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Chapter 1: UK Metric for Peatland Restoration

1.1 WP1(a)i Review of the metric

1.1.1 Context: The UK metric for peatland restoration builds on existing GEST vegetation proxy modelling developed by the Crichton Carbon Centre and published by Natural England and Defra in June 2013, and focuses on blanket bog restoration.

1.1.2 Brief review of latest evidence on peatland vegetation metrics to identify where the metrics can be refined.

a) Peatland Condition categories – need for a classification system that allows for the reversal of degradation, that can include both rewetting (by grip blocking) as well as restoration by grazing/burning management; and whose terminology is understood by both landowners and scientists. Clarify definitions; e.g. of bare peat (use of key indicator species 'dominance' or 'cover', bearing in mind likely future need for survey via remote sensing). Table showing the new, refined definitions. Dick will lead, first draft by 24 Feb. Probably focus on ecosystem functionality, hence sphagnum dominance/cover and bare peat dominance/cover. Need good clear definitions of ecosystem states that can be used by non-ecologists.

DRAFT TEXT FOR REPORT:

1.1.2 Peatland Condition categories

The purpose of this section is to provide more precise definitions for the 5 blanket bog condition categories (or ecosystem states) identified by Birnie and Smyth (2013)[1] in the course of the previous Defra study (see Table 1). These definitions use readily observed features, either from aerial photography or through reconnaissance field survey, and they provide the practical link between field assessments of peatland condition and the estimation of GHG emissions from any blanket bog site in the UK. They also provide the foundation for subsequent monitoring of any peatland restoration project.

Ecosystem State	Peatland Condition Category[2]	Description	Impact on peat-forming function
1	Intact	low impact	intact
2	Moderately Degraded	moderate impact	reduced
3	Highly Degraded	heavy impact	lost
4	Eroded	severe impact	lost and peat mass itself is being destroyed
5	Artificially Drained	presence of artificial drainage channels typically @15-20m apart	reduced and possibly lost

Table 1 Descriptions of the 5 blanket bog ecosystem states/peatland condition categories provided by Birnie and Smyth (2013) and their respective impacts on the peat forming function of blanket bog ecosystem.

1 http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=18522&FromSearch=Y&Publisher=1&SearchText=NE0136&SortString=ProjectCode&SortOrder=Asc&Paging=10

2 It is important to note that the word "*degraded*" is often seen as pejorative by land managers. Here it is used in the context of the provision of ecosystem services to indicate the effect of land management on peat-forming ecosystem function. The peatland may still perform other ecosystem functions which provide benefits.

Because the original peatland condition categories were devised so as to capture the impacts of differing intensities of land management (e.g. burning, trampling, grazing) on peat-forming function of the peatland ecosystems, it is logical to define them more precisely using the impact indicators available from existing published guidance, specifically that from SNH used for surveying land management impacts in upland habitats (MacDonald et al., 1998). This approach has several obvious advantages. Firstly, the SNH guidance is in the public domain and is intended for practical use by people with a general rather than a specific knowledge of vegetation, such as might be involved in peatland restoration projects. Secondly, the guidance is based upon impact indicators which are clearly and comprehensively defined, including both large-scale and small-scale indicators. Thirdly, the systematic methodology provided can be used for both baseline assessment and subsequent monitoring of peatland restoration projects.

MacDonald et al. (1998) propose two levels of indicators: large-scale and small scale. Because of the practical considerations relating to cost-efficiency of surveys involving the use of small-scale indicators of impact (these require fairly intensive field programmes to operate), we confine our definitions to the use of the large-scale indicators of impact. MacDonald et al. (1998) describe these as follows:

…….the large-scale indicators are meant to be used from some distance away from the assessment unit, generally at distances between 100m and 1km. Some do require closer inspection of small areas but the results of this inspection indicate conditions over a much larger area (Volume 2, p.15).

We would add that some can be identified by air photo interpretation. They identify 17 Large Scale Indicators of land management impacts on blanket bog habitats. These indicators are grouped into sets in relation to the three main types of impact (e.g. a) drying and peat loss; b) burning; c) trampling and grazing). These indicator sets and the way that we propose to use a selection of them, are described in more detail below.

Indicator Sets

a) Drying and peat loss. In the SNH guidance, the set of indicators which point to drying and peat loss include two which relate to artificial drainage (spacing and depth). Because we have chosen to identify artificially drained blanket bog as a separate condition category, dealt with in a later section, these are not included here as indicators of drying and peat loss. We therefore suggest three indicators in this set as follows:

1. Presence of an irregular patterning of sphagnum moss hummocks (each up to several m^2 in size) producing a gently undulating surface.
2. Extent of bare peat.
3. Extent of *Calluna vulgaris.*

Table 2a provides short definitions of the impact classes relating to each indicator.

	Low impact **Lightly dried/disturbed**	**Moderate impact** **Moderately dried/disturbed**	**High impact** **Heavily dried/disturbed**
1. Presence of an irregular patterning of sphagnum moss hummocks	Conspicuously and predominantly hummocky	Hummocky in parts	Not obviously hummocky
2. Extent of bare peat	Most of assessment unit well vegetated with little peat exposed	Bare peat showing through a thin vegetation cover over limited areas (<100m^2) or	Bare peat showing through a thin vegetation cover over extensive areas (>several

		completely bare peat in small, sparse patches	100m²), or completely bare peat in large and/or multiple patches(individual patch size <2m²) dispersed over the majority of the assessment unit. NOTE Extensive bare peat with gullies is defined as SEVERELY DEGRADED AND ERODED
3. Cover of Calluna vulgaris.	Absent or very scattered. Any denser patches are non-linear	Scattered patches, mostly on higher ridges?	Conspicuous and extensive over most of the assessment unit.

Table 2a Indicators of drying and peat loss.

b) *Burning.* The SNH guidance identifies two sets of indicators relating to burning intensity and frequency respectively. On the basis of further field experience, and to reduce subjectivity (e.g. judgements about colour) and criticality of timing of filed visits (relative to how recent burning events are), these have been combined and re-defined here. A modified set is proposed which comprises 5 indicators of burning, two of which may be determined primarily by air photo interpretation (marked by *):

4. Extent of bare peat in the burnt patch.
5. Pattern of burning.
6. Degree of difference between vegetation of unburnt and burnt bog.
7. Occurrence of extensive (100's m2) dark brown, black, grey, greyish green, dark green or bright yellow-green crusts or carpets of lichens, algae, or mosses.
8. Intensity of long term fire regime.

*Table 2b provid*es short definitions of the *impact cla*sses relat*in*g to each indicator.

