Interreg Care-Peat

Deliverable WP I3 1.1

Restoration plan of the UK pilot:

Winmarleigh Carbon Farm

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Date	Author	Description
12/01/2020	SJ, ML, JK	Version 1
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Table of Contents

Table of figures

Chapter 1. Introduction

General information

Deliverable number	I3 1.1
Deliverable name	Jointly refined restoration plan
Deadline deliverable	September 2019
Status	Completed
Remarks, changes	The plan is under constant review in order to capture necessary changes as progress proceeds.

Summary of activities

This report provides an overview of restoration process trialled to transition an area of low-productive farmland on a former lowland raised bog to a 'Carbon Farm' designed for the long-term storage [sequestration] of atmospheric CO_2;

The restoration is achieved through raising the water table by blocking drains and the removal of the nutrient and seed rich, organic topsoil that has formed over the peat. The site will then be planted with Sphagnum moss species. It is also hoped that the rewetting of this farmland that adjoins a designated peatland nature reserve will improve conditions and reduce GHG emissions from the nature reserve as well.

Chapter 2. Background

Peatlands are not only habitats with a highly specialised flora and fauna, they also play an important role in global climate regulation. Peatlands are the most efficient carbon sink on the planet - northern hemisphere peatlands account for three to five per cent of total land area but contain approximately 33 per cent of global soil carbon. Therefore, peatlands have a strong natural potential to save carbon and play an important role in nature-based solutions for climate change.

Yet many peatlands are in poor condition through drainage, conversion to agriculture, peat extraction and historic pollution causing carbon that has been stored over thousands of years to return to the atmosphere, contributing to large-scale Greenhouse Gas (GHG) emissions and increased atmospheric carbon dioxide (CO2). These carbon stores are further threatened by climate change which will increase the rate of decomposition. The global annual greenhouse gas emissions from drained organic soils are twice that from aviation.

The restoration, rewetting and sustainable use of peatlands are therefore seen as vital in our battle against climate change and key to achieving the EUs aim to be carbon neutral by 2050.

This pilot is part of the EU-funded Interreg Care-Peat project which is investigating new methods to reduce carbon emissions and restore the carbon storage capacity in European peatlands.

Chapter 3. Aims and Objectives

Peat-friendly land use, which keeps carbon in the ground, will be essential to change current high emissions from peatlands into carbon sequestration sites, so that peatlands can once again play an important role in nature-based solutions for climate change, and help us achieve Net Zero Emissions targets by 2050.

The main objective for this pilot is the change in management of 4 ha of farmland in Lancashire, North-West England, to a ‘Carbon Farm’ designed for the long-term storage [sequestration] of atmospheric CO_2; the farmland will be planted with *Sphagnum* moss for the purpose of storing and protecting soil carbon on the farmland.

The pilot will test the effectiveness of this novel method of farming as a way of managing/restoring peatland to reduce carbon emissions from the peat soils and turn the current carbon source into a carbon sink.

The test site borders a Site of Special Scientific Interest (SSSI) designated lowland raised bog (Winmarleigh and Cockerham Moss Site) owned by Lancashire Wildlife Trust (LWT). The pilot is also assessing the effect of re-wetting this buffer zone farmland area on the functioning of the adjoining SSSI nature reserve and hope to demonstrate the viability of alternative land management techniques on peatland sites in buffer zones adjacent to wildlife restoration sites, and show benefits both in terms of carbon and improvement to the wildlife site.

The UK partners working with LWT include knowledge partners Manchester Metropolitan University (MMU) and Micro-Propagation Services (MPS), who are inputting into the design of the pilot and growing the *Sphagnum* moss required.

3.1 What carbon farming is and how it works:

Carbon farming involves implementing practices that are known to improve the rate at which CO2 is removed from the atmosphere and converted to plant material and soil organic matter. Carbon farming is successful when carbon gains resulting from enhanced land management and/or conservation practices exceed carbon losses. In addition, carbon can be stored long term (decades to millenia) beneficially in soil (carbon sequestration).

Carbon farming covers a whole spectrum of practices from growing cover crops to reduced or no tillage. In the trials at Winmarleigh we are growing a permanent, non-harvested cover crop of specialised bog species (*Sphagnum*), grown for the sole purpose of protecting soil carbon and sequestering further atmospheric carbon.

Carbon farming creates a carbon pump and carbon store - plants in the cover crop pull carbon in from the air and turn it into carbohydrates, which is pumped through their roots in the soil (in the case of *Sphagnum*, which has no roots, carbon is stored in the plant). The plants grow larger and this sets up an ongoing feedback loop that brings more and more carbon into the soil each year - moving carbon from the atmosphere into the soil and retaining soil carbon already present.

3.1.1 Product

The 'product' of the farm is the carbon that is captured in the vegetation and soils, and the reduction of carbon emissions. It is not about harvesting a crop to sell**,** although 'selling' the carbon kept in the soil (carbon offsetting) would provide some income to "Carbon Farmers".

3.1.2 Why grow Sphagnum?

Peat is formed in waterlogged, acidic, conditions, which are very low in nutrients, and only very specialised plants - like *Sphagnum* – can thrive in it, but more importantly for climate change, the carbon in these plants is trapped in perpetuity. As *Sphagnum* moss grows, underlying *Sphagnum* vegetation decays but decomposes very slowly, forming peat, the majority of which is carbon – effectively absorbing CO_2 from the atmosphere and burying it as peat below the *Sphagnum*.

3.1.3 Target areas for such carbon farming:

Poor quality, marginal land adjacent to / in buffers around a nature reserve or SSSI etc. Also degraded peatlands with shallow peat in need of replenishment or building up.

3.1.4 Opportunities

Carbon farming will help to limit future carbon emissions from peat soils and potentially lead to more sustainable systems for farmers that maintain wet conditions, protecting peat soils, reducing CO_2 emissions, cleaning water, benefiting wildlife, sharing knowledge and creating new opportunities. A carbon farming project can contribute to the data UK policy makers (e.g. Defra) need to develop new funding schemes and also demonstrate to farmers what they can do with poor quality marginal land that could bring them greater revenue in the future. It can also help to bring in carbon-related revenue for land that may not fit with current carbon offsetting schemes and help prevent miss-guided planting of trees on peatland, which unlike peat, do not permanently lock up carbon.

3.1.5 Challenges

To be successful, carbon farming may need support from government subsidies or carbon-offsetting schemes. Our project also aims to provide the data needed to be able to devise appropriate funding schemes.

Chapter 4. Location and site description

The location of the pilot site for the carbon farm is situated on an area former lowland raised bog near the village of Winmarleigh, Lancashire owned by LWT (see Figure 1). The land was drained in the 1970s and converted to agricultural farmland used for livestock and winter feed crops. It borders Winmarleigh and Cockerham Moss Site of Special Scientific Interest (SSSI) which is a lowland raised bog, also owned by LWT. Winmarleigh and Cockerham Moss SSSI is Lancashire's best example of a lowland raised peat bog. The site is designated as a SSSI for its raised bog habitat, a habitat of principal importance, as well as for the presence of Bog Bush Cricket and the Large Heath Butterfly. Whilst still supporting some areas of relatively intact bog vegetation (and associated species) other parts of the site have suffered significantly from the effects of drainage. Purple Moor-grass and scrub have invaded parts of the site and have accelerated the drying out of the site. LWT first bought part of the SSSI in 2010 to safeguard the plants and animals, and began restoring the invaluable landscape, and the whole of the SSSI (89.5ha) is now owned by the Lancashire Wildlife Trust, with the majority of the site being managed under a Stewardship Agreement with Natural England.

In 2019, LWT also purchased 20 ha of the farmland immediately adjacent to the SSSI, in which the carbon farm pilot site is located. A large drain sits between the SSSI and the pilot site and removes water from the farmland and, despite piling and other water retention measures, causes water loss on the SSSI raised bog. The field of the pilot site itself is relatively flat and is currently grazed by sheep. Agricultural grasses dominate the field, and although the field is on peat deposits, there is currently a nutrified topsoil of approximately 30cm.

