Peatland Restoration Advice for the Norwegian Environment Agency

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Contents

List of Figures

1 Introduction

1.1 Following a visit from members of the Norwegian Environment Agency to Bolton Fell Moss and Wedholme Flow in March 2017, Deborah Land and Alasdair Brock were invited to visit Norway to provide their advice on restoration methods for some of the damaged mires in Norway.

1.2 Whilst some of Norway's mires can appear superficially similar to those in the UK, the climate is very different giving rise to numerous different mire types as well as different characteristics. It was important to bear this in mind when applying our own restoration principles.

1.3 Owing to the enormous variety in climatic conditions together with the varied mountainous terrain, a total of nine separate vegetation zones occur in Norway. This gives rise to 4 different mire regions (Joosten et al, 2017):

a. Palsa mire region
b. Northern Fen region
c. Typical raised bog region
d. Atlantic bog region

1.4 On arrival to Norway, our hosts took us to Drengsrudmyr near Asker, where they had undertaking a programme of apprenticeship training demonstrating bunding techniques in the Swedish style. These bunds are constructed using ombrotrophic peat with the larger ones containing a timber core. The bunds were generally larger than those constructed in the UK but the methodology was otherwise sound. It was interesting to learn that unlike in the UK, works are largely confined to the spring and summer months owing to the difficulty of working in snow cover.

1.5 We took the opportunity to discuss the differences in bunding in the UK where over the years we have reduced the size of the bunds to that less than 20cm, since understanding that the most important area of the bund is where it keys into the surrounding good peat of the recipient bog.

Figure 1 On site discussing restoration techniques

2 Site visits

2.1 A number of site visits were arranged over 3 days. These were as follows:

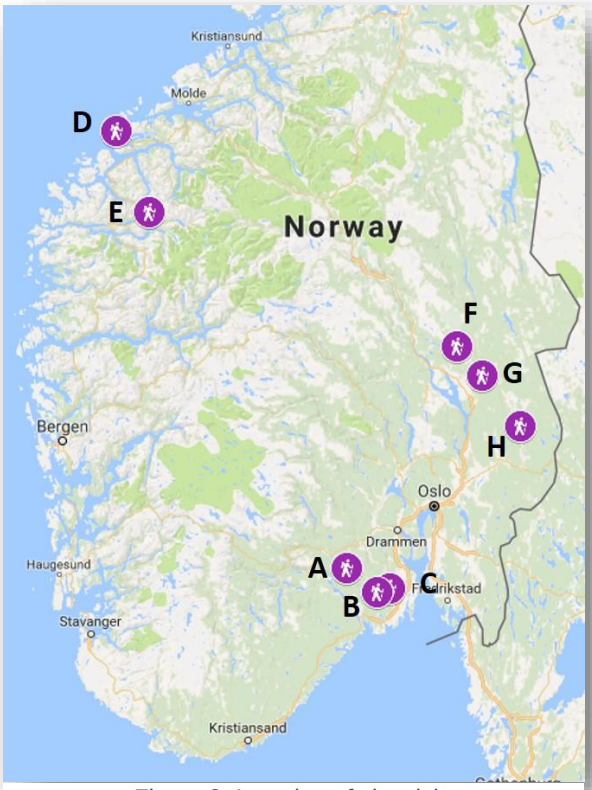

Figure 2 Location of site visits

Day 1

A. Sommersetermyr

B. Kringlemyr

C. Veggermyra

Day 2

D. Rørvikvatnet

E. Sætremyrane

Day 3

F. Harasjømyrene

G. Ebrustormyra

H. Rønnåsmyra

2.2 The brief for this visit was to visit the sites with the local advisers and discuss the potential restoration options that may be available to that site.

2.3 For each of the sites visited it was crucial to gain an understanding of the wetland processes of each individual site. It was then important to identify any modifications that had occurred that could impact this process and in what way. Only once this is clearly understood is it then possible to devise an appropriate restoration scheme.

"The key to protecting and managing a wetland is to understand the surface water and groundwater processes that have caused it form" (Rick Brassington, 2007)

A Sommersetermyr

A.1 This mire complex is located in Skien, Sauherad and Notodden municipalities in Telemark county of Norway. Sommersetermyr is a system of two valley header mires within a landscape of surrounding high rocky terrain connected by a small stream.

Figure 3 Our Norwegian colleagues introducing us to Sommersetermyr

A.2 Such Valleyhead mires tend to support small axial streams that originate within the valleyhead and help drain it, but in some cases the valleyhead, or at least the wetland area within it, is fed by small watercourses that originate upslope of the site (Wheeler, 2009). Valleyhead wetlands are essentially sloping systems, usually with lateral wetland slopes feeding down to the valley, as well as having down-valley flow, and are therefore primarily soligenous.