	Low Impact (lightly burnt)	**Moderate Impact (moderately burnt)**	**High Impact (heavily burnt)**
4. *Extent of bare peat in the burnt patch (use binoculars and air photography to identify burnt areas).	Little or no bare peat	Little or no bare peat	Bare peat showing through a thin cover of live or dead plant material over most of the burnt area, and/or completely bare peat in several patches (individual patch size >2m²)
5. Pattern of burning.	Very irregular with many patches remaining unburnt even on baulks and ridges	Ridges uniformly burnt but hollows missed or lightly singed	Uniform. No unburnt patches even in hollows
6. Degree of difference between vegetation of unburnt and burnt bog (look across fire line)	Little difference, similar vegetation composition on both side of fire line	Noticeably fewer patches of heather and shrubs in the burnt area when compared to unburnt area, "grassy" areas could be more extensive	Burnt area dramatically different and may be patchy and irregular with some trees and shrubs, "grassy" patches, and patches of mosses and lichens as well as dwarf shrubs
7. Occurrence of extensive (100's m²) dark brown, black, grey, greyish green, dark green or bright yellow-green crusts or carpets of lichens, algae, or mosses. Mosses likely to be Racomitrium lanuginosum or "bottle-brush" mosses (Polytrichum spp. or Campylopus spp.).	Absent or very scarce	Infrequent small, scattered patches (<0.5m across) or small tufts mixed with *Sphagnum*	Conspicuous, widespread
8. *Intensity of long term fire regime (assessed from air photography)	No or very limited evidence that there are	A small number of burnt patches evident, more	Many burnt patches across the site evident,

	burnt patches, if there are they are not frequently distributed across the site (they have been isolated events)	frequently distributed across the site (more likely they have been intentionally located)	some patches crossed over by other fires, patches at obviously different stages of vegetation recovery (suggesting frequent burning across whole site)

Table 2b Indicators of burning intensity and frequency.

c) *<u>Trampling and grazing.</u>* MacDonald et al. (1998) identify 5 indicators that relate to trampling and grazing impacts only 4 of which are suggested for use here:

9. Bare peat exposed by trampling, wallowing and rubbing by livestock and deer.
10. Extent of sheep, deer or cattle paths.
11. Amount of flowering of *Eriophorum* spp.
12. Luxuriance of Sphagnum, dwarf-shrubs, and sedges on very small islands (<1-2m^2) in permanent bog pools, <2m from the bank, relative to the surrounding bog surface.

Table 2c provides short definitions of the impact classes relating to each indicator.

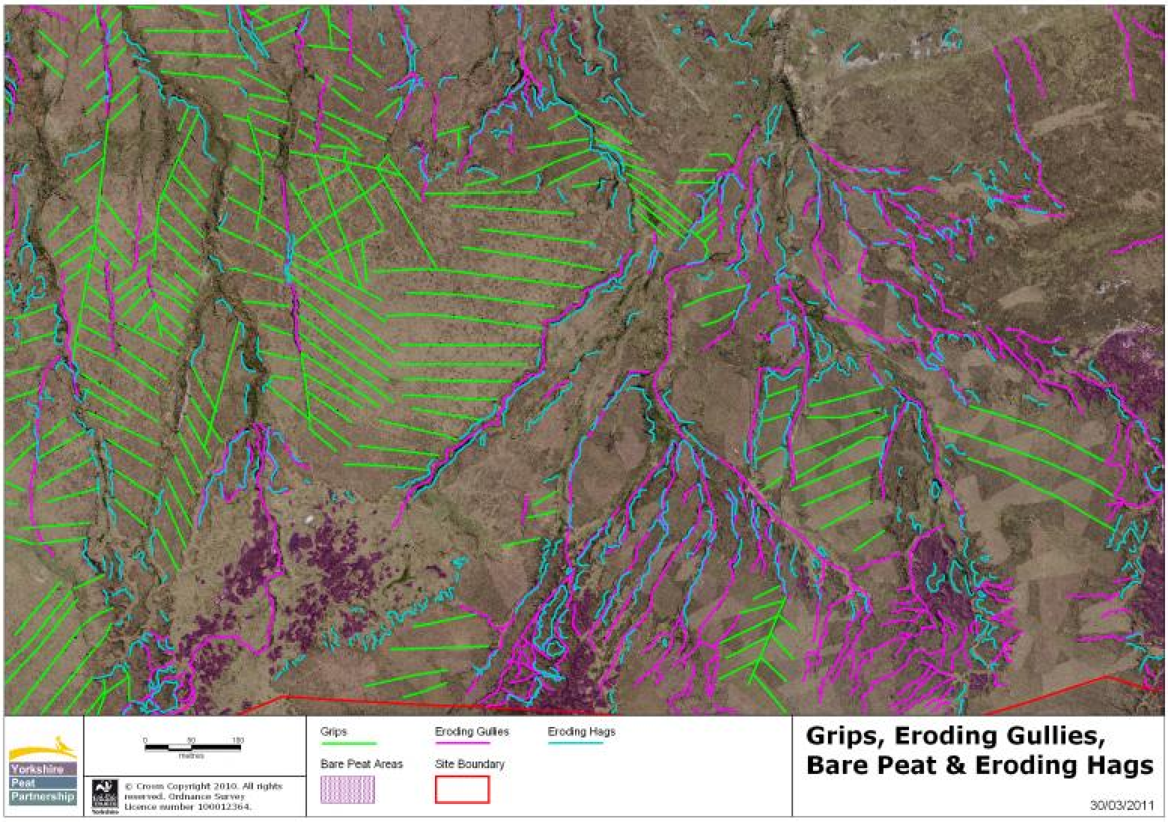
	Low impact **Lightly trampled/grazed**	**Moderate impact** **Moderately trampled/grazed**	**High impact** **Heavily trampled/grazed**
9. Bare peat exposed by trampling, wallowing and rubbing by livestock and deer.	Very scarce or absent, or if present then erosion inactive and ground re-vegetating	Localised and infrequent. Little or no active erosion	Frequent and conspicuous, perhaps actively eroding
10. Extent of sheep, deer or cattle paths.	Absent, or occasional single paths showing little branching	Conspicuous, but very localised, mostly restricted to dryridges or fencelines	Extensive and conspicuous, ramifying over most of the bog surface
11. Amount of flowering of Eriophorum spp.	Widespread and abundant. Very conspicuous	Patchily abundant, or widespread but thinly scattered	Little or none. Inconspicuous
12. Luxuriance of Sphagnum, dwarf-shrubs, and sedges on very small islands (<1-2m^2) in permanent bog pools, <2m from the bank, relative to the surrounding bog surface.	No difference	Island>surrounding bog	Island>surrounding bog

Table 2c Indicators of trampling and grazing.

Categories of Eroded and Drained Blanket Bogs

The indicator sets presented above provide the means for separating blanket bog into three impact categories. Birnie and Smyth (2013) have shown that, although these may be biologically degraded in terms of their peat-forming function, these categories are still generally associated with net positive GHG balances. However, the remaining two blanket bog ecosystem categories (“severely degraded & eroded” and “artificially drained”) which are physically degraded either by natural erosional processes (e.g. water, wind, frost etc.) or mechanical disturbance by managers (e.g. moor gripping, peat cutting etc.) appear to be associated universally with net negative GHG balances, with annual emission losses potentially an order of magnitude greater than the annual gains on intact blanket bog surfaces. So **whilst units of these categories may occupy a relatively small proportion of any potential restoration site they may have a disproportionate impact of the overall GHG balance for that site**. **It is therefore important to identify them as precisely as possible.** This section provides a set of suggested indictors, partly based on the SNH Guidance, especially as regards drained sites but also includes further field experience of the present authors more closely related to the factors determining GHG balance.

