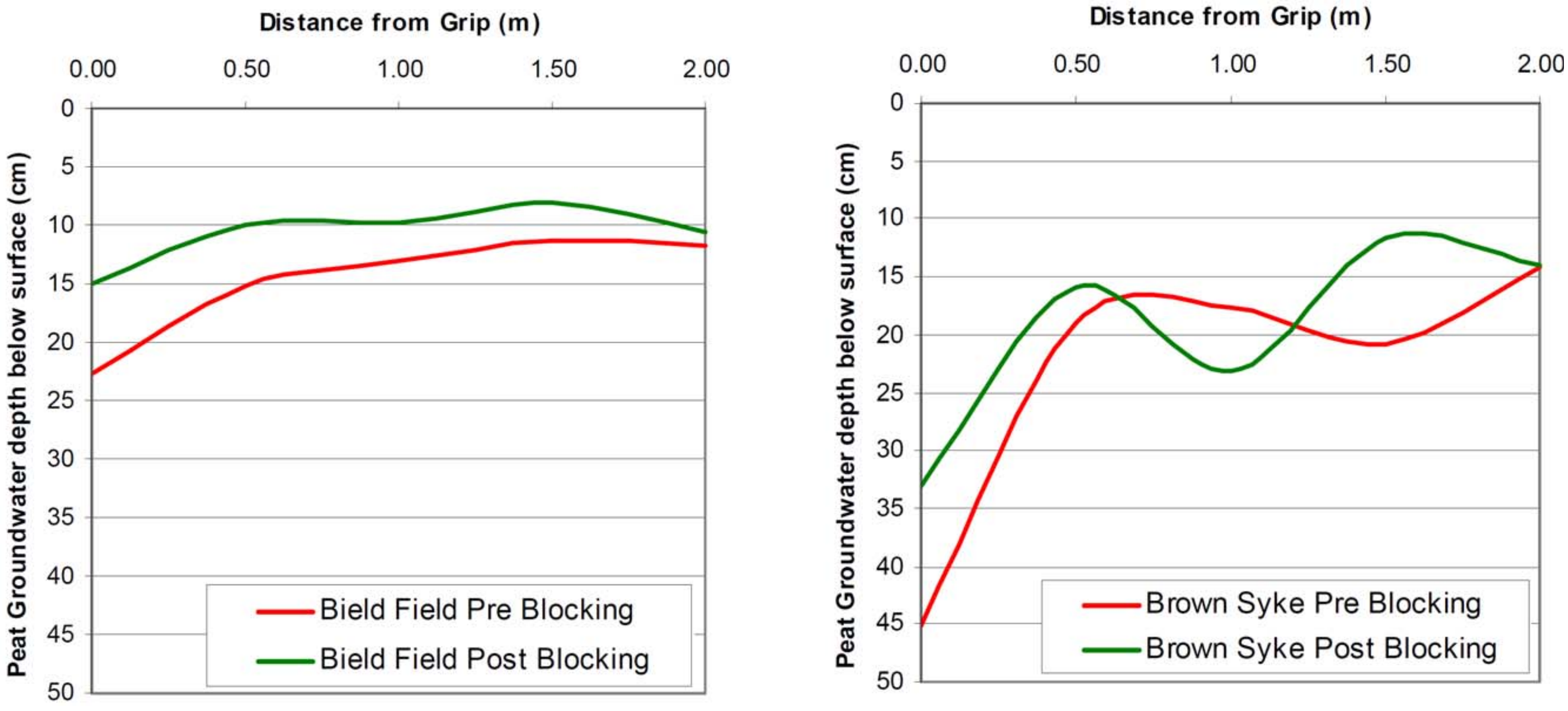


Figure 11 *Water Table Levels in the Peat Pre and Post Grip Blocking Brennand. Figure 11a Bield Field (western side of catchment), Figure 11b Brown Syke (eastern side of catchment, with greater level of grip erosion prior to damming)*



Total Carbon Loss Calculations from Colour to DOC Rating

Following the development and refinements of both colour to DOC and streamflow stage to discharge ratings, the data for the Goyt catchment have been converted to demonstrate actual estimated losses of DOC over time. Figure 12 (page 22) shows that the loss of DOC from the Upper Goyt study catchment is, in most part, less than 100kg per day. However, in storm flow conditions, the levels regularly reach up to 1000kg per day and in exceptional events, can reach up to 2500kg of carbon loss per day (see Table 2 below).

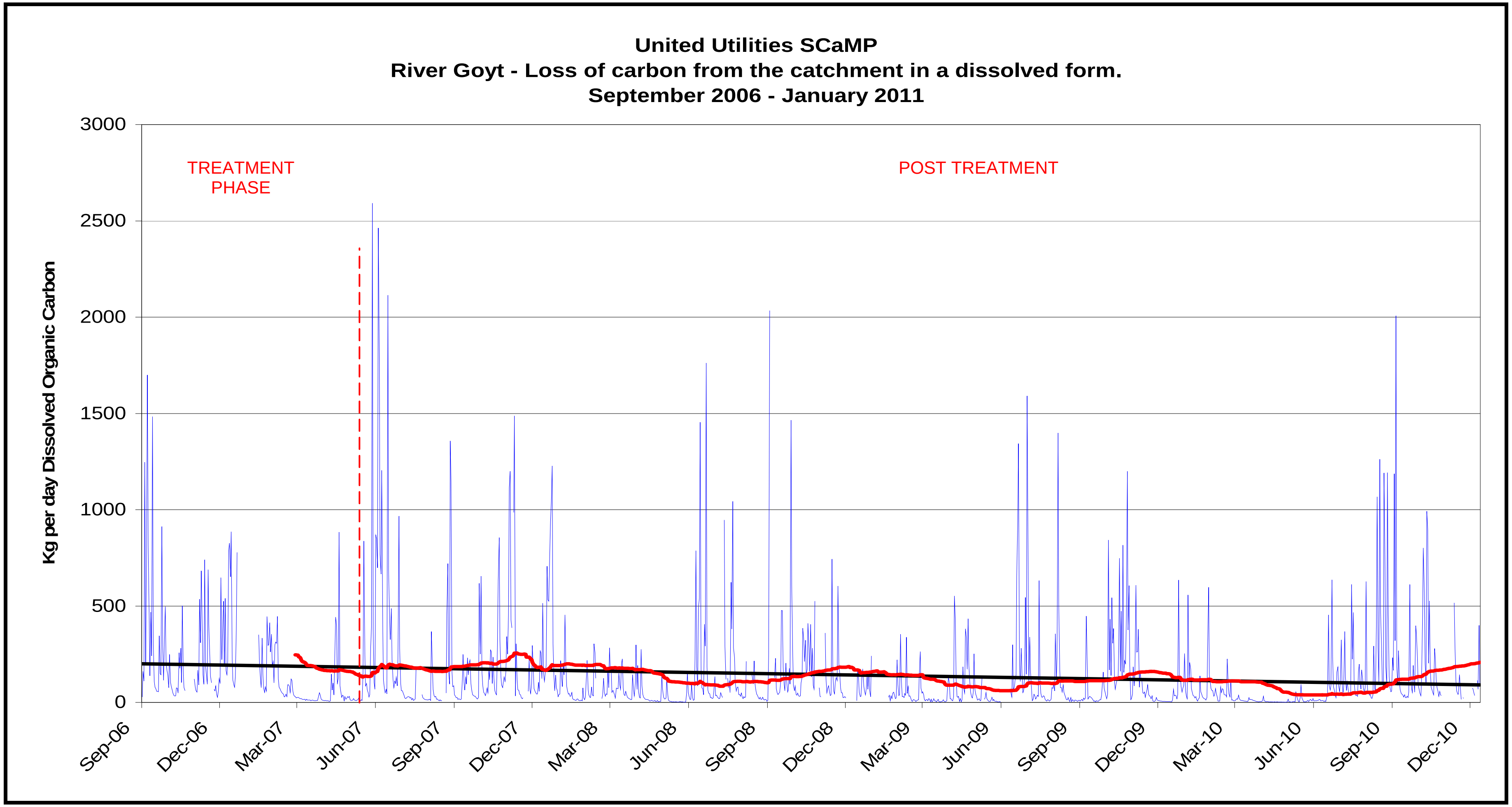
Table 2 *Calculated DOC Carbon Loss by Year – Upper Goyt Monitoring Catchment*

	Total DOC Loss per Year	Mean DOC Loss per Day	Median DOC Loss per Day	DOC Loss kg/year/hectare
September 2006-September 2007	67,355kg	206kg	72kg	89kg
September 2007-September 2008	48,121kg	145kg	53kg	64kg
September 2008-September 2009	38147kg	115kg	41kg	51kg
September 2009-September 2010	37,090kg	102kg	31kg	49kg

The data show that there has been a decrease in the levels of carbon in a dissolved form flushed from the catchment year on year. This represents a 55% reduction in streamflow DOC loss between the first and final years – a very significant result for water quality and carbon storage in the peat.

Worrall *et al.* (2006) demonstrated an areal loss of 4-7.4g of carbon lost per year for each m^2 area of catchment on upland peat catchments. The SCaMP data for the Goyt catchment show similar losses falling from 8.9g C/m^2/year in the first year of monitoring to 4.9g C/m^2/year in the year up to September 2010.

Figure 12 *Losses of Streamflow DOC in the River Goyt (kg day^{-1})*

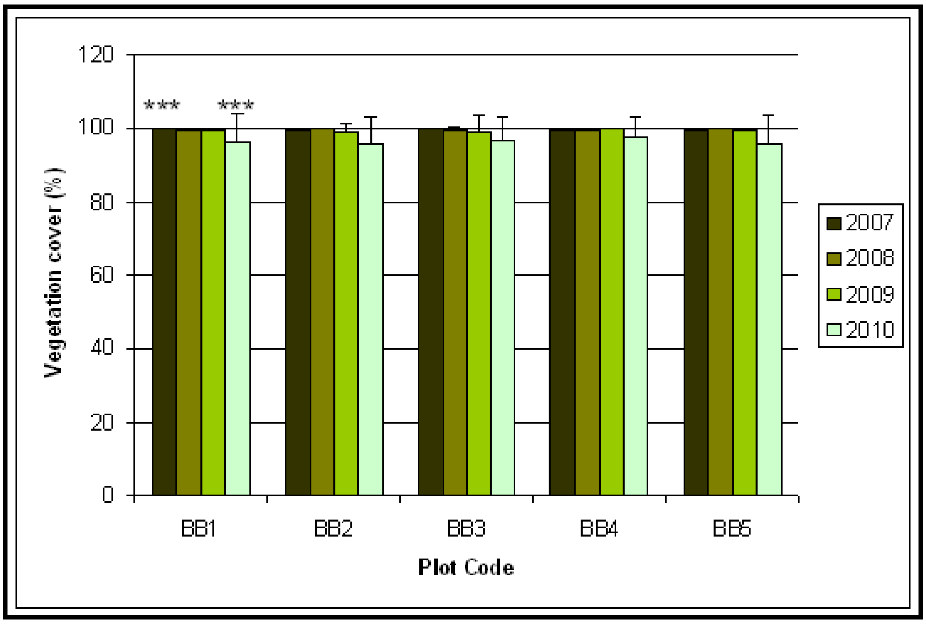


The Vegetation Response

Brennand

Vegetation cover remained stable over time for each site (Figure 13 below) with very few records of bare peat/damage to bryophytes indicating no erosion/over-grazing issues were occurring within the plots. There was a significant decline in cover between 2007 and 2010 for the reference site BB1 ($p<0.001$), however the overall statistic was not significant and the result is unlikely to reflect any ecologically meaningful change in cover.

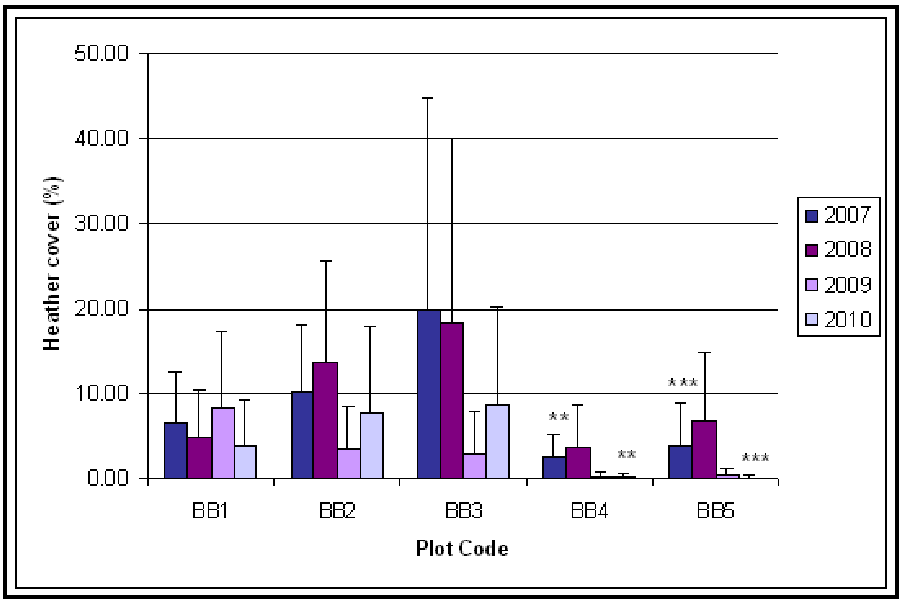
Figure 13 *Total Vegetation Cover (Mean and Standard Deviation) at Brennand Before (2007) and After (2008–2010) Restoration Measures. BB1 – reference plot, BB2 and BB3 - grips blocked eroded catchment, BB4 and BB5 - grips blocked uneroded catchment*



Dwarf shrubs showed an initial increase following reductions in sheep grazing (2007- 08) which was significant for one plot on the eroding catchment (BB3: $p<0.05$) and one on the uneroding catchment (BB4: $p<0.01$). In addition there was a decline in dwarf shrub cover following grip blocking (from 2008 to 2010), which was significant for BB3 only ($p<0.05$). These trends reflect the response of heather (see Figure 14 page 24) which shows a decline ($p<0.001$) likely related to grip blocking on the un-eroding catchment (BB4 and BB5), where heather cover was initially lower. The eroding catchment showed a similar trend but this was not statistically significant. The reference site showed no significant change in heather cover over time. This suggests grip blocking and subsequent rewetting may have weakened the growth and reduced the dominance of this species, although this was also combined with an outbreak of heather beetle in some areas.

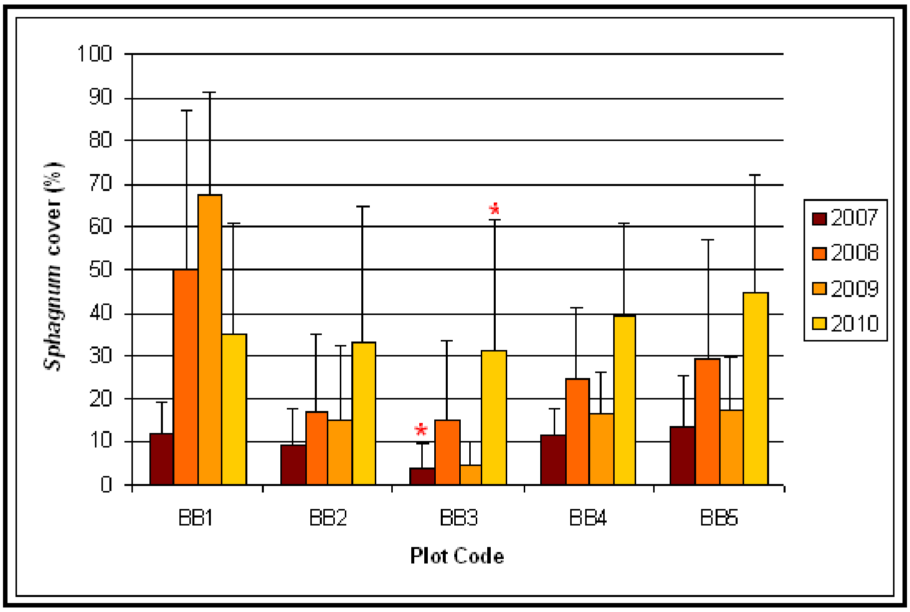
On the un-eroding catchment bilberry showed an increase following the reduction in grazing, then declined following rewetting (BB4, non-eroding catchment: significant decline $p<0.05$; BB5, non-eroding catchment: trend only), suggesting the initial release from grazing pressure was curtailed by the effects of grip blocking. The reference site continued to show a small but significant (BB1: $p<0.05$) increase in bilberry from 2008 to 2009 suggesting the positive benefits of the reduction in grazing continued where there were no additional changes to hydrology.

Figure 14 *Heather Cover (Mean and Standard Deviation) at Brennand Before (2007) and After (2008–2010) Restoration Measures. BB1 – reference plot, BB2 and BB3 - grips blocked eroded catchment, BB4 and BB5 - grips blocked uneroded catchment*



There was a trend towards increasing *Sphagnum* cover on the rewetted areas (Figure 15 below), related to grip blocking on the eroding catchment (BB3: $p<0.05$). *Sphagnum fallax,* the main contributor to this, is able to expand relatively rapidly under favourable conditions. Wavy hair-grass showed an increase ($p<0.001$) which were significant in some cases (BB3: $p<0.01$; BB4: $p<0.05$), but declined to pre-restoration levels. This reflects growth due to release from grazing pressure which then subsided.

Figure 15 Sphagnum *Cover (Mean and Standard Deviation) at Brennand before (2007) and after (2009–2010) Restoration Measures. BB1 – reference plot, BB2 and BB3 - grips blocked eroded catchment, BB4 and BB5 - grips blocked uneroded catchment*



Whitendale

Canopy height declined on both plots ($p<0.01$), as would be expected from the reintroduction of sheep grazing. In addition, no significant changes in vegetation cover or bare ground, loss of *Sphagnum* or dwarf shrubs and no increase in damage to mosses, indicating the newly introduced grazing levels are generally maintaining the blanket bog vegetation.

Assessment of the individual plant species indicates a slight decline in dwarf shrubs (largely bilberry) on the plot subject to additional grip blocking. It is unclear if this trend is related to the grip blocking resulting in increasingly wetter ground conditions, or the on-going effect of the new grazing regime (or a combination of both). Bilberry is sensitive to both increases in autumn grazing levels and increases in ground wetness.

Goyt

The ungripped plot on the Goyt (BB4) had a drier vegetation than other sites, dominated by heather. On this site, removing burning and reducing grazing resulted in increases in heather ($p<0.01$) and the moss *Hypnum jutlandicum* ($p<0.001$) as well as significant increases in grass cover ($p<0.001$) and vegetation height ($p<0.001$). These results demonstrate the effects of reducing grazing and removing burning only (on an area without grips), enabling the additional effects of grip blocking on other plots to be evaluated.

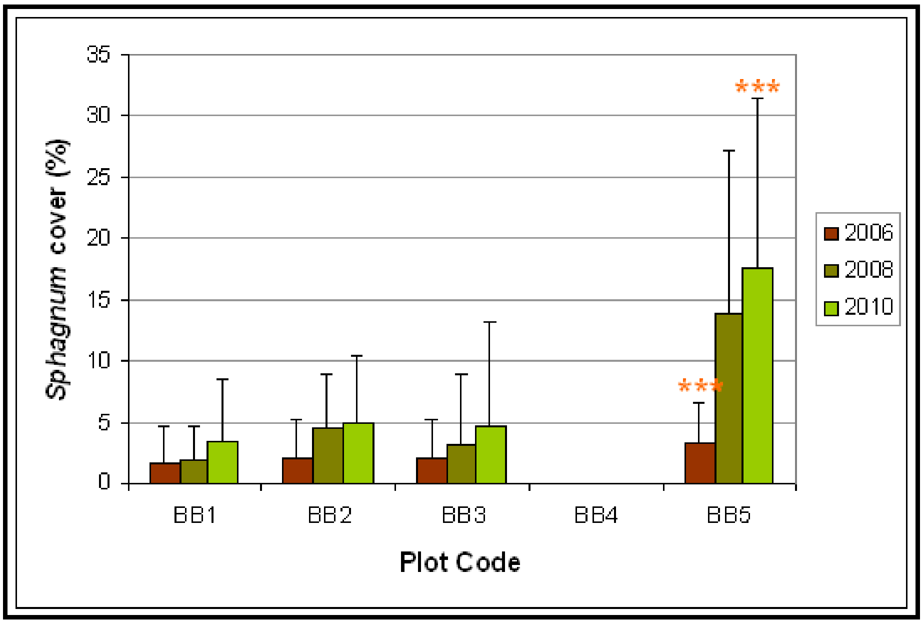
Across the wetter monitoring plots subject to grip blocking (BB1, BB2 and BB5), there was a similar trend of increasing heather, vegetation height and bryophyte cover, which relate to removal of burning and reduced grazing regimes rather than blocking of grips (Photographs 2 and 3, below). There was an increase and then decline in bilberry and similar trends for wavy hair-grass, again an initial response to reduced grazing/burning regimes with grip blocking and re-wetting showing later in 2010 through the checking/slowing of growth.