A.3 A stream connects the two mire systems although this has been modified and in places straightened and deepened and is therefore acting like a drain. Since there are no receptors upstream that would be impacted by altering the water levels or course, it is possible in this instance to block the modified sections of the stream using good peat dams from adjacent borrow pits.

A.4 Some additional small surface bunds could also be used to encourage the stream to spread out over the bog where is can once again find its own path. The middle section of the stream passes through a rocky pass which appears to have been disturbed by the use of dynamite. There is little benefit with doing anything in this area and a nice area of fen has developed below the upper mire which is interesting in its own right.

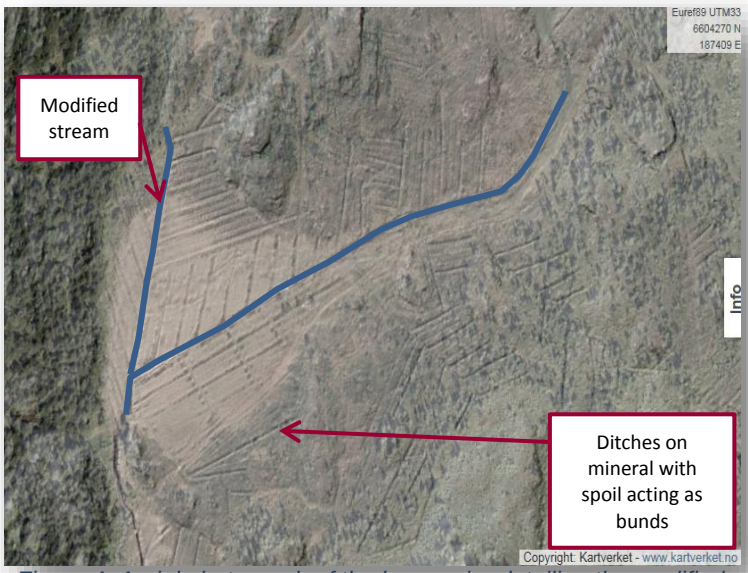

Figure 4 Aerial photograph of the lower mire detailing the modified stream and extensive herringbone ditches

A.5 The lower mire comprised a flat area supporting numerous herringbone ditches. The ditches within the mire should be blocked using good ombrotrophic peat dams from borrow pits at regular intervals using the methodology described by OpenSpace (2015).

A.6 In a relatively flat system such as this, approximately 10m should suffice. The ditches cut into the margins of this lower mire system would also benefit from some small and sensitive damming. These are largely into mineral ground which appears to be glacial material and therefore the dams will be more permeable, but this is acceptable since this area provides part of the water source for the mire system.

A.7 Some of the spoil from these marginal ditches are also acting as surface bunds and are therefore preventing water from entering the mire system. Is would be advisable to disrupt these bunds so that the water can once again flow down slope and into the lower mire.

A.8 The upper mire system also has multiple ditches through the mire system many of which are channelling the water quickly through the mire to the central modified stream. Again, the network of herringbone drains need to be blocked, be it with peat or the glacial moraine material dependant on what the underlying material is available.

Figure 5 Aerial photograph of the upper mire detailing the modified stream and showing extensive herringbone ditches

A.9 There is also considerable areas of trees that have established in this upper area. Tree removal will be necessary where ditch blocking work is required, it would be necessary to remove these, but elsewhere it may be more sensitive to leave the trees and allow the raised water level post restoration to determine the natural extent of tree colonisation.

B Kringlemyr Nature Reserve

B.1 This is a fascinating site not seen in the UK. The site lies west of Lågen in the Lardal municipality. The Mire is located in the delta area with large sand and gravel deposits and is formed within one of the former meanders of the River. According to the Norwegian Naturebase, Kringlemyr is a flat, non-centric rainfall complex, i.e. ombrogenous mire.

B.2 It is evident from the aerial photographs and Lidar images, that the site has received some considerable modifications including the construction of a road through the site and the development of industrial units adjacent. Despite this, the central area of the mire within the reserve area is in remarkably good condition. Unfortunately the entire oxbow mire is not within the reserve.

B.3 Whilst the central part of the mire remains in good condition, the northern end is highly degraded. There is considerable peat slumping, drying and cracking. This has enabled trees to become established and grow to a considerable canopy.

Figure 6 Panoramic view of the central area of Kringlemyr

B.4 The Lidar shows the large depression of slumping at the northern end of the site and it is clear from this that this has been caused by the numerous drains that have been cut into the northern end of the bog. In order to remedy this continued drying and cracking, it is first necessary to undertake some considerable tree removal.

B.5 The canopy of tree exacerbates the drying process through the interception of rain water as well as transpiration, but furthermore, trees of this size on weak peat rock in the wind creating further cracks in the peat.