The area of exposed bare peat is considered as the key determinant in driving carbon losses from physically degraded blanket bog, by providing both a reactive surface for direct oxidation and gaseous emission, and a source for losses of organic carbon in dissolved (DOC) and particulate (POC) forms. So it is logical to use the “extent of bare peat” surface as an impact indicator for both eroding and artificially drained categories. Whilst this is also used as an indicator of drying and peat loss (Table 2a) it is recognised that there is a transition from highly impacted but intact peatland surfaces (in terms of near-complete vegetation cover) to severely degraded and eroded ones. However, it is generally recognised that it is possible both to identify and measure the planimetric area of bare peat surfaces using aerial photography. Orthorectified aerial photography (i.e. geometrically rectified to fit the OS grid)at scales of around 1:10,000 is widely available for most if not all of the UK via mapping systems like Google Earth Pro. These systems also provide basic GIS measurement functions which can be used to provide quantitative estimates of bare ground. An example of this type of mapping is provided by the work of the Yorkshire Peat Partnership, reproduced here as Figure 1.



Severely degraded & eroded blanket bog is often described as being "hagged" or "gullied" (see for example Penny Anderson Associates, (2012). A full description of the geomorphology of blanket peat is given by Evans and Warburton (2007) but their differentiation of eroded peatland generally follows the simple two-type classification originally proposed by Bowers (1960). This differentiates between Type I, the complex jigsaw-type interconnecting gullying typical of hagged peats, often associated with peat flats (bare peat) and commonly found in valleys and on interfleuves, and Type II, generally parallel gullies more found commonly on valley sides. These Types are illustrated in Figure 2 below.

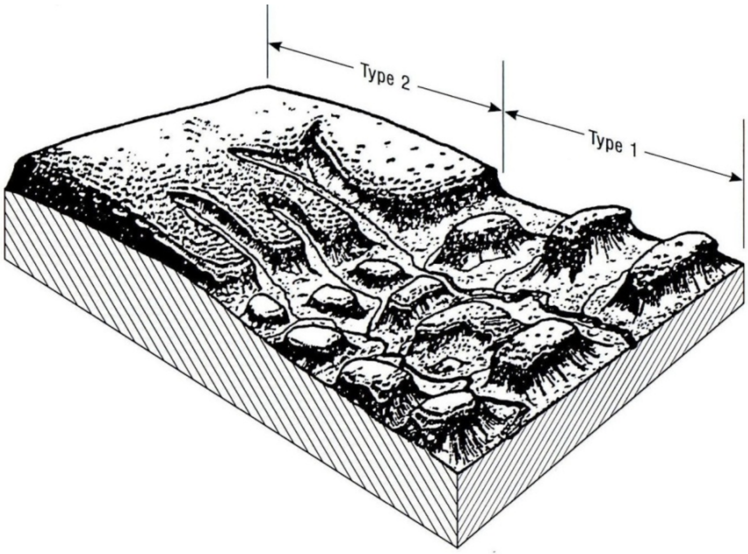


Figure 2 Main types of gully erosion found in blanket peats (after Bower, 1961[3]). Type 1 is commonly found in flat or gently sloping areas and comprises a series of gully systems that have cut into the peat to create a series of isolated blocks or peat hags. This is sometimes also called jigsaw erosion. Type 2 is found on slopes and the gullies generally run parallel to each other with headward extension into branches. Both types can have gullies that are entirely cut within the peat mass or extend downwards into the mineral substrate.

When they are actively eroding both Types of erosion gully system are associated with extensive bare peat surfaces. Because of the more complex geometry of their gully systems, the areas of bare peat tend to be greater with the hagged type (Type 1). However, the key point is that these bare peat surfaces are three dimensional, so **their actual ground surface area is always greater than their plan area as it is mapped from aerial photography.** Because it is the actual ground area not the planimetric area that is the reactive surface in terms of GHG fluxes it is important to consider how this might be estimated more accurately in our procedures.

Mapped (or plan) area is related to ground area via the cosine of the ground slope angle, ranging from 1.0 for a flat surface to 0.0 for a vertical surface (for a 30^0 slope the mapped area is 0.87 of the ground area, for a 60^0 slope it is 0.50 etc.). So **the mapped area become progressively less representative of the ground area as the ground slope approaches vertical**. Although it is possible to measure ground slopes from aerial photos it is not possible to do this at sufficient resolution and in a cost-effective way. So a more pragmatic approach is required which makes use of our understanding of the systematic under-representation of ground area by mapped area. So in the case of a typical gully in eroding blanket peat, it can be assumed that the depth of the peat is generally 1.5-2m and the vertical elements of the gully sides will be typically around 1m (see Figure 3). If we map a 4m wide gully in 2m deep peat then it is likely to have two vertical 1m elements on either side which will not be mapped. These will in effect add another 50% to the ground area and it is proposed to use the **relationship of ground area being 150% mapped area as a standard conversion factor**. Given the very complicated surface geometries involved in eroding peatland systems, this is considered to be a conservative value.

[3] Bower M.M. (1961) The distribution of erosion in blanket peat bogs in the Pennines. Transactions of the Institute of British Geographers 29, 17-30.

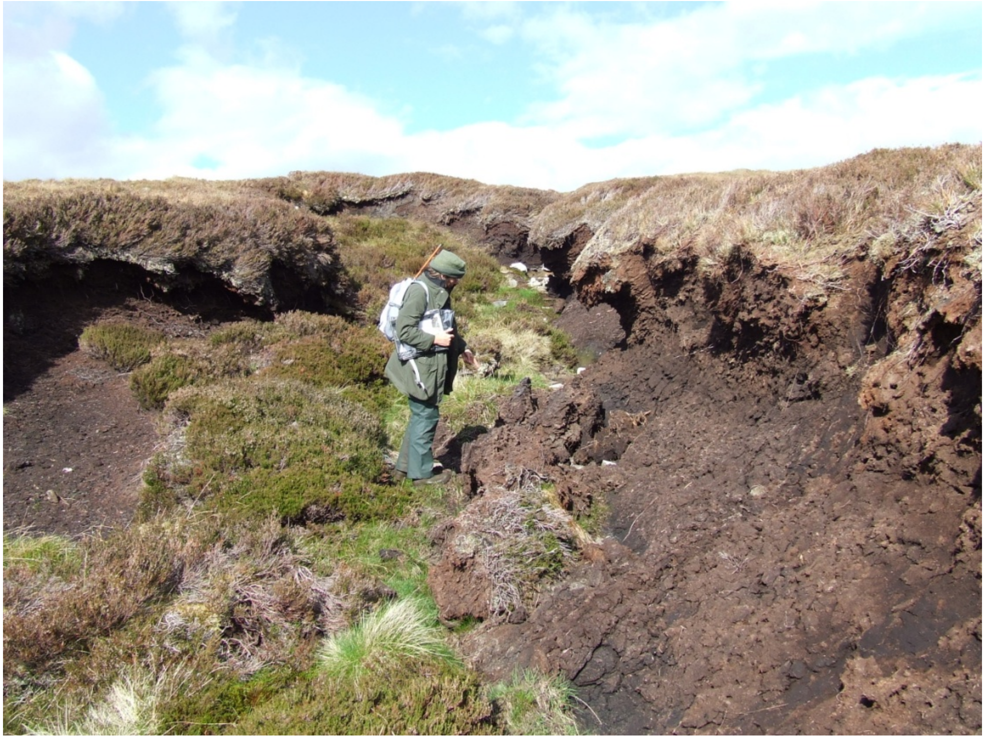


Figure 3 Erosion gully in blanket peat at Alladale Estate site in East Sutherland. Gully sides are near vertical and in some places overhanging. These would not be seen on aerial photography consequently the area mapped as bare ground would significantly under-represent the actual area on the ground.

