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Cloncrow Bog Restoration Case Study

REPORT

Cloncrow Bog Restoration Case Study

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Description of Site

The Cloncrow Bog pilot site is part of a Natural Heritage Area (NHA) located 2 km northwest of the town of Tyrrellspass, County Westmeath, Ireland. The entire NHA is approximately 230 ha while the project pilot site focuses on approximately 33 ha within areas of formerly drained high bog (26 ha) and cutover bog (7 ha). The pilot site was impacted by over 28,000 m of extensive ditching in the high bog and cutover as well as legacy effects of from conversion to agriculture and bog cutting. This scenario provided an opportunity for restoration works to be included as part of the initial project proposal.

Cloncrow Bog is situated within the midlands region of Ireland, an area characteristic of raised bog formation. Current land-uses adjacent to the NHA and pilot site include active peat extraction to the east of the high bog margin and afforestation on both the high bog and the cutover. Areas of cutover have been reclaimed for agricultural purposes to the north and west of the site and the grassland is used for grazing. Damaging activities associated with these land-uses are primarily from drainage of the high bog. All activities that have resulted in a reduction of bog area and substantial lowering of the water table.

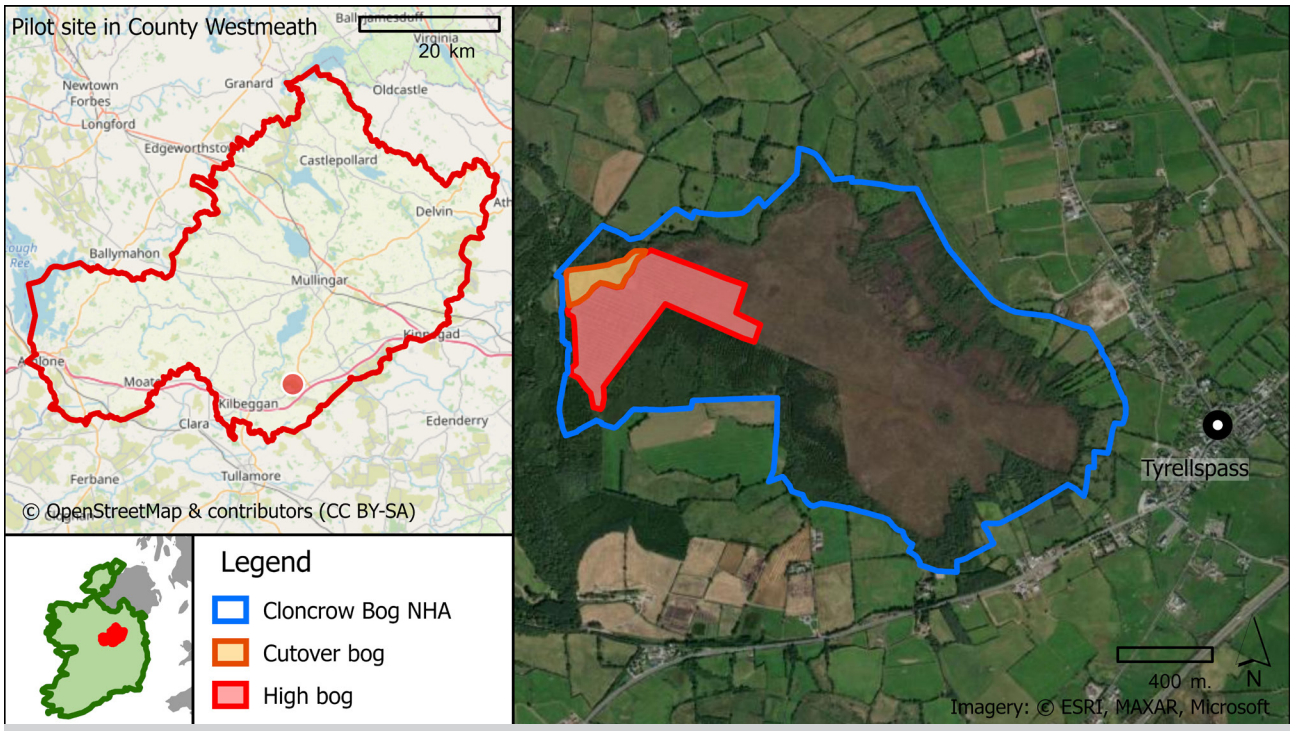

Figure 1: General area of Irish pilot site. (Image: QGIS, Open Street Map, University of Galway)

1.1.1 Land Ownership

The National Parks and Wildlife Service (NPWS) is one of several landowners on the site and are a sub-partner on the project tasked with the restoration planning, implementation, and oversight. Plus Monitoring. The state forestry company (Coillte) also owns a portion of the site in the southern end of the NHA, while the remaining sections are comprised of degraded cut over bog in multiple private land ownership. The NPWS has previously been negotiating with landowners for purchase of the lands to the northwest of the site. NPWS continues engaging with adjacent landowners in order to make progress implementing the entire NHA restoration plan.

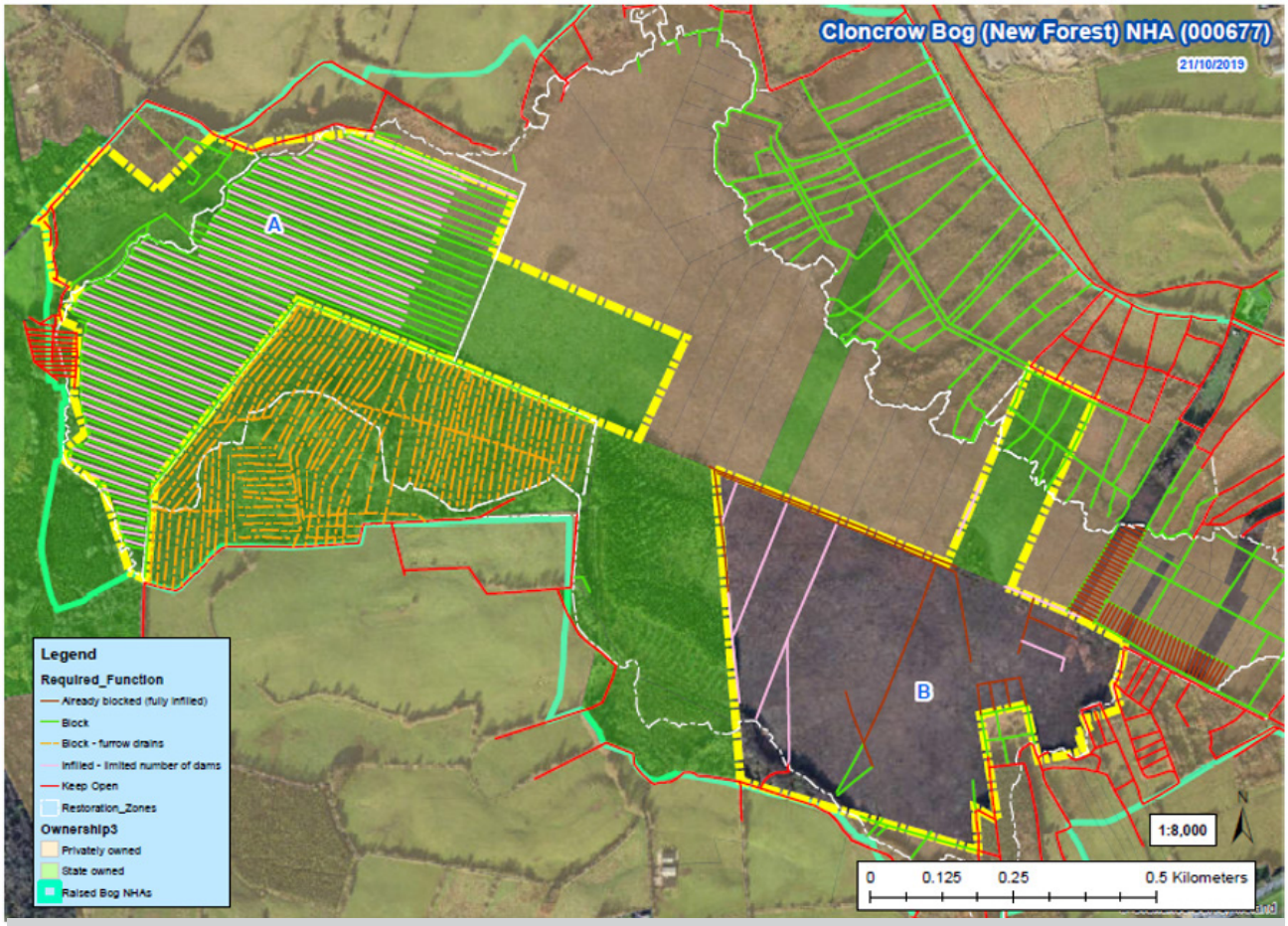

Figure 2: Overview map of the entire bog complex with project area highlighted as part 'A' (Source: NPWS)

1.1.2 Existing Conditions and Impacts

Historically, the primary impact to the site is physical degradation from physical drainage and turf cutting, land reclamation, and conifer plantations. Nitrogen deposition from surrounding intensive agricultural activity can cause pollution effects on adjacent bogs but this issue has yet been recorded at Cloncrow Bog. Currently, restoration focuses on reducing impacts from these legacy activities. Former peat-cutting has entirely ceased at the site as a result of its designation as an NHA, however, areas of cutover have been reclaimed for agricultural purposes around the site.