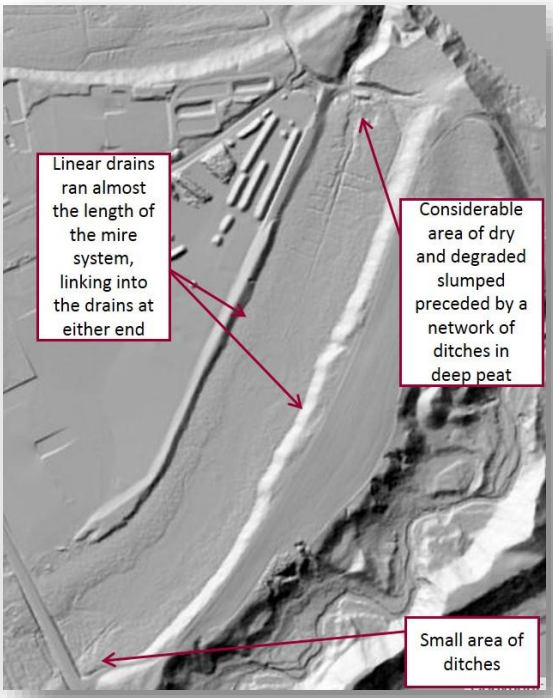

Figure 7 Lidar image of Kringlemyr

B.6 The decision of what to do at the far northern end is complicated. There appears to be an old alluvial dam that may have lead to the formation of this feature thousands of years ago. However this may have been compromised through construction works and now presents a leaky edge to the mire. It may be worth considering some sort of bunding to reinforce this dam or the creation of new bunds at the terminal end of the mire to help keep the water levels elevated. Some of this could be informed by investigating the peat depths in this area to determine where bund could be constructed.

B.7 Towards the center of the mire, a clear zone where the peat becomes too wet for the trees to dominate is evident. At this point the hydrology is keeping the trees in check and tree removal is not necessary.

B.8 Following tree removal at the northern end, it will be necessary to block all the drains using regular spaced peat dams.

B.9 From looking at the growth of the trees along the periphery, it appeared that the peat profile deepened sharply along the length of Kringlemyr. The shallower margins supported a dense canopy of mature pine which did not encroach onto the deeper peat, therefore being kept in check by the hydrology. Therefore no tree removal should be necessary along the shallow peat margins.

B.10 There was however, a perimeter drain running the full length of Kringlemyr on both sides and this was having a drying effect. It would however be advantageous to block these drains at regular intervals using good ombrotrophic peat dams at regular intervals.

B.11 The southern end of the mire system also shows some signs of drainage and again the Lidar shows some drains present. These simply need to be blocked with peat dams. There may be a limit to what can be done here owing to the presence of the road, although the road does appear to be acting as kind of bund!

C Veggermyra

C.1 Veggermyra (Vuumyra) Nature Reserve is located in the municipality of Sandefjord. It is a soligenous valley mire with a highly developed ombrogenous dome comprising some nice concentric pools and ridges.

Figure 8 View of Veggermyr where the impact of drainage is lessened and the trees are kept in check by the hydrology

C.2 The majority of the mire is intact and in good condition. However, the southern edge has been subject to what appears to be domestic peat cutting, creating a number of oblong cuttings in the peat body. These effective behave as large ditches, drawing the water table downwards and leading to the drying of the peat surface. As a result, the balance of vegetation has shifted towards a greater cover of shrubby heather and increased tree cover onto areas of the bog that should be sphagnum dominant.

C.3 The remedy for this damage is to construct a number of low trench bunds within the cuttings, using good ombrotrophic peat and ensuring that the bunds are keyed into the underlying and adjacent peat body.

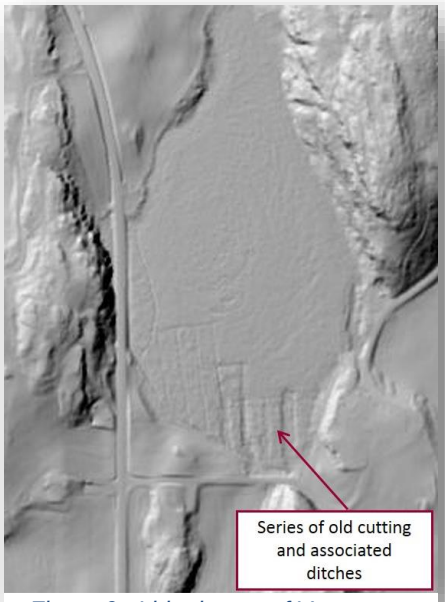

Figure 9. Lidar image of Veggermyr showing old cuttings

C.4 Where steeper cut face exist, it may be possible to re-profile these using the technique shown in the film produced by Cumbria Wildlife Trust (2016).