Photographs 2 and 3 *Goyt Plot (BB5) With Reduced Summer Grazing/Off-wintering, Removal of Heather Burning and Block of Grips with Peat and Plastic Dams, 2006 (left) and 2010 (right), Illustrating Significant Re-vegetation of Damaged Area*

The wettest site, BB5 (plastic and peat dams), showed increases in *Sphagnum* ($p<0.001$) related to increases in *Sphagnum fallax*. This site had a greater initial cover of *Sphagnum* and responded more rapidly to the rewetting (Figure 16 page 26). Other gripped/blocked plots show a trend towards increasing *Sphagnum*, again largely related to increases in *Sphagnum fallax,* but several other *Sphagnum* species were also recorded for the site. No *Sphagnum* was recorded on the drier plot (BB4). The unblocked gripped site (BB3) showed a significant decline in hare's-tail cottongrass (*Eriophorum vaginatum*: $p<0.001$)

but no increase in *Sphagnum*, suggesting there was no significant increase in wetness where grip blocking was not completed.

Figure 16 Sphagnum *Cover (Mean and Standard Deviation) on the Goyt Plots Following Restoration. All plots reduced grazing; BB1 and BB2 - peat-blocked grips; BB3 - reference site grips, unblocked; BB4 - reference site, drier no grips; BB5 - plastic-blocked grips*



Assessing Sites Against Key Targets

Table 3 (below) summarises the achievements of the restoration programme against the key targets set by the HLS Agreements and the SSSI Site Objective Statements. The HLS Agreements were at the end of their third year in 2010, but many of the targets to be met by years 5 and 10 were already achieved or likely to be achieved in the 10 year term of the agreement.

Table 3 *Summary of the Progress of Each Monitoring Site Towards Relevant Key Targets Across Brennand, Whitendale and Goyt. Key: ✓✓ = meets target; ✓ = moving towards target/met in some areas; X = does not yet meet target*

Farm	Relevant Key Targets (HLS/SSSI)	Key Results Achieved by 2010
Brennand	**HL10 – moorland restoration indicators of success:** By Yr 5 – Cottongrasses and heather flowering frequent, dwarf shrubs should be at least frequent, <10% *Sphagnum* damaged/dead, <10% bare peat. By Yr 10 - >33% *Sphagnum* cover, at least 2 dwarf shrub species should be frequent, dwarf shrub cover 33% - 75%, <75% cover grasses/sedges/rushes. **HL13 moorland re-wetting indicators of success:** Overall - Grip blocks should always hold	Comparing 2010 results against indicators of success for Yr 3: ✓✓ pools of water noted in blocked grips, no erosion noted in relation to blocks, and *Sphagnum* also colonising grips (HL13) Comparing 2010 results against indicators of success for Yr 5: ✓✓ cottongrasses noted as healthy and flowering ✓ heather appears dead/ dying on BB2 and BB3, likely due to rewetting in combination with heather beetle attack, but flowering well on other areas

Farm	Relevant Key Targets (HLS/SSSI)	Key Results Achieved by 2010
	back water, no erosion from any grip overflow. By Yr 3 - grips should be actively silting behind blocks, standing water should be evident behind blocks after rain, vegetation should be colonising the grip both upstream and downstream.	✓✓ dwarf shrubs frequent to abundant ✓✓ <10% *Sphagnum* dead/damaged ✓✓ <10% bare peat (mean <2% on all plots) Comparing 2010 results against indicators of success for Yr 10: ✓ *Sphagnum* cover >33% (mean 30–45% across plots) ✓✓ dwarf shrub cover <33% (mean 13-21% across plots) ✓ grasses/sedges/rushes >75% (mean 65-80% - above target for 2 plots only)
Whitendale	**HL10 moorland restoration indicators of success:** By Yr 3 – no evidence of localised overgrazing By Yr 5 - *Eriophorum* and *Calluna* flowering frequent, <10% Sphagnum damaged/dead. By yr 10 - >33% Sphagnum cover, at least 2 dwarf shrubs frequent, dwarf shrub cover 33% - 75%, <75% cover grasses/sedges/rushes. **HL13 moorland re-wetting indicators of success:** Improve conditions for peat forming bryophytes.	Comparing 2010 results against indicators of success for Yr 3: ✓✓ grazing increased but no localised overgrazing ✓✓ <10% bare peat (mean <1% both plots) ✓ pools of water noted behind some but not all grip blocks, and *Sphagnum* colonising blocked grips (HL13) Comparing 2010 results against indicators of success for Yr 5: ✓✓ heather and cottongrasses noted as healthy and flowering ✓✓ <10% *Sphagnum* dead/damaged Comparing 2010 results against indicators of success for Yr 10: ✓ *Sphagnum* cover <33% (on one plot only) ✓ dwarf shrubs frequent to occasional ✓✓ dwarf shrub cover >33% (mean 35-55% across plots) ✓✓ Grasses/sedges/rushes <75% (mean 60-70% across all plots)
Goyt	**SSSI Objectives –** to move blanket bog towards favourable condition in relation to CSM. Bryophytes to be abundant, *Sphagnum* frequent, dwarf shrubs >33% cover, 2 dwarf shrubs frequent, grasses/sedges/rush <50% cover, little bare ground, localised erosion only, localised heavy grazing <5% of area.	Comparing 2010 results against CSM targets/SSSI Objectives: ✓✓ bryophytes abundant ✓ *Sphagnum* frequent and widespread over majority of plots ✓ dwarf shrubs >33% (30-95% on average, one plot <33%) ✓✓ 2 dwarf shrubs frequent ✓✓ grasses/sedges/rushes <50% (35-50% across all plots) ✓✓ little bare ground (<3% across all plots) ✓✓ localised erosion ✓✓ localised heavy grazing <5%

2.5 Conclusions

The Goyt and Brennand sub-catchments have shown a statistically significant shift towards declining DOC generation, with Whitendale demonstrating a longer-term response in terms of stabilising and decreasing DOC in relation to land management change. The SCaMP data for the Goyt catchment show losses falling from 8.9g C/m^2/year in the first year of monitoring to 4.9g C/m^2/year in the year up to September 2010, a 45% reduction which is highly significant for the project.

Turbidity levels have remained constant suggesting that grip blocking causes no long term disturbance to sediment losses from the catchments monitored, where the losses are fairly low in all cases.

The stream flow of all sub-catchments monitored has maintained water yield characteristics following land management change. However, there is growing evidence (particularly on the Goyt) that the nature of catchment hydrological response has changed to a less flashy, more attenuated character.

All three automatic dipwell instruments on the Goyt show statistically significant increasing monotonic trends in water table levels, with a corresponding reduction in variability. The water table levels are highest behind the dipwell placed behind a grip dam. The manually measured water table changes in Brennand after gripping show an elevated level extending to 1-1.5m from the grip and increased wetness of the surface is regularly observed on the ground. The automated data from dipwells in Brennand are skewed by the significant 2010 drought period and do not yet show statistically significant positive changes.

Brennand meets the majority of the HLS indicators of success after only three years and should continue to move towards those that are currently not met. On the eroding catchment, the total cover of grasses/sedges/rushes is above target and will be re-assessed over the next four years to ensure these species do not gain dominance over the dwarf shrubs. Dwarf shrub cover, especially heather, is lower than target but this is not necessarily detrimental to the targets set as it is linked in part to localized heather beetle outbreaks so a proportion is expected recover. In addition, bilberry is benefitting from the reduced grazing levels on some areas and it is likely that other dwarf shrubs typical of blanket bog such as cross-leaved heath (*Erica tetralix*) and bog-rosemary (*Andromeda polifolia)*) are expected to increase as a result of grip blocking and grazing reduction.

On Whitendale where grazing was re-introduced along with grip blocking, the grazing has reduced the vegetation height (as would be expected) but has not significantly altered the vegetation community type. On the grip blocked site there a trend towards lower dwarf shrub cover (largely related to bilberry) which may be a response to the increased wetness following grip blocking as bilberry is known to favour slightly better drained peatland sites, but the reintroduction of grazing may also be contributing to this trend. Whitendale also meets the majority of the HLS indicators of success at the end of three years and monitoring trends indicate the area should continue to move towards others. *Sphagnum* cover on the recently blocked site needs to increase from 10% to 33% to meet the relevant target by 2017. The monitoring indicates that the target for rewetting is beginning to be met, therefore, it is likely that *Sphagnum* cover will increase over this site within this time-scale.

Overall, for the Goyt, the effects of changing the burning and grazing regime are beginning to show in the vegetation via the changes in vegetation height, total vegetation cover, moss cover (excluding *Sphagnum*) and heather cover. This is occurring alongside changes that are linked to increasing wetness as a result of grip blocking, in particular the increases observed in *Sphagnum* which is statistically significant on one plot. Over time, as the competitive ability of heather declines with its aging, the cover of other blanket bog species is likely to increase and the area re-establish as a more diverse blanket bog vegetation community.

All three areas are moving towards favourable habitat condition in terms of CSM targets and could now be considered as achieving ‘favourable recovering’ status, although it is too early for all monitoring plots to meet all the targets set. Such improvements were a key driver for SCaMP, and their generally good progress illustrates the success of the project. Over the next monitoring period (2011-2014) these targets are likely to be more fully achieved.

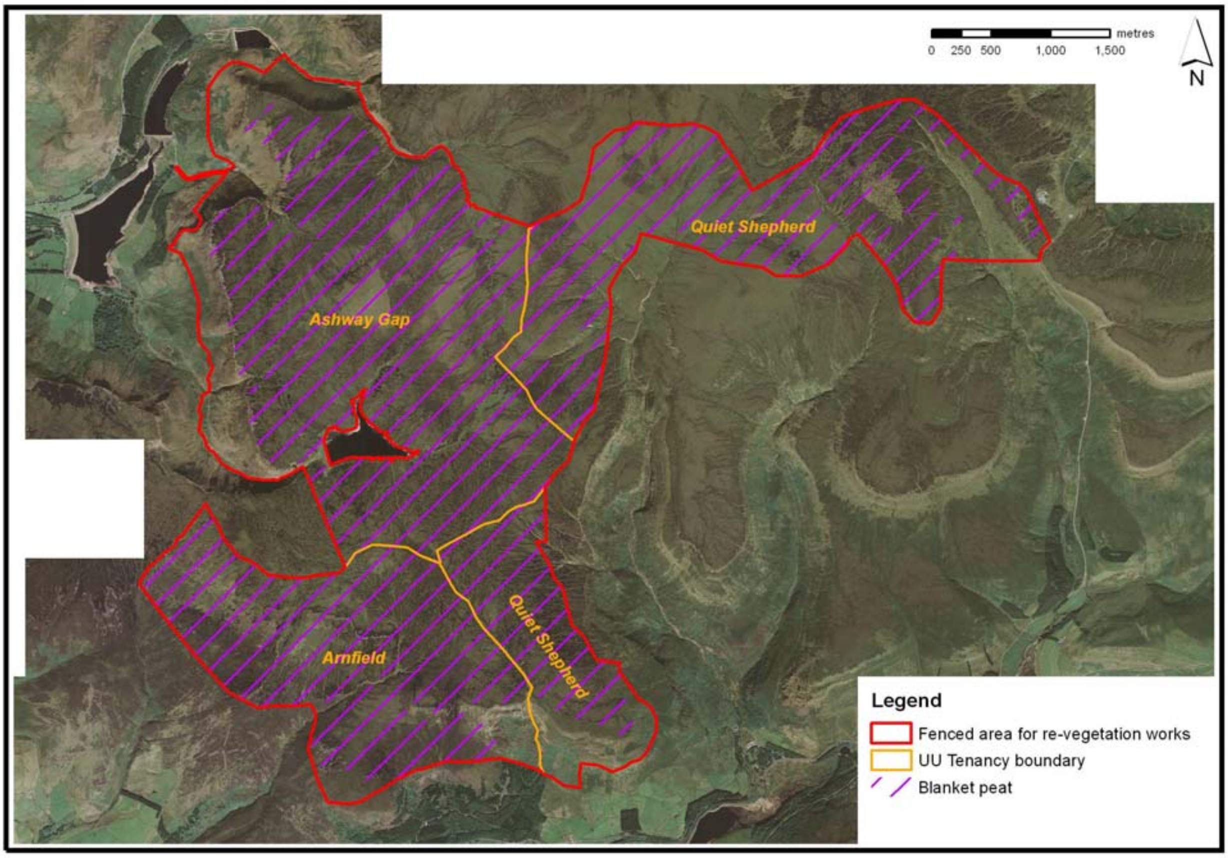
3 RESTORATION OF HIGHLY DEGRADED BLANKET BOG

3.1 The Character of the Area

The three Estates in North Longdendale where restoration works have been carried out are dominated by blanket bog merging into heather covered heathland or acid grasslands. All lie within the Dark Peak Site of Special Scientific Interest (SSSI). However, much of the blanket bog (some 12.5%) has been heavily gullied, severely eroded and incorporates much bare peat. The extensive bare ground is thought to be related to repeated wildfires, but the loss of *Sphagnum* about 230 years ago across the Peak District is linked to air pollution (Tallis 1964) and a coincident increase in the rate of erosion, both of which would have contributed to increased bare peat exposure (Photograph 4 page 31). On-going heavy grazing and air pollution have prevented effective regeneration of the vegetation in the recent past.

SCaMP has provided the opportunity to restore these areas of damaged blanket bog with the dual objectives of improving the water quality in the nearby reservoirs (Figure 17 below) and restoring the habitat as part of the SSSI condition targets.

Figure 17 *Land North of Longdendale Subject to Restoration*



The vegetation of the area is poor in species and dominated by hare's-tail and common cottongrasses (*Eriophorum vaginatum* and *E. angustifolium*) with crowberry (*Empetrum nigrum*) and bilberry (*Vaccinium myrtillus*) on the drier peat. Heather (*Calluna vulgaris*) is only locally abundant. *Sphagnum* and other mosses are scarce but currently increasing as a response to reductions in sulphur dioxide.

Photograph 4 *Degraded Nature of part of Ashway Gap Prior to Restoration*

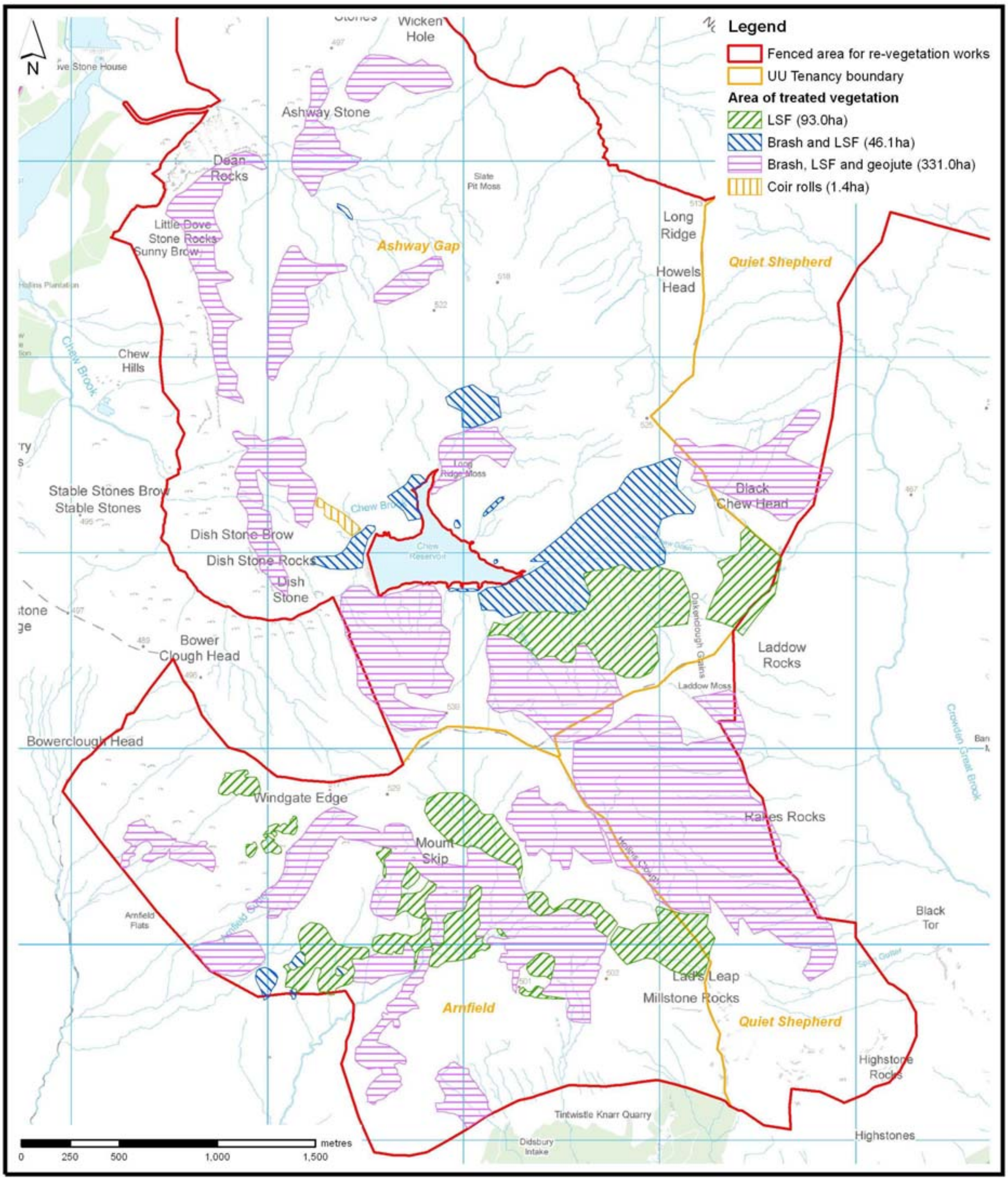
3.2 The Restoration Programme

The restoration works were implemented within a stock-proof fence (covering 1,675.9ha of blanket bog, see Figure 18 page 32) in the winters of 2007/8 and 2008/9 and focused on the worst affected areas within the western half of the fenced site. The scale of the measures is significant (Figure 18 page 32), reflecting the integrated approach that SCaMP has taken, with lime, seed and fertiliser added to some 93ha and heather brash with lime, seed and fertiliser applied to a further *c*.377ha. Rolls of a geotextile; geojute totalling 12.97ha, have been pegged out onto the steeper peat slopes.

The specifications (expanded in Volume 3), which were based on experimental work undertaken within the Moorland Management Project (Anderson *et al*. 1997), were:

- the addition of lime and fertiliser with a grass seed nurse crop mix;
- the addition of cut heather with pods and seeds still attached (brash) to the lime/seed and fertiliser-treated areas;
- securing geojute geotextile to steep, bare gully sides with the addition of lime/seed and fertiliser with or without the brash also added;
- some experimental placing of coir rolls in peat pans to stabilise the peat and reduce peat loss and rill development; and
- some gully blocking with stone (deeper gullies) or heather bales (shallower areas) in selected sites.

Figure 18 *The Treatment Areas on the Estates North of Longdendale*



The natural re-colonisation of plants on these bare, acidic and nutrient poor peat areas can be very slow, even with lime, fertiliser and geojute or heather brash application and is particularly vulnerable in its first few winters due to the inherent nature of upland environments. A grass nurse crop is used to stabilise the eroding peat and comprises a seed mix of native and low-persistence non-native grass species that will provide some protection for the slower establishing heather seed. The nurse crop should then die out after about five years (Anderson *et al*. 1997) whilst the heather increases before locally native blanket bog species invade over a ten year period.

3.3 The Monitoring Sites and their Objectives

The hypotheses that guided the monitoring are that re-vegetating areas of bare, eroding peat would:

- move degraded blanket bog vegetation towards favourable condition status by re-establishing vegetation, reducing bare peat cover, reducing erosion and increasing the wetness of the peat;
- raise the water table for longer; and
- reduce colour (DOC) and suspended sediments (POC) in raw water.

Evaluating the different re-vegetation techniques helps identify the most appropriate method in different circumstances. Figures 19 (page 34) and 20 (page 35) show the location of the monitoring plots within the extensive treatments sites.

The vegetation monitoring plots selected on these three estates (summarised in Table 4 below) are all closely tied with the hydrological monitoring. The sites were reported as being in unfavourable condition in terms of CSM in 2005 (prior to restoration treatments) and are within Tier 2B Moorland Exclosure option of the North Peak ESA.