Artificially drained blanket bog is often described as being “gripped”. Anderson Associates (2012) suggest that gripped peatland is generally easy to detect on aerial photographs, the individual grips appearing as parallel lines often herring-boned together at their downstream ends (please see Figure 2). But they also note that their visibility depends on a number of factors including whether the vegetation has been recently burnt, the depth and width of the grips and the presence of water in them. In our experience, grips are often indirectly picked out by the vegetation on the drier spoil ridges alongside them (often *Calluna*).

MacDonald et al. (1998) use both spacing and depth as indicators of impact of drains or grips. From our experience drain depths have to be measured in the field and also tend to be relatively constant at around 0.5-0.6m so for these reasons depth is not used as an indicator here. The pattern or density of drainage is relatively easier to observe. Again from field experience, there tends to be 3 types of drainage system: one where grips have been cut at very wide spacings and sometimes almost at random; one where grips have been cut on a regular basis often around 20-25m apart and lastly, a few situations where there appear to have been multiple phases of draining, often with drain lines cutting across each other to form a reticulate pattern of drains. In all cases there are examples of where the drain lines have formed the focus for the further development of erosion gullies.

Figure 4 Artificial drainage channel in blanket peat showing both in-channel erosion and the development of secondary erosion channels on left hand side (bottom left foreground).

Following Lindsay (2010)[4] and others research on the extent of the hydrological impacts of surface drains on blanket bog vegetation and microtopography, we propose a procedure of mapping the drain lines on the air photos and then using a 50m buffer either side of them to estimate the area affected by them. This procedure generally follows the "dry shadow" approach proposed by Paul Leadbitter (pers. comm.) of the North Pennines AONB. This approach conforms with the procedure adopted by Penny Anderson Associates (2012) in relation to their mapping of "gripped" peatland from air photos, done on behalf of Natural England. In essence this means that for any assessment unit with a drain spacing of less than 100m, we will assume that the whole unit is "drained". For units with very widely spaced drains the affected area will be less but will still be accounted for. This is a departure from the procedure used by Penny Anderson Associates who discounted drains more than 100m apart.

General Relationships Blanket Bog Ecosystem States and Land Management Impact Indicators

[4] Lindsay, R. (2010) Peatbogs and Carbon, a Critical Synthesis. RSPB Scotland

Using the indicators proposed above the appropriate peatland condition category for *each assessment unit* within a blanket bog can be established. There are no absolute allocation rules and not all indicators will be applicable at all sites or within any one site. MacDonald et al. (1998) suggest the use of as many indicators as possible and not rely on just one or two. They also suggest that *the decision on the overall impact class for an assessment unit should be based upon the average of the class results for all the indicators used*. Table 3 below provides a summary of the general relationships between the blanket bog ecosystem states and the Phase 1 Large Scale Indicators of land management impacts proposed here.

		Average Impact Class[5]				
		Low	**Moderate**	**High**		
	PEATLAND CONDITION CATEGORY	**1. INTACT**	**2. MODERATELY DEGRADED**	**3. HIGHLY DEGRADED**	**4. SEVERELY DEGRADED & ERODED**	**5. ARTIFICIALLY DRAINED**
Large Scale Indicators	*a) Drying and peat loss*					
	b) Burning					
	c) Trampling and grazing					
	Erosion gullies (presence/absence) Area of Bare Peat x1.5 conversion factor					
	Artificial drainage (presence/absence) Drain lines plus 50m buffer					

Table 3 General relationships between peatland condition categories and Large Scale Indicators (based upon and developed from MacDonald et al., 1998).

For practical purposes it is helpful to provide a summary table which includes all the large scale indicators against the relevant peatland condition categories. This is presented as Table 4.

b) Data sources. Note IPCC guidelines on data source reliability – Published and peer reviewed data required. Using publically available data also avoids any IP issues. Take account of and be consistent with recent developments including upcoming IPCC guidelines on accounting for GHG emissions from peatland restoration projects (expected late 2013). Chris will lead, with input from Rebekka. Commentary - behind the measurements. Meetings by phone and face-to-face, morning 12 February; some excel data shared, outline of critique shared. Meeting planned Edinburgh 13th March.

c) Additional data to strengthen the metric. Incorporate relevant data generated elsewhere in the UK to ensure that the best available modelling and evidence underpins the Code. Use any unpublished data to verify the metrics (but not to build the metric)

[5] Average impact class is based upon the results for all the indicators used (please see text above).

- Flux data: Take account of new scientific evidence, for example on methane emissions from blanket bog restoration, such as those available to CEH (Wales) and JHI (Flow Country). Include relevant data from blanket bogs in Ireland (ie for non-cutover 'mountain bogs'; *cf.* Wilson 2013). Output: a table of recent references (2012-2014) linking Blanket Bog Condition to CO2eq flux, to add to the data-source spreadsheet in the 2013 metric.
- DOC/POC data: Check consistency with IPCC, for example regarding 'off site' CO2 fluxes from DOC. Note recent references relating POC and DOC loss from blanket bogs. High Emissions rates for eroded peat? (reactive surface area is far greater than plan/mapped area; so rate of loss will be greater). May need to clarify that, as far as the peatland is concerned, if the carbon has left the site (peaty acid in a river or peat dust blowing in the wind) it has been 'emitted' even if there may be a few years before it all becomes chemically reactive (eg. timing may depend on reservoir dredging periodicity, or on river characteristics). Recent SNH data suggests 90% of the carbon has left the rivers before they enter the sea. Refine metric as necessary
- Peat accumulation rates data: CEH peat accumulation rate data will be relevant to the GEST approach (available by Aug 2014, Welsh Axis 2). Link to peatland condition, cross reference with CO2 flux data.
- Mas will send excel sheet to Chris, he will add extra references. Rebekka will send her refs to Chris. Rebekka has offered to run the regression equations (Emily to check). Early draft by 24 Feb; workshop meeting 13th March Edinburgh.

d) Table showing the new, updated 'standard values'.

1.2 WP1(a)ii Future research needs to support the Code

Outcomes from virtual round table: a list of requirements in order to add other peatland habitats to the Code (raised bogs); discuss parallels with the European GEST (could/should fens use European GEST instead of the UK one; would there be gaps/overlaps?) (table format, first column = research need, second column = benefits) MAS to organise early March.