C.5 Contour bunding was discussed during the site visit, but upon reflection this may not be necessary in this case as once the cuttings are bunded and re-profiled, it should allow the water table to be held suitably high enough to favour the re-dominance of sphagnum mosses.

C.6 It would be advantageous to remove the larger trees that have become established on the deep peat so as to ensure that the maximum amount of rainfall can reach the bog surface and also to prevent further cracking from wind rocking.

D Rørvikvatnet

Figure 10. Panoramic view of Rørvikvatnet with the wetland managed for birds to the right and the previously cut over area to the left, separated by the large, treed peat baulk

D.1 Rørvikvatnet is a wetland protected under the Ramsar Convention for its importance to breeding birds. The habitats the Atlantic bog mire type. It is located immediately adjacent to Ålesund Airport in the municipality of Giske.

D.2 The mire is an Atlantic mire type typical of the boreonemoral and southern boreal zones of the highly oceanic vegetation section (Joosten, 2017).

D.3 The mire has been highly modified through peatland extraction, drainage and tree planting. There is also a history of sand extraction in the area. The current boundary of the nature reserve only include the more damaged areas of the bog, omitting large areas of intact but degraded bog. Such boundaries immediately present issues with any restoration that is proposed.

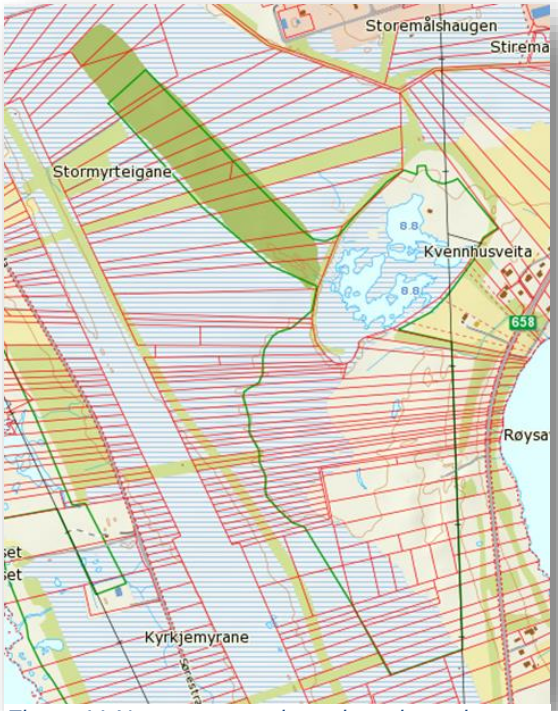

Figure 11 Nature reserve boundary shown in green and ownership in red

D.4 The current management plan focuses on the bird interest and discusses options to make the part of the site managed for bird interest, wetter. It is proposed that this is achieved through the removal of more peat from the site. However, this may not be necessary since the water level in the lower basin can be raised through the simple introduction of a dam and weir system that can regulate the water level.

D.5 On inspection, a small structure had been installed at the boundary of the site and was working satisfactorily, but a more robust structure would be more appropriate and easier to control the water levels. The installation of such a structure would negate any need for further peat removal whilst also increasing the desirability of the habitat for the bird assemblage.

Figure 12. Small dam on the periphery of the reserve

D.6 A further priority of the management plan is to remove the tree cover. Whilst this is desirable when restoration a peat bog, it is only really worth undertaking such an operation if you can also undertake the necessary re-wetting works. If this is not done the trees will return since the bog surface will not have the necessary water table to prevent encroachment. The suggestion of burying the felled trees under peat is not advisable since this will only create more problems with discontinuities within the peat and possible further erosion pathways.

D.7 The cut peat faces form part of the boundary of the nature reserve. These are over 2m high in places and will be having a considerable impact upon the water table of the bog. They require considerable re-profiling as demonstrated in the video by the Cumbria Wildlife Trust (2015) together with the creation of cell bunding at the top and foot of the slope to assist with holding the water table close to the surface.

D.8 The methodology should follow the design for shallow bunding as described by OpenSpace (2015). It is acknowledged that restoration outside of the nature reserve boundary may present challenges to complete this part of the restoration.

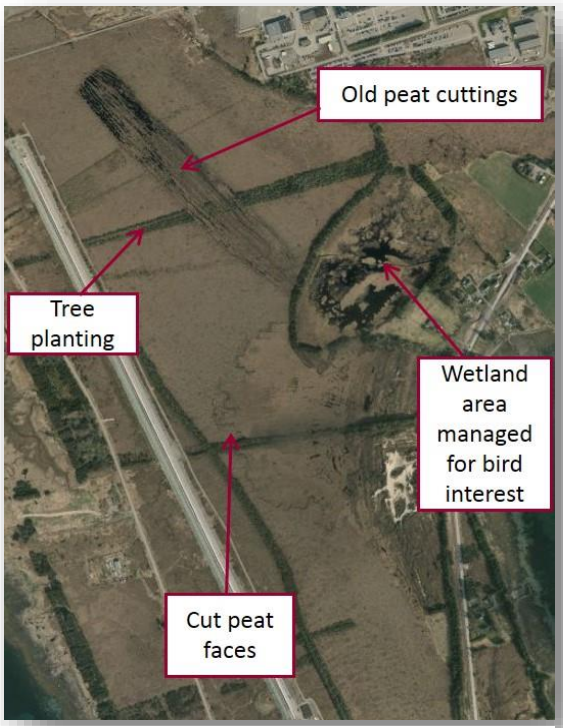

Figure 13 Aerial photograph showing the extent of damaged peat.