Table 4 *Summary of the Restoration Treatments and Objectives for Vegetation Monitoring Sites Across North Longdendale*

Estate	Monitoring Plot	Treatment
Ashway Gap	BB1	*Treated plot:* Gently sloping bare peat gullies treated with lime, fertiliser and nurse crop seed
Arnfield	BB5	
Quiet Shepherd	BB6a	*Treated plot*: Steeper sloping bare peat gullies with lime, fertiliser, nurse crop seed and heather brash 2007/8
	BB6b	*Treated plot:* Steeper sloping bare peat gullies with lime, fertiliser, nurse crop seed and heather brash with geojute 2007/8
Arnfield	BB7	*Reference plot*: Untreated bare peat gullies
Ashway Gap	BB2a	*Reference plot*: Bare peat 'pans' – sheep grazing removed prior to monitoring
	BB2b	*Treated plot*: bare peat 'pans' – sheep grazing removed prior to monitoring, coir rolls installed to reduce peat erosion and surface water run-off , March 2007

Figure 19 *The Monitoring Site Locations in Longdendale*

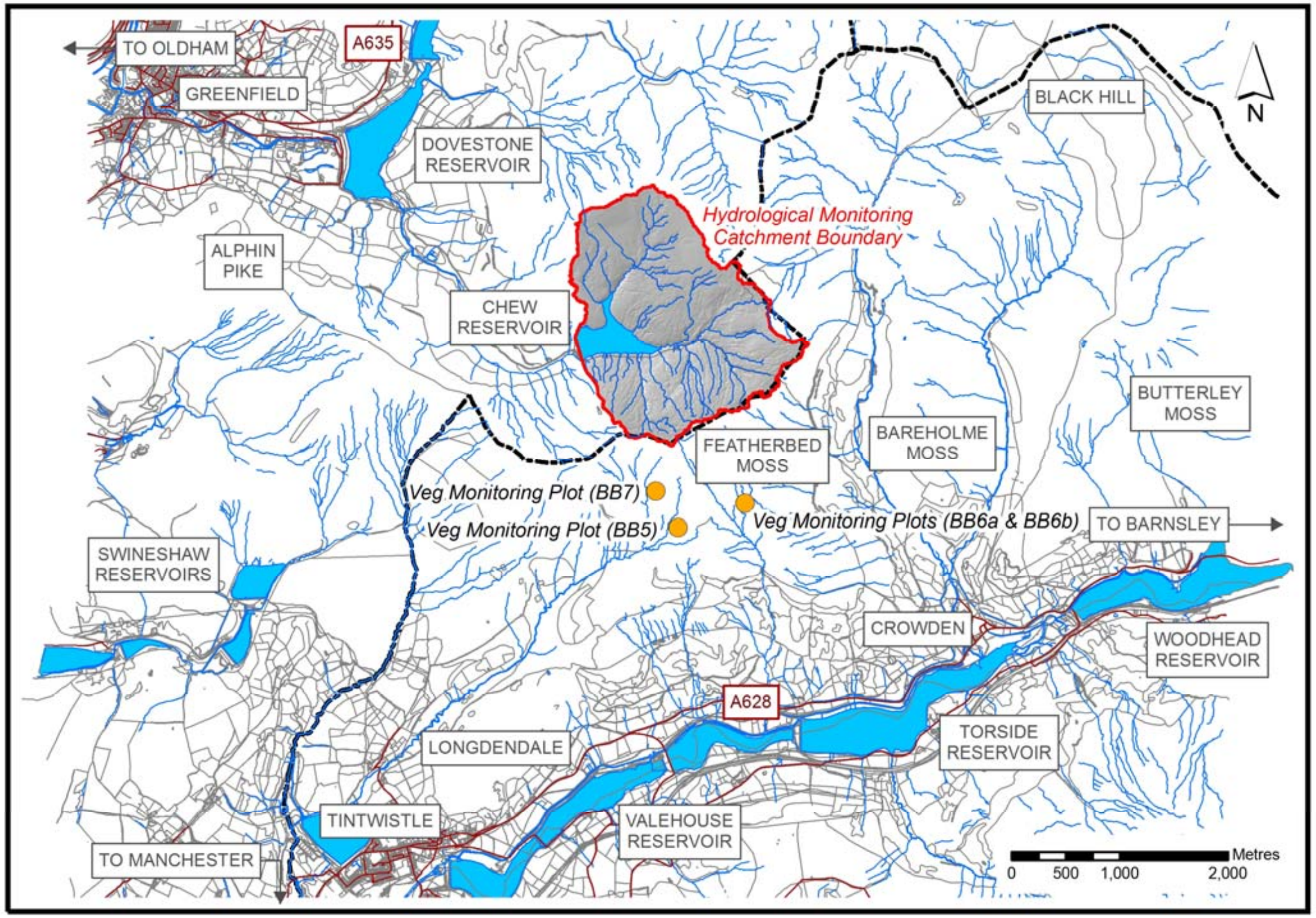
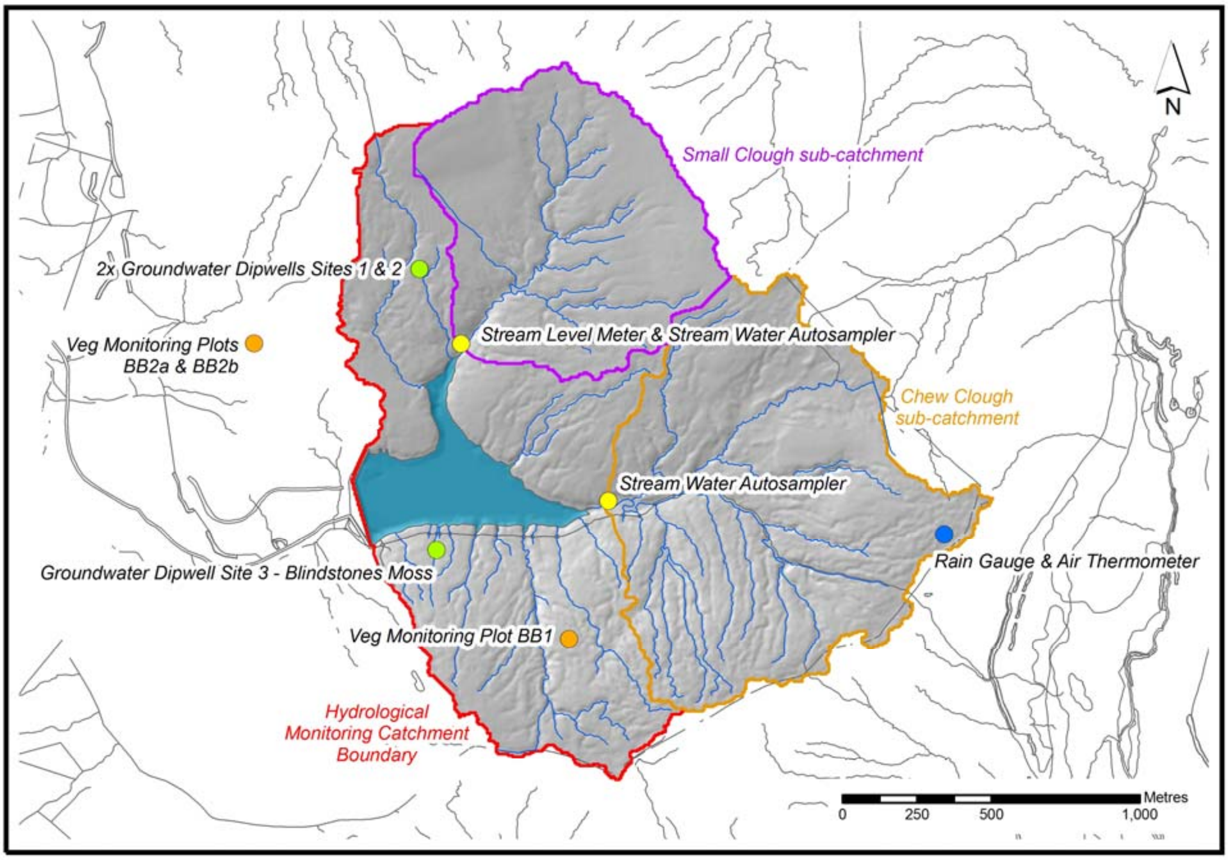


Figure 20 *The Monitoring Plot Locations Within the Ashway Gap Estate*



3.4 Results and Discussion

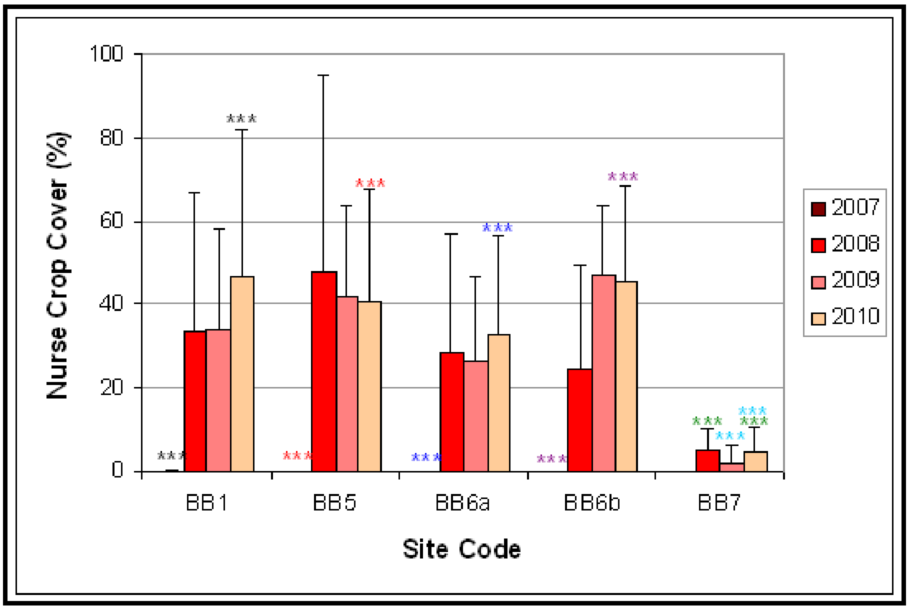
The Vegetation Response on Re-vegetated Bare Peat

The nurse grass seed mix and heather brash successfully established in 2009 - 10 where they were sown. There was an overall trend toward increasing vegetation cover on all treated plots, whilst the untreated plot (BB7) showed a small but significant reduction in vegetation cover ($p<0.001$) (Photographs 5 and 6 page 36). By 2010 the vegetation cover was significantly greater ($p<0.01$) on the plot treated with lime, seed and fertiliser (LSF), heather brash and geojute (BB6a) compared to the plot treated with LSF and brash only (BB6b). However, comparisons need to be treated with care since the geojute and brash plots are on very steep gully slopes where restoration is most difficult. For areas where some vegetation is already present and on more gentle slopes, the application of the LSF treatment encouraged a good rate of vegetation establishment. The establishing vegetation is largely at the expense of bare peat, which shows a simultaneous decline on the treated plots and a small but significant increase on the untreated plot ($p<0.001$ for all plots).

The majority of the increase in vegetation cover was related to the establishment of the nurse grass species (Figure 21 page 36), in particular blue fescue (*Festuca longifolia*), Highland bent (*Agrostis castellana*) and wavy hair-grass (*Deschampsia flexuosa*). By 2010, the overall cover of the main nurse grass species had stabilised after a rapid period of expansion up to 2009, but wavy hair-grass has maintained its cover or continued to increase (it is native to the site).

Photographs 5 and 6 *Lime, Seed, Fertiliser Plot Treated With Brash Plus Geojute (BB6b) on a Steep Slope, September 2007 (left) and July 2010 (right)*

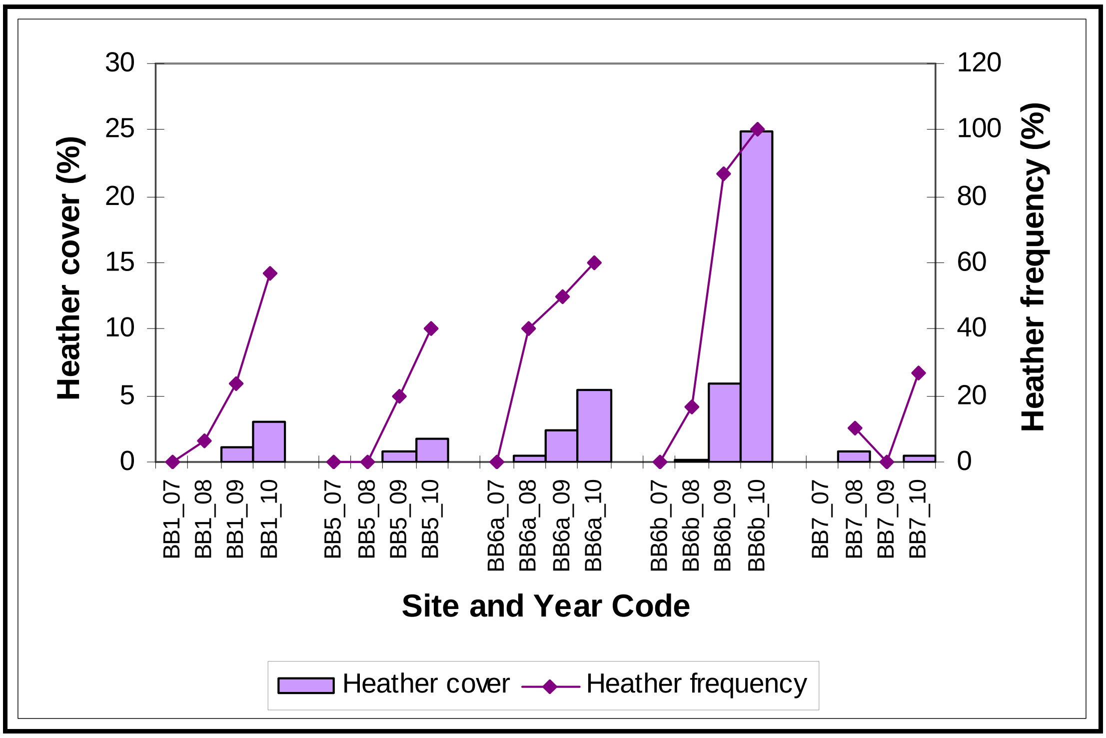
Figure 21 *Nurse Crop Cover (mean and standard deviation) across North Longdendale Before (2007) and After (2008 onwards) Restoration. BB1 and BB5, gently sloping, treated with lime, fertiliser and grass seed, BB6a and BB6b on steeper slopes treated with lime, fertiliser, grass seed and heather brash, BB6b with geojute as well. BB7 reference site untreated. NB – No Data Available for BB7 in 2007*



All treated plots had significantly greater cover of nurse grass species than the untreated plot ($p<0.001$) and differences between years is also significant ($p<0.001$) and the increase from 2007 (the baseline year) to 2010 is significant for all treated plots while the decrease on the untreated plot (BB7) is largely related to a reduction in the existing cover of wavy hair-grass. The addition of brash and geojute (BB6b) appeared to aid the establishment of vegetation more effectively than brash alone (BB6a). For areas where some vegetation is already present and on more gentle slopes, the application of lime, nurse crop and fertiliser (LSF treatment) has encouraged a good rate of vegetation establishment (BB1 and BB5).

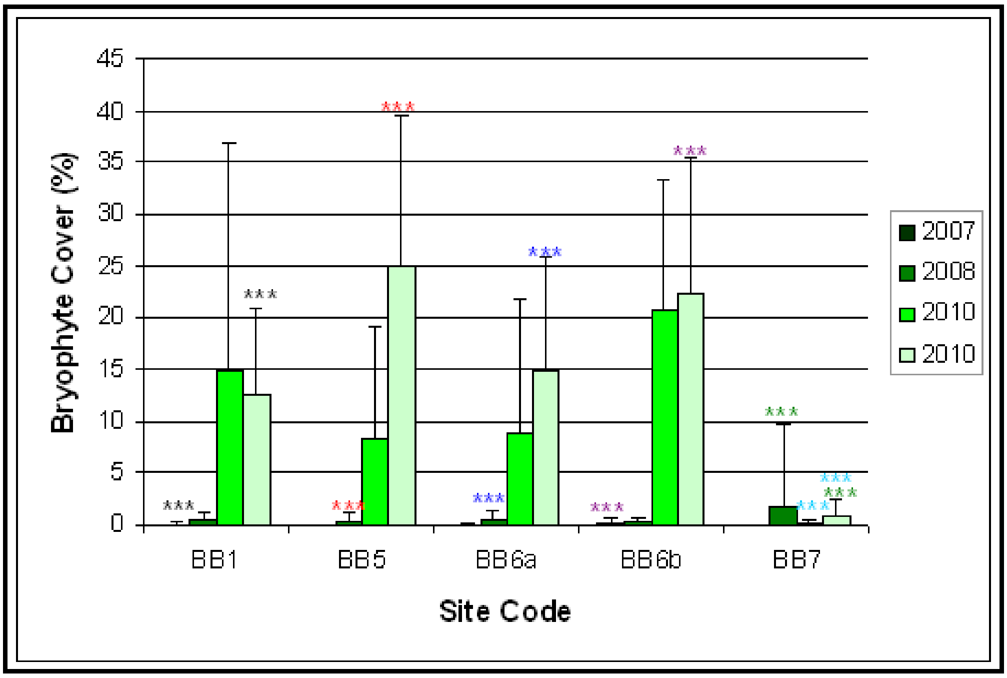
The treated plots had a greater cover of heather (Figure 22 below) than the untreated plot (p<0.001 for all plots) and 2010 is significantly higher than the baseline year (2007), while for the untreated plot (BB7) there is a small but significant reduction. By 2010, heather cover was greater (<0.001) on the plot treated with LSF, brash and geojute (BB6b) compared to the plot treated with LSF and brash only (BB6a), suggesting the geojute confers some additional benefit to heather establishment on these steeper slopes.

Figure 22 *Heather Cover and Frequency Across North Longdendale Before (2007) and After (2008 onwards) Restoration. BB1 and BB5, gently sloping, treated with lime, fertiliser and grass seed, BB6a and BB6b on steeper slopes treated with lime, fertiliser, grass seed and heather brash, BB6b with geojute as well. BB7 reference site untreated. NB – No Data Available for BB7 in 2007*



Mosses (Figure 23 page 38) showed similar trends, with all treated plots showing significant increases in cover compared with the untreated plot (p<0.001). This is largely attributable to an increase in *Campylopus* species, but also relates to some increases in *Hypnum jutlandicum*, particularly on the plots treated with brash (BB6a and BB6b), possibly a result of propagules being introduced with the brash.

Figure 23 *Moss Cover (mean and standard deviation) Across North Longdendale Before (2007) and After (2008 onwards) Restoration. BB1 and BB5, gently sloping, treated with lime, fertiliser and grass seed, BB6a and BB6b on steeper slopes treated with lime, fertiliser, grass seed and heather brash, BB6b with geojute as well. BB7 reference site untreated. NB – No Data Available for BB7 in 2007*



Assessing Sites Against Key Targets

Table 5 (Page 39) summarises the achievements of the restoration programme against the key targets set by the SSSI Site Objective Statements which themselves link to CSM targets for the SSSI.

All three estates are moving towards favourable condition in terms of CSM targets and could now be considered as achieving 'favourable recovering' status. Some targets are not fully met, nor would they expected to be in only three years since treatment, but continued restoration management should bring the areas closer to these targets over time. These include lack of dwarf shrub cover (heather still establishing), grass dominance (grass nurse crop required in the short term for peat stabilisation) and abundance of bare peat/erosion (although significantly reduced by restoration).

The results need to be interpreted with care as the treatments were applied to different degrees of bare peat slope. Anderson *et al.* (1997) and Buckler (2007, 2010) both showed that it is more difficult to re-establish vegetation on the steepest slopes. The brash and geojute treatment has had a significant stabilising effect in the first years' post-works compared with brash alone. However, over the three years since establishment, these differences decline in significance. Where there is some remnant vegetation cover and/or on less steep bare peat areas, lime, seed and fertiliser treatment alone appears to be effective in enabling vegetation establishment.

The newly establishing vegetation is still quite fragile and vulnerable to severe frost heave and the pressure of heavy rain. The sown grasses are currently providing a valuable nurse crop in terms of stabilising the peat sufficiently for other species to establish. Heather establishment is slow, but is enhanced on steeper slopes by the addition of geojute along with the brash, lime, seed and fertiliser treatment. Over time the bryophyte layer should continue to increase and diversify. It is notable that there are no *Sphagnum* species colonising as yet, a key component of blanket bog vegetation.

The establishment of locally typical blanket bog vegetation is in its early years and a more diverse cover of species is expected over time as the non-native nurse crop species eventually die out and heather cover increases. The heather should then start to decline as a more diverse range of blanket bog species colonise over the next 10 years or so as found on the earlier trial plots nearby (Anderson *et al.* 1997).