The entire high bog was peat forming and thus supported Active Raised Bog (7110 EU Habitats Directive code) at some stage before cutting and drainage was initiated centuries ago. In addition, all natural lagg zones surrounding the bog have been lost. Currently the presence of Degraded Raised Bog (7120 EU code), which is capable of regeneration to Active Raised Bog, indicate that the bog is currently degraded and that there is a possibility to restore the conservation condition of the site.

The peat within the project area is relatively intact but has suffered drainage and drying as a result of the ditches. Heather (*Calluna vulgaris*) has taken over in the drained areas of the bog and *Sphagnum* development is impeded due to the impaired eco-hydrological status of the project area.
At piezometer installations in 2019 we encountered peat depths ranging from 3.35 m to 8.4 m with the deepest portion at in the undrained high bog area.

1.2 Pre-restoration monitoring and Habitat Assessment

Much of the high bog has vegetation typical of a degraded Midlands Raised Bog. The northern half of the bog is firm but wet and with a hummock/hollow microtopography, while in the southern and eastern sections the bog is wetter and spongy with good hummock/hollow microtopography, pools, inter-connecting pools, quaking areas and a flush. The site supports such species as Heather (*Calluna vulgaris*), Common Cottongrass (*Eriophorum angustifolium*), White Beak-sedge (*Rhynchospora alba*), Bog Asphodel (*Narthecium ossifragum*) and a range of bog mosses including *Sphagnum austinii, S. pulchrum, S. beothuk*, and *S. cuspidatum*. Midland Raised Bog indicator species include Bog-rosemary (*Andromeda polifolia*) and Cranberry (*Vaccinium oxycoccos*).

Prior to restoration, 20.5 ha of ditched high bog were mapped by William Crowley and Fernando Fernandez[1] in. Only 0.85 ha of the area surveyed were classified as sub-central ecotope, which corresponds to Habitats Directive (92/43/EEC) Annex 1 priority habitat Active Raised Bog (ARB) (code number 7110) and the only vegetation type within the high bog area deemed to function as a carbon sink at the site. The rest of the ecotopes mapped were deemed to be CO_2 emission sources. The extent of facebank ecotope within the site, which is characterised by tall, robust C. vulgaris and corresponds with the highest seminatural vegetation type CO_2 emissions source on a high bog, was particularly high (10.4 ha). This was the result of the dense network of drains within it. Cutover areas were also mapped based on the Irish cutover vegetation classification[2]. The survey mapped 0.34 ha of high *Sphagnum* content (>40 % cover) vegetation types. Only 0.15 ha were deemed to correspond with ARB (7110), the only high *Sphagnum* content cutover types that have been reported so far as CO_2 net sinks as reported by Swenson[3] et al. (2019).

[1] Fernandez, F., Fanning, M., McCorry, M. & Crowley, W. (2005) Raised Bog Monitoring Project 2004-5. Unpublished report, National Parks & Wildlife Service, Department of Environment, Heritage and Local Government, Dublin.

[2] Smith, G.F., Crowley, W. (2020) The Habitats of Cutover Raised Bog. Irish Wildlife Manuals 128, NPWS, Department of Housing, Local Government and Heritage, Dublin, Ireland, 73 pp.

[3] Swenson, M.M., Regan, S., Bremmers, D.T., Lawless, J., Saunders, M. and Gill, L.W., 2019. Carbon balance of a restored and cutover raised bog: implications for restoration and comparison to global trends. Biogeosciences, 16(3), pp.713-731.

Table 1: Vegetation classifications (ecotopes) and relative area on the raised bog pilot area during initial surveys.

Ecotope	Area (ha)	Percent of total
Facebank	11.3	46
Submarginal	6.7	27
Drain	3.4	14
Marginal	1.9	8
Subcentral	0.9	3
WD4	0.3	1
TOTAL	**24.4**	**100**

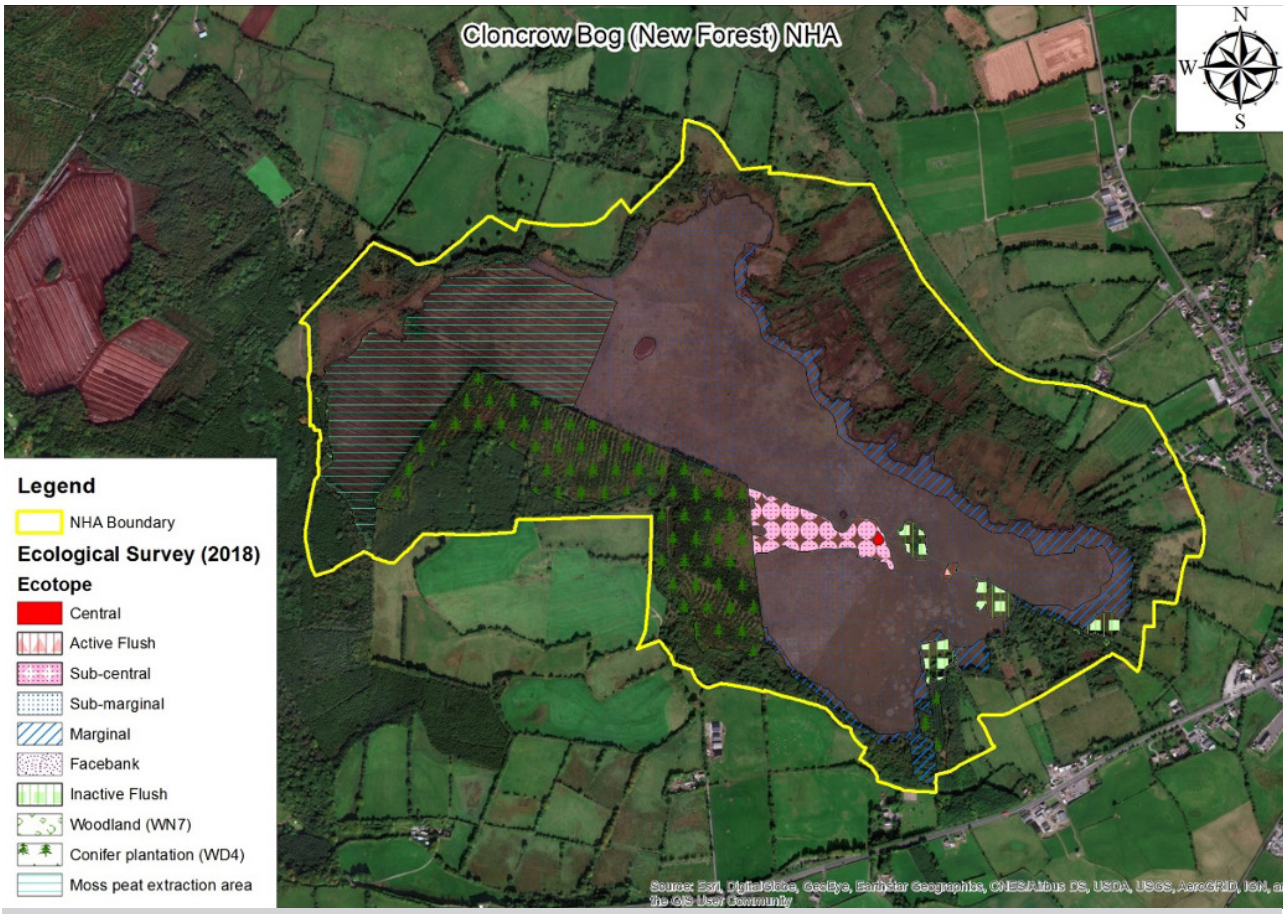

Figure 3: Ecological Survey of Cloncrow Bog in 2018 as part of baseline surveys for all Natural Heritage Area sites

Figure 4: General state of pilot site before restoration (Source: Dr. Terry Morley)

Figure 5: Initial aerial image of degraded bog (Source: Google Imagery)

1.3 Restoration Planning

A Degraded Raised Bog (DRB) (7120 EU Habitats Directive Annex code) ecohydrological model has been developed by NPWS for Irish raised bogs (NPWS, 2014). This model is based on a NPWS restoration plan for the entire NHA in 2017. This was part of an ambitious programme to restore habitats within the network of designated raised bogs (SACs & NHAs).[4] The model predicts the distribution of those high bog areas which could be turned into ARB (7110) within less than 30 years if restoration works are implemented. An ecohydrological model was also developed for potential peat forming habitat (PFH) areas on cutover by NPWS (2018). Some of these cutover areas have the capacity to develop into embryonic ARB if restoration works are implemented, but it will take longer periods of time (50-100 years) for this priority habitat to develop. The ecohydrological models at Cloncrow Bog have predicted that nearly 1.5 ha of high bog could support ARB and 1.1 ha of cutover is likely to develop PFH, as a result of restoration works implemented at the site.