D.9 Finally, the restoration of the extensive peat cutting in the northern part of the reserve presents a serious challenge! The cutting are very large, deep and extensive. The associated cracking extends well beyond the nature reserve boundary suggesting that further restoration works would be required adjacent to the cuttings.

D.10 Owing to the size and complexity of the cuttings, it would require a highly skilled contractor, with considerable experience to construct suitable dams and bunds within and between the cuttings. It would likely be an iterative process whereby an experienced contractor would 'feel' their way through the construction of any structures. It may be a consideration to invite on of the UKs more experienced contractors to Norway to undertake some works and use the opportunity to train your local contractors.

D.11 Additional thoughts with regard to this site are that the current reserve boundary presents a serious problem for restoration. Any works undertaken as described above are likely to be compromised by not being able to ensure that the edge of the peat bog is in good hydrological condition. It may be an opportunity in the future to discuss the future intentions of the Airport with a view to negotiated a carbon trade-off for any future extensions in return for securing the restoration for the rest of the site.

E Sætremyrane

E.1 Sætremyrane Nature reserve is located in the Municipality of Hornidal. It is an eccentric sloping mire comprising relatively thin peat over glacial moraine. It supports both soligenous and ombrogenous water regime. It is quite unlike any mire type found in the UK and therefore the questions posed regarding its restoration are carefully considered.

Figure 14 Eroded peat on Sætremyrane

E.2 There are old abandoned peat workings and associated cuttings that can be clearly seen on the Lidar image. Theses date back to the early 1900s when peat was carried by railway across the bog. On reading the Management Plan for Sætremyrane, it is evident that there is a rich and diverse cultural history associated with the use of this bog; from peat cutting, to grazing, hunting and foraging.

E.3 It is clear that the peat extraction has caused considerable damage to this mire, resulting in high dry baulks of peat with tree cover and wetter depressions where the peat was cut. There is also evidence of past management that may affect the water

regime of this mire such as the large drystone wall at the head of the system that may be diverting water flow, and evidence of further peat disturbance at the eastern end of the mire.

E.4 There is also a considerable sized tip of miscellaneous waste material above the area where the 'hole' has appeared. It is unclear if this is related to the formation of the 'hole'.

E.5 Of further interest on this mire is the amount of bare peat that is present. It is not immediately clear what has caused this erosion and whether this is still happening or is a consequence of past activities. Nonetheless, it presents the need to approach

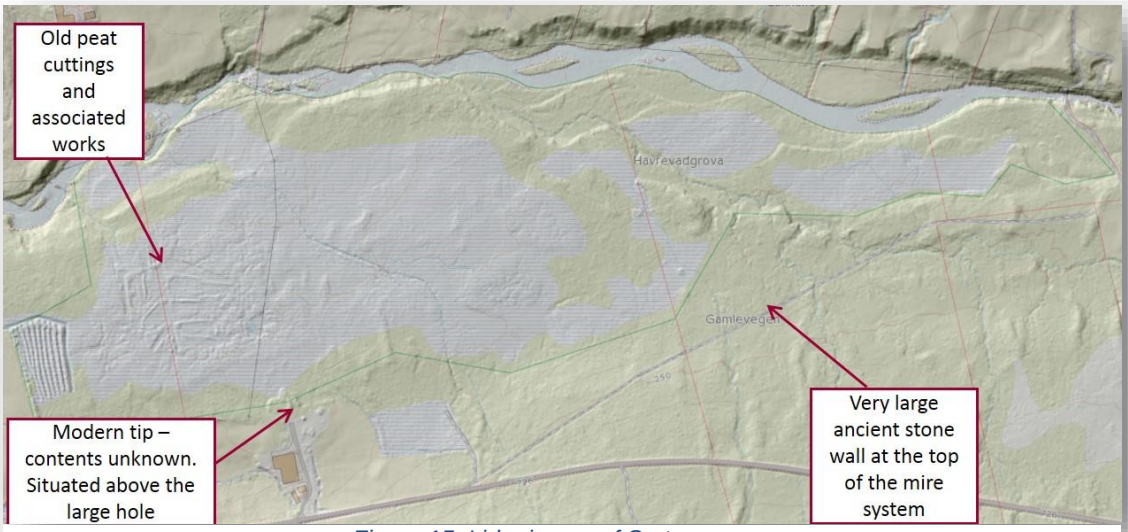

Figure 15 Lidar image of Sætremyrane

the restoration with caution as the peat is obvious fragile.