GPS position at the centre of the carbon farm: SD44214808

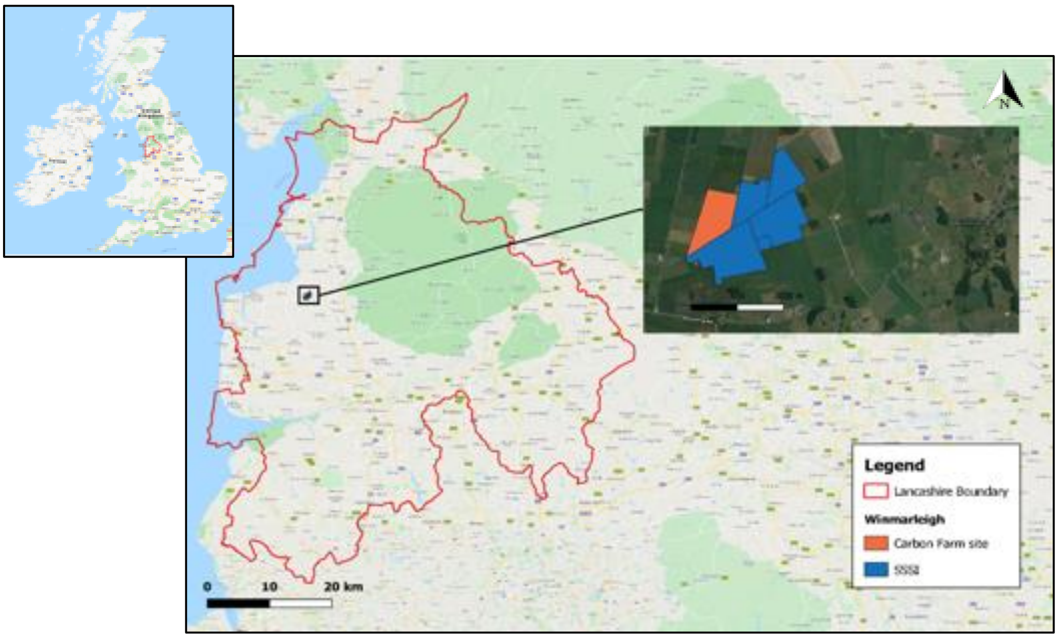


Figure 1: Map showing the location of the Carbon Farm pilot site and Winmarleigh and Cockerham Moss SSSI in Lancashire, NW England

Chapter 5. Site summary and current status

Table 1: Carbon Farm site summary

GPS of the site centre	SD44214808
Size of the site - as a whole and area of the pilot (Ha)	20ha. 4ha of this is being used for the carbon farm pilot (see Figure 2).
Type of peatland	Lowland raised bog, reclaimed as farmland through drainage and improvement in the 1970s. Borders Winmarleigh Moss SSSI lowland raised bog.
Landowner	Lancashire Wildlife Trust
Ownership of surrounding land	LWT and private landowners. Almost all the immediately surrounding land is owned by LWT. The SSSI is owned and managed by LWT, and the majority of the remaining surrounding land, which is currently used for grazing/winter feed, is owned by LWT and managed by a tenant farmer (with input on management by LWT?) Approx. 1 ha (?) of the trial plot will border privately owned farmland, which is managed by a tenant farmer.
Local stakeholders	Stakeholders include LWT and the adjacent landowner, as well as Natural England due to the surrounding area’s SSSI status. Other stakeholders could include local residents and other local businesses/landowners who may be interested.

What is the position in the landscape?	The area designated for the pilot site borders on two sides lowland raised bog habitat designated as SSSI. The rest of the surrounding habitat is farmland used for livestock and winter feed crops.
Current site management	The site was in tenancy until 31st October 2019. For both Livestock and winter feed. this involves e.g. application of fertilizer, cutting the crop, sheep grazing. For the immediate future the remainder of the field not directly impacted by the carbon farm will continue to be grazed by sheep of a local tenant farmer, but with management input from LWT (for example no fertilizer application will be allowed.)
Is the site currently degraded? If so, what activities have caused the degradation?	Used for agriculture. Drained and fertilised.
Is the site impacted by pollution, historic or current?	Nitrogen deposition? Site is approx..60 Miles from Manchester, centre of NW industrial revolution. Surrounding area is agricultural (fertilizer/nutrient application or run-off?)
Avg. meteorological conditions at the site	Average July temp: 19 degrees C Average January Temp: 5 degrees C Average rainfall: 4.99 cm (data source: BBC weather)
Site hydrology / topography	
How wet is the site on a scale of 1-5? 1 representing a firm heathland, 5 representing a Swingmoor floating bog?	Currently 2-3 due to drainage
Is the site currently losing water? Are there any local sources of water that could be used to aid rewetting?	Site is currently drained on 3 levels. Crawley's dyke can be used to help rewetting and locating the drains.
What is the overall site topography?	Area has been levelled due to agricultural usage, although there are deep open ditches.
Does the site have potential for rewetting?	Large areas have potential to be rewet and restored.
Current surveys of topography / hydrology?	Lidar data available. Dipwells installed in 2019. Nearby data available for SSSI
Site vegetation and wildlife	
Current vegetation on the site?	Currently heavily grazed improved grass land with low biodiversity value.
Are there any peat forming species present?	No, but the peat layer is approx. 30 cm from the surface.

Which *Sphagnum* moss are present?	N/A for the pilot site but the local area has 11 species recorded including *Palustre, Frimbiatum, Fallax, Capafollium, Cuspidatum, Magnellicum*
Recent vegetation survey to form a baseline study?	N/A
Does the site support breeding birds or other key fauna?	Water voles present in the ditch system on the perimeter of the site. Surveys carried out to identify locations of burrows.
Peat status and site chemistry	
Current peat depth	Unknown to be surveyed winter 2019/2020
Any bare peat at the site?	No.
Current peat quality/state of decomposition?	Nutrified top soil of approximately 30cm Check Peat core data? From chris
Physical condition of the peat? loose peat, surface crust, evidence of cracking, wastage, slumping etc?	?
Was the peat formed from?	Sphagnum Moss
What is the site pH? Are there any minerals present in the peat?	See below / check data from Chris
Desired state / outcomes	
Desired state and objective for the site	The desired medium and long-term vegetation is for a carpet of *Sphagnum* to form within the carbon form, in order to protect the carbon stocks in the existing peat in the shorter term and sequester additional carbon in the medium to longer term.
What key ecosystem services does it/will it the CF hopefully support post-pilot?	*Climate:* Conservation of carbon fixed in peat and reduction of CO_2 emissions by rewetting degraded peatlands. *Environment:* Reduction of the emission of pollutants into ground and surface water (eutrophication) in comparison to agricultural land use; renewed function of water purification and water retention in peatlands as well as a local cooling effect due to increased water evaporation. *Social & Economic:* Providing income on marginal land to farmers to support the local community. *Wildlife:* Providing habitats for *Sphagnum* species and associated mossland flora and fauna. *Landscape:* Conservation of open landscape.
Is any site monitoring already as part of regular surveys or are any planned?	GHG, hydrology and chemical monitoring is planned as part of the project alongside vegetation surveys looking at species cover

Chapter 6. Design and methodology

The overall plan for this pilot is the change in management of 4 ha of the farmland to a 'Carbon Farm' planted with *Sphagnum* moss and designed for the long-term storage [sequestration] of atmospheric CO_2. It is also hoped that the rewetting of this buffer farmland that adjoins the SSSI will improve conditions and reduce GHG emissions from the SSSI.

This will be achieved through a series of steps:

- Removal of the top layer of nutrient- and seed-enriched soil
- Raising of the water table to re-wet farmland by ditch-blocking and bund creation.
- Creation of water storage areas and irrigation means
- Planting of appropriate mix of sphagnum moss species, using BeadaHumok™ sourced from the sub-partner, Micropropagation Services.
- Low intensity management of site (hydrology/weeds) and on going monitoring of the carbon farm and adjacent SSSI.

Figure 2: Map indicating the location of the 4ha carbon farm trial area within the agricultural field buffering the SSSI.

6.1 Carbon Farm Design

6.1.1 Design process

The carbon farm design has been based on the process explained below:

- Initial site visits to proposed pilot site at Winmarleigh

- Data collection & analysis by LWT and MMU (see Appendix). Includes:
  - Peat condition / depth
  - Nutrient levels
  - Hydrology
  - Topography (see Figure 3).
- Draft plan drawn up for and discussed at September PCG meeting including questions from Care-Peat stakeholders.
- Further draft plan meetings and discussions both internally and with partners and sub partners to revise and refine the pilot design. Also taking into consideration complementary, but separately funded, restoration working taking place on the SSSI in 2020 (see 6.1.4 for details)
- Carbon Farm policy brief drawn up in collaboration with UK partners, outlining aims and aspirations.
- Procurement / tender