Provide ex-ante carbon estimates to guide potential sponsors. Using five peatland 'states', develop and present a quick way for potential sponsors to appreciate the likely costs, tonnes carbon, and timescales for different types of restoration project – rules of thumb for peatland restoration. This will be aimed at landowners and agents, with photo illustrations, aimed at being user-friendly, and readily comparable with existing rules-of-thumb for the carbon benefits of woodland planting. Summarise in Appendix 1. Dick will draft, building from CCC/LFR note for the Heather Trust annual report; develop in co-ordination with Stephen Prior and Andrew Moxey's outline requirements for their financial model. Draft by end Feb. Need to remember key difference between Woodland Code (which is all about carbon sequestration) and Peatland Code (which is mostly about carbon safeguarded, i.e. emissions reductions; emissions avoided)

1.3 Rules of Thumb for assessing site suitability for Peatland Restoration

1.3.1 Introduction

The aim of this section is to provide straightforward guidance to landowners/agents on how to initially assess a site in terms of its suitability for peatland restoration under the terms of the draft Peatland Code. The objective is to establish whether a site has potential or not, and if so what the order of net GHG emissions reductions might be. Where relevant, any information gathered at this stage can also be used in the completion of the Project Design Document (PDD).

1.3.2 What is the Peatland Code about?

Landowners and land agents in the UK will be more familiar with the **Woodland Carbon Code** than they will be with the evolving draft **Peatland Code,** so it is very important to understand the ***fundamental differences between them***. The Woodland Carbon Code is concerned with ***accounting for the net sequestration of carbon*** within a woodland site. It does not account for any avoided emissions because of any change in land use involved in creating the woodland, nor does it consider other possible co-benefits like biodiversity. The Peatland Code, on the other hand, is primarily concerned with ***accounting for avoided or reduced emissions from the previous land use.*** It is also concerned with other possible ecosystem co-benefits deriving from restoration such as water quality and biodiversity improvements. This is recognised by the fact that **it is called a Peatland Code and not a Peatland Carbon Code!**

The Peatland Code aims to be the **voluntary standard for peatland restoration projects in the UK** that want to be sponsored on the basis of their climate and other benefits. The Code is designed to support funding from businesses concerned with restoring damaged peat bogs primarily through Corporate Social Responsibility (CSR) interests. It **provides standards and robust science to give business supporters confidence that their financial contribution is making a measurable and verifiable difference to UK peatlands.**

1.3.3 A Bog Standard Way of estimating Greenhouse Gas Emissions from UK Peatlands

Peatlands cover about 26,000km^2 in the UK with the majority of them in Scotland. They are our largest store of surface carbon, holding approximately 40 times more carbon than all of the UK surface vegetation combined, including woodlands. This is because, unlike surface vegetation, peatlands have been accumulating carbon over thousands of years. However, it is estimated that around 80% of UK peatlands are degrading and eroding and, instead of capturing and storing carbon, they are presently emitting large amounts of greenhouse gas (GHG).

Restoring degraded peatland is a natural and effective way of cutting down GHG emissions. The amount of carbon that can be saved is significant – one hectare of eroding peat gives off as much greenhouse gas every year as the average UK family. Repairing thousands of hectares of peat can not only provide real benefits through reduction in greenhouse gas emissions, helping us to meet our international obligations to do this, but also can save money through improved water quality and reduced flooding risk downstream.

Before starting any peatlands restoration project, it is important to be able to assess the potential costs and benefits in terms of the actual GHG emissions reductions it might achieve. Because of the time and the instrumentation involved, it is **not cost-effective to directly measure losses of greenhouse gases at every potential project site.** So alternative indirect methods are required, preferably based on more **easily observed features like vegetation, and for which we can use standard values to estimate GHG emissions**.

By analysing all the available data from direct measurements of greenhouse gases over different types of peatland vegetation, research teams in continental Europe have identified what they call **Greenhouse gas Emission Site Types (GESTs)** and derived standard values for the greenhouse gas balances associated with them. They have now used these standard values for greenhouse gas balances to calculate the emission savings for a number of proposed restoration projects across a range of continental European peatland ecosystems. However, these European standard values do not include blanket bogs, which is the most common type of peatland ecosystem found in the UK.

So the continental European GESTs approach has been adapted and improved for use on UK blanket bogs by a team led by the Crichton Carbon Centre in Dumfries (Birnie and Smyth, 2013). This **method uses known relationships between blanket bog ecosystem state, vegetation, physical condition and the major pathways which determine overall carbon balance**. It includes carbon gains (e.g. carbon locked up or sequestrated by peatland vegetation) and carbon losses through both chemical pathways (e.g. gaseous emissions to the atmosphere and dissolved carbon to water), and physical pathways (e.g. loss of particulate carbon through erosion by wind and water).

Five ecosystem states commonly associated with UK blanket bogs are identified. These include blanket bogs that are eroded and/or have been artificially drained. These states can be described quantitatively in terms of their moisture status by using vegetation indicators (so-called "plant functional types"). All the available published measurements of greenhouse gases in relation to these plant functional types have been grouped together and analysed statistically. These analyses suggest that **there are consistent and statistically significant differences between these ecosystem states in**

terms of their greenhouse gas balances. This allows standard values for greenhouse gas balances for each of the five blanket bog ecosystem states to be estimated (Table 5). More information on how these states are identified is provided in the earlier sections and summarised in Table 4.

BLANKET BOG ECOSYSTEM STATE	***Plant Functional Types***	***Main carbon flux pathways***	***Mean standard greenhouse gas balance*** *grams carbon dioxide equivalent ($gCO_2eq/m^2/yr$)*	***Mean standard greenhouse gas balance*** *tonnes carbon dioxide equivalent per hectare per year ($tCo_2eq/ha/yr$)*
1. INTACT or SLIGHTLY DEGRADED	Peat-forming *Sphagnum* mosses	Photosynthesis, Oxidation	**-305**	**SINKS 3.0 tonnes**
2. MODERATELY DEGRADED	Non-shunt species	Photosynthesis, Oxidation	**-123**	**SINKS 1.2 tonnes**
	Shunt species	Photosynthesis, Methane production	**-112 *(uncertain)***	**SINKS 1.1 tonnes *(uncertain)***
3. HIGHLY DEGRADED	Dwarf shrubs	Photosynthesis, Oxidation	**-69**	**SINKS 0.7 tonnes**
4. SEVERELY DEGRADED & ERODED	Bare peat	Oxidation and physical erosion	**+3129**	**EMITS 31.0 tonnes**
5. ARTIFICIALLY DRAINED	Presence of artificial drainage channels typically @15-20m apart	Photosynthesis, Oxidation physical erosion	**+285**	**EMITS 2.8 tonnes**

Table 5 Standard values for greenhouse gas balances associated with peatland condition for the 5 blanket bog ecosystem states summarised as tonnes carbon dioxide equivalent, per hectare per year ($tCO_2eq/ha/yr$).

Because these estimates of standard values for greenhouse gas balances are based on a limited number of direct observations, over a limited number of sites, and attempt to describe highly variable processes, they have to be viewed as ***first approximations and should not be considered as absolute values***. However, it is believed that these estimates are accurate in terms of their relative orders of magnitude. Accepting this proviso, then the key points leading from this work for upland land managers in the UK are:

1. **Intact or only slightly modified blanket bogs are net sinks for greenhouse gases**, capturing around 3.0 tonnes of CO_2 equivalent per hectare per year. In effect they are natural carbon capture and storage systems.

