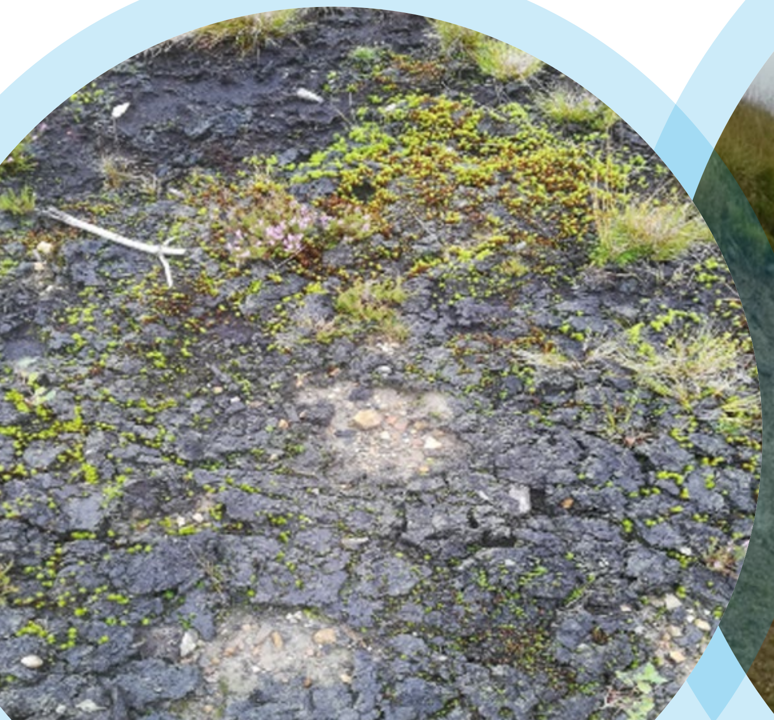
CREW CENTRE OF EXPERTISE FOR WATERS

Effectiveness of construction mitigation measures to avoid or minimise impact to groundwater dependent wetlands and to peat hydrology Appendices



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Effectiveness of construction mitigation measures to avoid or minimise impact to groundwater dependent wetlands and to peat hydrology

Appendices

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Hydro Nation International Centre
The James Hutton Institute
Scottish Government
Riaghaltas na h-Alba
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CENTRE OF
EXPERTISE
FOR WATERS

Published by CREW – Scotland's Centre of Expertise for Waters. CREW connects research and policy, delivering objective and robust research and expert opinion to support the development and implementation of water policy in Scotland. CREW is a partnership between the James Hutton Institute and all Scottish Higher Education Institutes supported by MASTS. The Centre is funded by the Scottish Government.

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Please reference this report as follows:
Daniel Gilmour, Ehsan Jorat, Andrew Minto, Irene Tierney (2022). Effectiveness of construction mitigation measures to avoid or minimise impact to groundwater dependent wetlands and to peat hydrology. CD2019_03. Available online with Main Report at: crew.ac.uk/publications

ISBN: 978-0-902701-95-3

Dissemination status: Unrestricted

Acknowledgements:
The research team would like to thank the steering group (Claire Campbell (SEPA) and Deborah Spray (NatureScot) and the following organisations for participating in the study. Green Cat Contracting, RSK, Mac Arthur Green, WSP, Force 9 Energy, Botanaeco, Scottish Power, Perth and Kinross Council, Antorr, LLTNPA, AECOW, MSS and R J McLeod.

Cover photographs courtesy of: Abertay University

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Appendix A – Semi-structured interview questions

Semi-structured interviews for consultees were carried out to elicit experience of working in wetland areas, such as, groundwater dependent wetlands and on peat.

Questions included were:

1. In your current role, what type of projects typically involve working on peatlands and wetlands?

2. In your experience, what impact do the following construction techniques have on peatlands and wetlands in terms of impact on soil water content, plants, peat soil properties and preferential flow routes for drainage:
   a. Cut and fill road construction;
   b. 'Floating' road construction including pre-loading;
   c. Excavation for borrow pits;
   d. Excavation for foundations;
   e. Trenching for laying pipelines, cables and other associated utilities infrastructure.

3. What is your experience with the following techniques in or near wetlands or peat soil:
   a. Culverts, cross drains, permeable construction and other drainage features applied to maintain subsurface water flow in soil across linear infrastructure such as roads;
   b. Using silt traps to prevent pollution of local water sources and wetlands;
   c. Removal of acrotelm layer separately, careful storing on site then careful reinstatement;
   d. Blocking of historical drains for rewetting;
   e. Scheduling construction for seasons where impacts will be reduced;
   f. Using native seeds or carpet spreading harvested peatland seed heads for re-vegetation;
   g. Reducing compaction by limiting construction traffic in certain areas;
   h. Using cut off drains and a swale or similar to redirect water from upslope of a borrow pit, move it and reintroduce as a diffuse flow downslope of the borrow pit;
   i. Borrow pit reinstatement (also known as restoration);
   j. Translocation of wetland plants;
   k. Any other mitigation technique not listed above.