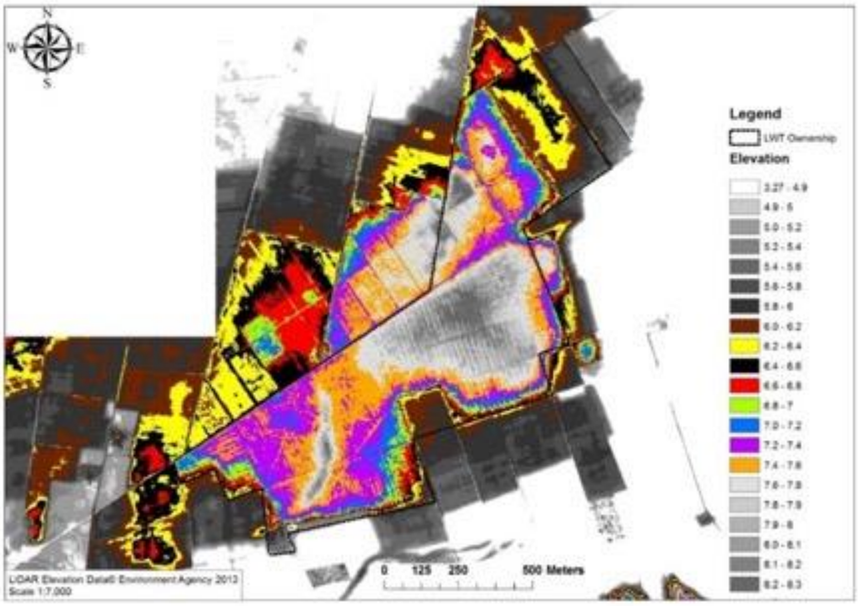


Figure 3: LIDAR data of the carbon farm area and SSSI

6.1.2 Overall scope of design

The farm will be a 2ha area, split using bunding into 8 sphagnum beds approx. 0.25ha each in size, and a water retention area of 1 ha, split into two. Water irrigation ditches will take water from the water retention area to the sphagnum beds (Figure 4).

A further 1 Ha will be used as a control area: Agricultural grassland (left intact, not grazed but we may need to cut, will be rewetted as may not be possible to separate but we will try. Will be located furthest from the irrigation system).

See section Chapter 8 for further details on the challenges and solutions during the design phase.

6.1.3 Investigation of nutrient requirements and removal

4 of the 8 sphagnum beds will have nutrient added at specific levels through the irrigation system and the other 4 cells will not, in order to test the influence of nutrient input on sphagnum growth – and undesired plant spp. (weed) growth. Level of nutrient application will be based on advice from MPS but will be much lower (approx. one-tenth) the level of agricultural application. The SSSI has a higher elevation than the carbon farm so there should be no risk of nutrient run off onto the SSSI. The irrigation system will be set up to keep the nutrient enriched water out of the 'non nutrient supplemented' cells.

All of the carbon farm pilot area will have top soil stripped (see 7.1.1 below for details) - in order to remove excess nutrients from past fertilizer/lime application - with the exception of 2 sphagnum beds, furthest away from the water retention area (see Figure 4). Topsoils will be retained in these two cells and we will grow *Phragmities* (or other crop) in the first year to manage the nutrients before trying Sphagnum colonisation. This is to test whether this would be an alternative method of removing nutrients to the physical removal of topsoil. *Caution: this could enhance the weed problem in other areas and in those cells long term we could end up with a Sphagnum/Phragmities. This would still store carbon though. Obviously, this would delay sphagnum colonisation and associated carbon data in those cells, but we should at least be able to collect data on nutrient removal.*

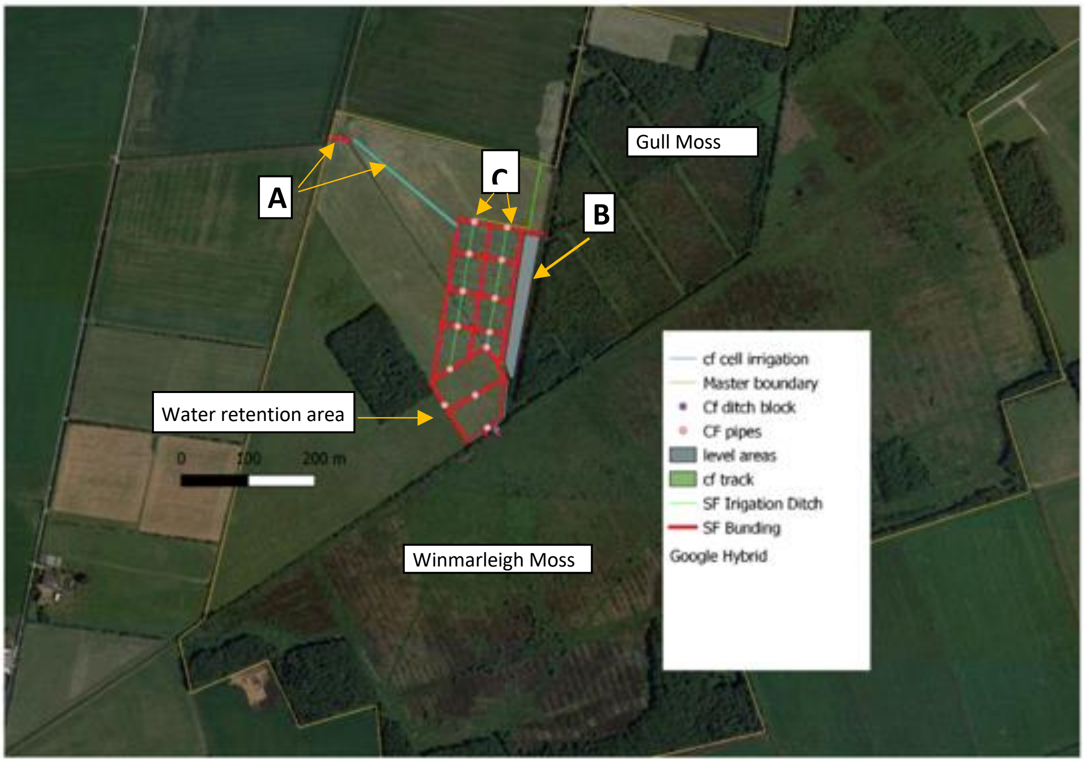


Figure 4: Final design of Carbon farm sent to contractors as part of tender

A. *By enclosing the area fully with the access track and small section of bunding by the entrance we will compartmentalise the lower-lying areas at the north of the field; this will help to start the re-wetting process and help to slow the movement of water which will help in retaining water in the carbon farm area.*

B. *By levelling the areas close to the ditch between the SSSI and Gull Moss we are using the topsoil in the most economical and sustainable way. This will help with the carbon balance as the ditch blocking along this area (as part of the LEF work) will rewet stabilising the peat and minimising emissions.*
C. *Last two cells of the trial area - keep topsoils and grow Phragmities (or other crop) first to manage the nutrients before trying Sphagnum colonisation.*

6.1.4 Capital works on the SSSI

Rewetting and restoration works, separately funded through the Lancaster Environment Fund (LEF) are also planned in 2020 on the edge of Winmarleigh Moss SSSI itself (see relevant maps in Appendix 9.4). The aim of the works is to improve the hydrology of the bog habitat by blocking internal drainage ditches, infilling ditches, inserting plastic piled dams within the ditch system and creating water retaining bunds to raise water levels and promote the growth of bog vegetation.

In total approximately 680m of bunding will be constructed along the northern edge of the ditch that separates Winmarleigh Moss from Gull Moss (see relevant maps in Appendix 9.4Appendix). There is already a corresponding bund on the southern side of the ditch. The bund will benefit in two ways, first it will allow water to back up further into Gull Moss and second, the cross bunds running between the existing and the newly constructed bund to the north will allow water levels within the ditch to be raised up, reducing the hydrological drawdown of water into the ditch.

Although funded separately and for the main benefit of the SSSI, both these restoration works and the carbon farm restoration plans should complement each other.

6.1.5 Work plan

Table 2: Work plan - updates due to COVID19-related delays

Activity	Start Date
Initial site visit to proposed pilot site at Winmarleigh	Feb – April 2019
Data collection & analysis by LWT and MMU. Data includes: 1. Peat core / soil samples taken on site – peat depth, condition, nutrient analysis 2. Hydrological data from dip wells and water samples, 3. Laser level and LIDAR data to analyses ground levels (see Figure 3).	March – Sept (2019)
Draft plan drawn up for and to be discussed at September PCG meeting including questions from Care-Peat stakeholders.	July – Sept (2019)
Further planning discussions within team, with partners and sub partners to revise and refine the pilot design (Sept – Dec 2019).	Sept-Dec 2019
Local landowner engagement to finalise site access agreements; organise any appropriate licenses/consents, check	Sept2019 – Feb 2020
Spec of Works drawn up and tendering process (spec sent out to contractors, tenders reviewed, contract awarded)	Oct 2019 – Jan 2020

Ground prep works (access track creation, topsoil removal, creation of water retention area, ditch blocking, irrigation system creation, cell bunding etc)	Feb – Apr 2020 Update: May 2020
Restoration works on adjacent SSSI	Feb-Apr 2020
Repeat nutrient sampling on carbon farm site	Before planting
Sphagnum planting	Spring / summer 2020 (see 7.2.3) Update: August 2020
Site management (irrigation, weed control etc), data collection and monitoring (see 9.6)	Feb 2020 onwards

Chapter 7. Carbon Farm restoration plan in detail

7.1 Ground Preparation works

(Taken from Spec of Works sent out to tender)

7.1.1 Removal of nutrient enriched top layer & re-profiling (levelling)

7.1.1.1 Background

The area where the Carbon farm is to be developed was part of the existing lowland raised bog habitat until reclaimed for farmland in the 1970s.