Based on this the NPWS, with consultation from the Care-Peat partners via site visits in September 2019, developed a restoration action plan. This included new bunding restoration measures not initially conceived in the application and resulted from international knowledge exchanges during the course of the project. As part of the Care-Peat project we also surveyed the pilot site with UAV/drones to assist with restoration planning.

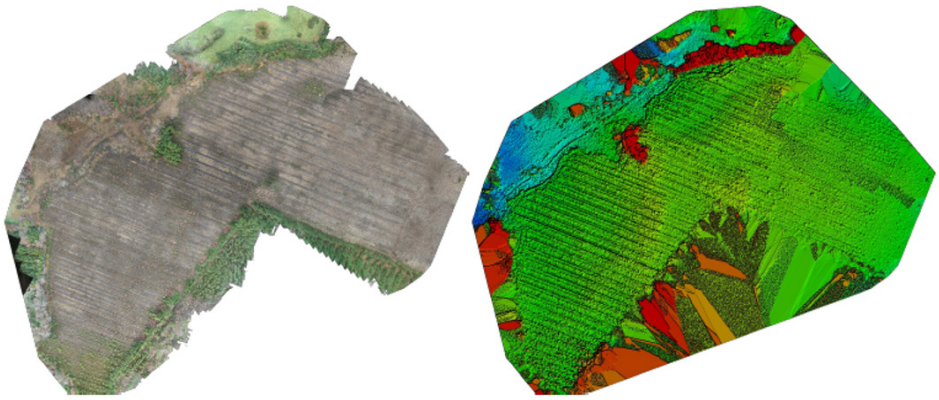

Figure 6: Orthomoasic (L) and digital surface model (R) of pilot area of Cloncrow Bog (Source: Dr. Eugene Farrell).

The restoration plan was further discussed with the partners in January 2020 (telecons) and February 2020 (PCG meeting). Sub-partner NPWS has gained significant benefits from taking part in this workshop (and also from attending the start conference in June 2019). This has resulted in considering additional measures into the restoration activities at the pilot site and added approximately 4 ha of new works to the project. Restoration works were only slightly delayed due to COVID (from Spring to Autumn 2020). Restoration best practice calls for blocking the existing drain network (Figure 2) with earthen dams at a ratio of 1 dam for every 10 cm rise in elevation. This was completed by diggers and resulted in some exposed areas of bare peat which were used as experimental areas from which we will use *Sphagnum* transfer from the adjacent raised bog area.

[4] more info, follow this link

1.3.1 Restoration Works

Table 2: Restoration Works, drain blocking and bunding at pilot site.

Dam Type	Dam Length (m)
Length of drains to be blocked with peat dams (metres)	15,107
Berm Type A - High Bog narrow Trench bunding with fingers (m)	497
Berm Type B - Cutover wider Trench bunding with fingers (sensitive veg) (m)	195
Berm Type C - Cutover wider Trench bunding with fingers (m)	792

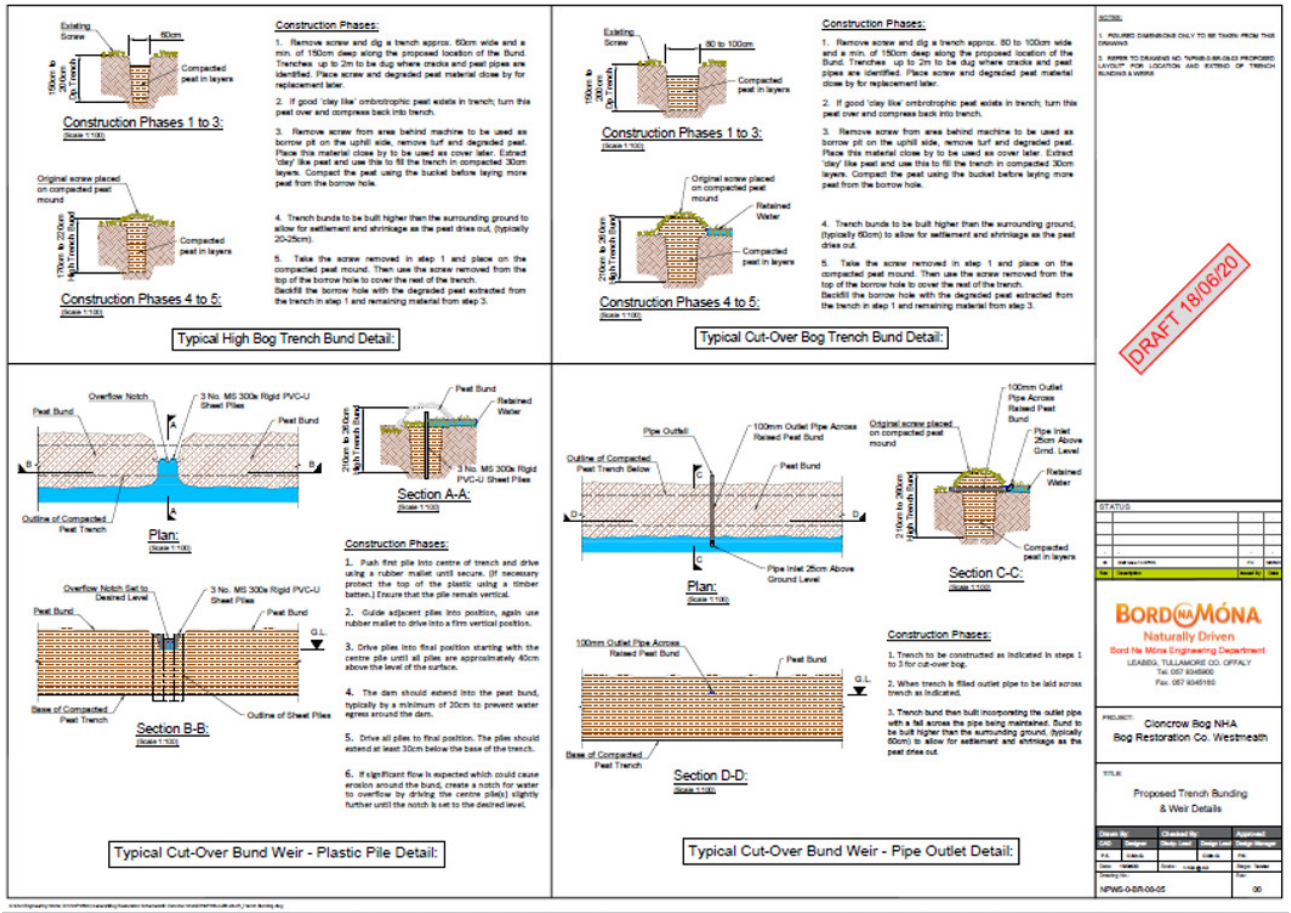

Figure 7: Details of bunding works at the pilot site
(Source NPWS tender documents, Bord na Mona)