4. If you have you ever been involved in field trials to assess the suitability of the following techniques, please describe the field trial and who to contact for further info.:
   a. Culverts, cross drains, permeable construction and other drainage features applied to maintain subsurface water flow in soil across linear infrastructure such as roads;
   b. Using silt traps to prevent pollution of local water sources;
   c. Removal of acrotelm layer separately, careful storing on site then careful reinstatement;
   d. Blocking of historical drains for rewetting;
   e. Scheduling construction for seasons where impacts will be reduced;
   f. Using native seeds or carpet spreading harvested peatland seedheads for re-vegetation;

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i. Borrow pit reinstatement (also known as restoration);
j. Translocation of wetland plants;
k. Any other mitigation technique not listed above.

5. What in your experience are the most effective mitigation techniques to preserve the existing water table level, rate of water supply, the existing plant community and peat soil properties when constructing on peatlands and on or in proximity to wetlands?

6. How much consideration is given to environmental factors compared with the cost of mitigation?

7. In your experience, how essential is post-completion monitoring to ensuring peatlands and wetlands are properly reinstated?

8. In your experience, how long will it take for peatlands and wetlands to be reinstated to pre-construction levels, if at all?

9. Have you looked into long-term assessment of applied mitigating measures?

Appendix B - Interview findings

B.1 Interviews

Semi-structured interviews were undertaken with 17 practitioners (2 contractors, 7 hydrologist/ ecologists, 5 environmental consultants, 2 planners and 1 developer) to gain feedback on their experience with techniques and mitigation measures when designing and constructing on GWDTE or peatland.

The interviewees were asked to consider based on their experience:

What impact do the following construction techniques have on peatlands and wetlands in terms of impact on groundwater and on habitat?

Through these interactions, interviewees experiences of successful and unsuccessful construction practice on wetlands and peatland were collected. Their composite experience has been compiled under the general themes of the semi-structured interview questions (Appendix A) to present a coherent discussion, as would have been possible in a workshop. A summary of key points related to the level of effectiveness has been compiled and incorporated into an evaluation matrix shown in graphical form for each thematic area. The level of effectiveness is based on the findings of the literature review and interviews conducted by the Project Team. 1 being the least effective and 5 being the most effective.

B.1.1 Themes

A. Planning, avoidance and GWDTEs

The starting point for the developers and designers is avoidance. Thorough site investigation prior to design is an important factor in reducing construction impacts on peat. Detailed design surveys are needed to avoid sensitive areas. The interviewees use guidance documents as part of the design, avoiding sensitive areas and areas of deep peat. This provides an opportunity to look at the negative effects of development and manage these positively. A number of interviewees pointed out that classifying GWDTEs is sometimes a challenge. Potential GWDTE wetlands are often fed by water from a range of sources: surface runoff, rainfall, as well as groundwater. The need to focus on wetlands which are critically dependent on

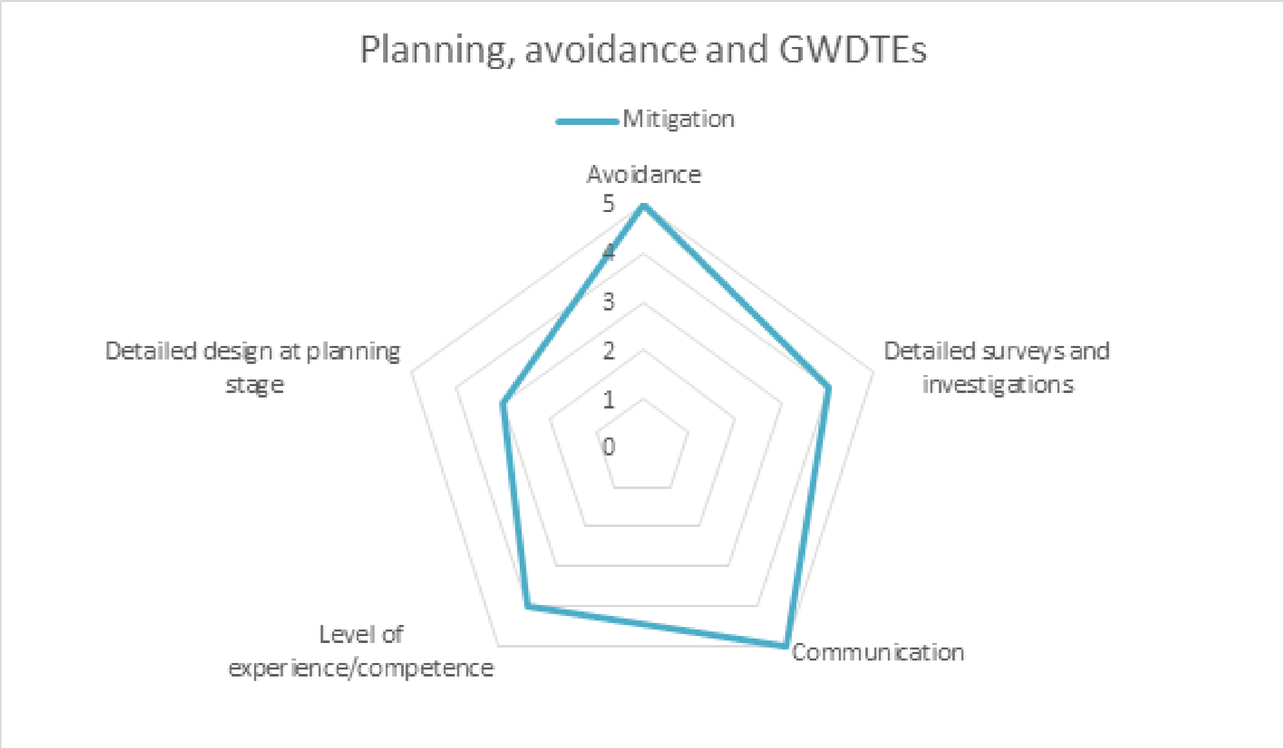

Figure B1. Planning, avoidance and GWDTE evaluation matrix.

groundwater was something consultants have identified as a priority. There may be a skills problem (in determining NVC/ GWDTE) in ensuring that those carrying out the survey can read the topography as well as determine the type of vegetation on the ground.