The top layer of soil has been enriched from past fertiliser and liming activity when uses for agriculture and will need to be removed as a first step. Surveys have found that the peat approximately 30cm below the surface is in good condition (undisturbed) and the removal of just the top 10 cm should remove the biggest nutrient pool, plant material, seed bank and rooty layer (based on the profile of the peat core and depth of rooty, and humified upper layer); removal of just 10cm rather than 30cm would reduce the volume of top soil needed to be stripped

7.1.1.2 What is required?

The top 10 cm of enriched top layer is to be removed from the 2 ha pilot area. The area of peat underneath will be laser-levelled to create the correct profile for the hydrological requirements.

7.1.1.3 Topsoil utilisation

Removing the top 10 cm of surface soil will result in 3468m_3 of soil. Much of the soil can be utilised as follows (also see Figure 4):

- To create an access track (L, W, H) 200m * 5m* 1.5m.
- Placed between the eastern edge of the carbon farm and the adjacent ditch. The ground slopes down to the ditch in this area and the soil can be used to re-profile the slope. By levelling the areas close to the ditch between the SSSI and Gull Moss we are using the topsoil in the most economical and sustainable way. This will help with the carbon balance as the ditch blocking along this area as part of the LEF work will rewet stabilising the peat minimising emissions.
- Soil below the first 10cm will be used to construct the water retaining bunds.
- The upper 10cm of soil can be used to cap the outer and upper edges of cell bunds to also encourage veg colonisation on the bunds (nutrient from this soil should not leach into the cells). Heather brash taken from Gull Moss to be spread over both the topsoil used in the track construction and levelling. **Update 06/05/20:** Due to Bird breeding seasons we can’t take the heather brash from Gull Moss until August. After consultation with Paul Thomas at Natural England we have decided to use straw to cover initially and add heather brash (using volunteers) once it seeds in the winter. We can repeat this process over the next couple of years

7.1.2 Creation of irrigation ditches

7.1.2.1 Background

To allow for the stabilisation and control of groundwater levels in the *Sphagnum* beds throughout the year, irrigation ditches will be used to feed water from a water-retention area during the summer months.

7.1.2.2 What is required?

604 m of irrigation ditches are required around the *Sphagnum* beds; the ditches should be approximately 0.5 m deep and wide. The ditches must not penetrate the mineral layer beneath the peat. The peat excavated is to be used in the construction of bunds. The irrigation ditches will need to have gently sloping sides

970m of irrigation channels (Figure 4), the channels are to be 30 cm deep and 45 cm wide. There will be 3 channels per cell allowing for water to reach central areas.

See Appendix A

7.1.3 Installation of Overflow Pipes

7.1.3.1 Background

Overflow pipes are installed to control the groundwater level in the *Sphagnum* beds throughout the year to create optimum conditions for growth.

7.1.3.2 What is required?

In total 13 12" overflow pipes with adjustable right angled ends need to be inserted into the bunds/ditch blocks (between the Sphagnum beds and the water retention area?) at the points marked on the restoration map (Figure 4). The pipes will be set so that when fully turned up, the top of the right-angle is just below the level of the bund. The pipes will be set to slope up to the right-angle, to prevent water flowing the wrong way.

7.1.4 Peat Bunding

7.1.4.1 Background

The bunding will be constructed along the western edge of the ditch that separates the agricultural land from Gull Moss (see relevant maps). The bund will benefit in the following way: it will allow water to back up into the new *Carbon* farm area creating good conditions for growth.

7.1.4.2 What is required?

In total approximately 1133 m of bunding is required:746 m to the specification in the Appendix B / Figure 9 and 387 m to Appendix B / Figure 8 specification along the Eastern edge of the farmland adjacent to Gull Moss, the location of each is shown in Figure 4Figure 4: Final design of Carbon farm sent to contractors as part of tender.

A shallow ditch will be dug along the line of the proposed bund. Where the farmland irrigation pipes cross the proposed ditch, these must be blocked with compacted peat. (approximately 1m in depth). Once the area has been re-profiled and scraped clear of vegetation and old degraded peat soils. The peat must be compacted down into the shallow ditch to form a solid peat surface before the bund is then constructed on top. The bund itself must be constructed out of good quality and compacted peat. The surface will need to be sculpted to form a shallow slope. The bunds need to be constructed to 1m in height and 1.5 m in width. The top soil can still be used to cap the outer and upper edges of cell bunds to also encourage veg colonisation on the bunds

7.1.5 Installation of Piled Ditch Blocks

7.1.5.1 Background

As noted under the section on ditch infill, the area a number of large drainage ditches which are causing a drawdown of water resulting in the drying out of the bog surface. The complete infill of the ditch systems is not possible, due to the presence of the protected Water Vole (*Arvicola amphibious*). The installation of ditch blocks will allow the drawdown effect of the ditch to be ameliorated, whilst at the same time providing areas of open water to benefit the voles.

7.1.5.2 What is Required

1 piled ditch blocks will be created. The piled ditch blocks will be 10m in length and 4m wide and should be created using 3m lengths of plastic shuttering inserted into the ground/ditch until the underlying mineral soil is reached. The plastic shuttering will extend into the edge of the ditch by at least 0.5 of a metre. The ditch will then be infilled to 5m out either side of the plastic shuttering (see the specification for ditch infill). Due to the presence of Water Vole within the banks of the ditch, the ditch block must be designed so that voles are not trapped inside their burrows when either breeding or hibernating. The central length of plastic shuttering can either be set at the current water levels the pipe laid on top and a length of plygene sheeting inserted down to the pipe or the pipe can be set the same as the others to the height of the ditch bank, but with a 6inch hole through the shuttering (see Figure 8). A 6-inch diameter control pipes will then be installed along the length of the dam so that water levels in the ditch do not exceed the normal maximum winter levels. These pipes will be blocked by LWT at an appropriate time of year to allow Water Voles to leave the burrows either prior to breeding or hibernation.

7.1.5.3 Working near Water Voles

The fully protected Water Vole has recently been recorded within the ditch systems and there may well be breeding burrows within the banks of the ditch. The Trust will undertake a Water Vole survey of the areas to be infilled/blocked and will identify areas where the works can proceed without affecting breeding voles. Any burrow identified close to the works will be marked by canes and these areas must be avoided and large scale machinery/vehicles must not pass or work within 5 meters of the burrows, unless agreed with by the client and Natural England. Where appropriate safe routes will be identified where machinery can operate.

Table 3: Summary of capital works to be carried

ITEM	DESCRIPTION	QTY	UNIT
	Removal of nutrient enriched top layer & re-profiling (10cm depth). Allow for moving some soil to the side of the carbon farm and create	3	Ha

	general levels. Contractors (OpenSpace) have allowed for a laser level operation for the soil strip.		
	Irrigation ditch creation. Allow for using a V Bucket and laser level on digger to achieve correct depth and gradient.	604	M
	Irrigation channels. Allow for using a V Bucket and laser level on digger to achieve correct depth and gradient	970	M
	Construction of Peat Bund – see enclosed diagram to show likely cross section of area. Agreement will be obtained about the final depth of the ditches. Price allows for laser levelling the bund tops.	1198	M
	Installation of 12” overflow pipes (3m length). Note Contractors have allowed for 300mm twin walled pipe, ribbed for strength and a 90 degree bend per pipe. & levelled in.	13	item
	Ditch Block (installation of plastic piling dam 10m wide as site plan)	1	item
	Creation of access track. Assume the track is 200m long with 5m wide at base and 1.5m high. Allow for 45 degree batter and the track will settle by up to 30% in height over time.	1	item
	Spread heather brash over track and levelled area. Supply and Use native heather brash. Allow for brash to cover about 80% of the area at a depth of 25-50mm with some gaps. NOTE – The brash will have little seed in and the soil will grow weeds. There will be a need for weed control after the heather brash has been applied. *See alternative option proposed by contractor.	0.5	Ha

*Alternative seeding option: OpenSpace suggest an alternative to the heather brash. This based on three factors:

- *Harvesting heather at this time of year will not yield much seed. Therefore, there will be no seed added to the bare soil. This creates a mulched area with no new seed. This will therefore create an area of weed growth.*
- *The soil being used will more than likely be of a neutral pH and relatively high nutrient loading. This soil in our opinion is not suitable for heather growth and would be loaded with weed seed and weed/coarse grass roots.*
- *The alternative option should give a better uptake of vegetation and is cheaper than the heather brash option.*

OpenSpace recommend preparing the soil for both areas, allowing for one weed spray, allow for soil harrowing and sowing a fescue based grass mix which is an agricultural mix. Sowing rate of 25g per m2. If required, the above mix could be a native seed mix but this would alter costs and site preparation/after care. Openspace have not allowed for any aftercare BUT we would recommend this.