2. **Blanket bog systems that have been modified through grazing and/or burning still have the potential for being net sinks of carbon but this potential is only about 25% of the potential from an un-grazed or un-burned intact bog**. However, this potential will only exist in situations where the blanket bog is not being too frequently burned and/or being excessively grazed by either domestic or wild herbivores.

3. **Blanket bogs that have been artificially drained are generally net emitters of greenhouse gases, losing about the same amount of carbon that an intact blanket bog ecosystem captures**.

4. **Severely degraded and eroded blanket bogs are major sources of greenhouse gases, emitting an estimated 31 tonnes of tonnes carbon dioxide equivalent per hectare per year. This loss is ten times greater than the ability of an intact blanket bog to sink carbon.**

1.3.4 How do you apply these standard values on your site?

This section provides a step by step guide to deriving a baseline assessment of the net GHG balance of a potential restoration site. They should be done prior to attempting to complete the Peatland Code Project Design Document (PDD) and are essentially aimed at establishing whether a site has potential for restoration or not.

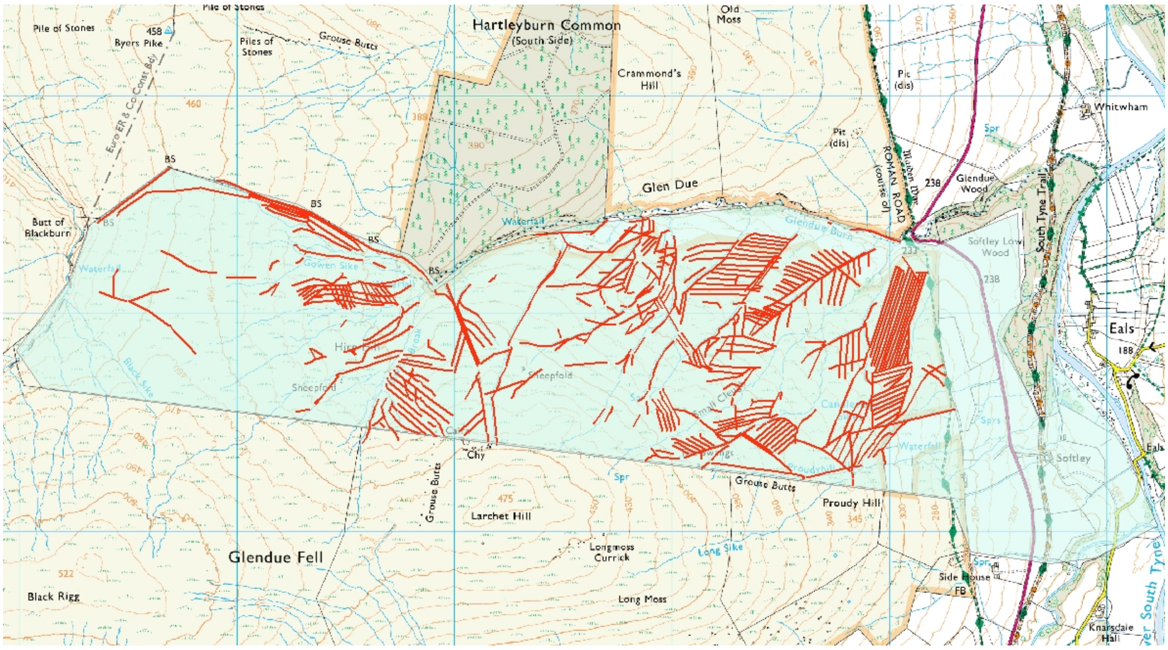
Step 1 ***Definition of the restoration area***

The Peatland Code requires a **consistent and accurate method for defining restoration area**. In this context, it is important to remember that peatlands are wetlands so *site hydrology is one key element in defining the restoration area*. One of the primary purposes of restoration is re-wetting through re-establishing a high water table. Recent discussions hosted by the IUCN UK Peatland Programme have revealed differences between the ways that various UK restoration projects (e.g. Moors for the Future, Peak District; Exmoor Mires Project) calculate the area of peat that has been affected by grip-blocking, and this has initiated further discussions on developing more accurate and consistent ways of measuring peat restoration area.

Three different methods are routinely used in the UK. These are **(a) "buffer" method, (b) "dry shadow" method and (c) the "parcel" method.** These have been well summarised by Paul Leadbitter (pers. comm.) Both the buffer and dry shadow method depend on assumptions about the hydrological impacts of artificial drains in peatland. A common assumption is that drains may only affect an area or buffer up to 10m either side. However, research summarised by Lindsay (2010), suggests that on some sites the impacts of drains (subsidence and water table lowering) may be observed up to 100m from the drain. On sloping sites the interruption of overland flow by drains upslope may have an impact on hydrology up to 400m downslope, thus creating what is termed a "dry shadow" downslope. However, it is *very important to acknowledge that artificial drainage is only one of several factors that impact on peatland ecosystem condition*. Other management factors like burning, grazing and trampling are also important drivers which can lead to drying out of blanket bog sites *even where there is no artificial drainage or grips*.

So, whilst drains and their hydrological impacts are important where they exist, it is not sufficient to define the restoration area solely on the basis of them. The third approach is the so-called "parcel" method (illustrated in Figure 5). This derives from agri-environment schemes like the Higher Level Stewardship (HLS) scheme in England and Wales and in effect applies to a management unit. Leadbitter (pers.comm.) recognises that whilst this approach has some disadvantages (e.g. it might include non-peat areas) its key advantage is that *"it views grip-blocking as being just one part of a* *wider restoration programme across a parcel that could also include changes in stocking rates, burning management or bare peat restoration. Taken together these measures will all contribute to the restoration of the whole parcel."*

Figure 5: Shows the total agri-environment scheme area linked to the blocked grips (area shaded pale green). (c) Crown copyright. All rights reserved DCC. LA100049055. 2013.



Given this, it is our recommendation that **a modified variant of the "parcel" method is used to define restoration area**. **The "parcel" is in effect the management unit in which uniform conditions of stocking and burning apply or can be applied, but the "restoration area" is only that portion of the management unit that contains peat over 0.5m (as defined in the draft Peatland Code).** In some cases these management units will be defined on the basis of stock or deer fences in other areas more pragmatic means of defining "restoration area" may need to be found but in general terms grip blocking on its own without other management interventions (e.g. no burning, reduced stocking) is unlikely to lead yield significant reductions in net GHG emissions.

Step 2 ***Definition of the peatland area***

It is **important to be consistent about the definition of peatlands and peat soils**. However, this is not helped by a situation where there are different soil mapping conventions for identifying peat soils both between the different countries of the UK, and internationally. A comprehensive summary of these different conventions is to be found in the JNCC report on the state of UK Peatlands[6] and the IUCN Commission of Inquiry on Peatlands report[7] both published in 2011, and the main points are summarised here.