The interviewees identified that planning is crucial with the importance of detailed ground investigations at the planning stage emphasised. The length and direction of access tracks, choice of machinery etc., is crucial to minimise disturbed peat and should be given more consideration in planning to prevent these decisions having to be made on site, without all the information. On wind farm projects, detailed design of roads through peat, for turbine access, should be done after careful topographical and hydrological analyses in advance of the construction. The interviewees noted that closest distance between turbines is not necessarily the best construction option in relation to peat preservation.

The interviewees identified the kind of techniques employed are always guided by SEPA guidance documents. It is also important that the designer and contractor make sure that the guidance is then followed. It is important on site to have clear regulations to keep the contractor compliant and it is helpful to refer to regulations and guidance documents. Issues can arise where standards don't always seem to be followed. An example identified was where culverts are properly designed with levels etc., when they are part of a specific catchment or license, but then there are other watercourses which are almost left to the judgement of the foreman (or whoever else is on site). Issues arise due to the lack of design guidance given where sizing, levels, etc., aren't given in advance or properly designed. Interviews also identified that a lack of communication between the site agent and foreman, where the site agent might agree to a certain size of pipe in a specific location, but the foreman chooses to do something different or miss it out entirely.

The interviewees raised the importance of any change of plan in construction should be discussed with and approved by the project's ecologist. Considerations, such as, construction activities on peat during winter season, can result in pollution incidents and possibly damage to peat. For prevention of peat slide on slopes on thick blanket bogs, removing some peat to reduce angle of the slope could be an option. A number of interviewees noted they were looking at Controlled Modulus Columns (CMCs) intensely for various types of development as it can possibly be used for crane platform hardstanding, roads etc., in deep peat. The piling method avoids excavations and therefore avoids habitat loss with interviewees identifying that the footprint of hardstanding is often much greater than the footprint of the turbine. The situation often arises that hardstanding is situated in shallower peat and the turbine in deeper peat because of the footprint. With the use of CMCs, it may be possible to locate turbines in shallower peat and hardstanding areas in deeper peat supported by CMCs. This approach will reduce the amount of material needing excavated.

B. Impact of cut and fill

Interviewees stated that the cut and fill technique is most damaging. In constrained sites, it is often difficult to store peat turves and keep these wet during excavations and placing of material. It was noted peat then oxidises if it is not kept hydrated, and it then will not regenerate when placed back again but was not always possible to avoid. The interviewees noted that generally, the design phase is not the issue. Normally the issues arise when site work begins. One interviewee stated "With cut and fill, sometimes you'll see where there is a cut off drain on the high side of the road, it should be that at least every 50 m any water caught by that drain will be piped under the road and let away through a spreader bar or similar to put it back to a diffuse flow but when it comes to practice people are often reluctant to put pipes under the roads and often there is an issue of timing". In this context, the scheduling of the activities at the design stage is not in keeping with the way the contractor would phase the work on site. Timing of work as an issue, often there might still be earthworks to do before the final level is reached and the contractor might not want to put a pipe in at that time. The feedback from the contractor is that they do not want to put the pipe in early because they do not want to subsequently damage it when doing earthworks operations. Better forward planning to ensure a more achievable programme that can better reflect the work on site may be the best solution for this type of issue.

Mitigation to maintain subsurface flow is a recommended good practice measure, e.g., cross drains to maintain flow. The interviewees identified that this needs to be appropriately designed to conduct the expected flow rate. The designer is often not involved in construction phase it is therefore left to the contractor to judge the topography.

The interviewees identified that, during cut and fill process, there is often a time delay between when the peat is excavated and then reinstated. It was identified that contractor experience is crucial again because more experienced contractors will have everything ready so that delays are minimised. Sometimes peat layers are mixed by less experienced contractors, emphasising the skill and experience of the contractor and how important that is to any mitigation technique. In practice, the process of taking turves and storing them is not as straightforward as sometimes suggested because of programme constraints. Particularly with linear structures because finding areas to store the turves can be challenging.

The interviewees noted for either cut and fill roads or floating roads, the project relies on depth and quantity of peat. If the peat is deep and covers a vast area, floating roads are the recommended option (an example of a 100 m long road over a 2 m deep peat was made on which a floating road was built on the peat). The group also noted when having a small thickness of peat over a hard ground or having peat in one side of the road and hard ground on the other side, peat is usually excavated and placed in borrow pits. An example was provided where cut and fill roads have been used as dams for peat, so what seems like a negative can be a positive. It is possible to follow the land contours for track construction, thus avoiding steep slopes and also deep peat deposits.