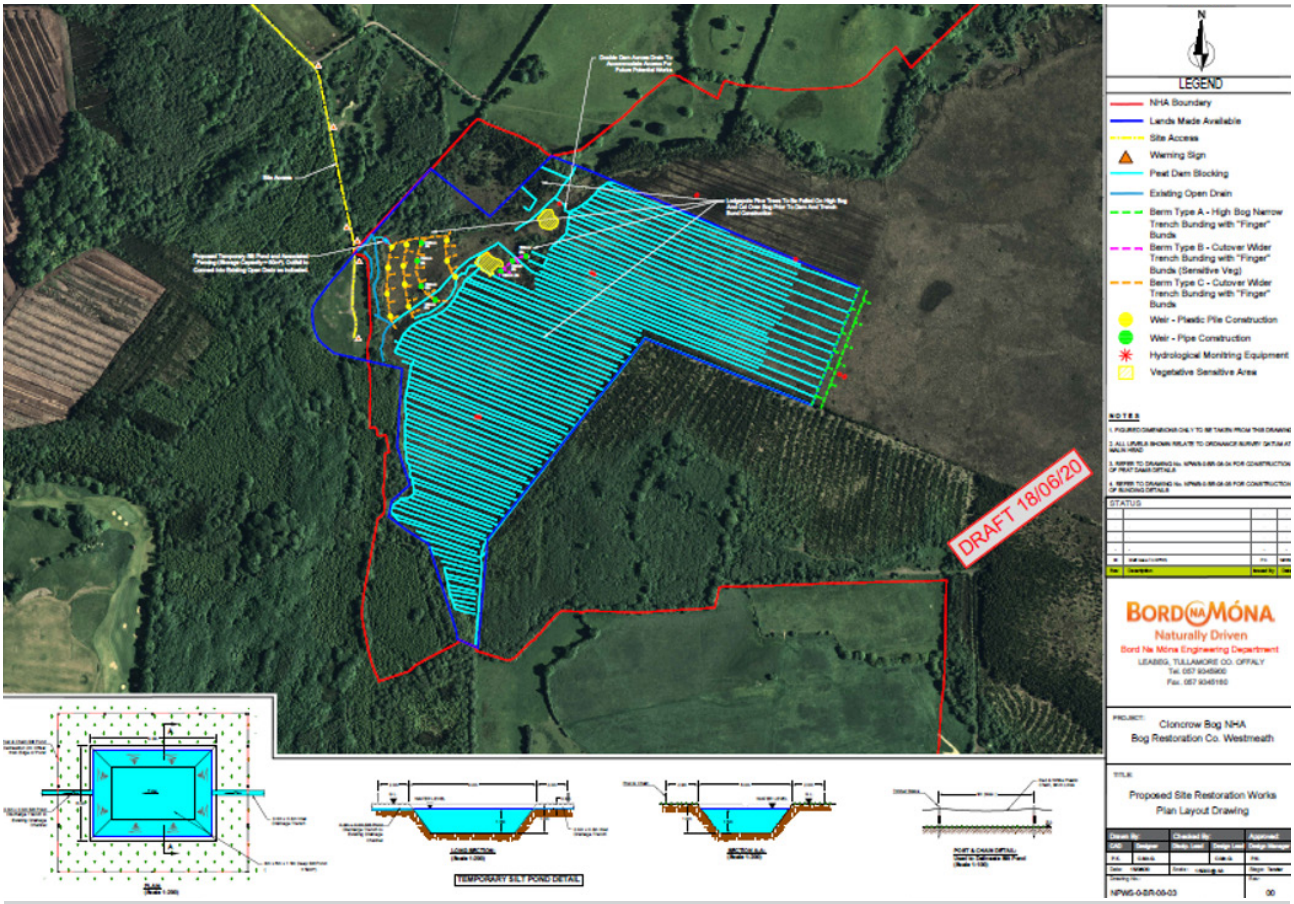

Figure 8: Restoration plan at the pilot site (Source: NPWS tender documents, Bord na Mona)

Summary of Restoration Works

The restoration works implemented at Cloncrow bog (from September to October 2020) consisted of blocking drains using 991 peat dams and 8 plastic dams consistent with best practice guidance from Mackin et al. (2017) within the high bog and cutover sections, and 865 m of trench cell bunding in the cutover areas (Figures 4 and 5). Plastic pipes and weirs were also installed to prevent trench bunds failure. The use of trench bunding on cutover areas is one of the first of its kind within the Republic of Ireland and the purpose is creating a shallow layer of water (<30 cm) within the cells to allow the establishment of peat forming vegetation.

Figure 9: Drain blocking at pilot site (Photo: Eugene Dunbar)

Figure 10: Extensive bunding at pilot site (Photo: Eugene Dunbar)

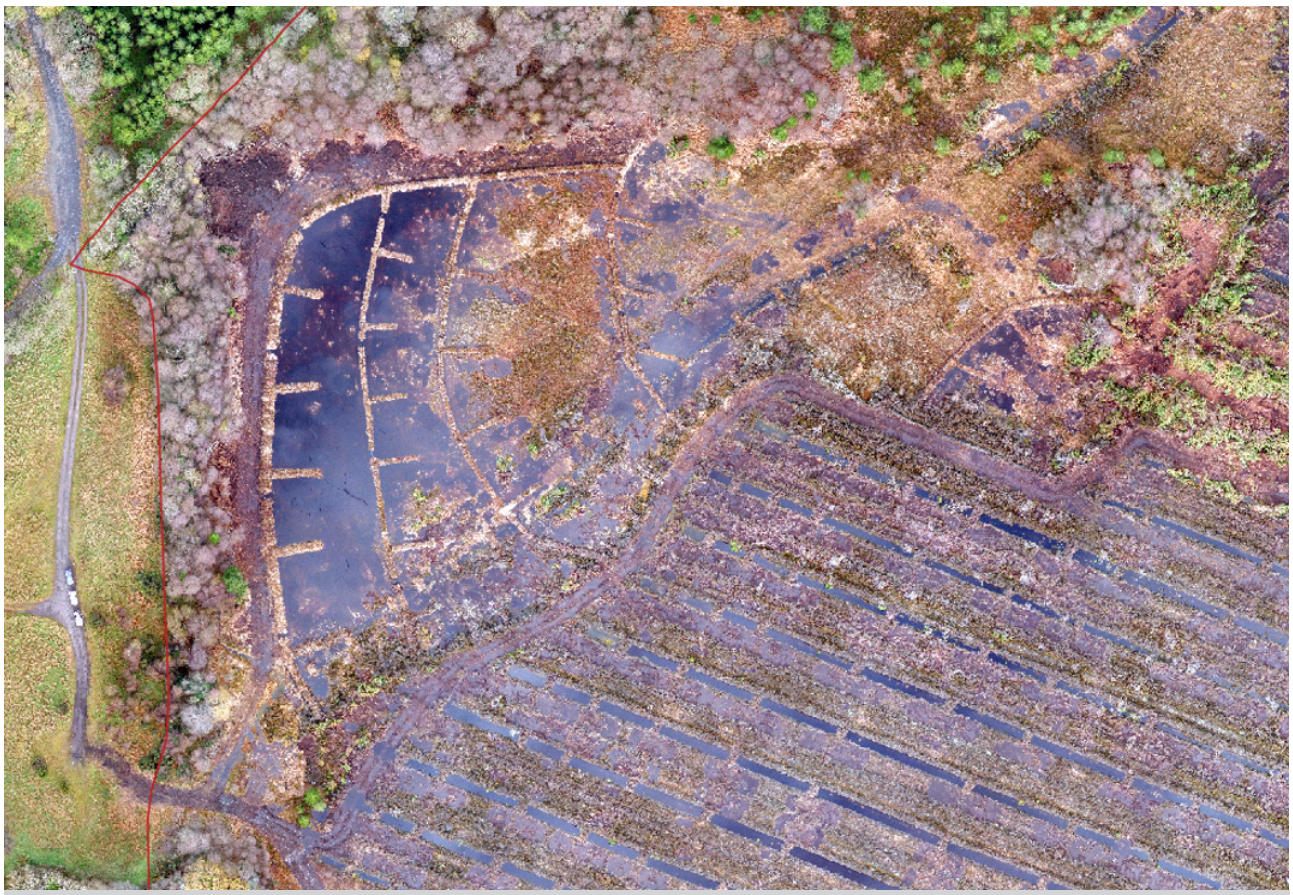

Figure 11: Aerial image of restorations in November 2020, one month after works (Photo: Bord na Mona, taken November 2020)

Monitoring and Restoration Outcomes

To document initial conditions at the site and monitor the effects of restoration, project scientists installed a suite of environmental monitoring devices (Table 3). In total we installed seven shallow (~2-8 m) piezometers, and four dataloggers that collected important environmental parameters. these included atmospheric parameters (light, precipitation, air temperature), soil moisture and temperature, and water level and temperature. These data were used in conjunction with monthly greenhouse gas measurements to allow us to develop more complete emissions models of the site. The data were also used to feed into the carbon toolkit and to inform management best practices.

Overall, the restoration activities at the pilot site have been deemed an overwhelming success. Initial works encountered limited issues and only one post-restoration intervention was required to strengthen several peat dams after a wetter than expected initial winter period. The weather station was installed in October 2020 and continuous measurements were recorded until March 2023.

Table 3: Environmental Data collection.