Table 5 *Summary of the Progress of Each Monitoring Site Towards Relevant Key Targets Across North Longdendale.*

Key: ✓✓ *= meets target;* ✓ *= moving towards target/met in some areas;* X *= does not yet meet target*

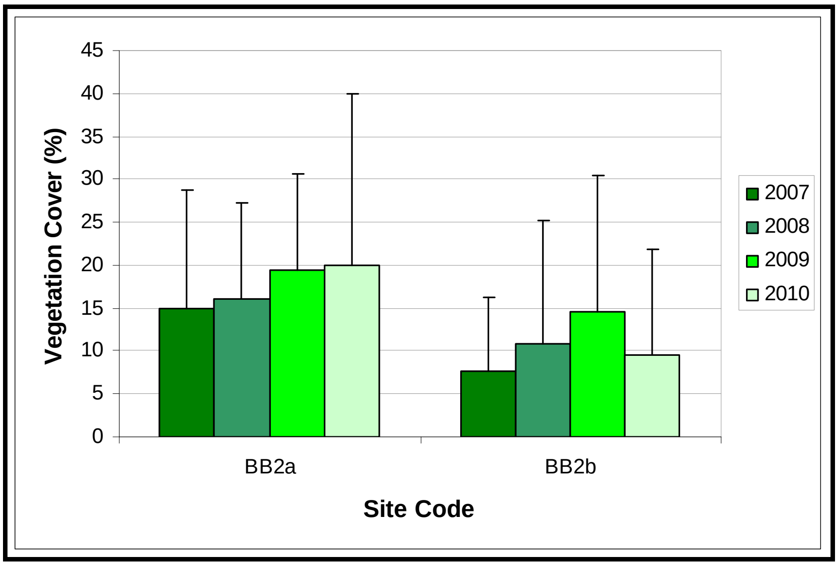
Estates	Relevant Key Targets (SSSI)	Key Results Achieved by 2010
Ashway Gap, Arnfield, Quiet Shepherd	SSSI Objectives – to move blanket bog towards favourable condition in relation to CSM. Targets to achieve:	Comparing 2010 results against CSM targets/SSSI Objectives:
	bryophytes to be abundant	✓ bryophytes abundant, but *Campylopus* is more widespread than appropriate for habitat at present
	Sphagnum frequent	X *Sphagnum* not recorded in any plots and still rare across the site
	dwarf shrubs >33% cover	✓ dwarf shrubs <33% (5-25% on average), but increasing as seedlings establish
	2 dwarf shrubs frequent	✓ dwarf shrubs only occasional across area, but increasing
	grasses/sedges/rush <50% cover	✓ 45-60% across all plots, but includes sown grass species required for bare peat stabilisation that will decline over time
	little bare ground	✓ bare ground still 10-20% cover but significantly lower following treatment
	localised erosion only	X erosion still present but active erosion reducing in areas following treatment
	localised heavy grazing <5% of area	✓✓ no stock present on site

The Vegetation Response on the Bare Peat Pans

The bare peat pans were not subject to any lime, seed or fertiliser treatments, or the application of heather brash or geojute (unlike the bare peat gullies), therefore re-vegetation was reliant on natural regeneration following the removal of grazing and the installation of coir rolls to reduce peat erosion/surface water run-off. The changes recorded in the vegetation were therefore expected to be much slower than for the bare peat gully sites and this is indeed the case.

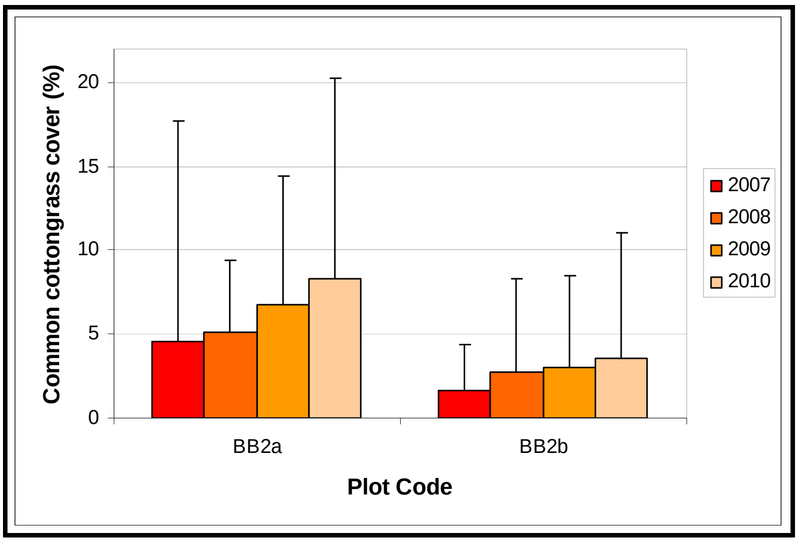
In terms of total vegetation cover, there was an overall trend towards increasing cover on both sites (Figure 24 page 40) and while the increase in vegetation cover over time was not statistically significant, there was a significant difference between the two plots ($p<0.001$). This indicated that plot BB2a had greater vegetation cover than BB2b and that this difference in the starting point in terms of vegetation cover was maintained throughout the monitoring period, irrespective of the addition of coir rolls to BB2b.

Figure 24 *Total Vegetation Cover (mean and standard deviation) on Ashway Gap Bare Peat Pans for Baseline Year (2007) and following Restoration Measures (2008 onwards). Plot BB2a is Ungrazed and Plot BB2b is Ungrazed with Coir Rolls Installed*



Changes in the vegetation on the two plots indicate that the removal of grazing appears to be having the greatest effect on the plant species, with both plots showing trends towards increases in dwarf shrub cover and frequency, common cottongrass cover (Figure 25 page below) and moss cover and frequency over time. However, the increases are very small as would be expected on such a severely degraded peatland. As yet there are no statistically significant differences over time for either plot, although photographic evidence shows some visible changes (Photographs 7 and 8 page 41).

Figure 25 Common *Cottongrass Cover (Mean and Standard Deviation) on Ashway Gap Bare Peat Pans for Baseline Year (2007) and following Restoration Measures (2008 onwards). Plot BB2a is Ungrazed and Plot BB2b is Ungrazed with Coir Rolls Installed*



Photographs 7 and 8 *Bare Peat Pan With Grazing Removed and Coir Roll Installed (BB2b), September 2007 (left) and July 2010 (right), Illustrating the Expansion of Common Cottongrass During the Monitoring Period*

The Hydrological Response

Turbidity

The focus at Ashway Gap was primarily on reducing particulate organic carbon delivery to streamflow by re-vegetation of the degraded blanket peat body. The two key findings are that raw streamflow turbidity shows a slight, though statistically significant decrease over the monitoring period, for the Chew Clough sub-catchment ($p<0.001$), although on the Small Clough sub-catchment, streamflow turbidity appears now to be increasing very slightly ($p<0.001$) after earlier reductions.

These results are different to previous years, where turbidity has always shown a consistent decrease, primarily due to increasing vegetative cover (and subsequent peat stabilisation) across the restored areas. However, 2010 was an exceptional year in terms of weather conditions and the changes in trends can be entirely explained within these circumstances. The extreme dryness in 2010 continued through spring and summer and only ended in later summer / early autumn, where rainfall events became heavy. This unusual weather had three main effects:

- vegetation die-back due to extreme desiccation;
- cracking and mobilisation/re-mobilisation of dried peat; and
- development of algal blooms in gauged watercourses on Chew Clough and Small Clough.

The net result of these combined effects was an observed increase in turbidity in both gauged streams. As turbidity is event-driven rather than seasonal in nature, several large turbidity ‘spikes’ were observed in the autumn re-wetting period, which have subsequently affected the outcome of the time series trend testing by ‘skewing’ the results leading to a change in the calculated strength (slope) and significance of monotonic trends observed in the data.

As recorded in the Year 4 report, on the Chew Clough sub-catchment, median raw turbidity levels decreased from 27NTU (SD65.90) over the 15 months pre-treatment, to 17NTU (SD40.54) for the nine months during treatment, finally settling at 22NTU (SD 109.38) over the three years post treatment, ($p< 0.001$). The only major difference was the observed post-treatment standard deviation, which rose from 26.03 to 103.38, a result generated entirely from the extreme observations recorded in mid to late 2010.

In contrast to the results reported in the 2009 report, the raw turbidity results for Small Clough do not now mirror the decreasing trend observed on Chew Clough, but show a slight increasing trend, with pre-treatment raw turbidity of 29NTU (SD 70.34), decreasing to 16NTU (SD 83.76) during treatment works and subsequently increasing post-treatment to 22NTU (SD 139.75); ($p<0.05$). Again, the massive increase in standard deviation is a result of the extreme weather conditions observed across the catchment for the majority of 2010.

From a review of all available evidence, it is concluded that turbidity levels are still in slight decline across the Ashway Gap sub-catchments, but that this pattern is currently obscured by the extreme weather conditions observed throughout 2010. The continuation of monitoring on this key site is thus critical in order to assess the long-term effectiveness of the restoration of severely degraded blanket bog.

Total Carbon Loss Calculations Based on Turbidity to POC Rating

To calculate an indicative carbon budget, a number of samples with known turbidity levels (taken to equate to suspended solids) have been analysed for their Particulate Organic Carbon (POC) to derive a statistical rating relationship so that losses of sediment from the studied upland catchments may be characterised. Assuming that up to 80% of the losses of sediments from the uplands are organic, peat based materials (Clive Agnew pers. comm. World Wetlands Day Conference Feb 2010 and Evans *et al.* 2007), the value in terms of carbon savings of the efforts made to restore the upland ecosystems can be estimated. This rating equation has then been used to derive approximate estimates of actual particulate carbon losses (by mass) per unit area from the Small Clough and Goyt sub-catchments; in the case of Ashway Gap, for both pre and post treatment periods.

The calculations are based on a single, daily water sample and so are representative only, as daily sampling will not always be representative of POC fluxes generally, which can be highly variable over timescales much less than 24 hours. The rating also assumes that the greatest proportion of suspended sediment (measured as turbidity) is particulate organic carbon, whereas there will be a non-organic fraction of up to about 20%.

The Goyt sub-catchment, with its continuous vegetation cover and minimal area of eroding peat has an annual POC sediment budget of 39.31 tonnes of carbon per square km, from a total catchment area of 7.53km^2. In contrast, the Ashway Gap Small Clough catchment, having an extensive bare and eroding peat area, albeit with a recently established vegetation cover, has an annual POC sediment budget of 50.77 tonnes of carbon per square km per annum, from a total catchment area of 0.754km^2. These figures are consistent with those quoted elsewhere (Evans and Warburton 2007) and show the range of variation in sediment delivery due to differing ground conditions.

In terms of a response to the restoration works, Small Clough had some 14.35ha of bare peat (19%) of the catchment prior to restoration. The re-vegetating work reduced this to 10.3ha, representing a 28% reduction in bare peat across the sub-catchment as a whole.

The apparent effect of this reduction on the sediment load into the system was to reduce the annual loss of POC per square km from 61 tonnes (pre-treatment annual load) to 42 tonnes (for the short period during treatment works). The post treatment POC load has since increased back up to 50.7 tonnes of carbon per square km, but still represents a highly significant decrease in annual sediment yield of over 10 tonnes per square km, especially when considering the relatively modest 28% reduction in bare peat across the catchment. The most significant figure is the difference between the pre and post works sediment loads, since the ‘during restoration’ period is short and therefore probably not as representative as the before and after totals.

This is a significant result with multiple benefits though reductions in the organic sediment loading and loss of capacity in the reservoir, reduction in the sediment needing removal in the reservoir system and water treatment works and reduction in carbon and peat loss from the moor.

The estimates also fail to account for the non-organic fraction of suspended sediment and assume, simply, that all suspended sediment leaving the sub-catchments are POC. Again, this is clearly not the case as perhaps 20% of sediment material may be mineral origin, even on upland peat catchments, and so estimates must be treated with caution.

Colour

Raw water colour (measured in Hazen units) as a surrogate for dissolved organic carbon (DOC) shows a slight, although statistically significant increase from the Chew Clough sub-catchment monitoring site ($p<0.001$) and an increasing trend on the Small Clough sub-catchment which was not found to be statistically significant ($p>0.05$). These results are consistent with previously reported outcomes, both for Ashway Gap and other studies, and suggest that it will be some time before output colour levels are affected by major land management changes.

Water Table in the Peat

After dipwell failures and vandalism, a single automated dipwell was installed on Blindstones Moss 18 months into the project, on bare peat that was then re-vegetated. The peat water table level and temperature have been recorded at 15 minute sampling intervals from February 22nd 2008 to the present and summarised into daily mean peat water table level and temperature variables for analysis in conjunction with colour, turbidity and climatic variables. Figure 26 (page 44) shows the time series plots of peat water table level and temperature for this dipwell, which shows a characteristic pattern of exaggerated draw-down and rebound associated with degraded, gullied blanket peat sites, as illustrated by Evans and Warburton (2007) and Allott *et al.* (2009).

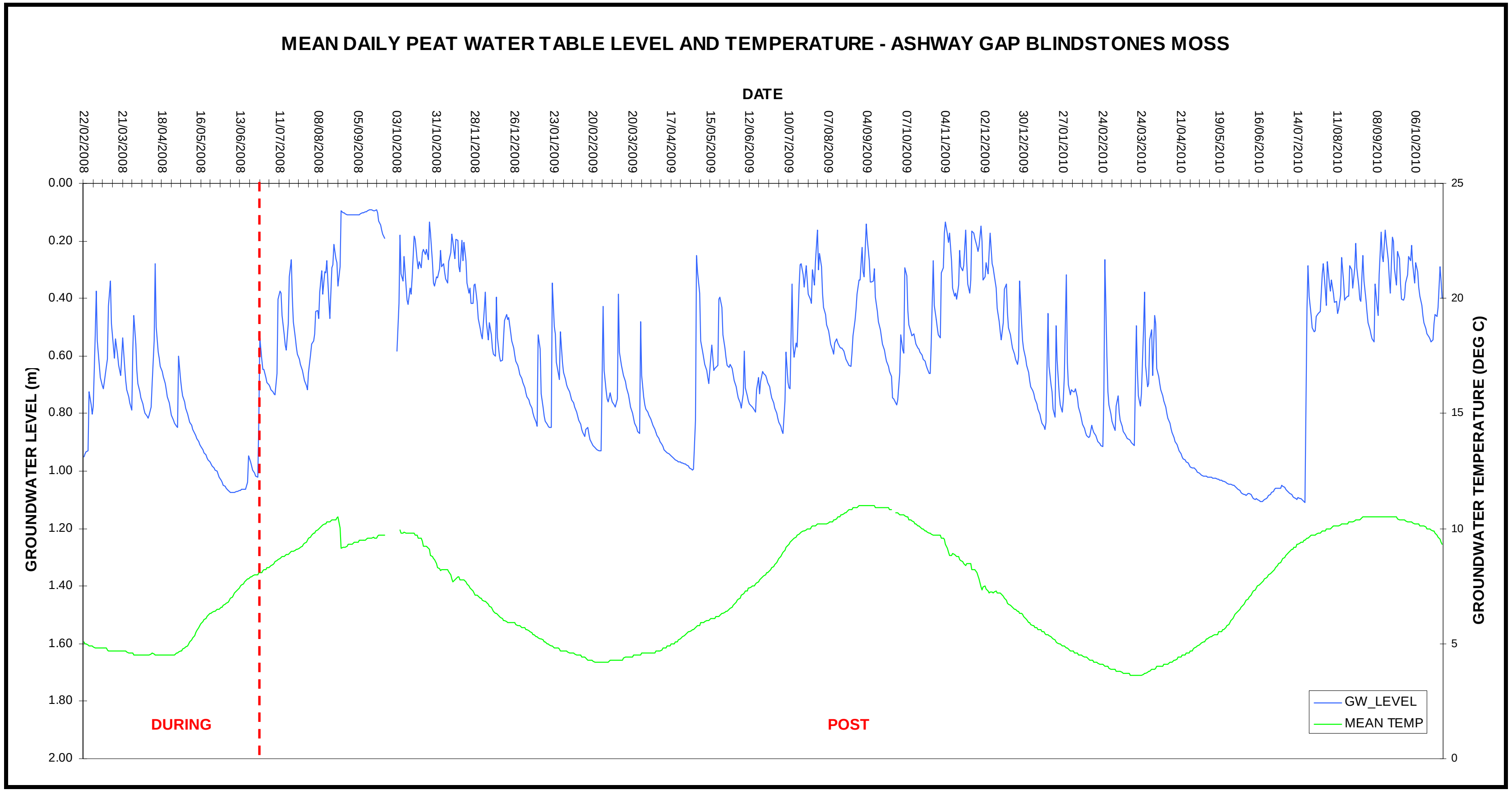
When analysed for trend, the entire data series shows no overall trend. This represents a slight change from results found in 2009, where a very slight increasing trend in peat water table level (not statistically significant at the 95% / 0.05 level) was reported. However, the pattern and behaviour of water table levels at the Blindstones Moss site are more complex than the monotonic trend test suggests and the extreme weather conditions of 2010 have inevitably had an effect on the statistical outputs.

In 2010, the water table in the peat showed an extreme response, drawing down to 1.2m due to the drought from the beginning of April until the middle of July. The level then rebounded to within 30cm of the surface from mid July onwards with reduced amplitude and a more stable appearance. However, no significant trend could then be detected over the whole period (February 2008 to October 2010).

The results of a Mann-Whitney U test on the data show that there is a statistically significant decrease in water table depth (ie. increase in level relative to the surface) rising from a mean water table level of 80.02 cm depth (median of 79.87cm, SD 18.82cm) during the treatment phase and adjusting upwards in the peat profile to a mean level of 55.95cm depth (median 58.65cm, SD 25.20cm) post-treatment ($p<0.001$, $n = 584$). The standard deviation also shows a corresponding decrease, indicating that the variability of peat water table level is decreasing to a more stable amplitude.

Overall, the results presented indicate that the water table is responding (albeit slowly) to the development of a continuous vegetation cover by recovering to a more natural position and pattern of behaviour. It remains to be seen if these trends continue, but initial results are nevertheless encouraging at this stage.

Figure 26 *Time Series Plot of Mean Daily Peat Water Table Level and Temperature at the Blindstones Moss Dipwell Monitoring Site*



Effectiveness of Gully Blocking

No quantitative analysis has been undertaken regarding the effectiveness of the stone gully blocks which were only installed early in 2010. It is anticipated that over time they will lead to further elevation of water tables in the peat, as many already contain standing water and are causing localised re-wetting of the peat body.

3.5 Conclusions

It is clear that the works on the Longdendale Estates have had a significant positive impact. The amount of bare peat has been substantially reduced, replaced by a stabilising vegetation cover that is expected to change gradually over the next five years to resemble more closely the surrounding blanket bog vegetation, albeit with more heather cover. There has been a simultaneous reduction in sediment reaching the streams into Chew Reservoir, although the declining trends have been challenged by the effects of the 2010 drought, and the results are likely to have been repeated for flows into the Longdendale and Greenfield Reservoirs as well, as the scale of the restoration works has been greater in their catchments. Any improvement is of significant value in retaining carbon in the system and increasing resilience to climate change as well as impacting on water quality and treatment requirements. There is an indication that the new vegetation is helping to raise the water table in the peat. However the water level is not yet sufficiently high to support active blanket bog.

4 THE RESTORATION OF UPLAND VEGETATION

4.1 The Restoration Programme

A number of different habitat restoration treatments were implemented as part of the agri-environment agreements in order to enhance the condition of blanket bog or upland acid grassland/dwarf shrub heath. For blanket bog areas this focused on improving the cover and diversity of typical bog species and reducing the dominance of less desirable species (eg. purple moor-grass – *Molinia caerulea*). For the heath areas, there was a driver to increase cover and diversity of dwarf shrubs and to re-instate heather (*Calluna vulgaris*) cover where it had been largely lost. The details are presented in Volume 4.

For blanket bog areas the restoration treatments comprised reductions to the sheep stocking levels and/or changes to the sheep management regimes (ie. further reduction in sheep stocking levels over the winter period) for sites in Bowland. For the site in North Longdendale, the restoration treatment focused on the reversion of purple moor-grass-dominated vegetation to a more diverse moorland vegetation type using herbicide, burning and the addition of heather seed, in combination with summer-only cattle grazing.

For upland acid grassland/dwarf shrub heath areas, a combination of sheep removal (exclusion) and the introduction of dwarf shrub seed comprising bell heather (*Erica cinerea*) and/or heather with or without herbicide and mowing was used to attempt to diversify the vegetation and in particular to increase the cover and diversity of dwarf shrubs.

No hydrological restoration was necessary at these sites, as the blanket bog sites had not previously undergone drainage, although there is some gully erosion. The upland heath sites were not on peaty soils. Monitoring therefore focuses on changes in the vegetation only.

4.2 The Monitoring Sites and Their Objectives

The monitoring plots, their locations, treatments and objectives are presented in Table 6 (page 47). Two sites in Bowland (Sykes and Lamb Hill) are located on blanket bog habitat, mostly within the Bowland Fells SSSI and were described as being in unfavourable condition in 2005 (prior to SCaMP). All sites are within Higher Level Stewardship (HLS) agreements and therefore have ‘indicators of success’ as targets to achieve over the term of the agreement. A further blanket bog site also in unfavourable condition pre-ScaMP is located on purple moor-grass *(Molinia)*-dominated moorland in North Longdendale (Pikenaze) and lies within the Dark Peak SSSI and the North Peak Environmentally Sensitive Area (ESA) scheme. Three other sites are located on acid grassland/dwarf shrub habitats, two in the Goyt and one on Ashway Gap. All Peak District sites are within SSSIs (Goyt Valley and Dark Peak, respectively) and are covered by ESA schemes (South West Peak and North Peak, respectively).