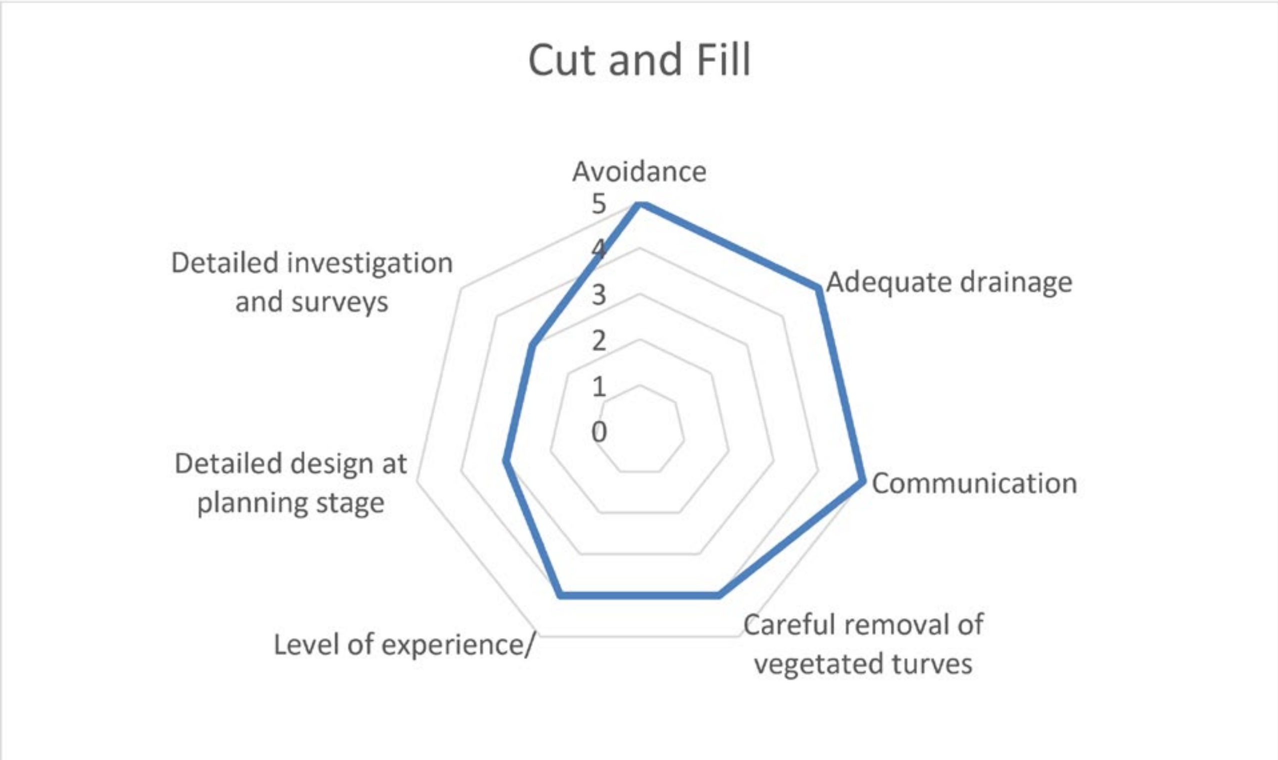

Figure B2. Cut and fill evaluation matrix.

C. Impact of floating roads

The interviewees considered that well-constructed floated roads are the most effective technique, in terms of, having the least amount of impact. Floating roads cause less disruption because less material has been excavated. Often, contractors still want to cut off drains when using floating roads, which sometimes may do more harm than good. The interviews identified that if you can get the grade on the floating road right, the water will diffusely run off to one side. This works very well when the land is relatively flat but is more difficult with a gradient. The interviewees noted that the pre-loading phase can be difficult to get right because it is quite technical. Programme constraints can influence the pre-loading phase. The time it takes to get the process right can influence how successful the mitigation is.

Interviewees identified that floating roads cannot be made on steep slopes; in these locations cut and fill roads seem to be the only option. For sites where stones are readily available, floating roads are the best option especially where deep peat is present in the site. For drainage of floating roads, if there are existing channels, drainage can be maintained through them, underneath the road, or use an upstream cut-off ditch for clean water where the road crosses and a downstream dirty ditch to convey water into silt traps, for silt management. For surface water, installing a pipe at the ground level to drain water along the road is an option.

Interviewees noted floating track is always the first thing considered, if possible, because of the reduced impact, and always consider a path for subsurface flows if possible, especially if there is a GWDTE downslope. Interviewees suggested cross drains should be standard on floating tracks, which can be done as several pipes over a certain stretch of track that will encourage subsurface flow in that direction. It was also noted that drainage design should try to keep flows within the same catchment or sub-catchment, if possible. Floating tracks would not typically be constructed on a slope with more than 5-degree cross slope where peat stability guidelines suggest that they do not become effective. Roadex guidance (see https://www.roadex.org/) also uses this 5-degree cross slope as a limit for floating roads. An example presented was the combination of floating roads with piled load transfer platform to avoid excavating on a steeper slope.

It was identified that floating roads tend to sink gradually over time, although no timescale was given to the potential associated deterioration of the cross drains below. Accordingly, floating roads should be designed to the highest geotechnical specification. It was recognised that all types of construction, whether it's a floating road or even a dug road, are going to have an impact on the flow of water.