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[6] Joint Nature Conservation Committee, 2011. Towards an assessment of the state of UK Peatlands, JNCC report No. 445. http://jncc.defra.gov.uk/pdf/jncc445_web.pdf

[7] http://www.iucn-uk-peatlandprogramme.org/sites/all/files/IUCN%20UK%20Commission%20of%20Inquiry%20on%20Peatlands%20Full%20Report%20spv%20web.pdf

In general terms, there are **three main ways of defining peatlands in the UK, these employ: a) soil-based, b) vegetation-based, and c) geological-based** criteria respectively.

a) Peatlands in the UK have been most commonly identified and mapped on the basis of **soil-based criteria**, all the UK soil surveys defining peat and peaty soil types on the basis of the intersection between %organic matter content and minimum depth, However, the threshold criteria employed vary considerably. Whilst a minimum organic matter threshold of 20% in used in Scotland, England and Wales, 40% is used in Northern Ireland. Whereas **the depth threshold for "deep peaty soil" is >0.4m in England, Wales and Northern Ireland, in Scotland "peat soil" is defined as being >0.5m and "deep peat" is restricted to sites where the peat layer is >1.0m.**

It is to be noted that these types of definitional differences are not unique to the UK, and there have been considerable efforts towards the creation of international standards as exemplified by the **World Reference Base (WRB) soil classification**. This has been adopted by EU institutions to provide pan European soil maps. Like most soil-based systems it uses soil horizons to distinguish between soil types and does not use horizon depth. Whilst there is some correlation with the WRB "histosol" type (>0.4m of peat with 20-30% organic matter content) and the use of "deep peat" in parts of the UK, the JNCC report notes that there is no clear link between other WRB soil types and UK peaty soil classes. It also highlights the fact that soils in the UK have never been mapped with the WRB definitions in mind and the WRB maps for the UK are in fact a reinterpretation and translation of UK national soil maps.

b) Surveys of **peat-forming vegetation** are normally undertaken in the UK for the purposes of biodiversity mapping and monitoring rather than for determining the extent or condition of peat soils. However, in the majority of cases where soil surveys are based on information from soil pits and/or auger samples, the extent of peat units is often interpolated using information on vegetation interpreted from aerial photography. The presence of vegetation dominated by species adapted to waterlogged and generally nutrient-poor conditions and known to be peat-forming, is a useful indicator of peatlands.

There are several important caveats and limitations to this approach. Firstly the absence of peat-forming vegetation does not mean that peat is absent. The opposite also holds true in that peat-forming vegetation associated with deep peat is also found on shallow peaty deposits. So whilst **vegetation is a useful indicator of peatland it is not possible to directly correlate vegetation types with peat depth**.

c) Because of the age of many UK peat deposits the British Geological Survey have considered them to be **surface geological deposits** dating to post-glacial period of the Quaternary. BGS surveys of superficial deposits therefore include peat deposits extending >1.0m below the ground surface, which is the equivalent of the Soil Survey of Scotland definition of deep peat. Uniquely the BGS mapping uses the same criterion to cover the whole of the UK.

For the purposes of the draft Peatland Code, peatlands are defined as those "dominated by peat soils over 50cm deep". It can be seen from the paragraphs above that this definition of "peat" is generally consistent with the soil-based criteria used by the various soil survey organisations across the UK so it would be possible to use their soil maps as a first approximation to the peatland area within a restoration site. However, the available maps are generally from 1;50,000 to 1:250,000. Whilst these map scales are appropriate for reconnaissance mapping purposes, they are not suited to the identification of peatland areas at the more detailed level required for peatland restoration projects. So **whilst existing soil maps may be used for general intelligence purposes, each restoration project will need a peat depth survey to define the peatland area more consistently. The guidance in the draft Peatland Code suggests that these are required to demonstrate an average peat depth**

of at least 0.5m (p.48). However, it the case of severely degraded and eroded peatland which is defined by the presence of erosion gullies and hags, and where peat depth is likely to be highly variable, it is assumed that the average depth criterion applies to those remaining areas of intact peat.

Step 3 ***Identifying assessment units: creation of base map by air photo interpretation***

Aerial photographs provide a more complete representation of ground surface details including vegetation and ground surface features than is available on OS maps, and therefore provide the most suitable base map for peatland restoration projects. Orthorectified aerial photography (corrected to fit the OS national grid) is available for most of the UK via sites such as Bing and Google Earth. It is also possible to obtain aerial photographic cover from the national air photo libraries. Interpreting aerial photography requires a degree of expertise and preferably some familiarity with the ground conditions. Whilst it is desirable to do the interpretation with the aid of a digital mapping, GIS or image analysis system, it should be noted that several of the commercial map sites like Google Earth Pro offer basic GIS tools including the ability to draw lines and/or polygons and computation of lengths and areas. These tools are likely to be sufficient for the needs of most restoration projects.

i) Identify the boundaries of the "restoration area" and these should be plotted on the aerial photo base. Any information on the extent of peatland within the "restoration area" from the available soil survey maps can be added as an additional layer/coverage if this is appropriate for the site. Actual peat depths will be added during the field visit (Step 4).

Penny Anderson Associates (2012) report shows that across a wide range of sites in England it was possible to consistently identify the following categories: burnt, gripped, hagged/gullied (eroded), bare and peat cuttings. These categories correlate with the five peatland states identified in Table 4. The restoration area should be interpreted with respect to these categories. Because the aerial photographs contain a lot of fine detail which is retained as part of the baseline information, the key objective at this stage is to identify units within the restoration area that have similar properties. **This will result in a map showing the main assessment units**. An example of base map for a site in Dumfries and Galloway is provided in Figure 6 below.