Type	Number	Description	Frequency
Hydrology	7	Piezometers to bottom of peat (2-8m)	
	7	Water level loggers	1 hour
Temperature	1	Air temperature	15min sample 1hr average
	3	Soil Temperature (5cm)	1 hr
Precipitation	1	Tipping bucket logger	15min sample 1hr average
Moisture	4	Soil moisture sensors (10cm)	1hr intervals
Light	1	PAR sensor	15min sample 1hr average

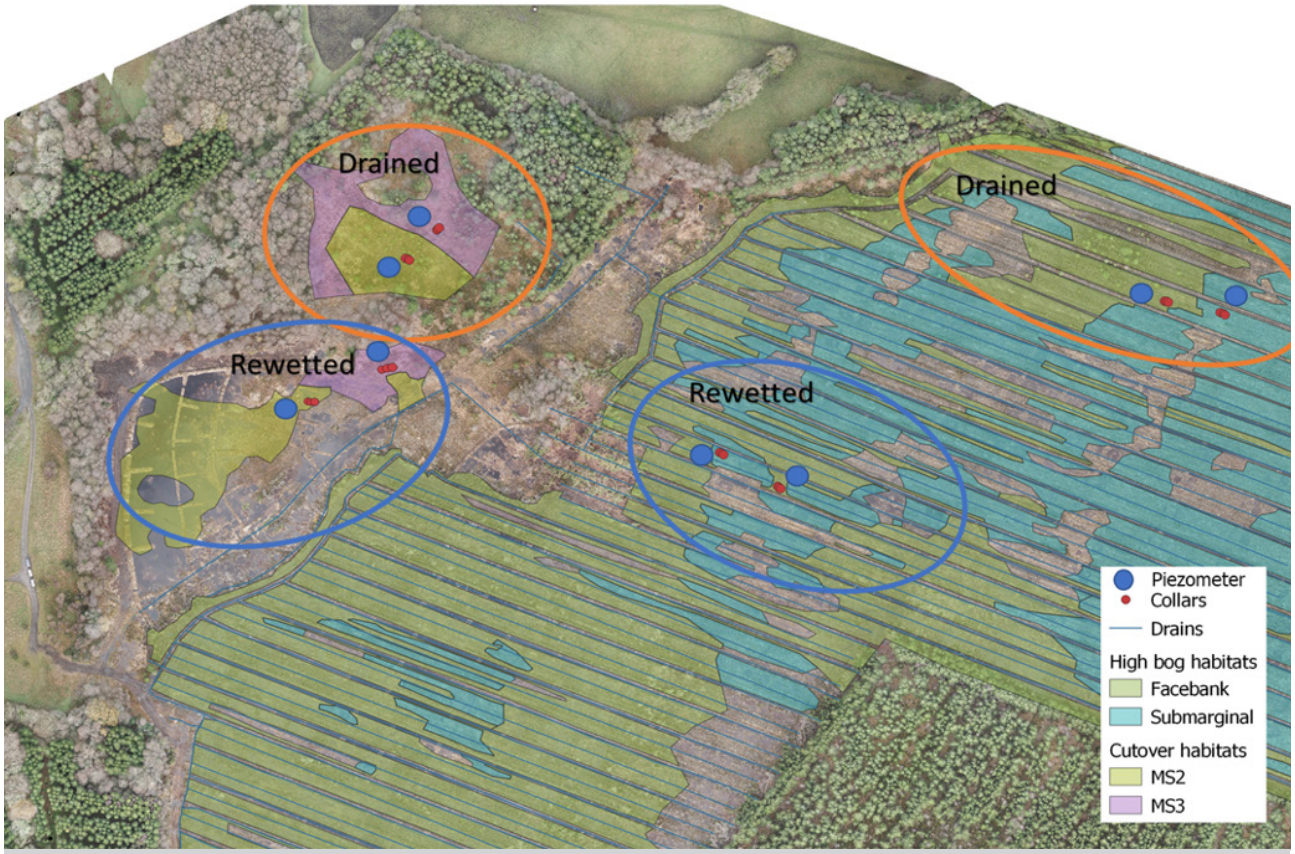

Figure 12: Care-Peat project research design in Cloncrow bog

3.1 Hydrology

The main aim of rewetting is to increase and maintain the water level to within 10 cm of the surface throughout the year. To this end, the restoration works on the high bog areas have been very effective. Mean rewetted table depth was -1.6 cm below ground level, almost always within 10 cm of the surface and significantly higher than the control area in an adjacent drained section of the bog (Figure 13).

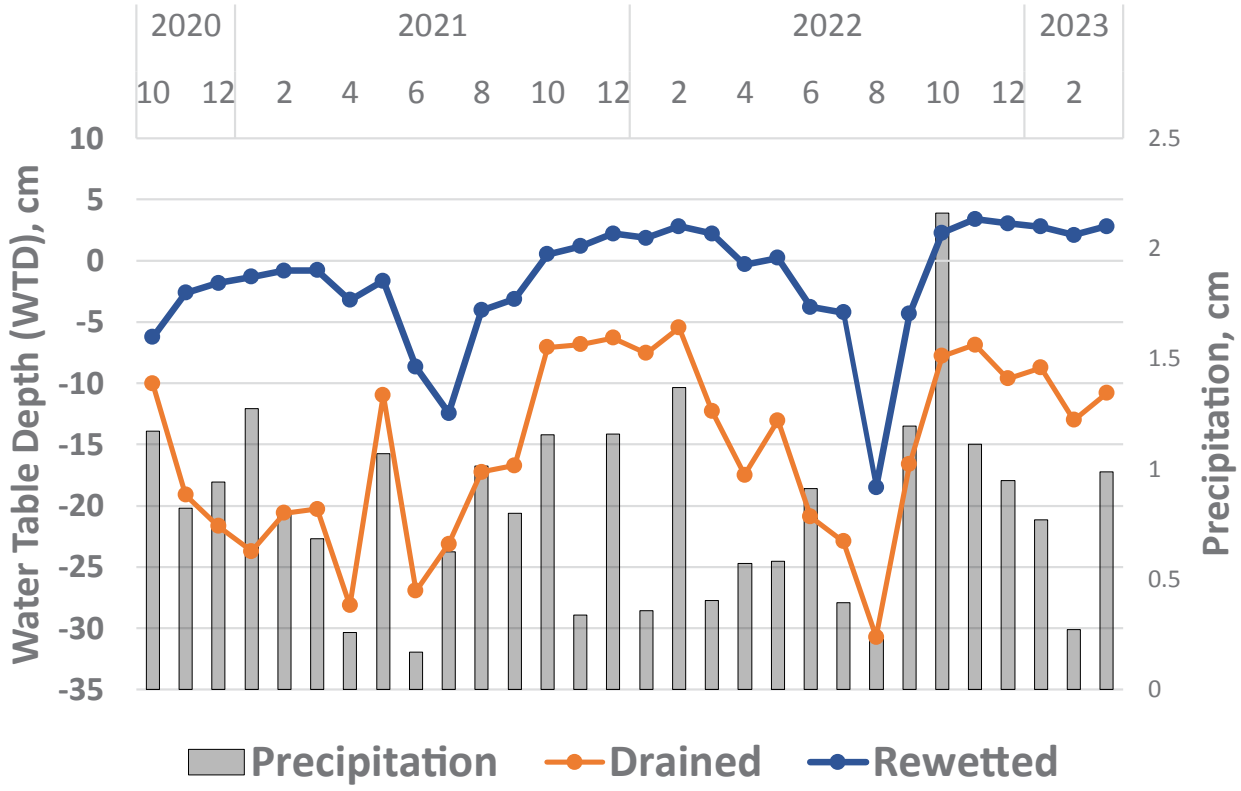

Figure 13: Monthly average watertable depth from Cloncrow Bog pilot site from the onset of rewetting

3.2 GHG emissions

GHG fluxes were measured from the two dominant ecotopes in each of the high bog and cutover bog areas, in rewetted and drained parts of the bog. High bog included Submarginal ecotope (defined as having typical peatlands vegetation including a few *Sphagnum* species) and Facebank (defined as having *Calluna vulgaris* as the dominant species) ecotopes. The cutover bog area has medium *Sphagnum* spp. cover ecotopes (less than 40 % of cover) dominated with *Molinia caerulea* (MS3) and *Eriophorum* spp. (MS2) respectively (Figure 12). Each ecotope had 3 monitoring collars installed (24 collars in total).

Over 80 days of field measurements representing over 2300 flux measurements were completed. The GHG measurements started in March 2021 and finished in March 2023.