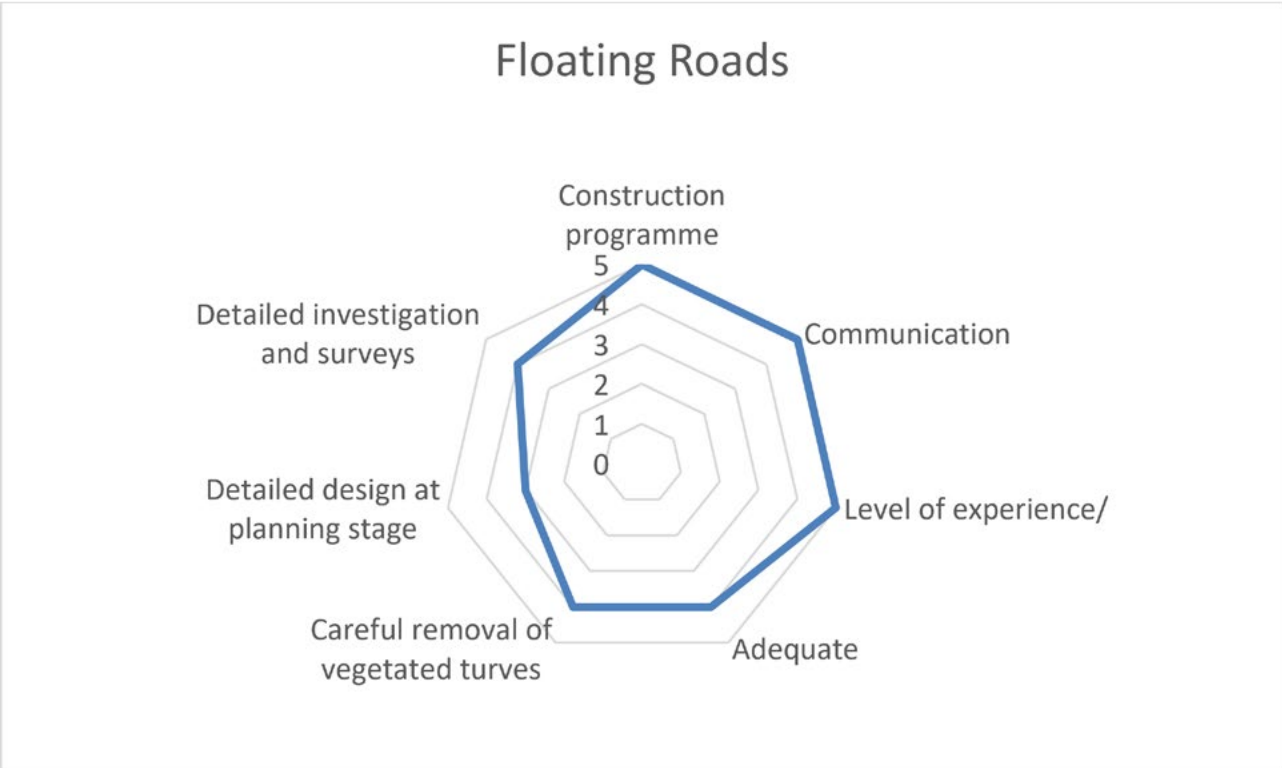

Figure B3. Floating roads evaluation matrix.

D. Borrow pits

The interviewees identified that during the excavation of borrow pits and foundations, the management of surface and groundwater flow are particularly important. Borrow pits will permanently alter flows within the footprint so, to minimise the impact of borrow pits, the selection of the right location in the Phase 1 outline design and Phase 2 detailed design is required. For borrow pits on a slope, side cut and fill will be required. To stop silt from getting into a borrow pit, building drainage into the uphill side is required. For proper drainage, water flow during winter should also be considered and drainage should be designed appropriately. Borrow pits and foundations tend to have a lot of effort put into drainage solutions which is required to prevent surface water getting into the excavation. Although sometimes with programming issues, the cut off drains are installed too conservatively, and drains may occur around a wider area than is necessary. For example, where cut-off drains are put in place before final micrositing of the turbine takes place. This ends up a larger area of peat damaged than is necessary. It was identified as important to divert water away from excavation and direct it into sediment ponds so that sediments can be collected prior to discharge. The group also noted that recommendations may change for each quarry depending on hydrology and topography.

The soil and peat management plan will provide the information on borrow pit reinstatement so that material balances out, as planned, hence calculation drives action rather than rules of thumb. Borrow pit reinstatement is normally successful but for one project out of three, peat settlement was observed, where there is a noticeable depression on the surface of the borrow pit. No solution to this was identified during the interviews.

The appropriate choice of measure and the effectiveness of the mitigation is a balance between sensitivity, peat thickness and practicality of construction. It is therefore important to survey drainage and water course identification. The reality of not knowing the full site conditions until starting on site was raised, "It is that you are often going into something unknown and you don't know what you are going to get. You don't know the extent of your excavations, layout and therefore don't know your mitigation until you have undertaken task on site."

The interviewees raised the importance of recognising the fluidity of the site and the site team's willingness to respond to site conditions. Sometimes the final design of silt mitigation may not be like the mitigation plan. This can occur when contractors change during the project or are engaged late in the process.