Table 6 *Summary of the Restoration Treatments and Objectives for Vegetation Monitoring Sites Across Sykes, Lamb Hill, Pikenaze, Ashway Gap and Goyt*

Farm	Monitoring Plot	Treatment (see Appendix I for full details)	Monitoring Objectives
Sykes	SF1	*Treated plot*: Reduce sheep grazing from 2.14 ewes/ha to 0.78 ewes/ha summer and 0.52 ewes/ha winter	1. To assess if changes in the vegetation move the sites towards favourable condition status, in terms of SSSI CSM targets 2. To assess performance against the indicators of success identified within the relevant HLS agreement
	SF2	*Treated plot*: Reduce from no fixed level to 0.78 ewes/ha summer and 0.52 ewes/ha winter	
Lamb Hill	LH1	*Treated plot*: Reduce sheep grazing from 1 to 0.69 ewes/ha in summer and 0.34 ewes/ha in winter	
	LH2	*Treated plot*: Retain 1 ewe/ha sheep stocking levels in summer but reduce winter grazing to 0.18 ewes/ha	
Pikenaze	BB3	*Reference plot*: stocking changes only – removal of sheep and retention of cattle	1. To assess if changes in the vegetation move the sites towards favourable condition status, in terms of SSSI CSM targets and ESA targets
	BB4	*Treated plot*: Apply herbicide, burn, cut and seed with heather, in addition to stocking changes as above	
Goyt	DH1	*Treated plot*: Exclude stock (was 0.72 ewes/ha plus off wintering), herbicide and seed with heather and bell heather	1. To assess if changes in the vegetation move the sites towards favourable condition status, in terms of SSSI CSM targets and ESA targets
	DH2	*Treated plot*: Exclude stock (was 0.72 ewes/ha plus off wintering), herbicide and cut, and seed with heather and bell heather	
Ashway Gap	DH1	*Treated plot*: Exclude stock, apply heather seed via hydroseeding	

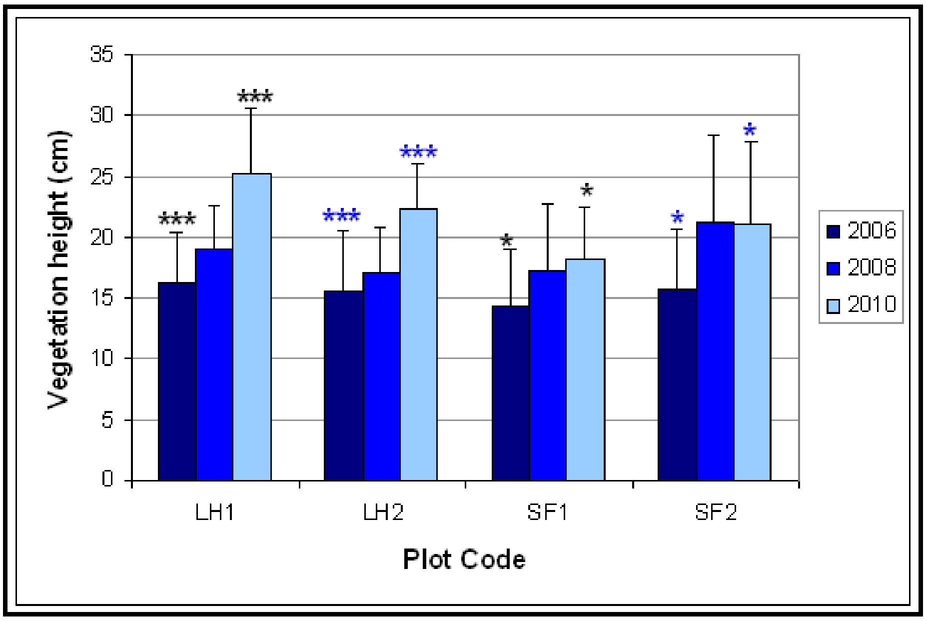
4.3 Results and Discussion

Changes to Grazing on Blanket Bog

Lamb Hill

In terms of the vegetation character, on Lamb Hill there was a significant increase in canopy height ($p<0.001$) (Figure 27 page 48) and vegetation cover ($p<0.001$) along with a significant decline ($p<0.001$) in bare peat cover on both plots. In addition, no losses of *Sphagnum* or dwarf shrubs were detected, and neither were there any increases in damage to mosses, all of which are important in terms of SSSI favourable condition status.

Figure 27 *Vegetation Height (mean and standard deviation) for Lamb Hill (LH) and Sykes Farm (SF). LH1, reduced grazing all year, LH2:, reduced grazing winter only, SF1: reduced grazing, SF2: reduced grazing*



There is a trend towards increasing heather cover on both plots, while bilberry (*Vaccinium myrtillus*) shows a trend towards increasing cover on the plot subject to stock reduction plus further winter reductions (LH1). There was a significant increase ($p<0.01$) in grass/sedge/rush cover (combined) on the plot with winter stock reduction only (LH2) and a trend in the same direction for the other site (LH1) (Figure 28 page 49). This was largely related to increases in hare's-tail cottongrass (*Eriophorum vaginatum*), a positive indicator species for blanket bog CSM.

There was a significant increase ($p<0.01$) in moss cover (excluding *Sphagnum*) (Figure 29 page 49), on the plot subject to stock reduction plus further winter reductions (LH1) and a trend towards increasing *Hypnum jutlandicum* (a positive indicator species in terms of CSM) on both plots. *Sphagnum* shows no significant difference over time, but retains a 7-15% cover throughout the monitoring period.

Sykes

Canopy height increased ($p<0.05$) over time on both plots, again reflecting reductions in stocking levels. There was no increase in bare ground, no loss of *Sphagnum* or dwarf shrubs, along with no significant increase in damage to bryophytes, again all important positive results in terms of CSM targets.

Grass/sedge/rush cover increased significantly ($p<0.05$) for both sites over time (Figure 28 page 49) and reflects increases in wavy hair-grass (*Deschampsia flexuosa*) and hare's-tail cottongrass, both likely to be a response to reduced grazing levels. Heather showed a trend towards increasing cover, particularly on the plot where grazing levels had previously been unrestricted (SF2).

Figure 28 *Total Grass/Sedge/Rush Cover (mean and standard deviation) for Lamb Hill (LH) and Sykes Farm (SF). (LH1, reduced grazing all year, LH2:, reduced grazing winter only, SF1: reduced grazing, SF2: reduced grazing)*

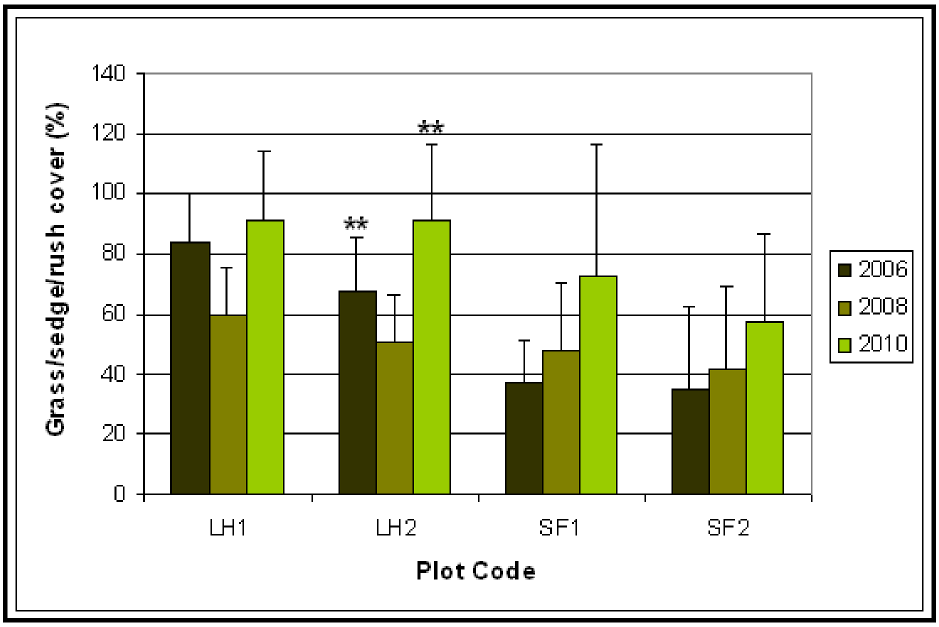
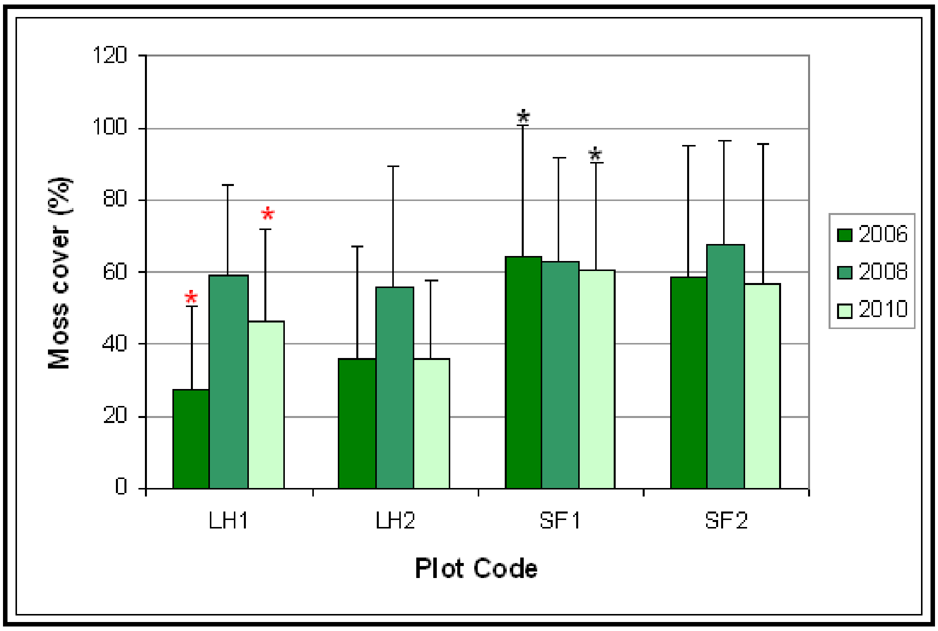


Figure 29 *Moss Cover Excluding* Sphagnum *(mean and standard deviation) for both Lamb Hill (LH) and Sykes Farm (SF). (LH1, reduced grazing all year, LH2:, reduced grazing winter only, SF1: reduced grazing, SF2: reduced grazing)*



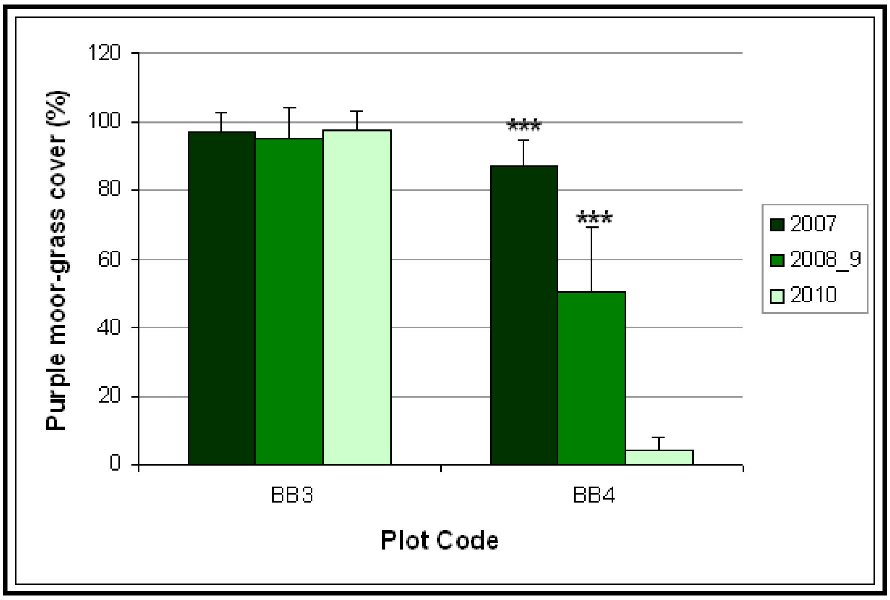
Moss cover (excluding *Sphagnum*) remained relatively stable (Figure 29, above, with a small ($p<0.01$) reduction in *Hypnum jutlandicum* cover on the plot where grazing levels had previously been unrestricted (SF2). In addition, *Sphagnum* showed no significant differences over time.

Purple Moor-Grass Reversion on Blanket Bog

Pikenaze

The restoration treatment on Pikenaze has resulted in a reduction in total vegetation cover (p<0.001), largely due to a reduction of purple moor-grass (Figure 30 and Photographs 9 and 10 below), along with significant increases in bare ground (p<0.001) and mosses (p<0.001), the latter largely increases in *Campylopus* species. As yet there are no significant increases in dwarf shrub species, but this is expected with time.

Figure 30 *Purple Moor-Grass Cover (mean and standard deviation) at Pikenaze, North Longdendale, Before (2007) and After (2008 to 2010) Treatment. (BB3: grazing changes only, BB4 Purple moor-grass treatment and grazing changes)*



Photographs 9 and 10 *Pikenaze Estate Illustrating Untreated (left) and Treated (right) Plots in 2007 After First Purple Moor-Grass Reversion Treatment, Showing Significant Reduction of Dominance of This Species Where Treated*

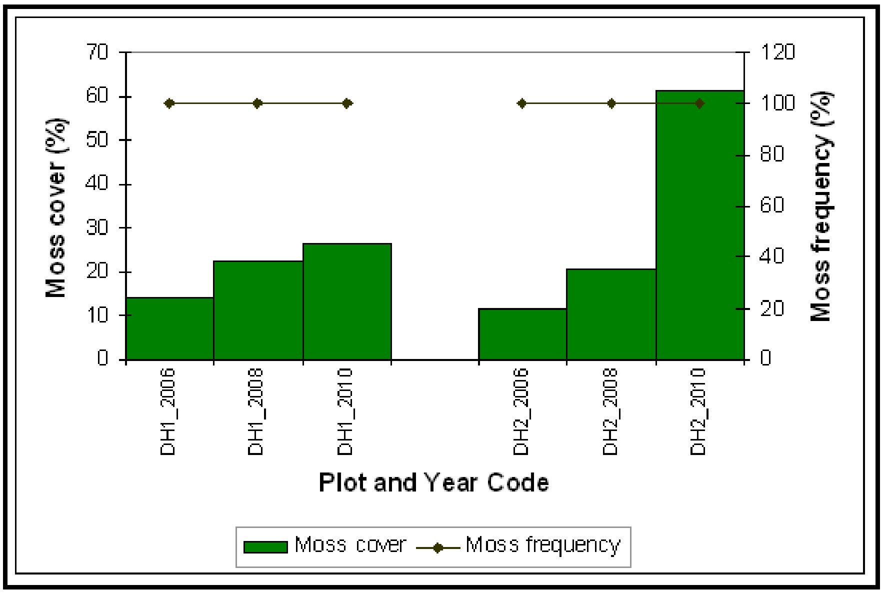
Diversification of Upland Dwarf Shrub Heath

Goyt

On the Goyt dry heath/acid grassland plots, the vegetation height decreased in response to cutting or/and herbicide management ($p<0.001$). On the plot that received additional cutting, bare ground also increased ($p<0.001$), total vegetation cover reduced ($p<0.001$) and, more specifically, grass cover reduced ($p<0.001$). Dwarf shrub cover shows a significant ($p<0.01$), small reduction on the plot that received additional cutting. This was largely attributed to bilberry, suggesting that the cutting and herbicide application combined has had a greater effect on the vegetation than herbicide application alone. There was no notable establishment of the sown dwarf shrub species (heather and bell heather), despite germination gaps being available.

Moss cover (Figure 31 below) increased significantly ($p<0.001$) on both sites, but this reflected slightly different species trends: *Rhytidiadelphus squarrosus* was the main moss to increase in cover on the site subject to herbicide and seeding (DH1), and *Hypnum jutlandicum* on the plot subject to additional cutting (DH2).

Figure 31 *Total Moss Cover and Frequency on the Dry Heath/Acid Grassland Restoration Sites, Goyt DH1: exclude stock, herbicide, add seed; DH2: exclude stock, herbicide, cut and add seed*

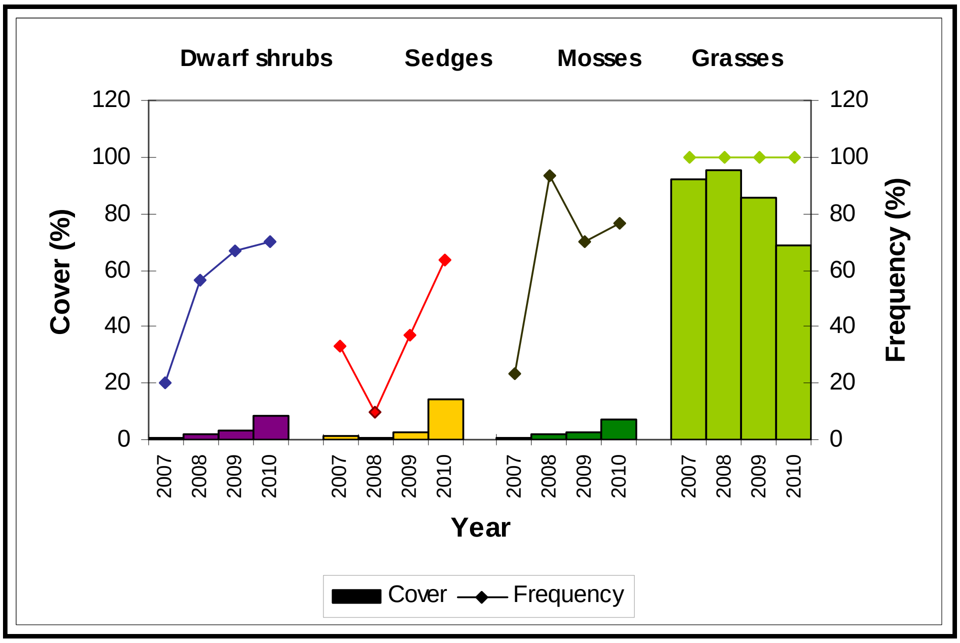


Ashway Gap

A significant increase in the cover ($p<0.001$) and frequency of dwarf shrubs, mosses and sedges was recorded on this upland heath site, which reflects small but significant increases ($p<0.001$) in the cover of heather and *Campylopus* species (Photographs 11 and 12, page 52) In addition there was a significant decline ($p<0.001$) in grass cover, largely of mat grass (*Nardus stricta*), indicating the removal of grazing has reduced its competitive ability to maintain its cover. These changes are summarised in Figure 32 (page 52).

Photographs 11 and 12 *Ashway Gap Dry Heath Site Illustrating Before 2006 (left) and After 2010 (right) Application of Heather Seed, Showing Establishment of Young Heather Plants*

Figure 32 *Summary of the Changes in Cover and Frequency of Key Species/Species Groups on the Acid Grassland/Dry Heath Restoration Site, Ashway Gap, North Longdendale. Pre-treatment monitoring is 2007; post treatment monitoring is 2008 to 2010*



4.4 Assessing Sites against Key Targets

Table 7 (page 53) summarises the achievements of the restoration programme against the key targets set by the SSSI Site Objective Statements and HLS targets, as appropriate, for each site. The HLS agreements were at the end of their third year in 2010, but many of the targets to be met by years 5 and 10 are already achieved or likely to be achieved in the 10 year term of the agreement.