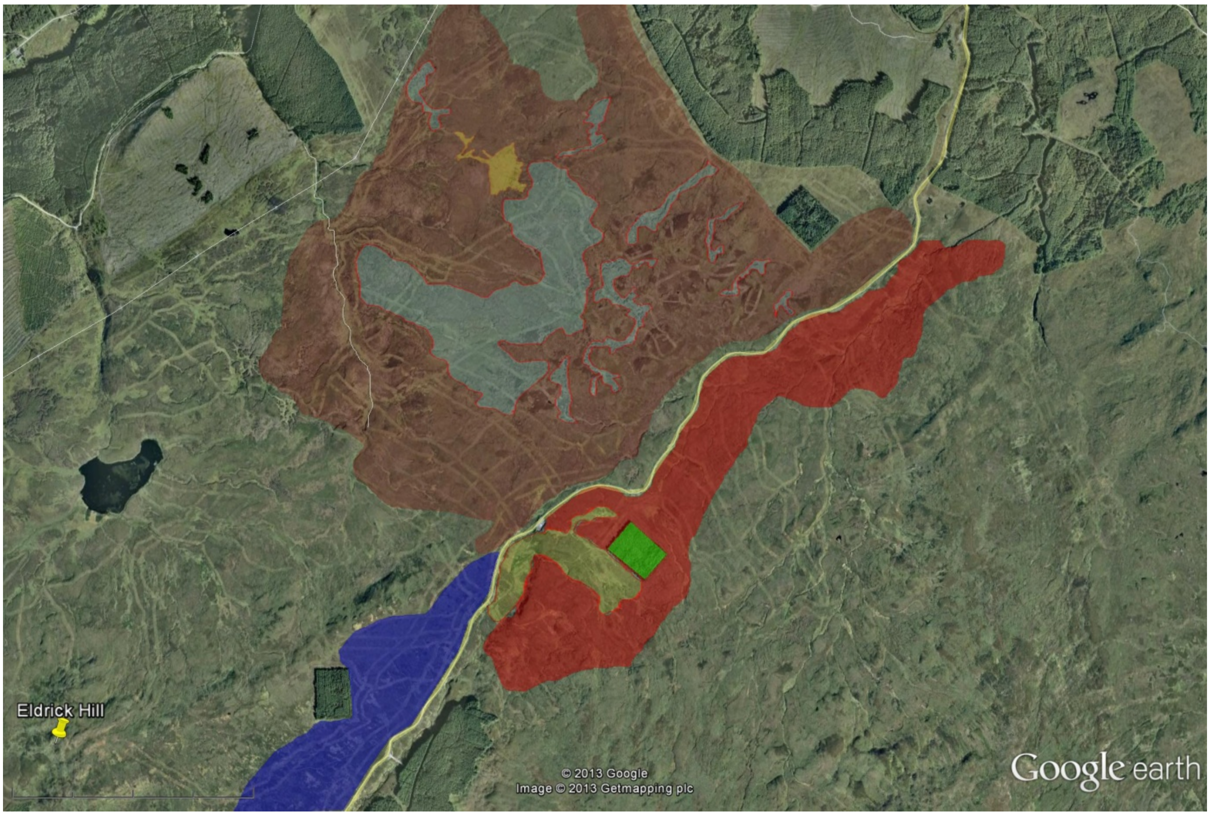

Figure 6. Assessment units identified via interpretation of aerial photography using Google Earth Pro.

Step 4 *Field checking: ground verification of assessment units and peat depth survey*

1.4 Protocols for peatland restoration. Set out field monitoring protocols to monitor GHG benefits (the success of the management actions (ditch blocking, dam failures, fencing/stock proofing etc) to achieve GHG benefits) over relevant timescales (air photos are still not good enough to show re-establishment of sphagnum? Disappearance of heather may be visible). Develop a publically available and user-friendly standardised methodology with associated protocols . Dick to lead, using previous starting points. Draft by end March

1.4.1 Note on the need for monitoring protocols which do not take more than one day per bog, in order to avoid the possibility that the monitoring becomes more expensive than the restoration works. Note on the need for a cost-effective survey and monitoring protocol which has the future potential to be carried out via remote sensing. Note on the protocols required, and when they should be used. These will be developed (in Word) as tick box sheets that can be printed off by projects. *Ask peat restoration projects across the UK to try the protocols – are they user-friendly, do they provide a workable balance of field data/air-photos? Should large areas (100s of hectares, often remote and inaccessible) be treated the same as small areas?* Monitoring is done for two reasons - partly for use in site management (so that management can be altered if needed) and partly to validate the site's carbon impact.. But both need to use the same protocol . Validation check by farm quality assurers In order to be efficient, need minimal monitoring for maximum return/effectiveness. Need to re-survey the peatland to see if condition has changed: but air photos are not yet up to date enough, or standardised, or taken at same time of year, so better to do initiate as a field survey to check wetted length of ditches, recolonisation.. Probably every ten years? Mas met AG to explain derivation of Standard Values and discuss monitoring: because you can't effectively measure the carbon flux itself, you can only measure the measures that have been put in place to manage it (so ensure the site is secure, that management is beneficial, and that restoration is being monitored).

a) Pre-survey decision trees: include land management surety (presence of a conservation covenant/continuation of peatland-positive tenure/ownership), Additionality, etc as per the Peatland Code

b) Mapping the Peatland
Site Description
Site Condition Assessment: Field and air photo mapping to divide the bog into units according to hydrology, topography and vegetation (Plant functional types).
Use GIS to measure the units.

c)Field work: Field survey needs to categorise bog by 'state', while at the same time understand trends. Make rapid assessments of bog state: note:

- bog-moss abundance/predominance;

- bare peat predominance/micro topography; and
- drainage effectiveness (drainage pattern (meandering or parallel/grid); ditch character, ditch spacing and size, % effective drains; % effective dams) (from which the size of the rewetted area can be calculated).
- Peat depths (if required for carbon stock calculation)
- Other site characteristics (peat pipes; gullies, hagging, sphagnum hummocks, flows and pool systems, etc)
- Indicators of grazing, trampling, burning, landuse (as per checklist)

Note which condition (of the 5 conditions) each unit is in.
Note which condition, in the opinion of the surveyor, the unit could be restored to in the lifetime of the project. (photograph nearby non-drained or non-grazed parts of the bog as evidence)
Mas; co-ordinate with Paul Leadbetter's peatland restoration mapping notes.

d) Listing the Risks and noting other site factors. Categorise risks into Low, Medium and High (or %; check with Code). Build check list, include risk of failure of the peat restoration project; risk of severe wildfire; risk of change of land-use, risk of future drought/ non-peat forming climate; etc. Note flailing, off-roading, etc

MAS send Mark Reed's latest docs to Dick, work out if this fits with the Vulnerability/Exposure assessment, and consider as part of the Monitoring framework (since monitoring can tell us whether risks are reducing over time, eg. if fire risk is reducing as the bog is rewetted).

e) Timescales and Scenarios. *Use metric plus expert judgment to predict what the bog would be like in 10, 30, 100 years (check with Code) with no bog repair programme (taking into account present day/ reasonably expected land use, predicted climate change, depth of peat, peat depletion rate, expected success rate of ditch blocking, etc), and compare this with what is expected if the repair does go ahead. Comment on whether the repair is likely to benefit the bog (in terms of biodiversity, flood management, water quality, land-use, wildfire risk)*

f) Summarising the results: table showing the expected carbon effect of restoration at this site.

1.4.2 Summarise in Appendix 2: Decision trees and field protocols for using the metric. Tonnes CO2eq per year

1.5 Report on Piloting the metric: working closely with the Peatland Code Steering Group (of which Defra and the Devolved Administrations are part) to ensure the tool and protocols are appropriately integrated into the Code and tested out on pilot restoration sites.

FIRST TEST IN GALLOWAY, W/C 17th March

1.5.1 Summary on testing the protocol, adjustments made to these tools as a result of testing on restoration sites over the course of the pilot phase; Summary statistics of feedback from pilot projects on carbon metric and methodology.

Appendix 3: Table on feedback from each of 7 Pilots: questions "is the protocol easy to use?" "Did the metric help you measure your carbon impacts?" "Would you consider using this system for future projects?" "Do the predicted outputs concur with measured flux data?"

Table on field visit notes; how the protocol worked; how it was understood, how it was used. Project calculation of carbon saved by the project, CCC estimate of carbon saved: would a verifier come out with the same answers? Notes on how protocol was adjusted in response to the feedback from the project to remove ambiguities and ensure repeatability; note on buy-in from key peatland restoration projects, and acceptance that the system is producing sensible results

1.5.2 Discussion on the results from use of the tools: where in the UK it would appear that peatland restoration is most carbon-beneficial: does this make sense? List of future research needs.

1.5.3 Note on dissemination: webinar, lectures, seminars and workshops provided to various partners and peatland projects.