Large, deep excavations require a drainage plan to be put in place for pollution prevention. Cut off ditches are used to avoid water going into an excavation and potential water issues. It is essential to reduce the amount of water getting into these spaces. There is always a clean water ditch up slope, to take water away using the principle of not mixing clean and dirty water. When digging the foundations (or borrow pit) of 3 to 4 metres, sub surface flows from the sides that enter the

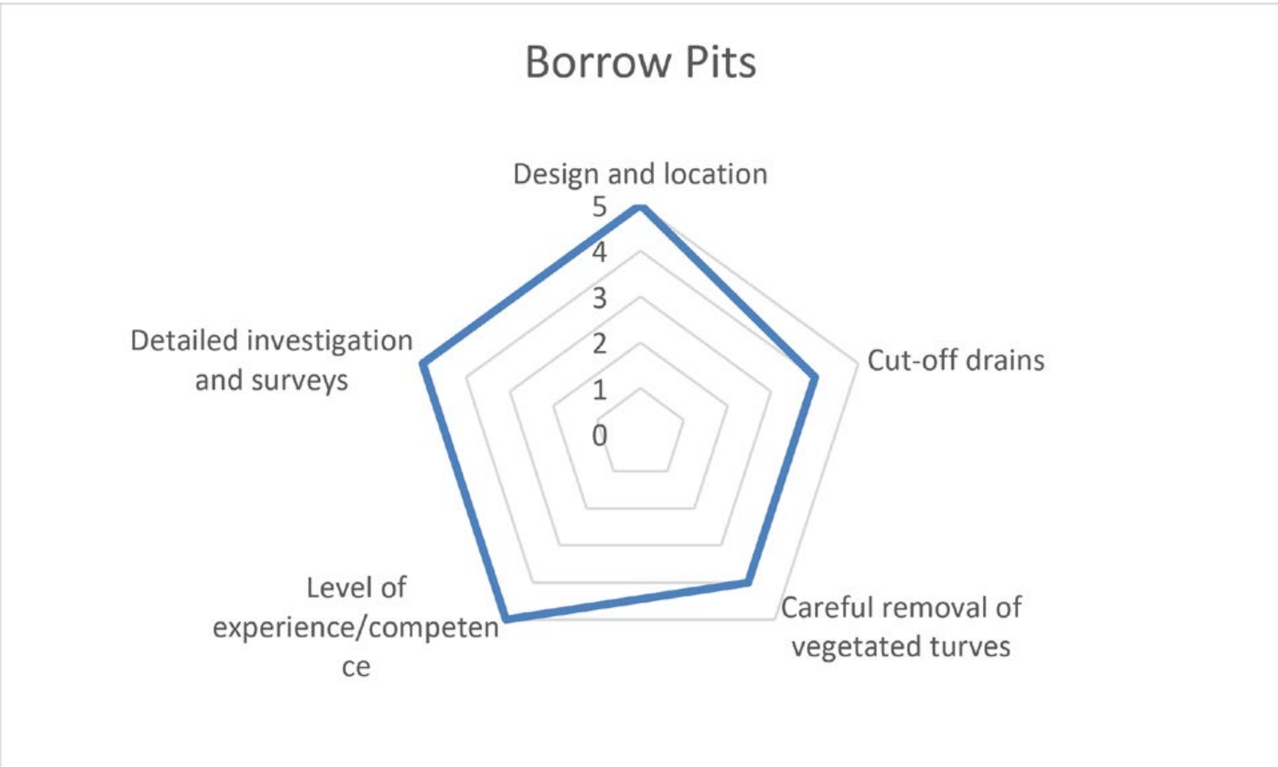

Figure B4. Borrow pit evaluation matrix.

excavation will be evident. It is recognised that water is being drawn in from other flows further up and this may change the hydrology or hydraulic head.

Interviewees identified that wind farms tend to have a high requirement for rock regarding the type and size of the tracks that they need and for crane pads, whereas hydro schemes have less rock requirement. If the borrow pit does not yield the type of material the developer thought they would get, then their site investigations have not been robust or good enough. Quite often, some developers will think that not having a borrow pit on site would be of benefit to the development proposal and importing material should be an ecological benefit. Conversely, it has a big impact on residents. Not having a borrow pit can be a significant material consideration to approval decision makers, as you could be looking at thousands or hundreds of thousands of tonnes of rock being imported. This will have associated traffic, road disruption, noise and air pollution impacts. Understanding what the geology is, what kind of rock will be yielded is important to most development proposals. It was noted that not understanding the environment that projects are working in, more fully, is a problem for development proposals going forward.

E. Cable and pipeline installation

Often, with cable trenches, sand is introduced into the peat environment. Standard practice is to include a clay or peat plug but this isn't always done correctly. Frequently, programme constraints mean that the contractor wants to lay as much cable as possible in the shortest period, and might not choose to excavate the trench, lay cables and then plug and backfill, which will take more time. In other countries, specifically Norway, all cables are laid underneath the road in the same way some utilities are laid under public road networks in order to prevent additional damage to peatland environments. This has been successful in reducing the construction footprint by removing the requirement for trenches running alongside the tracks.

An example was provided where cabling on a previous project was undertaken using drilling techniques which used a bentonite fluid, where bentonite seals the drilled shaft from water ingress downwards and at the sides of the shaft. The mineral forms a firm sludge cake on the bore wall which provides the borehole with additional stability. Two lines were put through, one for the cable and one was a redundancy line. There is an assumption that all cable trenches will follow the route of access tracks to the substation and considered as part of excavation during the design. Buffer zones to groundwater receptors, i.e., 100 or 250 m buffer, are considered depending on depth of excavation.