Table 7 *Summary of the Progress of Each Monitoring Site Towards Relevant Key Targets. Key: ✓✓= meets target; ✓= moving towards target/met in some areas; X = does not yet meet target*

Farm	Relevant Key Targets (HLS/SSSI)	Key Results Achieved by 2010
Lamb Hill	HL9 Moorland management indicators of success: • By year 5 – six positive indicator species present, cottongrasses and heather flowering frequent, <10% *Sphagnum* damaged/dead, <10% bare peat. • By year 10 - >33% *Sphagnum* cover, dwarf shrub cover 25-60%, <30% cover grasses/sedges/rushes. HL10 – moorland restoration indicators of success: • By year 5 – <10% bare peat, dwarf shrubs should be frequent, heather flowering frequent, <10% *Sphagnum* damaged/dead, <40% cover of purple moor-grass. • By year 10 - dwarf shrub cover 20% or more.	Comparing 2010 results against indicators of success for year five: ✓✓ six positive indicator species present ✓ heather flowering well on LH1 but noted as brown and possibly dead on LH2 ✓✓ cottongrasses noted as healthy ✓✓ <10% *Sphagnum* dead/damaged ✓✓ <10% bare peat (mean <1% both sites) ✓✓ dwarf shrubs occasional to abundant ✓✓ <10% purple moor-grass (<1% cover on average) Comparing 2010 results against indicators of success for year 10: X *Sphagnum* cover <33% (mean 7-15% across plots) ✓✓ dwarf shrub cover >20-25% (approx 35-45% on average) X grasses/sedges/rushes >30% (approx 90% on average)
Sykes	HL9 Moorland management indicators of success: • Overall - heather flowering frequent, <10% *Sphagnum* damaged/dead. • By year 5 - cottongrass flowering frequent, <10% bare peat. • By year 10 - >33% *Sphagnum* cover, at least two dwarf shrubs frequent, dwarf shrub cover 33-75%, <50% cover grasses/ sedges/rushes.	Comparing 2010 results against overall indicators of success: ✓✓ heather noted as healthy and flowering ✓✓ <10% *Sphagnum* dead/damaged Comparing 2010 results against indicators of success for year five: ✓✓ cottongrasses noted as healthy and flowering ✓✓ <10% bare peat (mean <3% both plots) Comparing 2010 results against indicators of success for year 10: X *Sphagnum* cover <33% (15-20% on average) ✓✓ dwarf shrubs frequent to occasional ✓✓ dwarf shrub cover >33% (45-55% on average) X grasses/sedges/rushes >50% (60-70% on average)

Continued next page

Table 7 *continued*

Farm	Relevant Key Targets (HLS/SSSI)	Key Results Achieved by 2010
Pikenaze	SSSI Objectives – to move blanket bog towards favourable condition in relation to CSM. Bryophytes to be abundant, *Sphagnum* frequent, dwarf shrubs >33% cover, two dwarf shrubs frequent, grasses/sedges/rush <50% cover, little bare ground, localised erosion only, localised heavy grazing <5% of area.	Comparing 2010 results against CSM targets/SSSI Objectives: ✓ bryophytes frequent only X *Sphagnum* not recorded in plot X dwarf shrubs <33% (<1% on average) X dwarf shrubs not frequent ✓✓ grasses/sedges/rushes <50% (<12% on average) ✓✓ bare ground around 40% - but required for heather seed establishment ✓✓ no erosion ✓✓ no indications of heavy grazing
Goyt/Ashway Gap	Goyt SSSI Objectives – maintain representative areas of acid grassland and encourage restoration of some areas to dwarf-shrub heath by excluding or reducing grazing. Ashway Gap SSSI Objectives - maintain representative areas of the range of acid grassland and restoration/reversion of grassland to dwarf-shrub heath where appropriate.	Key requirements for dry dwarf shrub heath are frequent bryophyte cover, abundant dwarf shrubs and appropriate levels of grazing. Both dwarf shrub restoration areas have positive results for increasing bryophyte cover and appropriate levels of grazing. The dwarf shrub cover remains low as heather seed has not yet established to any significant cover. On-going restoration measures should address this over time.

The two farms in Bowland: Lamb Hill and Sykes, are moving towards favourable condition in terms of CSM targets and are now achieving ‘favourable recovering’ status. Some targets are not fully met, largely due to a lack of *Sphagnum* cover and a higher cover of grass/sedges/rushes, but on-going restoration management should bring the areas closer to these targets over the 10 year agreement.

The purple moor-grass reversion site (Pikenaze) is in the early stages of a major restoration process. While the signs for reducing purple moor-grass dominance are good, the required cover and diversity of mosses and dwarf shrub species has not yet developed. On-going management should enable the site to be classed as ‘favourable recovering’ in terms of CSM, although maintaining a reduced dominance of purple moor-grass is likely to require on-going management for some time. Other trials support this prediction.

The sites on the Goyt are classed as acid grassland/dry heath and have therefore been reviewed against the SSSI Site Objective of encouraging dwarf shrub restoration by stock exclusion. In this respect, they meet the objective as they are no longer grazed by sheep and restoration measures to improve dwarf shrub cover are being applied. To date the cover and diversity of dwarf shrubs remains low, probably due to the dry spring, which coincided with the germination of sown seed, but the success of the measures in opening up the sward and creating germination gaps indicates that further restoration measures should be successful.

The dry heath site at Ashway gap (North Longdendale) also shows a promising change in vegetation composition from being largely grass-dominated with some bare ground to a greater mix of dwarf shrubs, sedges, grasses and bryophytes. The on-going restoration measures should ensure this continues, and findings from earlier studies support this prediction.

5 RESTORATION TO UPLAND OAK OR WET WOODLAND

5.1 The Scope and Objectives of the Management Measures

Although the main habitat focus of SCaMP has been upon blanket bog, one of the key objectives has been to support UU's Biodiversity Strategy. Thus areas of upland oak and wet woodlands have been included in the restoration plans. For areas outside SSSIs (which includes all the woodland sites except Holdron Castle), the broad aim has been to enhance the character of the woodlands through management in line with their development into better quality upland oak or wet woodlands, thus working towards meeting Biodiversity Action Plan (BAP) targets for the habitats at a national and local level. In addition, large areas of new upland oak woodland have been established outside the existing woods, but these have not been monitored for vegetation change as this will be a very slow process.

Nine upland oak woodlands and five wet woodlands located in UU's Southern Region and Bowland landholdings have been used to follow progress before and after management works (Figures 2 and 3, page 5). The canopy, sub-canopy and ground flora have been monitored in fixed quadrats. Details are provided in Volume 5.

The longevity of woodlands where natural succession is usually a very slow process means that the results after five years represent only the earliest of indications of change. The woodland management is also a continuous process over a period of time and is not complete at this point in time.

The key management changes were:

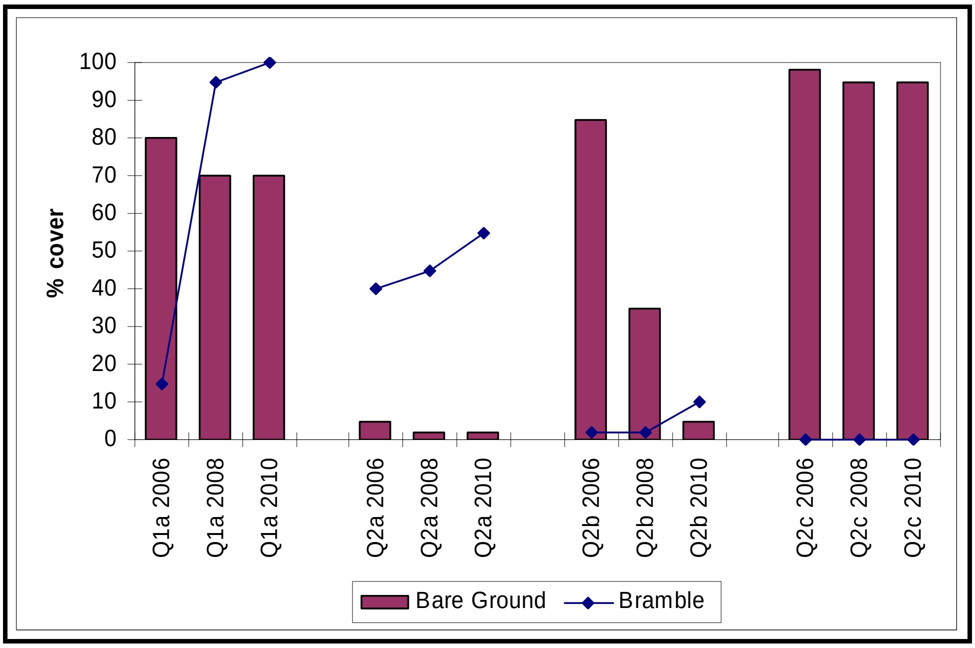
- removal of locally non-native broadleaved trees such as beech and sycamore through felling or ring-barking;
- removal of conifers;
- planting with native shrubs and additional locally native trees to match the character of local upland oak or wet woodlands;
- removal of rhododendron; and
- stock fencing.

5.2 Results and Discussion

The management measures have generally resulted in an enhanced structure to the woods, with less canopy dominance, opportunities for a new sub-canopy layer of shrubs, seedlings/saplings or brambles and re-establishment of a ground cover on bare ground previously shaded. Each woodland is individual, and the nature of the changes tends to differ between each, but some generalisations can be made.

Where large beech have been removed, the physical characteristics of the sites and the initial vegetation in the area all influence the development of the ground flora and the species of seedlings and saplings which develop (Figure 33 page 57). In general, the reduction in beech has resulted in an enhanced woodland structure, with good regeneration in some locations. However, there has also been a release of non native saplings on one site that will need ongoing attention in the future.

Figure 33 *Reduction in Bare Ground and Increase in Bramble Where Beech has Been Removed in Landslow Green Wood (Q1) and Swallow Wood (Q2)*



Ring barking was undertaken in two woods, one to thin alder and a second to reduce mature sycamore. The results indicate that no clear effect of ring barking can be expected until a minimum of three years after the management has taken place as the trees do not die immediately. The enhancements derived from the reduction in canopy are therefore expected to take place over longer than five years.

Removal of groups of conifers show clearly that the speed of a wood's response to conifer felling varies greatly depending on existing vegetation and sub-canopy, seed bank and whether or not the conifers, trunks and brash are left on the site or removed. In all cases the number of tree seedlings across the areas is increasing and so far there are few conifer seedlings amongst them.

Shrub and tree planting to supplement the sub-canopy layer and diversify or extend the wood has been undertaken at several sites. Two of the sites, Bottoms Beck (Photographs 13, 14 and 15 page 58) and Sykes Farm have shown good sapling establishment and growth whilst on other sites this is less apparent. A number of factors such as spring drought, deer browsing and competition under a canopy or with a dense ground cover such as bracken all affect how well new plants can establish. Establishment would be expected to and has been found to vary in its speed and degree of success. Where some new plants do not thrive, this adds to the future woodland structural variation with differences in density and variable growth rates.

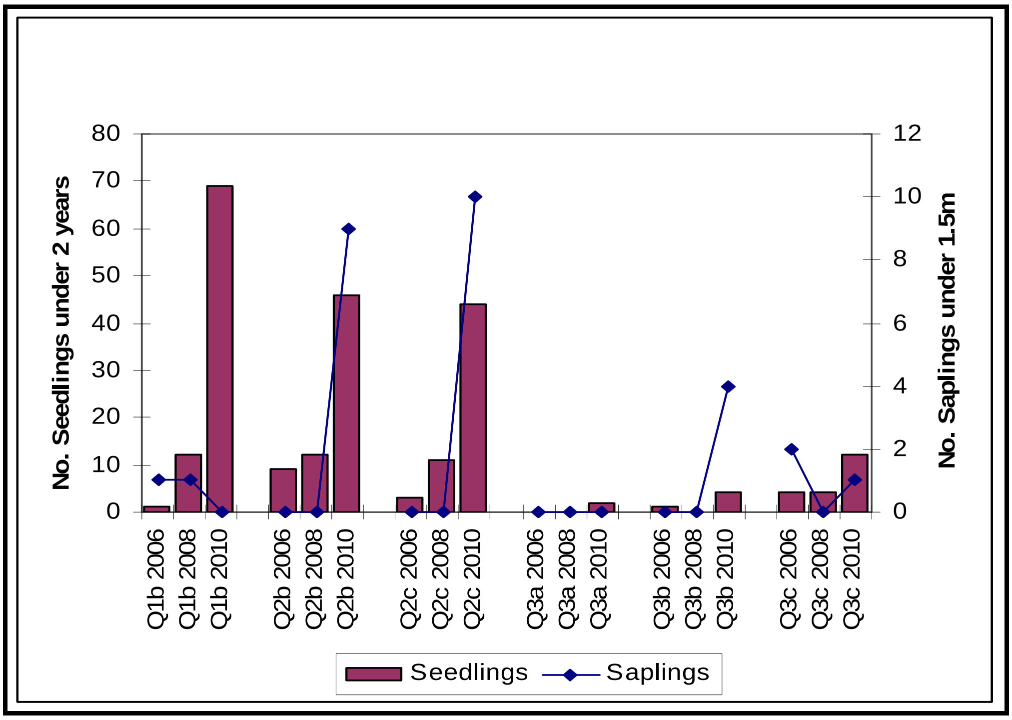
Rhododendron removal has been undertaken in four sites, although this clearance is not completed yet as regrowth has been witnessed.

Stock proofing woodlands is expected to lead to enhanced tree/shrub seedling and sapling establishment provided that there are suitable colonisation gaps. This has been recorded in Sykes Farm Wood, for example, in most of the quadrats (Figure 34 page 59).

Photographs 13 and 14 *Bottoms Beck Wood, (near Stocks Reservoir) Tree Establishment After Conifer Removal in 2006 (left) and 2010 (right)*

Photograph 15 *New Planting in Bottoms Beck Wood (Stocks Reservoir)*

Figure 34 *Tree and Shrub Seedling and Sapling Numbers on Sykes Farm Wood*



5.3 Conclusions

Even given the short time scale so far in woodland growth terms, it can be concluded that the structure and native species complement of the woods have improved where management has been undertaken, thus moving the woodland sites towards reaching their BAP targets. In the woodlands where no management has been undertaken, there are no or only very minor changes in the canopy and ground flora vegetation, which can be attributed to annual fluctuations in response to the weather or to grazing, for example. The results show only the initial changes in what is expected to be a long-term process.

6 RESTORATION OF UPLAND HAY MEADOWS AND RUSH PASTURES

6.1 The Scope and Objectives of the Management Measures

As for the woodland habitats, one of the key objectives for SCaMP has been to support UU's Biodiversity Strategy and thus areas of hay meadow, species-rich grassland and rush pastures have also been included in the restoration plans. The broad aim has been to improve the ecological status of valuable wildlife habitats and species. The details are presented in Volume 6.

Seven species-rich grasslands and seven rush pastures were selected where a change of management was proposed so that the effects of this change could be studied. Management changes were implemented to benefit botanical diversity and breeding birds under Environmental Stewardship Entry Level Stewardship (ELS) or Higher Level Stewardship (HLS) prescriptions. Sites were all located within agri-environment schemes in UU's Bowland Estate, Lancashire. Three additional sites were surveyed in 2009 only, to provide a comparison and a potential baseline for possible future monitoring. The treatments commenced in 2006 or later as the HLS agreements were finalised for each farm.

The management of the sites was determined by the options available under the stewardship agreements. For the species-rich semi-natural grasslands, changes in management were aimed at maintaining or restoring conservation value via either haymaking with cattle grazing or by cattle grazing alone (at revised stocking rates). For the rush pastures, the HLS options selected were primarily aimed at restoration of rough grazing for birds via rush management, scrape creation and cattle grazing, but enhancements in botanical diversity were also expected from these measures. Table 8 (below) gives the different Higher Level Stewardship (HLS) categories.

Table 8 *The Higher Level Stewardship (HLS) Categories Applied*

Category	Title
HK6	Maintenance of species-rich semi-natural grassland
HK7	Restoration of species-rich semi-natural grassland
HK18	Haymaking supplement
HL8	Restoration of rough grazing for birds (+/- scrape creation)
HR1	Supplement for cattle grazing to benefit environmental objectives
EL3	Permanent grassland with very low inputs
EL4	Management of rush pastures
Scrape Creation	Sometimes included with HL8

The evaluation of the pace of enhancement in the grasslands has been based on the positive and negative indicators adopted for habitat condition monitoring by JNCC (2004, Table 9 page 61) together with signs of reduction in dominance by the main species and concomitant increase in diversity (ie. species populations being more evenly represented rather than a few dominating).

Table 9 *Selection of positive and negative indicator species for Bowland grassland*

Positive Indicators Occurrence of plant species indicators for NVC communities for species-rich grasslands (ie. MG3, MG4, MG5 and MG8) and for rush pasture (ie. M22, M23, M24, M25 and M26) Presence of species which are indicators of local distinctiveness, eg. plant species of semi-natural grasslands, swamps and fens (Lancashire County Council 1998).
Negative Indicators Agricultural weeds (creeping thistle, cow parsley, spear thistle, cleavers, greater plantain, curled dock, common ragwort, common nettle, field horsetail, broad-leaved dock) Agriculturally favoured species (eg. perennial rye-grass, white clover, timothy, soft brome, Yorkshire fog) Rank grasses and sedges (eg. false oat-grass, cock's-foot, tufted hair-grass, larger rush species and large sedges) Incursion and spread of bracken, scrub or tree cover, or of any other undesirable species.

6.2 Results and Discussion

The key findings are that the grasslands studied have successfully maintained or increased their original diversity since the baseline collected in 2007. The grassland vegetation types in terms of the national vegetation community have not changed – this would not be expected in any case unless dramatic changes had been made (such as herbiciding and re-seeding to restore diversity) over this short time period. There are indications in all of those that have been entered into the HLS treatments that the dominant species have reduced and a greater representation of the rest of the species has occurred. In general there are more species per quadrat in most of the sites compared with the baseline in 2007. This is positive in such a short time period. Although the trends are consistent and positive, none are statistically significant – a result that would also be expected as such meadows and grasslands change only slowly. The drought conditions in spring 2009 and 2010 would also have contributed to a reduction in dominant grasses. As the meadows and pastures differed from each other, the detailed results for each are unique and further generalisations can not be made.

HK7, HK18 - Restoration of Species-rich, Semi-natural Grassland Plus Supplement for Haymaking

The three meadows that were entered into these HLS treatments all showed a slight reduction in grass dominance between the baseline and 2010 surveys and an increase in the number of species per quadrat, although these trends were not significant statistically. Only one meadow (Phynis in Croasdale) was suitable for yellow rattle – a useful semi-parasite that helps reduce grass dominance. This gained ground very effectively and assisted in the apparent increase in diversity (Photographs 16 and 17 page 62).

Photograph 16 Phynis *Meadow on 28th June 2007, Showing Dominance of Yorkshire Fog Grass and Low Abundance of Wildflowers*

Photograph 17 Phynis *Meadow on 20th July 2010, Showing a Shorter, More Wildflower-Rich Sward after Three Years of Traditional Hay Meadow Management*

HK7, HR1 - Restoration of Species-rich, Semi-natural Grassland, Plus Cattle Grazing Supplement

Of the two areas entered into this combination of measures, one was already very diverse and has maintained this whilst the northern part of the same field has increased its diversity (species/quadrat) slightly and shown a reduction in abundance of one negative indicator. These are positive results.

HK6, HR1 - Maintenance of Species-rich, Semi-natural Grassland, Plus Cattle Grazing Supplement

The single site to which these measures apply shows a low increase in species per quadrat and reduction in grass dominance. A nearby field surveyed for comparison but managed in a similar way with very low inputs under EL3 and HR1 shows comparable trends but few other changes. Improvements were not statistically significant.

HL8, HR1 - Restoration of Rough Grazing for Birds Plus Cattle Grazing Supplement.

Of the seven sites adopting the rush pasture management, HL8, the restoration through rush management and scrape creation has been applied to six, with the cattle grazing supplement applied to four fields, three of which have also been subjected to rush management.

The HLS objectives do not specifically cover enhanced botanical interest through the management for breeding birds (especially waders), but the opportunity was taken to explore whether this could be achieved as a side-effect of the management for birds.

The results indicate that in general the botanical interest in the sites managed for breeding birds did not improve. There was some variation across the fields with species numbers reducing slightly in some and increasing in others, but this was not consistent. Similarly, the numbers of positive indicators for good quality grassland did not increase. In general, the fields remained similar in composition to the baseline, although the vegetation structure was altered. In some cases, the cutting of rushes without the removal of the cut material tended to swamp out some species, with the regrowth of the rushes the most likely outcome through the cut material.

6.3 Conclusions

There are early signs of positive enhancement in the grasslands managed for hay with cattle (with or without sheep) aftermath grazing with the diversity maintained or enhanced with a concomitant reduction in grass dominance. The fields are generally well suited to continue the enhancement process through the HLS, with opportunities now to add further species in some sites where they have reached the desired target thresholds to stimulate this next phase.

In the rush pastures, the enhancements for breeding birds do not generally also increase the botanical species richness, but some sites suitable for grassland restoration have been identified in the study because they were found to retain elements of BAP grassland flora and other suitable characters.

7 ACHIEVING PSA IN SSSIs AND BAP TARGETS

7.1 Progress towards SSSI Targets

It was reported by UU at the April conference in 2010 (the papers are available at http://www.unitedutilities.com/SCaMPdatalibrary.aspx) that the Company own 58,000ha of upland, of which 17,478ha lie within SSSIs, mostly representing blanket bog and dwarf shrub heath habitats. Of all the UU land in SSSIs, only 35% were regarded as in favourable conditions in 2005. The Government's PSA target for 2010 was for 95% of all SSSI units to be in favourable or favourable recovering condition as deemed by Natural England (NE). Within the SCaMP Estates, Figures 35 (Longdendale) and 36 (Bowland) (pages 65 and 66) show the extent of habitat in unfavourable declining condition (red) or unfavourable no change (orange) in 2005. The majority of the Longdendale area was obviously in very poor condition, mostly driven by the amount of bare peat and eroding ground, with too high a level of air pollution contributing. The grip drainage, intensity of burning coupled with the grazing pressure led to the poor condition in the Goyt Valley. There was no bare peat of any significance here.

UU's Bowland moorland in the Bowland Fells SSSI was mostly in a favourable recovering condition in 2005, on account of the much lower levels of bare and eroding peat and through a number of NE agreements to reduce grazing which were in place. The grips in Whitendale had already largely been dammed, but SCaMP provided the opportunity to supplement or replace the grazing agreements through entry into HLS and to add extensive grip blocking on Brennand.