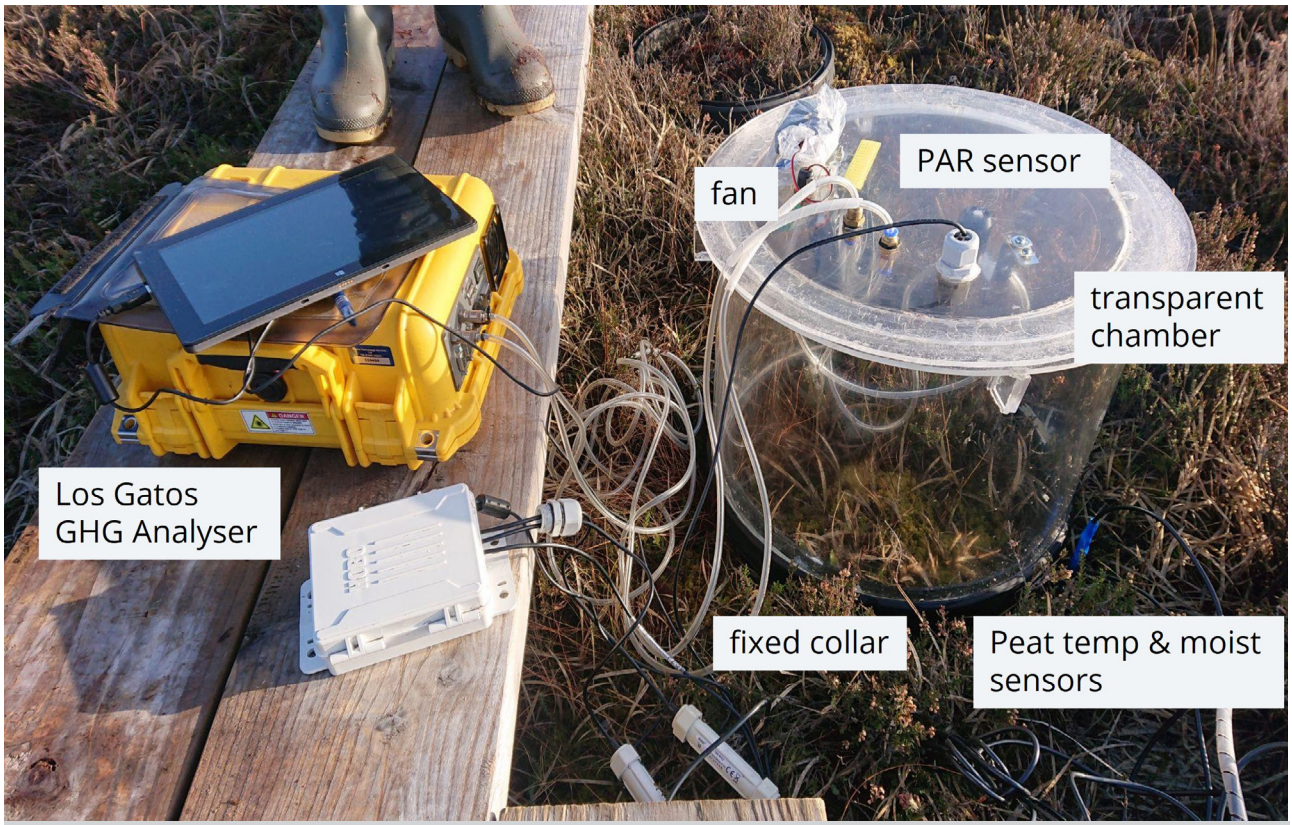

Figure 14: Examples of equipment used for GHG flux measurements

From these measurements and the environmental data, Net Ecosystem Exchange can be calculated and modelled for each area at daily intervals. The preliminary two-year results for the submarginal ecotope indicate that on the high bog, the drained section of the bog emits on average 345 g CO_2 m-2 yr-1, while the rewetted section sequesters 309 g CO_2 m-2 yr-1. This means that the degraded bog emitted approximately 3.5 t CO_2 ha-1 yr-1 while drained, and rewetting has produced a net sequestration of 3.1 t CO_2 ha-1 yr-1 (Figure 15).

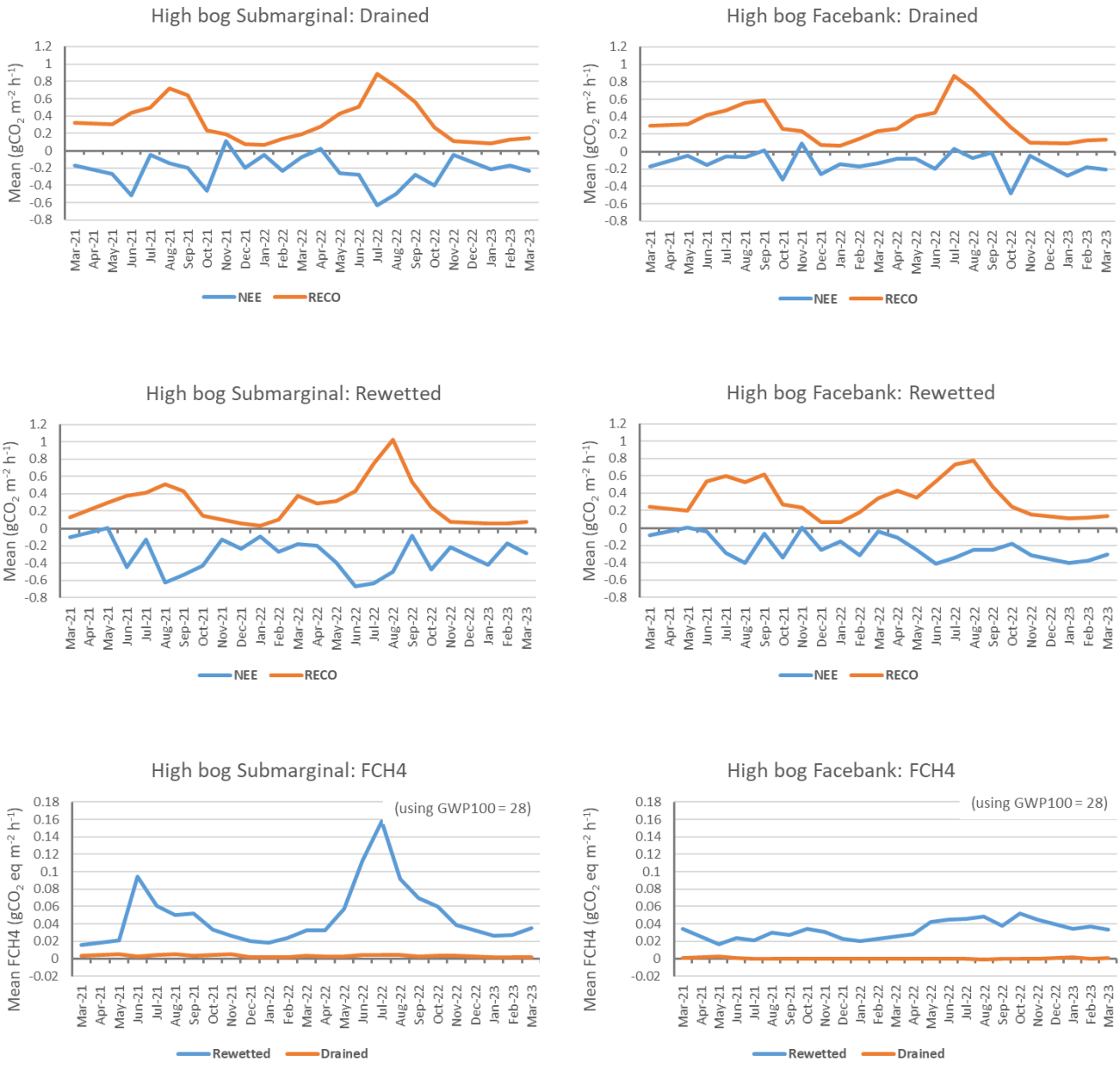

Figure 15: Time series of GHG fluxes (CO_2 and CH_4) measured within the two dominant ecotope (Sub-marginal and Facebank) of the high-bog at Cloncrow Bog pilot site. NEE = Net Ecosystem Exchange and RECO = Ecosystem Respiration

3.3 Earth Observation

Earth observation analysis was undertaken for the Cloncrow pilot site, to investigate the benefits of remotely sensed optical satellite imagery to monitor environmental change from peatland restoration. Initial observations were generated from time series (April 2018 – June 2023) Sentinel-2 image data (European Space Agency, Copernicus programme) for sample points distributed across the re-wetted cutover and high bog restoration areas, in addition to an adjacent control area. To provide a consistent time lag for further analysis, extracted index values were aggregated to quarterly averages, with missing values interpolated as the mean of the preceding and following quarter value.