7.2 Sphagnum planting

7.2.1 Species mix (updated 06/05/2020)

The *Sphagnum* will be planted in 6 of the 8 sphagnum beds (approx. 0.25ha each in size) in the first year. The remaining 2 cells will first be planted with *Phragmites* and then with the *Sphagnum* once the *Phragmites* has been cropped (6.1.3)

The specie mix and density of S*phagnum* moss to use on the carbon farm have been decided with advice from MPS, who will be providing the plug plants BeadaHumok™ used.

The species used will be the MPS peat forming Yorkshire Mix (SBHYP): mix of

S. capillifolium (30%),

S. palustre (30%),

S. papillosum (30%),

S. magellanicum (5%),

S. subnitens (%5)

This mix has a variety of tolerant hummock-forming species especially *palustre* and once fully covered would be maximise carbon storage.

Once planted the *Sphagnum* plugs will then be covered in (weed/seed and Round-Up free) straw to create microclimate and protect from elements. It is advisable to tread the straw into the ground to stop it blowing away. Nets are the alternative that could be used to secure the straw.

Update 06/05/2020

The species mixes to be supplied for the Carbon Farm have had to be amended due to impacts of COVID 19 and MPS continuing to operate but with fewer staff.

The supply now will be of

SBHYP BeadaHumok™ Yorks Mix (95530 plants)

SBHCH BeadaHumok™ Chunky (55000 plants)

The 2 recipe mixes are very similar so we do not anticipate this alteration creating any issues. The chunky mix may be slower growing, so the two mixes will be distributed evenly across the site to maximise even coverage across the site.

Species	Yorkshire (%)	Chunky (%)
S capillifolium	30	25

S papillosum	30	25
S palustre	30	15
S magellanicum	5	25
S subnitens	5	10

7.2.2 Planting density

8.8 BeadaHumok™ per square meter (Density planted by MPS in sphagnum growing trials with MMU at a raised peat mire at Cors Fochno, Borth Bog. The sphagnum plugs grown in the trials in 2017 grew up to five times in size in 16 weeks)

8 x 025ha plots = 8 x (50m by 50m) = 20,000m = 2 Ha

7.2.3 Planting – method and timings

Planting will be resource intensive (at Little Woolden Moss 3 people managed 2000 plants per day but this is unlikely to be achieved at Winmarleigh due to access etc). Contractors usually quote a rate of 1000 plants/day/person.

The sphagnum will be planted using a mix of staff, contractor and volunteer time, in part by hand and a portion may be planted using a semi-automatic planting system that MPS are developing - see Figure 5: Potential planting machine for BeadaHumoks from MPS below. If it is available, it could plant approx. 25000 (per?)

Figure 5: Potential planting machine for BeadaHumoks from MPS

Update 08/06/2020:

Planting is planned for August 2020, but the timing of planting is dependent on a number of factors, such as when the sphagnum mixes are ready, ground preparation works, weather and resource availability. (At a meeting in Nov 2019, MPS thought the *Sphagnum* could be ready by spring, so the planting could potentially take place in May just after cell creation to keep the time that the surface of the site is bare to a minimum, however due to the delays associated with COVID19, ground preparations will not finish until June 2020. Planting in June and July are out due to pressures on LWT staff from other projects, and also July is generally the driest time of year so not ideal for planting).

7.3 Irrigation of the sphagnum beds

To allow for the stabilisation and control of groundwater levels in the *Sphagnum* beds throughout the year, irrigation ditches will be used to feed water from a water-retention area during the summer months.

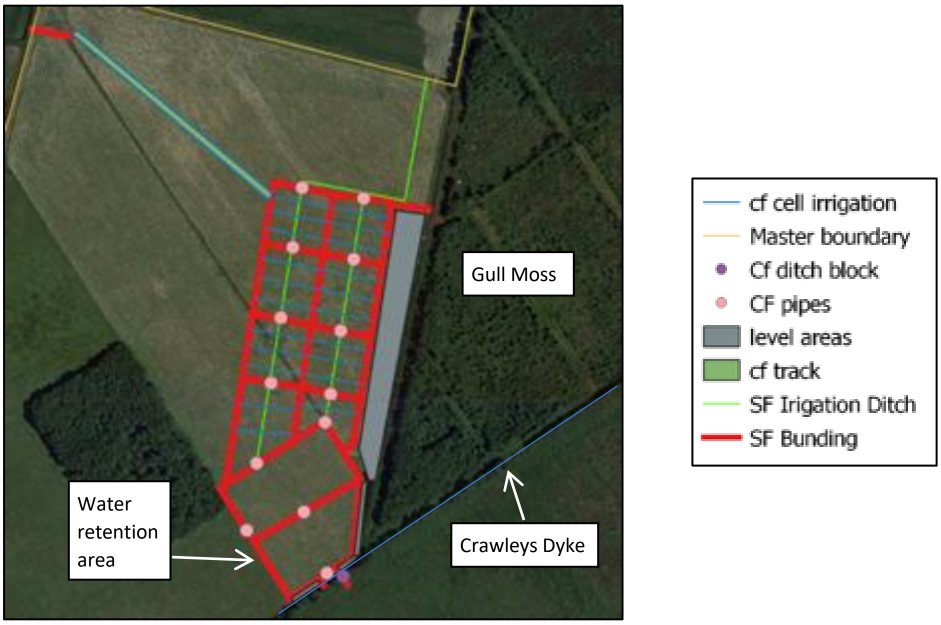


Figure 6: Carbon farm irrigation system design

7.3.1 Water retention area:

A water retention area is being created to supply enough water for *Sphagnum* to survive a prolonged dry period. Ideally be in place in time to capture winter rain.

The location has been chosen based on laser level & LIDAR data during initial surveys, which identified a 'natural bowl', adjacent to the dyke running between the CF and the SSSI (Crawleys dyke) See Figure 6.

Water levels in the retention area will need to be kept below the water levels which would contravene reservoir act (depth?). As such the water retention area is design such that it should provide the ability to manage water from the Crawleys Dyke when water levels are low (during hot weather) and water can overspill when holding too much into adjacent LWT land.

Sump pits are being dug in a hollow in the water retention area which will feed the water into the irrigation ditches.

MPS have recommended, as an insurance policy, installing a small solar back up pump to pump water from the ditch in the water retention area during hot weather.

Update 08/06/2020

Jeojute/coir matting will be installed in the water storage area to protect the bunds eroding (through wave action). This would be installed on one side of the outside bunds and both sides of the inside bund. It only needs to go on the side where the water level will be. The geojute is 1.2m wide and be wide enough for this. It can either be pegged down with biodegradable pegs.

7.3.2 Irrigation system:

Each cell will be irrigated with internal shallow ditches to allow water to reach centre of each 50*50m cell. Solar powered pumps will be used to pump water along each main irrigation ditch.

The Internal irrigation ditches in the middle of each cell will have smaller channels every 15m in each cell, to give more control on water levels between cells.

A float system will be investigated to control water (see diagram in Appendix 9.1.)

In terms of pumps MPS recommend pond pumps powered by solar panels with battery backup would be suitable. Two or three pumps of 80-140 W (to give some redundancy if blockage) similar to the sump pump used by MPS at Little Woolden Moss. Pumps like this running for long periods can pump are amounts of water at low pressure. They can be used to pump water from the ditch if the storage area runs dry and would also be appropriate to pump water from storage to Sphagnum area. Only a modest PV system would be needed to power them.

Update 09/06/2020:

A Lorentz Solar Surface Pump System and bilge pump system are to be installed. A solenoid control system will also be installed, which will control the flow and level in each individual cell. The solenoid system is designed to maintain the level of water within each cell. Float systems will be linked to solenoid control valves which will allow flow of liquid and engagement of pump based on level in each cell. A PS Communicator 3G Communication device is also being installed for remote monitoring and management of LORENTZ Pump Systems.

7.4 Monitoring

The site of the Carbon Farm is relatively isolated and not very easy to access, but particularly during periods of extreme weather (drought/heavy rain) the site will need to be closely monitored. Environmental data loggers will be used to monitor the site remotely via a web platform or connected to directly via GSM.

Include info (from MMU) on monitoring plans on carbon farm site and SSSI?