E.6 The methodology to restore the peat cuttings would be as discussed for previous sites, using peat bunding within the cuttings and, where peat faces occur, some re-profiling. Tree removal will be required and bunds should be keyed into the surrounding peat.

E.7 For the restoration of the bare peat areas, a series of small shallow bunds to slow the water flow in key locations will help to reduce the further loss of peat. The concern in this area is that the peat is already weak and fragile and the construction of large long contour bunds may hold too much water for the peat to hold and may result in a peat slide. Therefore a series of small strategic individual low bunds may be more appropriate.

E.8 The large 'hole' in this mire system is flowing out across the mire creating more erosion. Some strategically placed bunds to slow and disperse this flow using shallow peat bunds may be appropriate.

E.9 On completion of the construction of bunds, it may be helpful to apply a dressing of donor sphagnum material and a suitable brash cover such as chopped heather to protect it and provide a microclimate.

F Harasjømyrene

F.1 Brumund Sea-Harasjømyra Nature Reserve is located in the municipality of Hamar. The site comprises a mosaic of appa fens, forests and open water. The underlying geology consists of low-grade sand-rocks with a continuous supply of calcareous water. This gives rise to the considerable ecological importance of the site. Harasjømyra, consists of an almost untouched collection of string and flark mires. They are both groundwater and rainwater fed.

F.2 There has been considerable forestry development in the area, some of which is within the peat body of the mires. Forestry drainage has also impacted the reserve

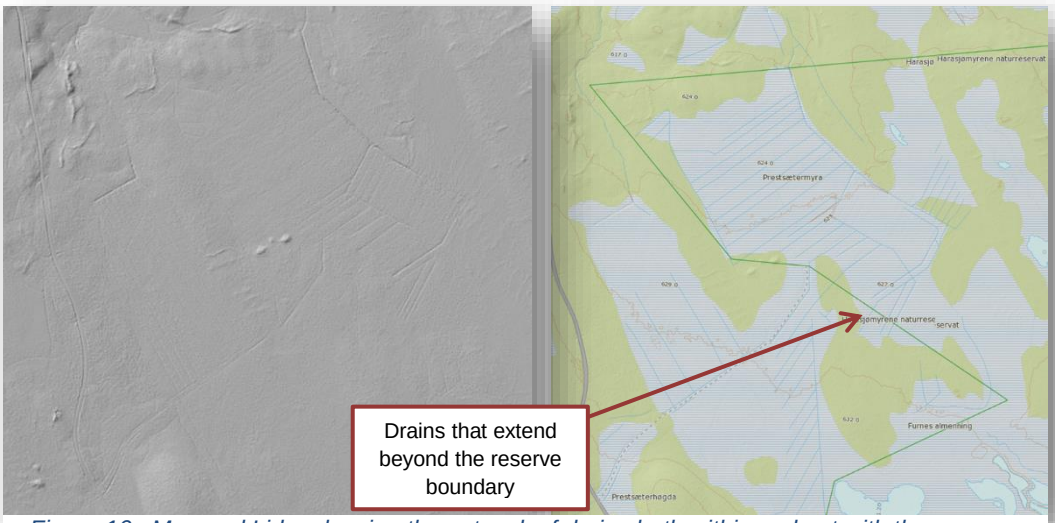

Figure 16. Map and Lidar showing the network of drains both within and out with the reserve.

area leading to considerable tree encroachment on the peat body.

F.3 In order to restore the hydrological functioning of these mires, all of the drains will need to be blocked using peat dams at regular intervals. It will be necessary to remove the trees from the bog surface where they occur on deep peat. This is not only necessary for the construction of the dams but also to ensure that there are no trees to intercept valuable rainwater to the mire.

F.4 The mire is gently sloping and contour bunding was discussed on site. However, since this is a soligenous system it would be inappropriate to interrupt the flow of water through the peat.

F.5 The greatest threat to the success of restoration this site is that the drains extend beyond the boundary of the reserve and into the adjacent forestry. This conflict in management will undermine the restoration efforts within the reserve. It is therefore advised that the boundary be reviewed if possible or a compromise about the drains on adjacent deep peat be negotiated.

F.6 A detailed peat survey on this site would be very useful to determine the extent of the deep peat.