Figure 35 *The Condition of the SSSI Units in Longdendale in 2005*

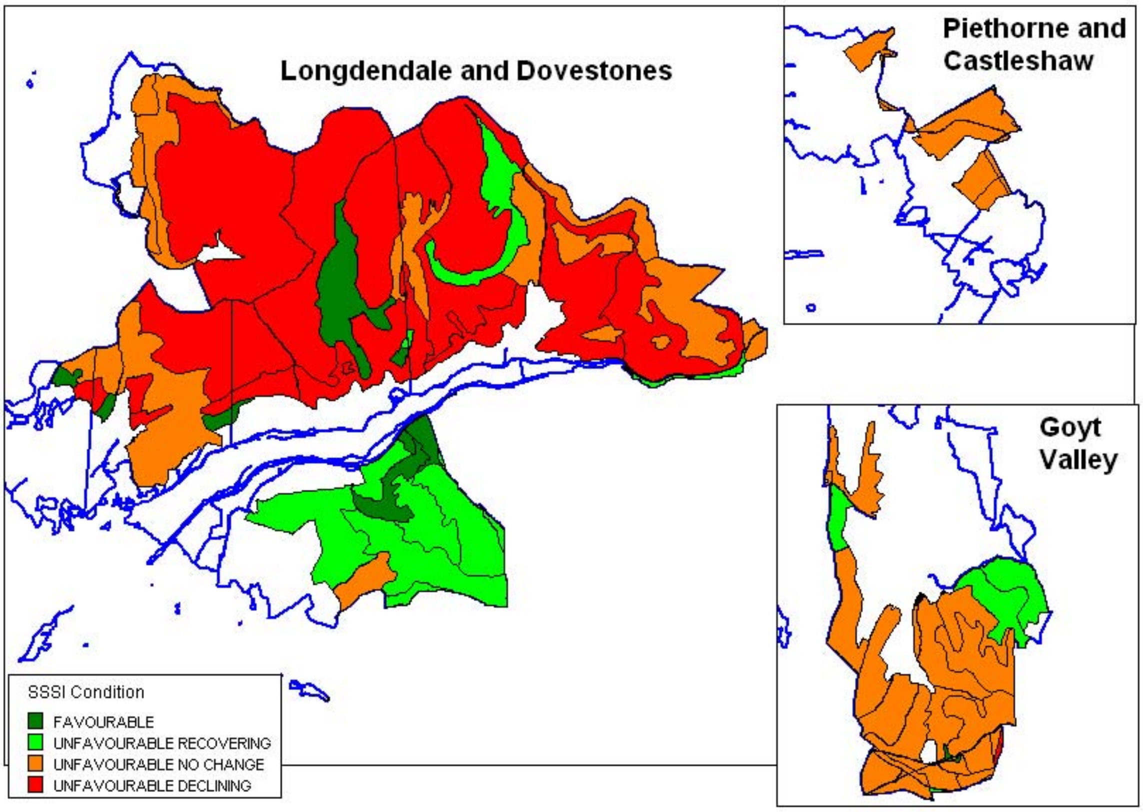
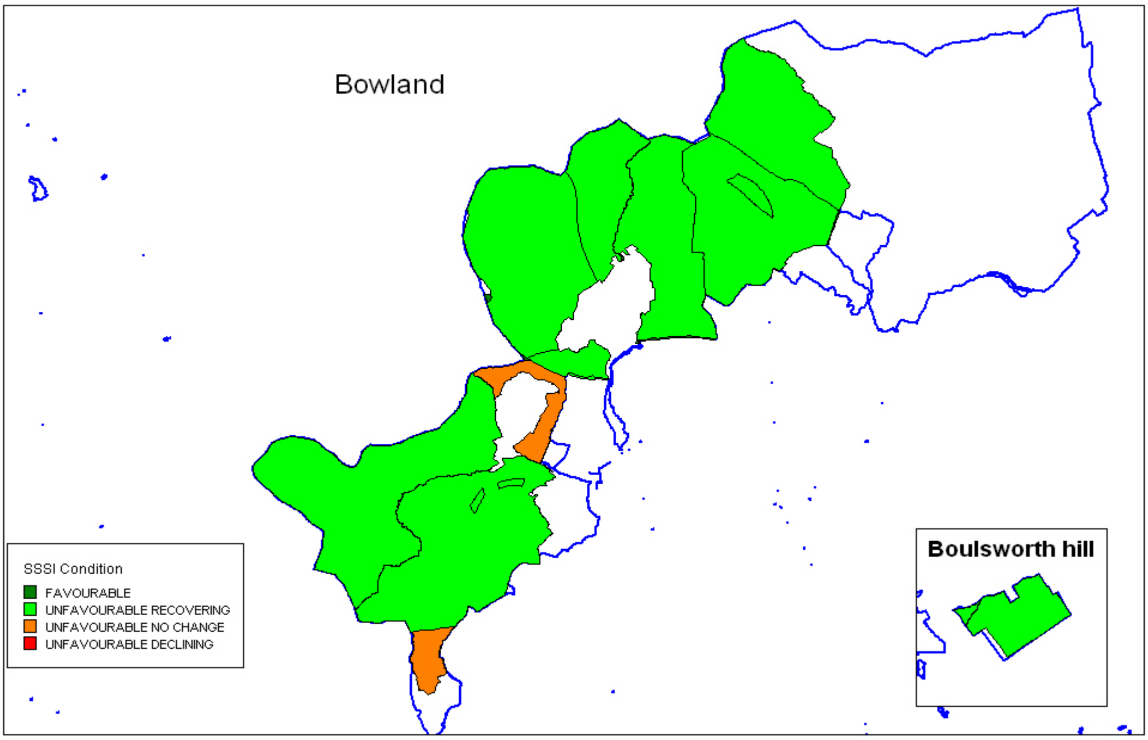


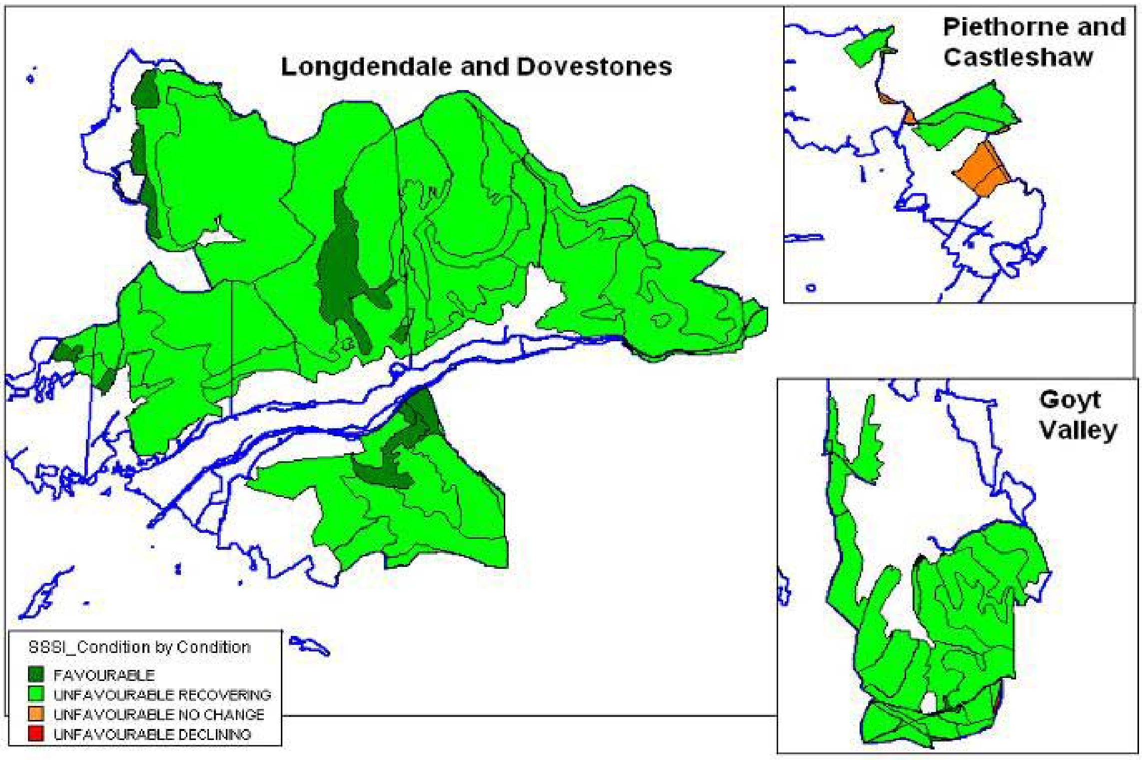
Figure 36 *The Condition of the Bowland SSSI Units in 2005*



By 2010, the condition of the SSSI units was regarded as enhanced adequately through the SCaMP project to be upgraded. Figures 37 and 38 illustrate this (pages 67 and 68).

The results of the SCaMP monitoring presented in this report provide additional support for the re-classification of the SSSI units as in recovering condition. Section 3 shows the substantial extent of re-vegetation of bare peat and the reduction in peat loss as sediment in the streams, which would be reflected in reduced erosion rates. Although not yet representing surrounding blanket bog communities, the recovering vegetation will move towards this over the next five years.

Figure 37 *The Condition of the SSSI Units in Longdendale in 2010*

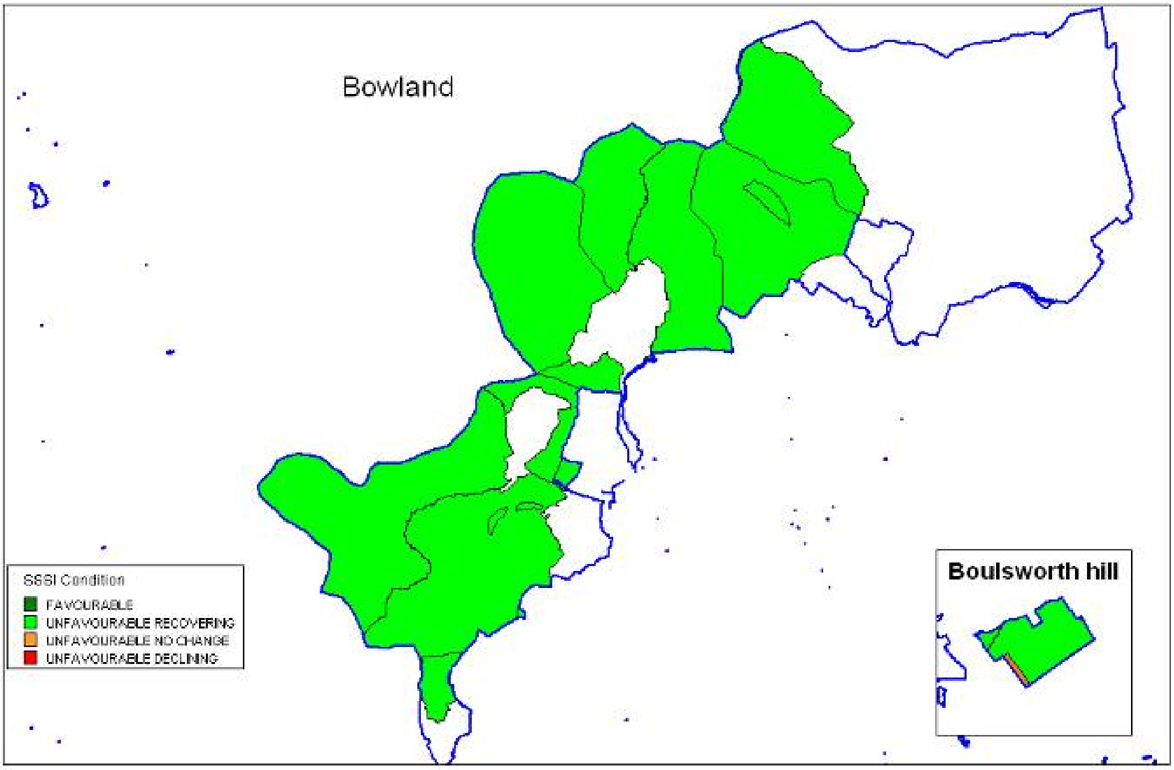


The grip blocking, cessation of burning and reduced grazing pressure in the Goyt and extensive grip blocking and grazing reduction on Brennand (Section 2) are having positive effects for the blanket bog condition by making the peat wetter which will support more blanket bog species. The initial increase in *Sphagna* in the Goyt is a prelude to this improvement. The reduction in grazing (and burning in the Goyt Valley) has also resulted in reduced consumption of heather and bilberry shoots with increases in their height in line with the reduction in suppression.

On other units like Lamb Hill and Sykes, where grazing pressures have been reduced seasonally or over the year, the reduction in grazing signs on the vegetation are a positive sign which continue to move these areas towards favourable condition (Section 4).

Combined across the SSSI units, the Figures show the significant scale of achievement through SCaMP. This overview of the findings are only presented in this Executive Volume.

Figure 38 *The condition of the Bowland SSSI units in 2010*



7.2 BAP Target Achievements

A number of the habitats and species that occur within the SCaMP Estates and affected by the restoration measures are included in the National BAP (see Tables 10 and 11 pages 70 and 71 respectively). The works also therefore contribute to UU's Biodiversity Strategy targets (which are cascaded down from the National BAP). The following overview is not repeated in any other Volume. The key achievements are:

- 516ha of new native broadleaved woodland planted (see Photograph 18 page 69), mostly to develop into upland oak wood, but including some wet woodland where appropriate in a number of sites;
- 1150 juniper saplings planted on Hareden Farm in Bowland to supplement existing plants and ensure adequate regeneration into the future (Photograph 19 page 69);
- 5.6km of dry stone walling installed or re-instated;

- 9.3km of newly planted hedgerows planted or restored;
- 100ha of species-rich grassland and upland hay meadow in Lancashire maintained or enhanced;
- 245ha of rush pasture brought into favourable management, principally for breeding birds under Environmental Stewardship;
- 11,000ha of moorland protected or restored through stewardship schemes in Bowland and the Peak District;
- 85km grips blocked to enhance peat and blanket bog condition; and
- >370ha bare peat restored, mostly in Longdendale.

Photograph 18 *New Woodland Planting*

Photograph 19*Juniper Establishment*

Table 10 *The BAP Habitats Relevant to SCaMP*

Habitat	Biodiversity Action Plans Featured			
	UK BAP	Lancashire BAP	Peak District National Park BAP	UU BAP
Blanket Bog	•	•	•	•
Boundary Features	□	□	□	•
Rivers and Streams	•		•	•
Rushy Pasture	•	*	•	•
Upland Heath	•	•	•	•
Upland Hay Meadow & Species-rich Grassland	•	•	•	•
Upland Oak Wood	•	*	•	•
Wet Woodland	•	*	•	•

Key • Specific HAP/SAP prepared, with targets

* No specific HAP, referred to under another heading. Often no targets

□ Not included

The habitat enhancements thus achieved will be able to support better populations of hen harriers, brown and mountain hares, otters, water voles and other species supported by the different habitat types. Moreover, the habitat enhancements are at a landscape scale, thus supporting the rebuilding biodiversity approach being promoted by Defra, the RSPB and the County Wildlife Trusts. Positive action has been taken on all UU's Habitat Action Plans which in turn will benefit a wide range of individual species, many of which themselves are BAP species with their own Action Plans. This achievement provides UU with a strong position to continue from which to protect and enhance biodiversity on their Estates into the future.

Table 11 *The BAP Species Relevant to SCaMP*

Species	Biodiversity Action Plans Featured: UK BAP	Lancashire BAP	Peak District National Park BAP	UU BAP
Brown Hare	+	+		+
Curlew			+	
Hen Harrier		+		+
Juniper	+			+
Lapwing		+	+	
Otter	+	+		+
Twite		+	+	+
Water Vole	+	+	+	+

In conclusion, SCaMP can be seen to have contributed significantly to achieving the SSSI PSA target in 2010 as well as supporting improvements in the habitats and therefore in the potential for several species that feature in the national BAP targets.

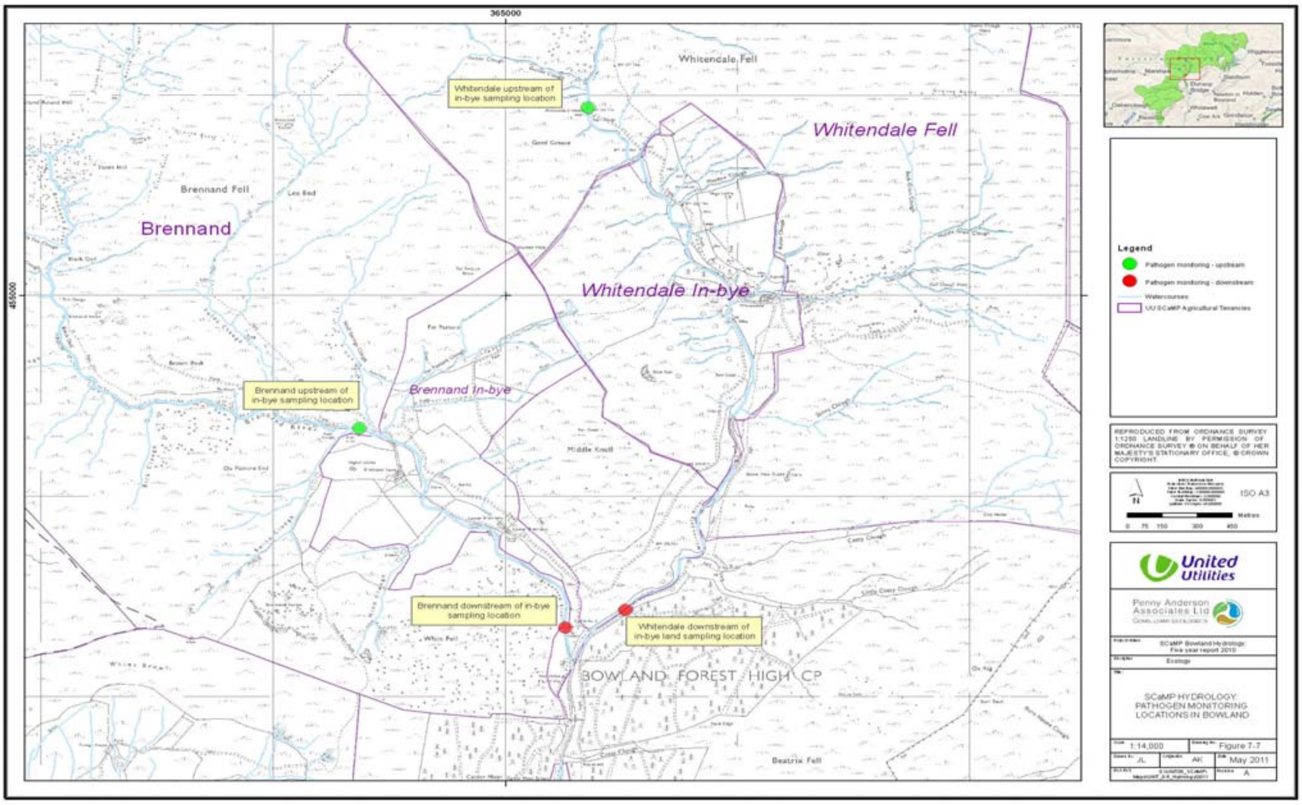
8 ADDITIONAL ASSESSMENTS

8.1 Total Coliform Surveys

Micro-biological data were collected between July 2007 and April 2009 during high flow conditions to observe the levels of Total Coliforms (presumptive) from both the moorland and in-bye land of two SCaMP catchments (Whitendale and Brennand, as shown on Figure 39 below). Total coliform analysis was used as a consistent measure to reflect the baseline pathogen character of the runoff from the selected sites. In future surveys the analysis will be refined to identify the types of coliform assemblage. However, it should be recognised that in the type of environments in which these sample efforts were made, the predominant coliform would be faecal, derived largely from livestock. As this additional assessment does not fit into the other volumes, it is presented here in its entirety.

Water samples were taken in sterile bottles, which were instantly chilled and kept dark in a cool box. The samples were all collected within two hours and driven to a lab for testing within a further two hours. Samples were tested for total coliforms per 100ml of water. Due to the high levels expected, the samples are diluted in order to provide an accurate result.

Figure 39 *SCaMP Total Coliform Sampling Locations – Bowland*



The results are shown in Table 12 and Figure 40 (page 73).

Table 12 *Total Coliform Survey Results for Two Catchments 2007-2009. Units – Total Coliforms Presumptive - Counts/100ml*

	Whitendale Upstream of inbye	Whitendale Downstream of Inbye	Brennand Upstream of Inbye	Brennand Downstream of Inbye
26/07/2007	53	1000	170	940
28/03/2008	2900	3900	70	3200
30/04/2009	500	700	1200	1300

These illustrate the logical trend that as the river passes through the in-bye land, the concentration of total coliforms in the water increases. These data are, however, a snapshot, only representing the situation on the day of sampling. With different flow regimes, land management practices and if sampling occurred at different times of the year, the relative concentrations upstream and downstream may change dramatically.