Include info on nutrient analysis we have already from MMU?

7.5 Access and Grazing

LWT do not own the access track to the carbon farm pilot site; therefore, it has been necessary to reach an agreement on access with local landowner Joe Davis (JD) (who previously owned the carbon farm field) from Birch house farm Gulf Lane Winmarleigh (SD445494):

It was agreed that the LWT could use the access track for 3 years initially, in return for JD to continue grazing in agreed areas (See map in Appendix E: Map of grazing agreement and access track9.5). The area currently covers approximately 11ha.

It was discussed that the areas highlighted for grazing may change when further funding comes online and that the amount of grazing available would diminish over the next few years, since the hydrology of the area will change over the period LWT carry out work and this may affect the area able to be grazed. Areas could be pulled from grazing by LWT starting in spring 2020. (Area 'Grazing 2' on map (in 9.5) most likely to come offline first.) The grazing and access will be reviewed every 6 months, by both the LWT and JD.

It has been agreed that the graziers will not apply fertilizer to enrich the grass sward in these areas; they will also erect appropriate fencing to keep sheep out of the carbon farm pilot area.

Chapter 8. Issues and solutions during the design phase

There have been a number of challenges to overcome during the design of the Carbon Farm, detailed in the tables below. These challenges were in part due to constraints of the pilot site location itself as well as the limited time frame of the project.

In the business case study, we will explain the methods we are using in our trial farm, and constraints we had to work within, solutions we found, and set out the alternatives for farmers/other land owners to mitigate these constraints – e.g. soil inversion or nurse crop cultivation instead of top soil removal; use of the top soil removed (sale or utilisation on other land), heat/steam treatment to reduce weeds.

Table 4: Issues encountered during research & design phase of Care-Peat Carbon Farm

Area	**Issue(s)**	**Solution(s)**	**Chosen & why**
Location	Choosing the correct location for trial plot. Including proximity to SSSI and accessibility. Birch House Farm fields Winmarleigh.	1. Two areas in buffer zone bordering on SSSI. 2. One is centrally located for good access.	Option 1. The area chosen borders the SSSI and access is by farm track. Permission granted to use track during trial. See **Fout! Verwijzingsbron niet gevonden.**
Drainage	The field. There are two sets of drains used by previous landowner to remove water from the field.	Block both sets of drains where bunds partition growing cells. Block one set of drains using upper to help irrigation	Block both sets due to being difficult to complete a circuit due to cell design. Former landowner (JD) to provide a plan of site drainage to help with blocking.

Area	Issue(s)	Solution(s)	Chosen & why
Water retention area	Location size & depth to supply enough water for *Sphagnum* to survive a prolonged dry period. Be able to plan work to capture winter rain.	During survey work a natural bowl was identified by laser level & LIDAR data. Options were down to deciding if we needed enough storage to contravene reservoir act.	To stay below water levels which contravene reservoir act, and to design the area so there was the ability to manage water from Crawleys dyke when short and overspill when holding too much into adjacent LWT land. MPS recommended the following: a small solar back up pump to provide a good insurance policy on water levels in hot weather
Irrigation and pump systems	MPS recommended that each cell needed to be irrigated with shallow ditches to reach centre of each 50*50 cell. With pumps used to pump water along each main irrigation ditch.	1. Outer irrigation ditches. 2. Internal irrigation ditches in the middle of each cell with smaller channels every 15m in each cell.	Option 2 was chosen to give more control between cells; a float system will be investigated to control water (see appendix 1.) In terms of pumps MPS recommended pond pumps powered by solar panels with battery backup would be suitable. Two or three pumps of 80-140 W (to give some redundancy if blockage)
Topsoil	Removal of top layer that MMU sampling showed to have high levels of nutrients and Calcium. This needs to be kept wet and used within LWT land to minimise carbon emissions and keep with in EA waste regulation. Also, volume to be removed.	1. Use to fill in ditches bordering SSSI. 2. Use to help stabilise hydrology, level areas around Carbon farm and improve access. Exposed peat to be covered in brash to minimise emissions.	It was chosen to remove the top 10cm as this would cut down on volume of soil to be managed. (This was done with advice of partners). Excess soil could not be used in ditches due to water vole presence. So the decision was made to manage top soil as highlighted in option 2

Area	**Issue(s)**	**Solution(s)**	**Chosen & why**
Sphagnum Mix	Which *Sphagnum* species would best to colonise the bare peat and the quickest to maximise carbon sequestration. This depended on chemical analysis and availability.	1. Specific *Sphagnum* mix for area chemistry & maximum colonisation. 2. Pre-made mix recommended by MPS including Species: MPS peat forming SBHYP: mix of *S. capillifolium* (30%), *palustre* (30%), *papillosum* (30%), *magellanicum* (5%), *subnitens* (%5)	After consulting with partners and checking availability, the highlighted mix was chosen from option 2. This has a variety of tolerant hummock-forming species especially *palustre* and once fully covered would be maximise carbon storage. Once planted the *Sphagnum* will then be covered in (weed/seed free) straw to create micro-climate, and protect from elements.
Day to day Monitoring & Management	The isolated location of the site and difficulty to access; during periods of extreme weather (drought/heavy rain) the site needs to be closely monitored.	1. LPI & Care Peat project team to monitor every couple of days. 2. Environmental data loggers to be set at levels for both too much and too little giving officer's time to react. The data can be accesses via a web platform or connected to directly via GSM, allowing water levels to be monitored remotely.	Option 2 was chosen as it allowed close monitoring remotely levels would be set to give officers enough time to react.
Weed control	Weeds have proved to be an issue in smaller trials slowing down colonisation, especially once nutrients are added.	1. Chemical through pesticides. 2. Manual weeding 3. Machine- Topping with strimmer	Areas owned by LWT will be managed to minimise weed input as much as possible. On the Carbon farm trial area weeds will be topped before seeding to control. As in option 3.

Area	Issue(s)	Solution(s)	Chosen & why
Nutrient input	To encourage the colonisation of *Sphagnum* mix a measured nutrient input has been suggested by MPS. This is a concern due to proximity to SSSI.	1. No Nutrient input 2. Measured nutrient input in all cells. 3. Measured nutrients to be trialled on one cell row furthest away from SSSI.	Soil chemical analysis to be done once top stripped to understand chemistry and nutrient levels present. Then option 3 to monitor and report best practice. This to be inputted at pump stage so only targeted areas receive additional nutrients.
Planting & density	Planting needs to be done between May 20 and September 20. Weather and hydrology dependant. £10,800 in kind volunteer contribution. Access is difficult for volunteers approx. 20 min walk in and out. The Beda Hummock turnaround from delivery to planting max 7 days.		Planting density £82,500 BeadaHumok™ cost 0.47p This will provide 175,530 BeadaHumok™ Species: Our peat forming SBHYP 8 plots of 50m x 50m = 20,000 = 2 Ha Equals 8.8 BeadaHumok™ per square meter (see figure 3.) A mixture of professional volunteers £150 per day and contract workers to plant. Deliveries to be spaced out based on 5 days of planting. 25000 hummocks to be planted by trial machine see fig 2.