Figure 17 Aerial showing the extent of tree cover on peat

G Ebrustormyra

G.1 Ebrustormyra is located in the municipality of Løten. It does not appear to be protected as a Nature Reserve despite supporting a number of Red List Species. The mire type is not similar to those encountered in the UK and is very interesting in its form. The mire comprises very large, dense hummocks of sphagnum in dense carpets, extending some distance above the underlying peat surface. Bog myrtle and small pines grow amongst the hummocks with abundant lichens, but the trees appear to be kept in check by the wet peat at the base of the hummocks. The drier hummocks are interspersed with lower wetter areas with shorter vegetation.

G.2 There are two obvious episodes of modification to Ebrustormyra. The older modification to the peat body is curious. The peat has obviously been commercially extracted from the site in the past but the method of cutting is unlike anything encountered before. The series of fan-shaped cuttings are very deep and judging from the suite of species present, have connected the mire with the underlying groundwater.

Figure 18 A view of the unique fan-shaped cuttings within the mire supporting rich-fen vegetation.

G.3 In themselves, the fan-shaped cuttings do not present a negative impact upon the peatland and add to the ecological richness of the site. It is therefore advised that no restoration works are required to these cuttings.

G.4 The most recent modification is the network of forestry drains throughout the western extent of the site. The remedy for this is straightforward using peat dams at regular intervals to block the drains. Some tree removal will be required to facilitate this.

G.5 The effect of blocking these drains will have a considerable positive impact through helping to maintain a high water table throughout this area.

G.6 On the edge of one of the areas of cuttings there is an active area of run-off over a drop in the peat of approximately 1 meter. It would be preferable to undertake some sensitive bunding in this area to slow this movement of water and dissipate it over the peatland. This could be achieved by using some strategically placed bunds to divert the flow of water and therefore slow its movement and erosion potential.

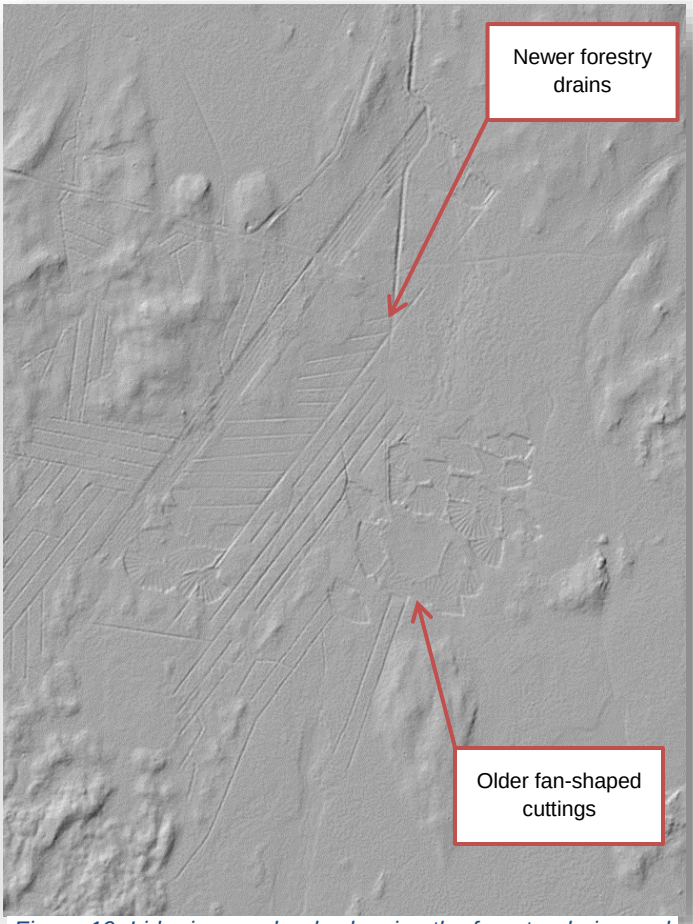

Figure 19 Lidar image clearly showing the forestry drains and the older fan-shaped cuttings

H Rønnåsmyra

H.1 Rønnåsmyra Nature reserve is located in the municipality of Grue and is one of the largest and most intact eccentric mires in Norway and hence is of considerable importance. According to Joosten (2017), it lies within the Southern boreal vegetation zone of transitional oceanic-continental section, one of the best developed and largest raised bog massifs in Norway (Joosten, 2017)

H.2 The site has already received considerable restoration where in the 1970s, over 10,000m of ditches filled in in the northern area of the mire (Joosten, 1970). There is little evidence of this work when viewing the Lidar image, concluding that this has been successful.

Figure 20 Aerial photo showing the eccentric patterning

H.3 However, on inspection of the Lidar image, it is clear that there is still some considerable damage that is impacting the southern extent of this site.

H.4 A number of large deep trenches have been created during past peat extraction. Whilst these have largely revegetated, they are still acting like large drains and channeling water from the site, leading to drying and cracking of the peat and the establishment of a dense tree canopy.

H.5 The tree canopy is further exacerbating the dryness through the interception of rainwater and causing further cracking through wind-rock.