Figure 40 *Total Coliform Results for Two Bowland Catchments*

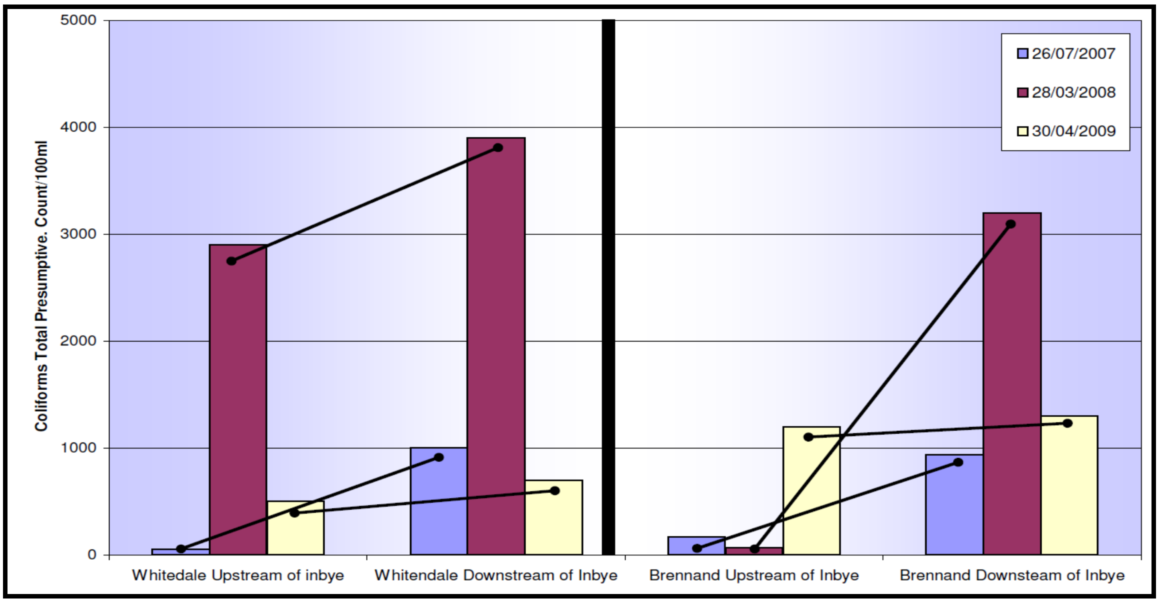
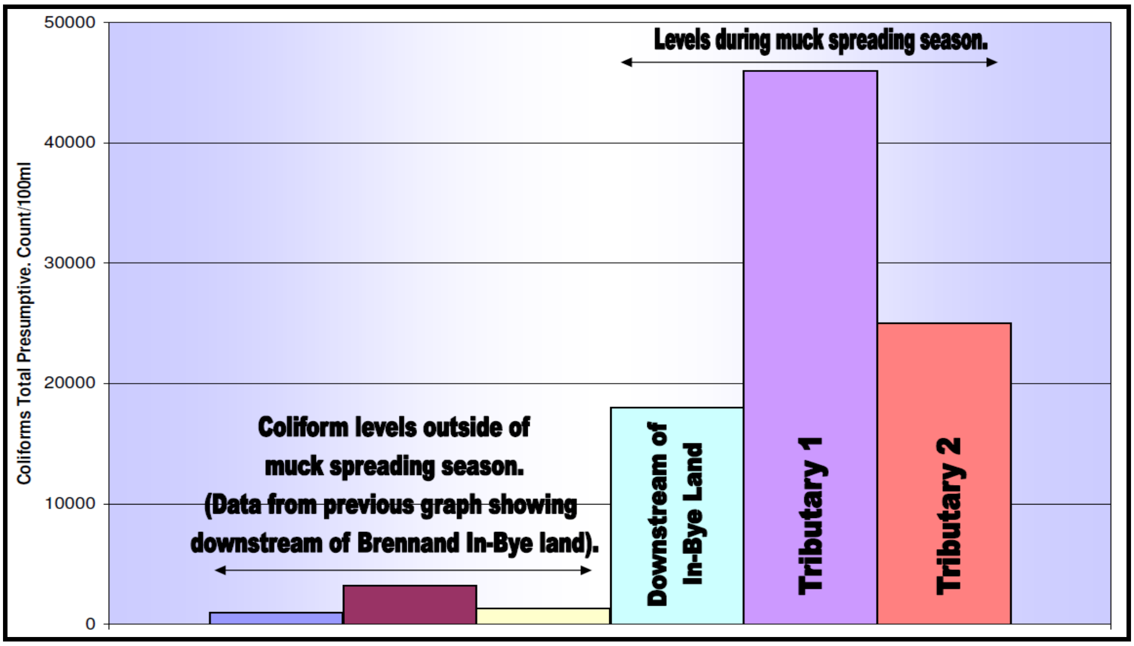


Figure 41 (page 74) shows the in-bye total coliform data for tributary streams in the Brennand catchment during a storm, following muck spreading. The results again demonstrate a logical trend where, following the application of slurry to the in-bye land, high levels of overland flow lead to a substantial increase in the levels of coliforms in the stream water. In this case, the levels of coliforms in the main Brennand River have risen from 3200 to 18,000 counts per 100ml, an increase of 560%.

The two tributaries run directly through the in-bye land and are crossed by a 4x4 track. Therefore, it is unsurprising that these streams contributed significant levels of coliforms to the river Brennand at this time, at levels of 25,000 and 45,000 counts per 100ml.

SCaMP has included a number of measures that will reduce the total coliform counts in the streams, thus enhancing water quality at the treatment works. These include providing water troughs and bridges instead of stock accessing the streams, stock fencing water courses, woodland planting alongside water courses and reduced grazing levels close to some streams.

Figure 41 *The Total Coliform Results After Muck Spreading Following a Storm in the Brennand Catchment*



8.2 The Colour Risk Assessment

Catchment Scale Colour 'Risk' Mapping

In addition to the routine monitoring of water colour associated with those UU sub-catchments that have undergone land management changes as part of SCaMP, there is a programme of monitoring targeted at determining the broad spatial variation of the delivery of 'raw water colour' at a catchment scale. This is described in more detail in Volume 2.

This Programme covers significant areas within the Peak District, Longdendale and Bowland estates where it aims to sample selected streams within the same day, with the objective of providing a means of identifying the relative risk of colour generation and delivery at the catchment scale through the production of colour risk maps.

Caution has to be exercised in using the data collected in this programme as they are a snap-shot of relative colour without any scale of colour generation because stream discharge is not measured at the time and the logistics of reaching the catchments at the same time restricts the amount of data that can be collected. In addition, storm events after dry spells invariably produce a colour flush in the initial stages of the hydrograph response and strategic 'snapshot' sampling of streams will often miss these critical periods and under-represent the amount of colour being delivered as DOC in streamflow from a catchment. Not all sub-catchments could be sampled at once and those shown were selected based on their characteristics and in agreement with UU.

Risk maps have been generated, see Figures 42, 43 and 44 (below and pages 76 and 77 respectively). In the Goyt, Figure 43 (page 76) clearly shows that low risk areas for colour generation are associated with mineral/ forested zones and that critical areas are those associated with the gripping. Compared with the Longdendale risk map (Figure 41), it indicates that the greatest risk of colour generation comes from the Goyt and not Longdendale. This is not supported by the detailed studies on the catchment themselves and exemplifies the limited usefulness of these maps.

Figure 42 *Raw Water Colour Risk Map – Longdendale Sub-Catchments*

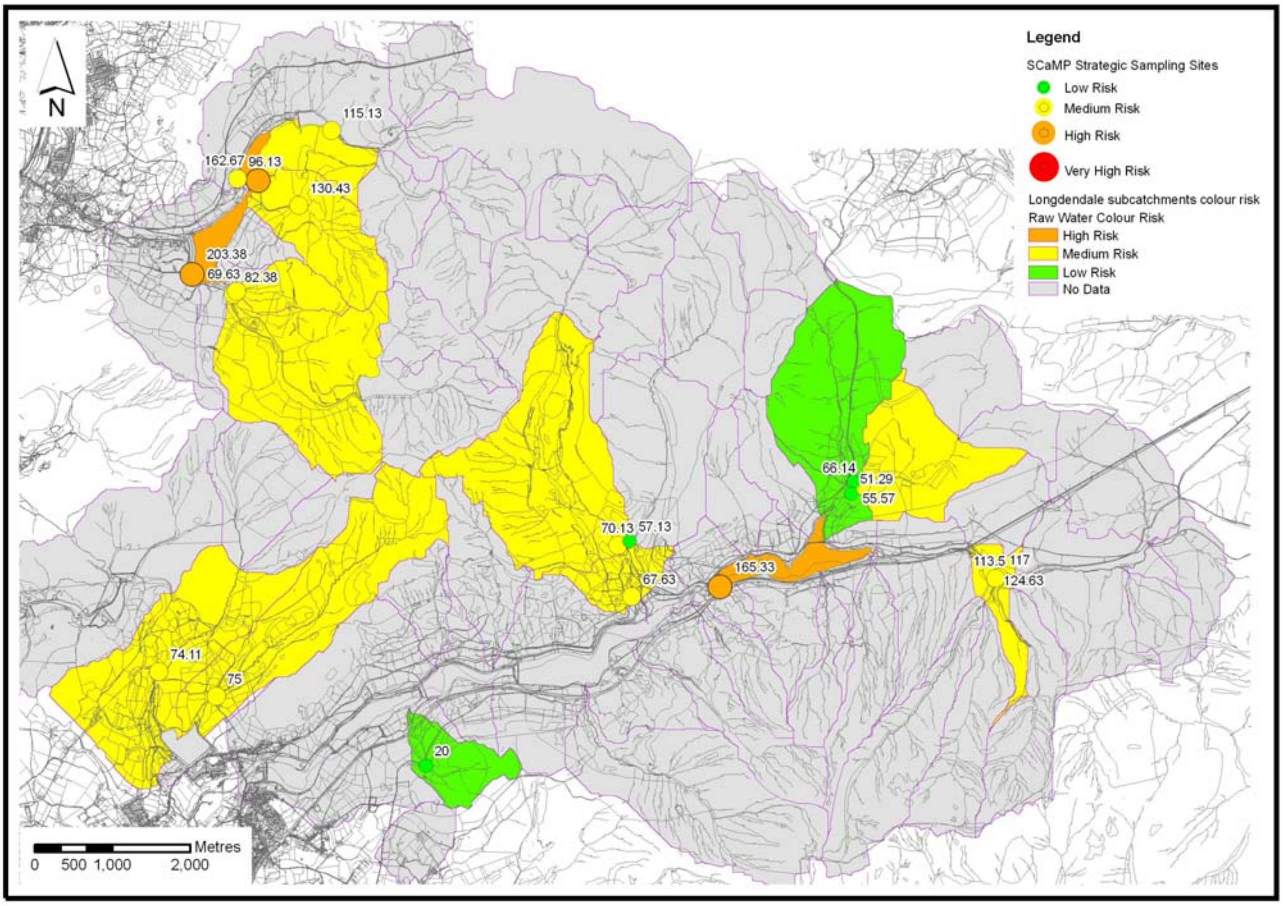


Figure 43 *Raw Water Colour Risk Map – Goyt Sub-Catchments*

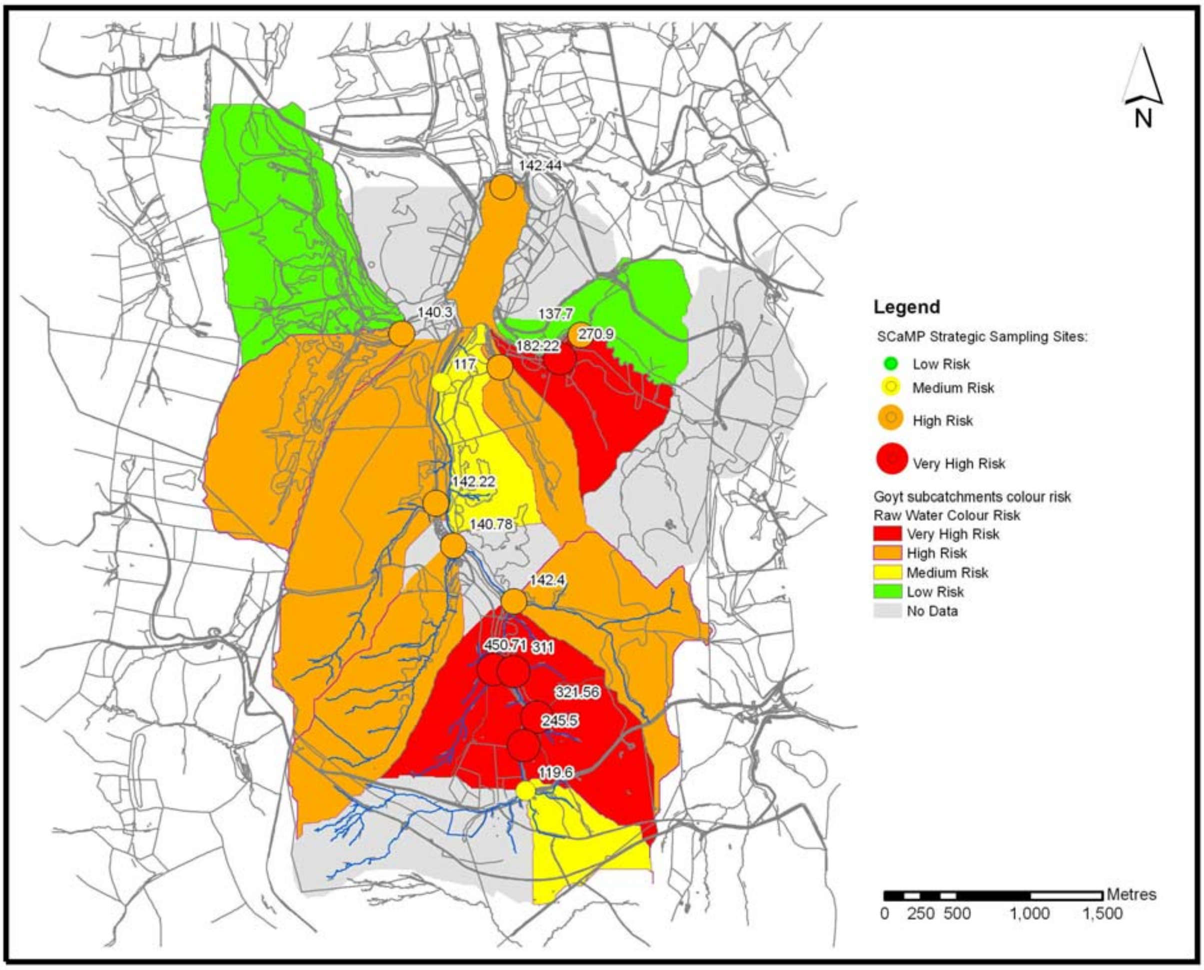
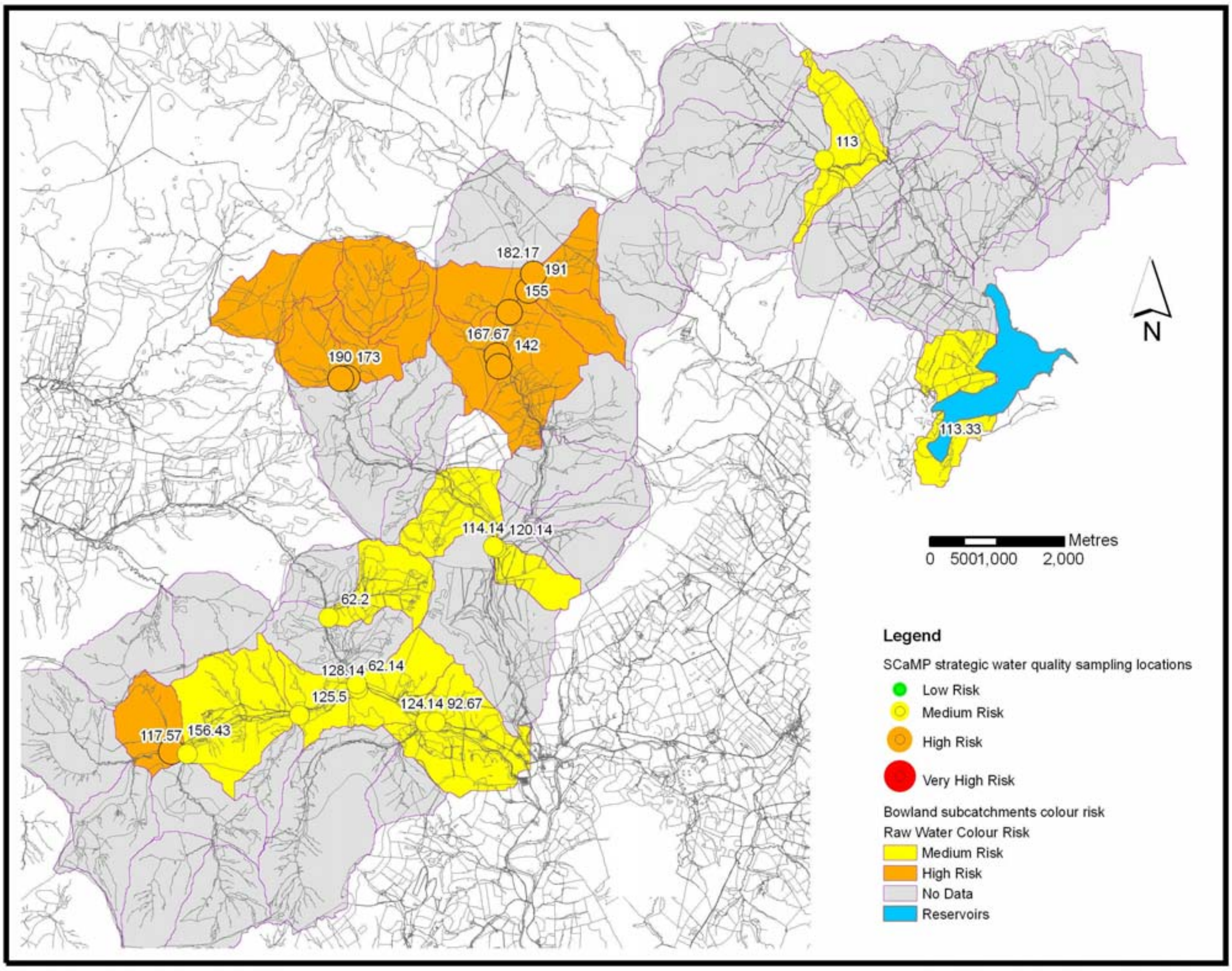


Figure 44 *Raw Water Colour Risk Map – Bowland Sub-catchments*



The colour risk map for Bowland sub-catchments (Figure 44) again clearly identifies those sub-catchments which consistently produce the most colour, ie. the Brennand and Whitendale catchments as a whole.

In general though, the maps do show that those sub-catchments identified as potentially high colour risk areas and subsequently treated or else managed accordingly under SCaMP, are those which consistently produce higher levels of colour in streamflow.

9 CONCLUSIONS

The SCaMP monitoring data presented in this Year 5 progress report demonstrates with a high level of confidence that the integrated approach to land management on a catchment scale is generating benefits which elevate the value of ecosystem services that the uplands can provide at both local and national scales of importance (Defra 2007). Taken as a whole, the data are showing that grip blocking, bare peat re-vegetation, reduced stocking levels and the cessation or altered management of moorland burning are all registering a momentum towards success in terms of water quality, upland hydrological function and habitat restoration.

The early responses to land management changes in the blanket bog sites are indicative of a system that is regaining a dynamic equilibrium that would eventually manifest itself in a more sustainable landscape. In addition, by converting the decrease in water colour and of turbidity on different sites to carbon, the opportunity arises to illustrate the multiple benefits that this apparent change offers to nationally important goals of carbon management. On top of this there are the implications that reduced colour generation could make to the ‘costs’ of supplying water to consumers, particularly as land management approaches may be deemed more sustainable than high-tech water processing.

The large scale of the project and integration of measures and activities across a landscape scale has made a significant contribution to the recovery of the previously unfavourable condition on the SSSIs in the programme. That so many SSSI units are now in favourable or favourable recovering condition is a special achievement.

The programme to enhance a wide range of other BAP habitats for which UU is responsible on their Estates has also shown the benefits of scale and integration, with a wide range of woodlands, meadows and rush pastures as well as the species that depend on them, all benefiting.

With reference to the key project drivers set out at the front of this report, there is no doubt that SCaMP has been very successful. It has achieved most of its objectives as follows:

- it has met the Government’s target of 95% of SSSIs being in favourable or favourable recovering condition by 2010;
- it has supported UU’s Biodiversity Strategy very significantly;
- it has shown improvements in water quality, particularly water colour;
- it has shown reductions in sediment load where bare peat has been re-vegetated.
- it has not yet demonstrated significant changes in runoff rates or the potential to reduce downstream flooding, but further analyses with additional data will examine this in future years; and
- it has shown significant reductions in carbon loss through re-vegetating bare peat and from grip blocking.

The monitoring of the blanket bog elements of the project is due to continue for an additional four years which provides the opportunity to examine some of the emerging relationships in more detail and with increasing confidence.

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