The Optical Trapezoid Model (OPTRAM; Sadeghi et al. 2017, Remote Sensing of Environment 198) indicates soil moisture as a response between short-wave infrared reflection and vegetation activity (NDVI) and requires a suitably large dataset to project patterns in two-dimensional point cloud space. OPTRAM has been successfully employed in other peatland studies to analyse Water table depth. Averaged OPTRAM values for the re-wetted areas are markedly higher during the post-restoration period (Figure 16), which indicate a general increase in soil moisture content. In contrast, patterns in averaged OPTRAM values for the control area are generally consistent over the monitoring period.

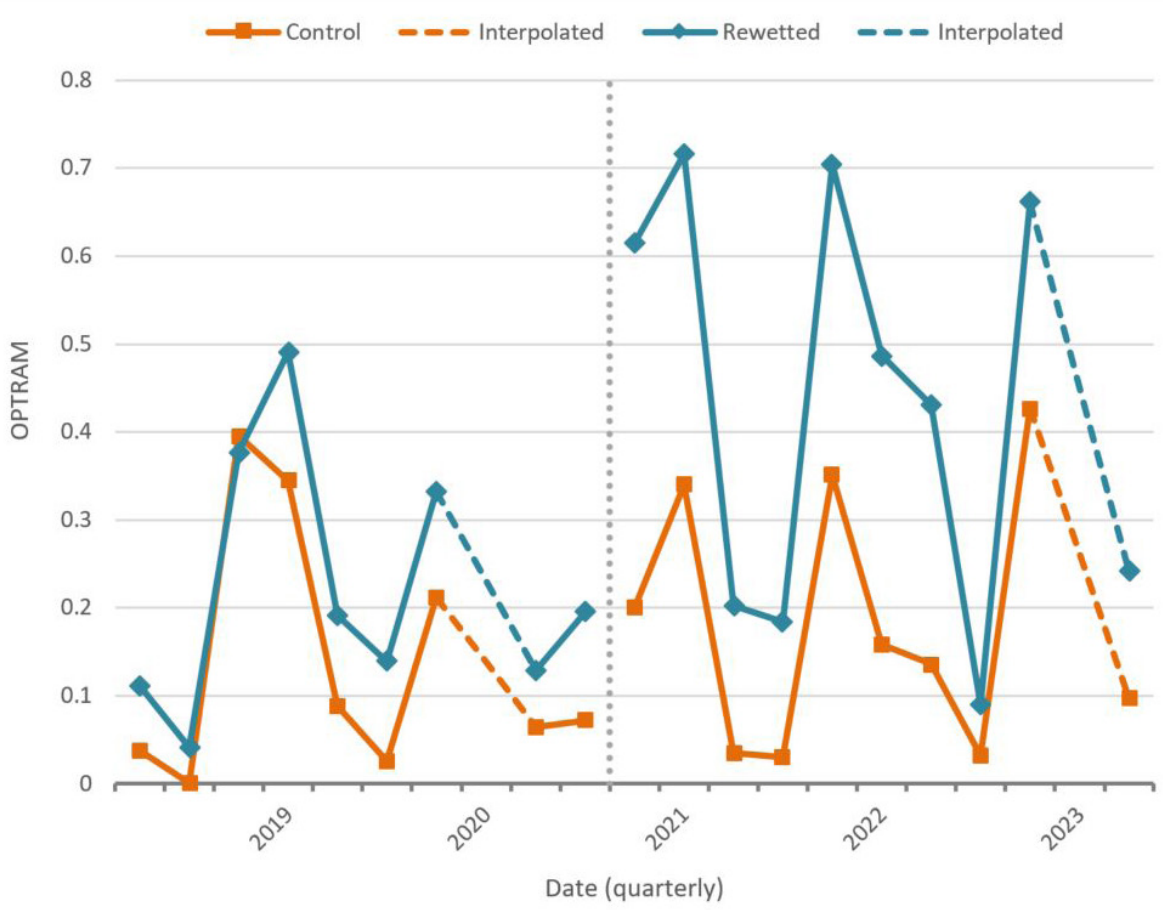

Figure 16: Aggregated average control and restoration OPTRAM for pre and post restoration period.

While differences in post-restoration OPTRAM values between re-wetted and control areas are similar to patterns observed through on-site monitoring, similar patterns are not observed for other moisture indices, the Normalised difference moisture index (NDMI) and Normalised soil moisture index (NSMI). Patterns here, correlate with patterns for vegetation indices the Normalised difference vegetation index (NDVI) and Enhanced vegetation index (EVI), in that averaged values for re-wetted areas are generally lower during the post-restoration period. A possible explanation is that initial re-wetting may have inundated areas of plant/soil material resulting in an average reduction in infra-red reflectance. Slight upwards trends in the NDVI, EVI and NDMI indices (Figure 17) could be indicative of post-restoration vegetation development in re-wetted areas. Further site investigation will be beneficial to assess whether these trends continue and if they represent change in cover of beneficial plant species. While all earth observation outputs are currently indicatory and require further cross-validation to site conditions to provide more robust information on pilot site developments, positive correspondence to site measurements indicate benefits in earth observation analysis to monitor peatland restoration.

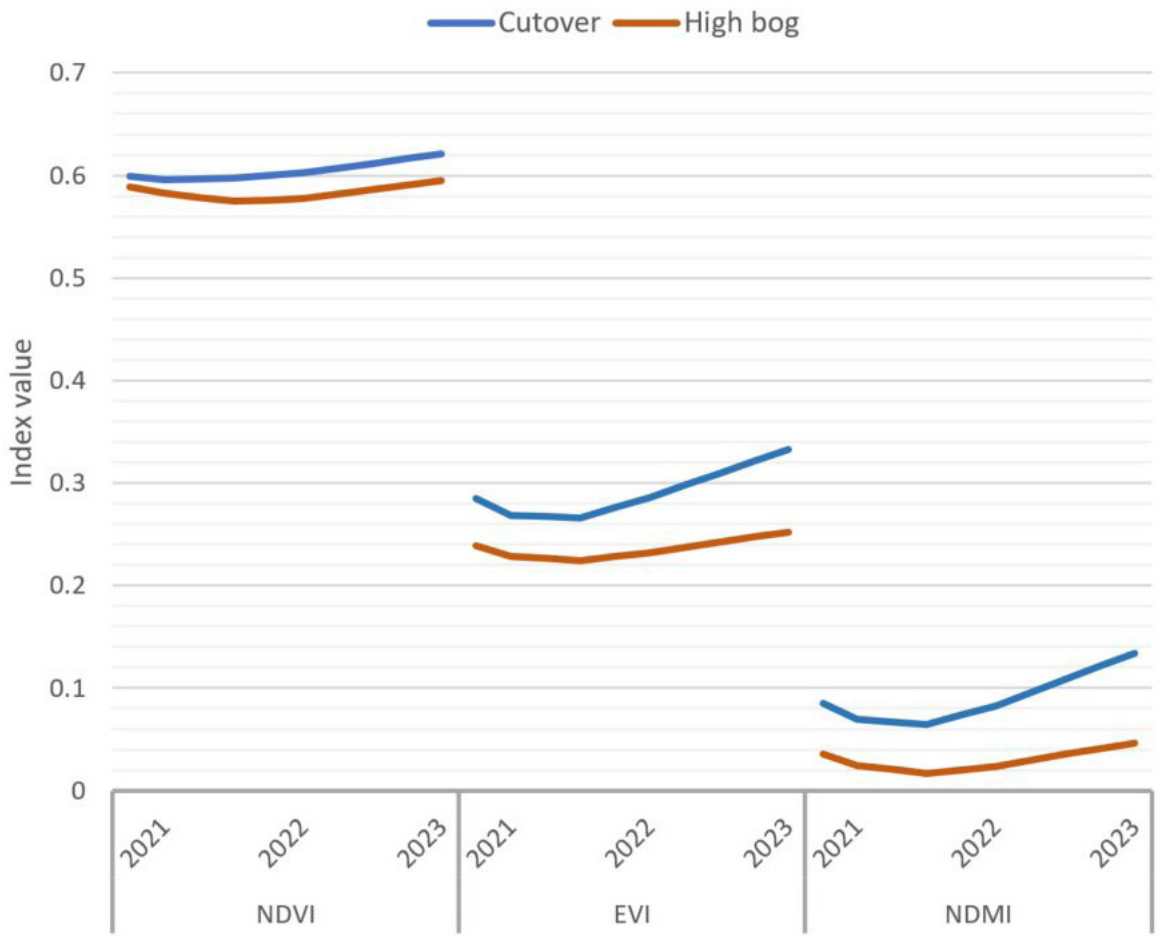

Figure 17: Averaged post-restoration trends decomposed from time series NDVI, EVI and NDMI values for Cutover and High bog areas