H.6 In addition to the large peat cuttings, the edge of the mire revealed considerable slumping with steep peat faces causing more cracking. The tree cover is dense and mature. The base of the slumped area is on thin peat over fine glacial sand.

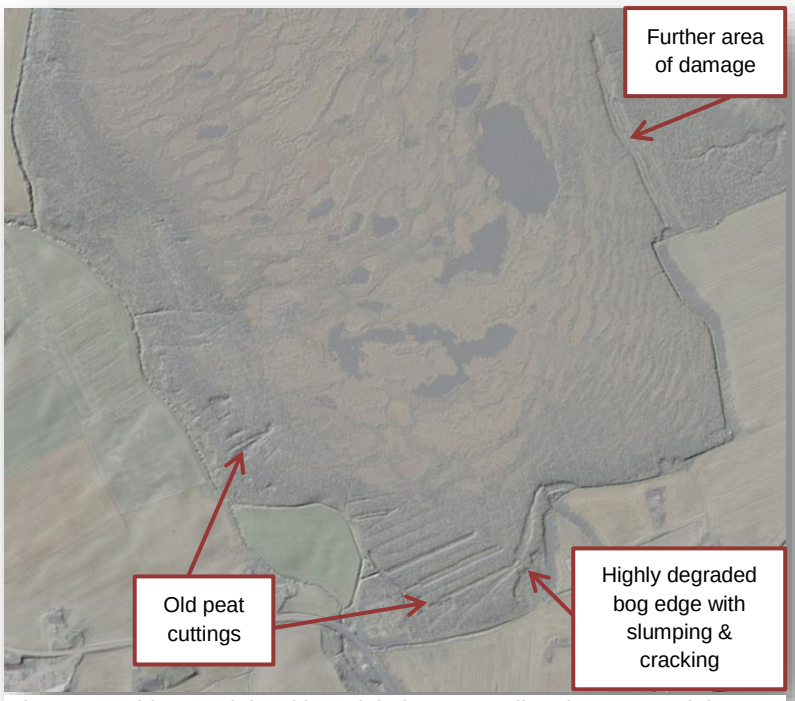

Figure 21 Lidar overlain with aerial photo revealing the extent of damage in the south of the site

H.7 The suggested restoration of the damaged edge of this mire will involve removing the trees so that it is possible to access above and below the slumped peat. There is little point trying to work the dry cracked peat as it is unlikely to hold water. The best option is to hold the water at the surface above the face and perhaps consider a bund at the foot of the face to hold water back against the peat. It is likely that this area will not recover fully for many years but with these measures, the area should be better able to function more like a natural rand.

H.8 The old peat cuttings require the installation of low shallow bunds across them to prevent the water flowing westwards off the bog. This will also increase the ability for these to hold water and encourage sphagnum to grow.

H.9 The baulks between the cuttings are high and dry with peat cracks and dense scrub coverage. There are two schools of thought with how to tackle these. One is to remove the trees and create small bunds on the top to collect water and therefore encourage a more mossy vegetation. Alternatively, the baulks can be left, accepting that they will remain tree covered with suboptimal vegetation but that they will eventually degrade downwards as the vegetation in the cuttings grows. This is a cheaper and less intrusive option but the choice is really dependent upon the desired timescales and budget.

Figure 22 Mire expanse on Rønnåsmyra

3 Summary

3.1 The mires of Norway present some very interesting challenges for restoration. Whilst they often look similar to the mires encountered in the UK, the additional factors from climate and seasonality will change the approach that is used in the UK. Nonetheless, the fundamental approach to peatland restoration using peat bunds and re-profiling techniques are appropriate and practical.

3.2 There was considerable discussion regarding contractor expertise during the trip. It may be prudent for the Norwegian Environment Agency to contract one of the experienced UK contractors to undertake a series of demonstrations during which they can pass on valuable skills and expertise to local contractors.

3.3 It is also recommended that peat surveys are undertaken on the proposed restoration sites. This can be extremely informative for restoration especially where the peat boundary, and therefore hydrological unit, extends beyond the boundary of the nature reserve. We have found where the boundary and the peat body is not harmonious, restoration can present some serious challenges and may be compromised.

3.4 It was noted during the trip that there are a considerable number of peat extraction sites in Norway. It would be very interesting to hear more about the future intentions of these sites and any potential restoration. Natural England have considerable experience in restoring such damaged peatland and would be more than happy to assist with any advice in this area in the future.

3.5 Natural England have thoroughly enjoyed taking part in this exercise and have learned a great deal from the Norwegian Environment Agency about Nature Conservation in Norway and how the Norwegian Government carries out the management of their Nature Reserves.

3.6 We hope that we can continue to forge strong links between our countries and agencies and can continue to work together in the future.

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