Chapter 9. Appendix

9.1 Appendix A: diagram of irrigation system

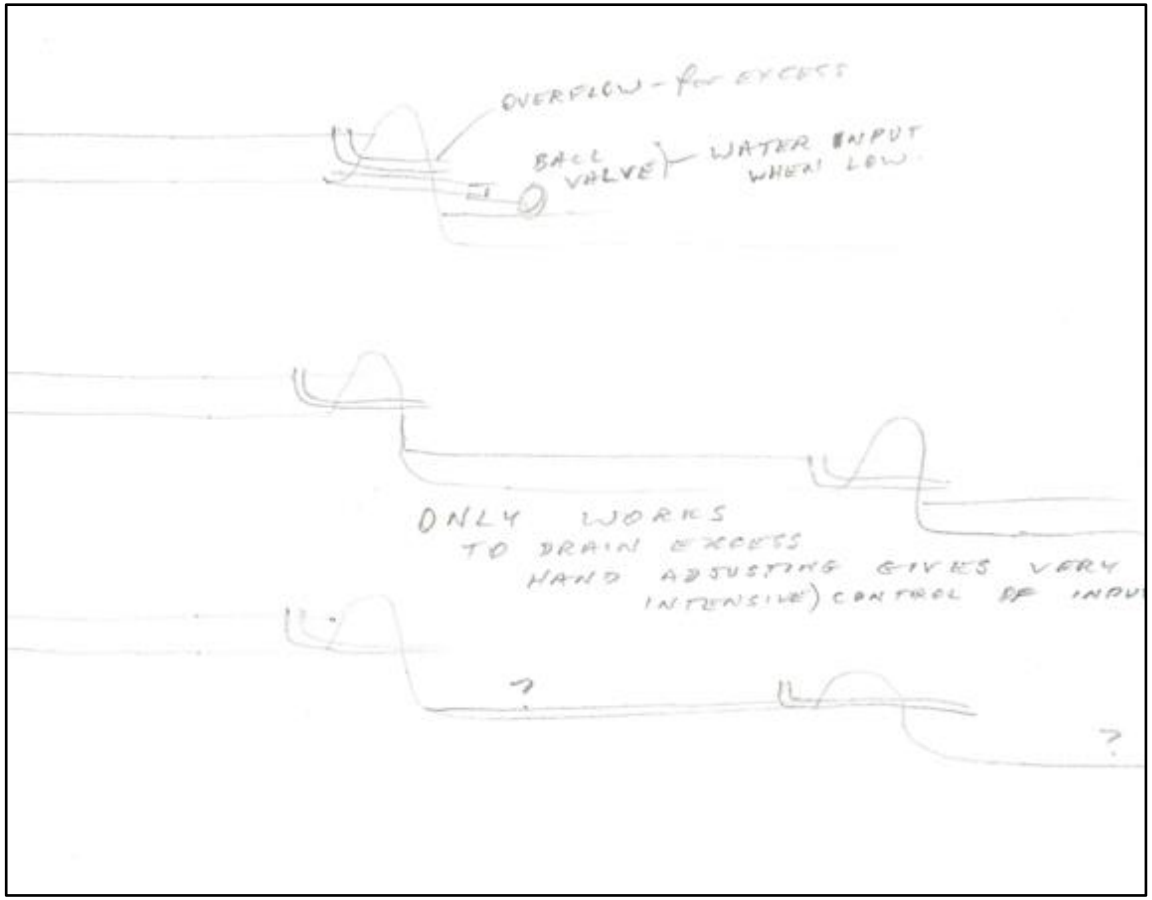


Figure 7 Irrigation System

9.2 Appendix B: Diagrams of a typical and profiled bund

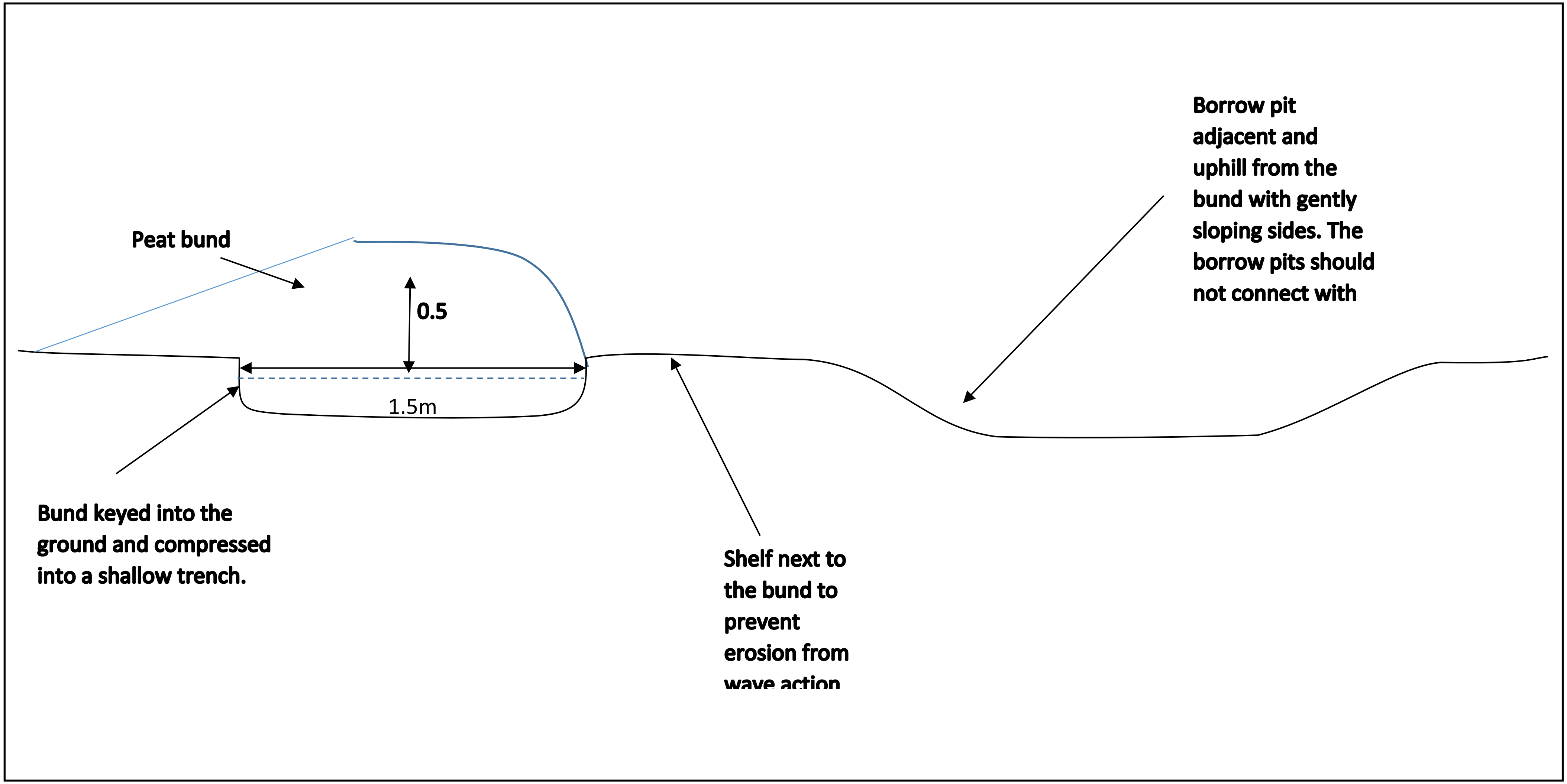


Figure 8: Profiled bunds.

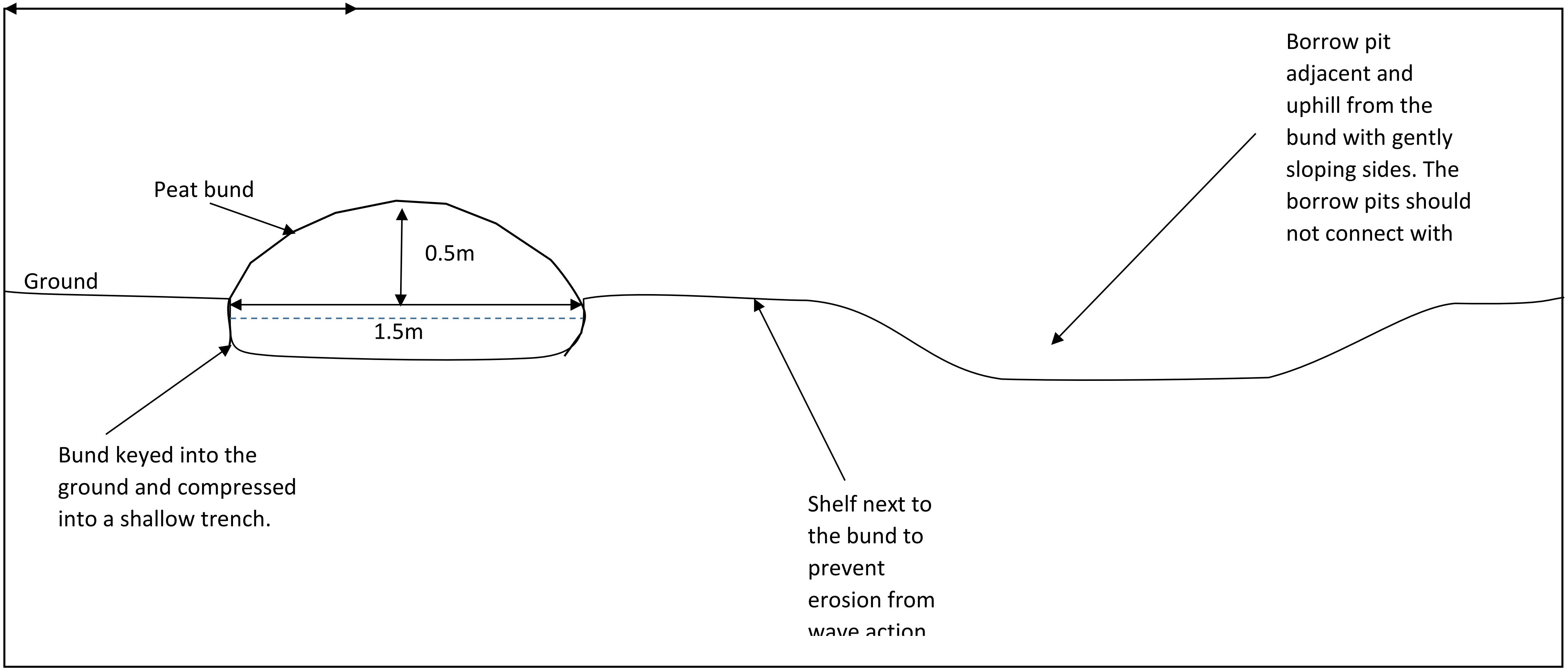


Figure 9: Typical specification of a peat bund

9.3 Appendix C: Budget

Budget?