3.4 Before and after pictures

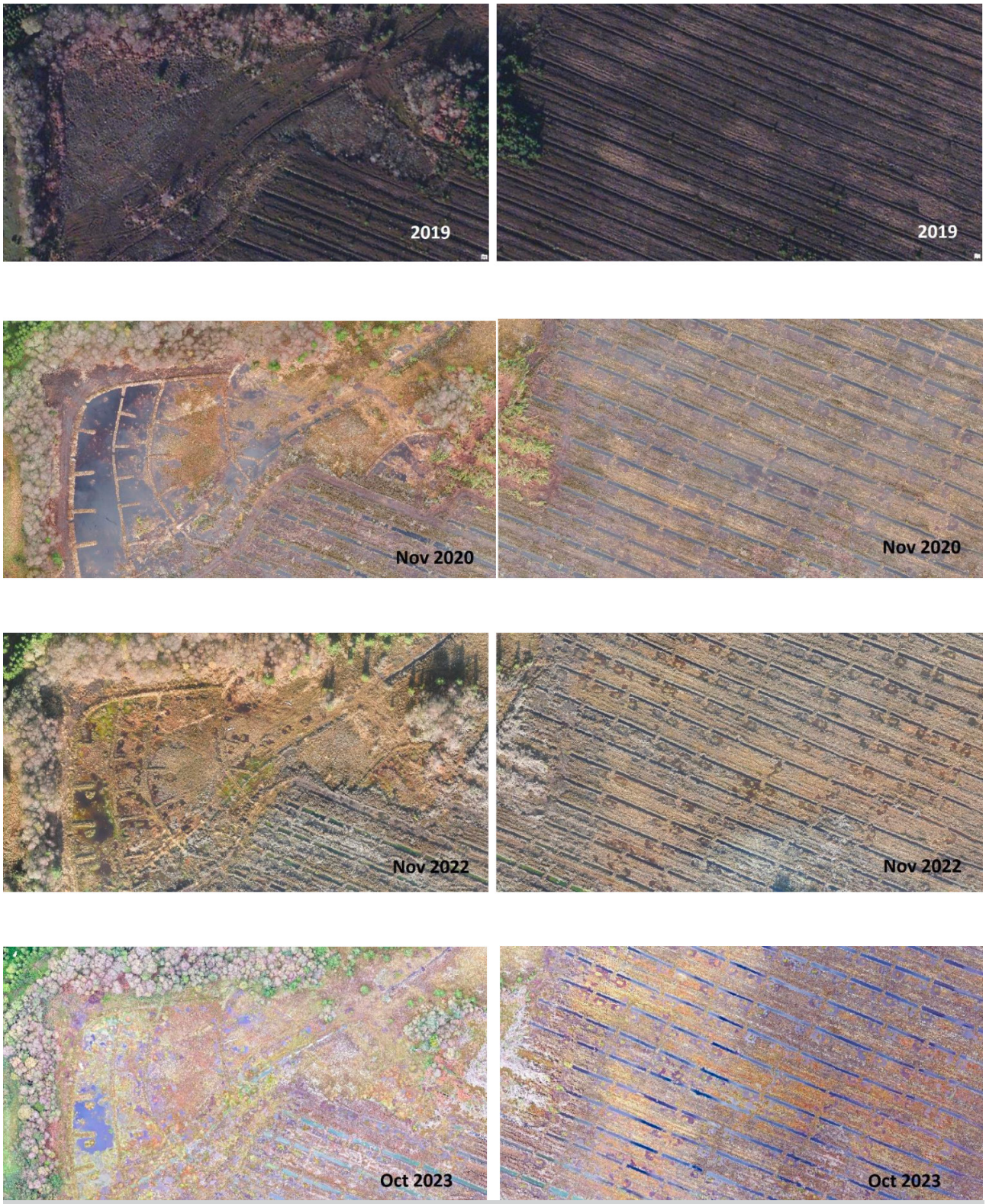

Figure 18: Aerial photographs of a section of the cutover (left) and high bog (right) portions of the pilot site before and after restoration activities

Figure 19: Cell bunding and plastic weir shortly after restoration (left, 2020) and after restoration (right, 2023)

Stakeholder Engagement

4.1 Stakeholder workshops

An important goal of the Care-Peat project was engagement with the general public, in addition to local and regional stakeholders, around the issue of peatland rewetting. Specifically, there was a need to engage local communities with restoration efforts and to reduce anxieties surrounding the issue of rewetting. This is a particularly pertinent issue as it is estimated that Ireland has over 400,000 ha of former peatland currently in agricultural use. Thus rewetting is a very controversial topic.

COVID delayed several of our initial field workshops thus several information sessions were completed online. However, by summer of 2021, we were able to host one public landowner workshop at the pilot site on 22 August 2021. This was attended by 21 local (and regional) members of the public and several local landowners and demonstrated the effect of rewetting at the pilot site. We took the public on a tour of the pilot site, and discussed the different techniques used to rewet peatlands and how these techniques can be applied at local scale areas. Of particular note, one of the man aims of the workshop was to discuss the common misconception that rewetting will inundate adjacent lands.

Figure 20: Local demonstration of rewetting successes at the pilot site
(Source: Dr. Terry Morley)

4.1.1 Heritage Week public demonstration

National Heritage Week is an initiative by the Heritage Council which brings together communities, families, organisations, cultural institutions, academics and enthusiasts, to build awareness about the value of heritage and support its conservation. It is supported by the Department of Housing, Local Government and Heritage (also the head of sub-partner the NPWS) and run in association with Fáilte Ireland. The Care-Peat event on the 20th August 2021, was attended by over 25 members of the public, other local Heritage officers and local officials.

Sub-partner the Irish Peatland Conservation Council (IPCC) was also present to discuss the importance of peatland conservation and brought along a peat corer. We demonstrated the amount of carbon stock of peatlands by coring a portion of the site. At this location, we observed peat depth to be over seven metres and demonstrating this carbon store by lining up people next to the corer had a profound impact on the public at this event

4.1.2 *Sphagnum* Transfer demonstration

This consisted of two events led by sub-partner IPCC and the University of Galway to demonstrate the utility using of a Canadian *Sphagnum* transfer technique at the pilot site. On the 12th October 2021, we had approximately 12 transition year students at the pilot site to establish *Sphagnum* trial transfers. Then on the 16th October, 2021 we had 14 members from the public to establish additional transfers. Both events were highly successful and the adult public meeting expressed interest in sharing their knowledge to additional local groups for trial this technique at other locations.

Figure 21: Transition year students at St. Josephs Secondary School posing at our placard after *Sphagnum* transfer event (Photo: Eugene Dunbar)

Figure 22: Aerial photo of public transfer event. The square to the left is a bare plot, while the square to the right as been seeded with *Sphagnum* (Photo: Elena Aitova)

4.1.3 International Demonstration

On the 28th and 29th of April 2022, the University of Galway hosted an international Peatland Conference as part of the Care-Peat project. The first day was focused on scientific dissemination and knowledge exchange while the second day consisted of two international demonstrations. This demonstration was attended by over 45 participants from across Europe.

Figure 23: International demonstration of restoration works at the pilot site (Photo: Robin Verachtert).

Figure 24: Public demonstration of Greenhouse gas monitoring at the pilot site. August 2021 (Photo: Dr. Terry Morley)

Main Conclusions

The most significant result for this pilot site is the successful transition of a degraded raised bog emitting 3.5 t CO_2 ha-1 yr-1 per year into a carbon sink of 3.1 t CO_2 ha-1 yr-1. Through the process of international discussions and knowledge exchange, the NPWS and Irish partners gained valuable insights into alternative restoration techniques. This knowledge exchange continues through involvement with the Peatland Management Working Group established by Eurosite as part of Care-Peat.

The Care-Peat project began at a significant transitional time period for Irish peatlands. The state turf company, Bord na Mona had only recent announced the ending of peat extraction and a transition from this practice toward one of peatland restoration. The Care-Peat project helped influence a movement toward restoration of degraded peatland for carbon reduction. Local demonstrations have helped to alleviate concerns of farmers and private landowners regarding rewetting of lands within and adjacent to active raised bogs, and have also engaged the local community through primary school activities and public participation in science and peatland conservation.

The rewetting engineering completed by the NPWS and their sub-contractors was so successful that Cloncrow bog is a prime example of restoration done right and continues to showcase traditional and leading-edge restoration practices and assessment.

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