The penstock may become a preferential flow for water depending on the material used to back fill the pipe. The materials and the design of the penstock were emphasised as important to halt the preferential flow of water. Putting in a clay or bentonite plug or similar that prevents the water from travelling down the penstock is useful. The interviewees identified

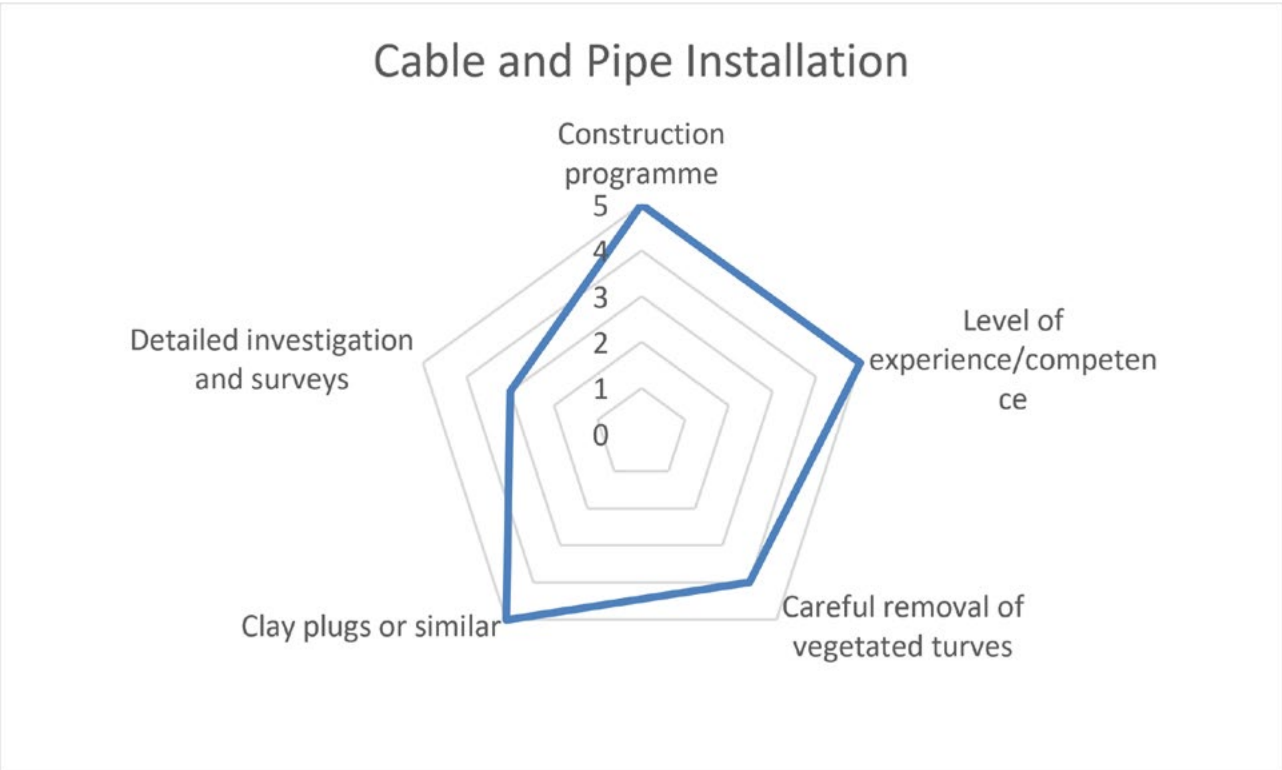

Figure B5. Cable and pipe evaluation matrix.

that clay plugs are effective, but the effectiveness is driven by how often these are added. The required spacing depends on the amount of groundwater, the size of the flush, over what area, and downstream impact. If the impact downstream is not significant, then, in the lower side of the penstock, clay plugs may not be needed. These were the only mitigation methods (for penstock) identified by the interviews and they stated that they do appear to work where they are used but their effectiveness is very reliant on installation by a diligent contractor.

If clay is not available, the interviewees identified the burying of sandbags would probably be preferable to use of imported materials. There is often a preference from NatureScot to avoid using imported materials, particularly for sensitive habitats. Locally won (e.g., from a borrow pit) materials are preferred, where there are not locally won materials, another man-made type of a solution would be better rather than importing clay from another source. Not every site has clay, in fact very few sites do, so finding another solution can be quite important.

The interviewees identified that, in pipeline projects, longer routes can be taken to avoid disturbance to a deep peat. During cable installation, putting cement bound sand periodically into the cable bed will prevent the cable excavation channel becoming a preferential pathway for water. Overhead cabling has a reduced impact because the footprint is much smaller as heavy-duty wooden posts don't require a massive foundation. It is important to consider the moisture content of the peat in the design as this will have an impact on the size of foundation required.

F. Temporary works for access

The interviewees identified options for temporary road access, with metal panel trackway for drier sites and wooden trackway for wetter areas. For more thorough temporary construction, a combination of geotextile and rock is an option. The selection of an appropriate method relies on engineering decisions and conditions of the ground. Contractors will most likely use bog mats for access, and these are normally the least expensive and easily sourced option. It is often the case that because bog mats are narrow, you end up with vegetation and peat being forced up around and in between bog mats. Most bog mats can be secured linearly but not to increase the width of the overall temporary track. Trackway, because it all fits together, has much less of an impact. When the top layer of vegetation is disturbed, regeneration is difficult and lengthy. Some contractors don't want the expense of actual trackway, because the suppliers tend to want to fit these tracks themselves, which costs much more money. Even using trackway, the works access areas need to be properly considered so that the machinery has sufficient room to manoeuvre and carry out the work.