9.4 Appendix D: LEF works on SSSI

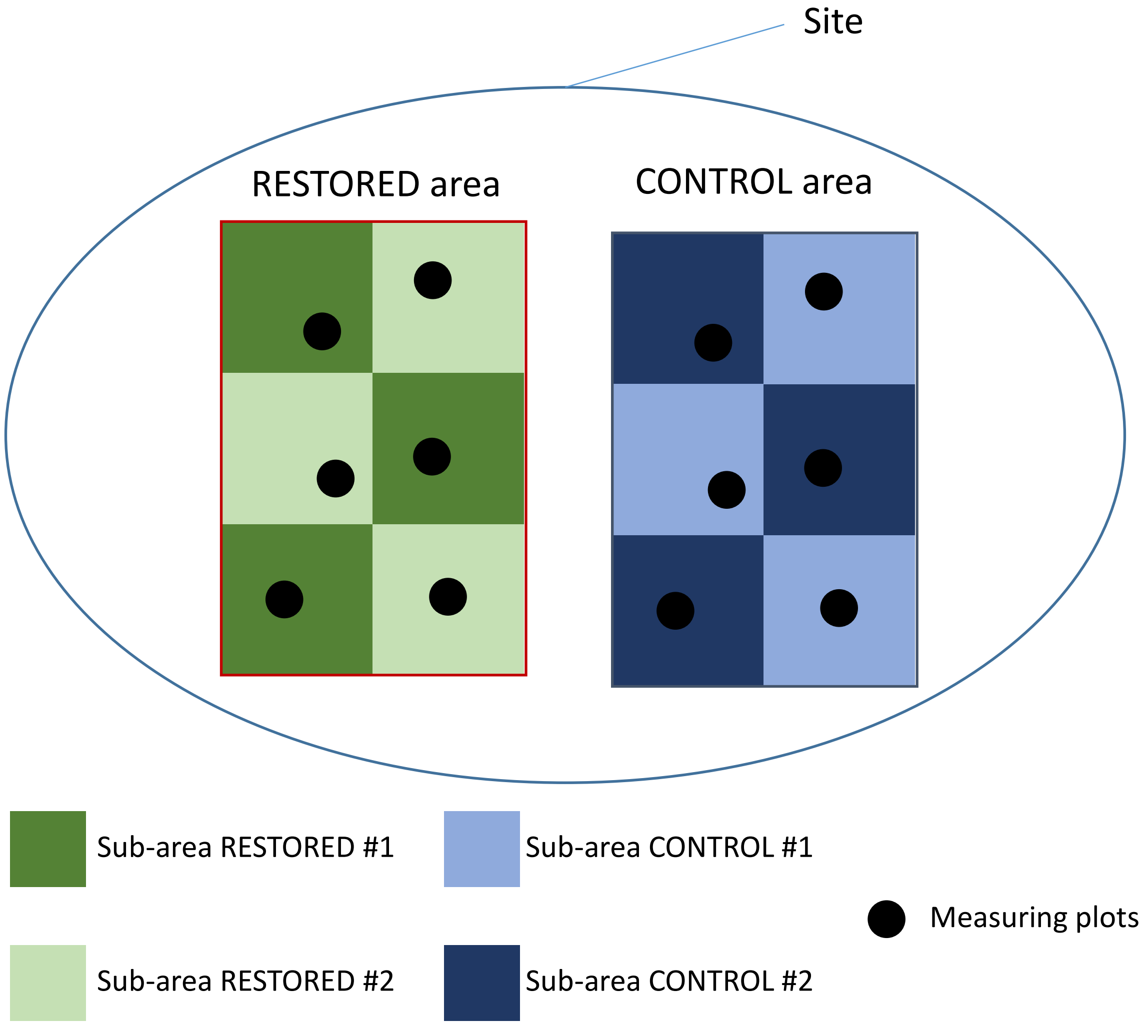
LEF works on SSSI maps?

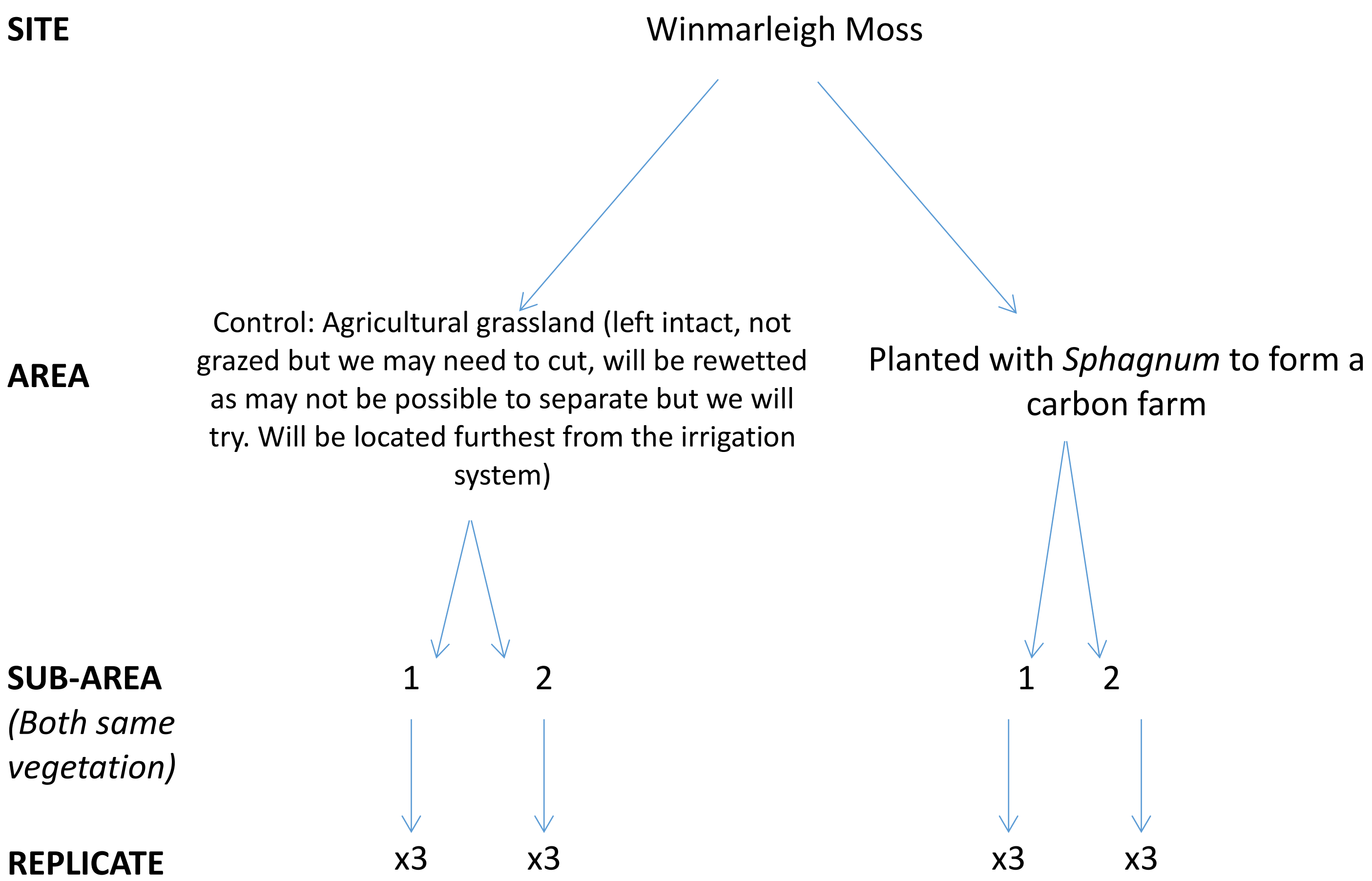
9.5 Appendix E: Map of grazing agreement and access track

Figure 10: Map showing agreas that will continue to be grazed in the shorter term and also the access routes to the CF

9.6 Appendix F: MMU monitoring plan

Monitoring plan from Chris Field MMU





As LWM, each replicate is a separate collar.

We hope to make addition flux measurements in an adjacent rewetted peatbog to see if the drain improves the situation