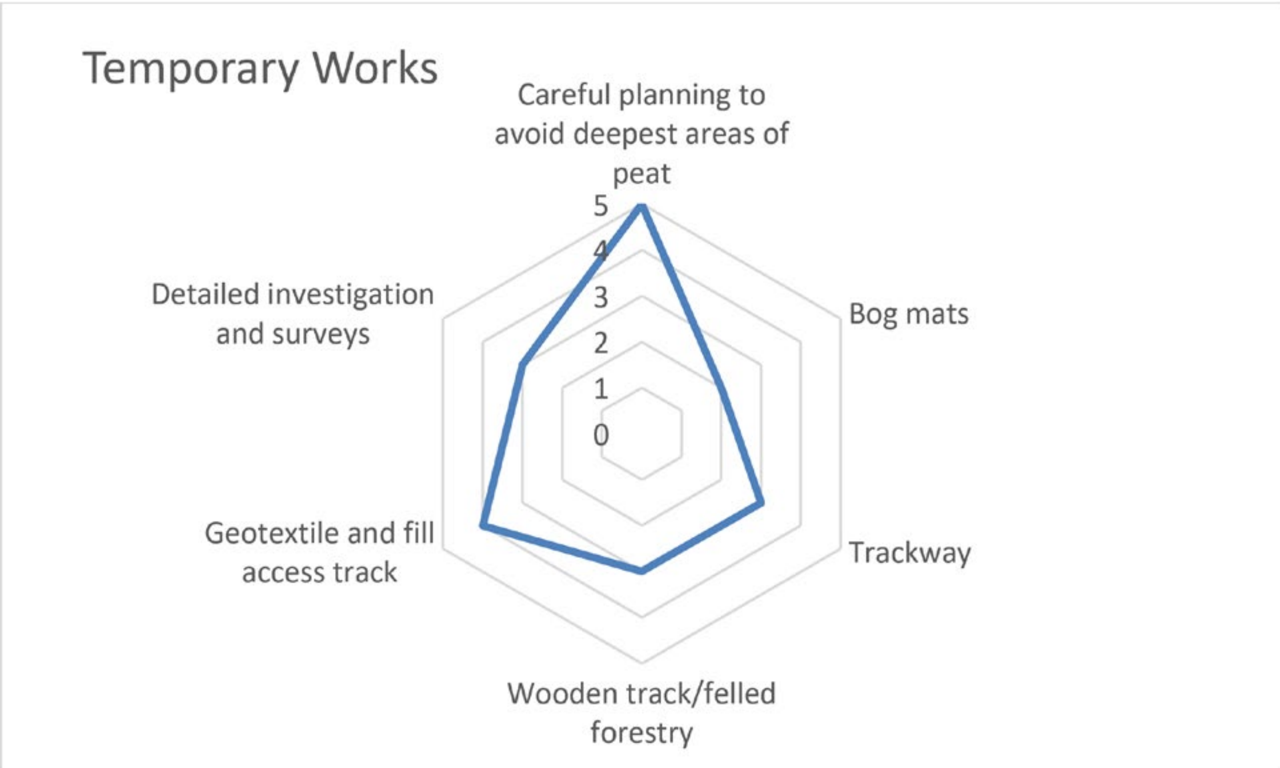

Figure B6. Temporary works evaluation matrix.

G. Planning

In planning the development, full consideration of environmental factors is required. In sensitive peatland, avoid deepest areas; some areas could be enhanced as part of the development of a habitat management plan. Planning aims to enhance the wider environment, with the additional benefits of restoration, so less intrusive construction techniques are preferable. Interviewees noted that even if you have positioned your structure, turbine and crane pad carefully to avoid deepest peat, you may need to orientate the infrastructure to avoid peat excavation. To minimise the impacts on peatland and wetland, selection of turbine models play an important role. Specifications from turbine manufacturers are important factor, i.e., on what type of machinery would be required during installation. Detailed design of a wind farm is an important factor but usually, due to a very high cost, a less detailed design is typical at the initial stages of planning. However, good preconstruction assessments to inform the ecologist on site, to inform the route of access and optimal construction methods, and putting these methods in place, are important factors to minimise impacts on peat.

The interviewees noted that it is important to seek to position borrow pits where peat is shallowest, although using this as the main location criteria during the design process may lead to these pits being difficult to access. This requires the consultant to finesse the design to avoid areas of deep peat and then to use a floating road to minimise the disturbance of peat. Consideration should be given to culverts to ensure that they don't undermine the track structure and that silt management is in place alongside tracks. Even with temporary trackway, temporary culverts can become crucial to maintaining flow. Sometimes the biggest issues come with historic drains that cause more flow, that isn't being held up anywhere, getting to the site.

The depth of peat will affect the design approach, for example, for big turbines 3 m deep foundations are a usual design; in a 3.5 m deep peat, a deeper foundation may be designed for a turbine as opposed to piling. Piling might be an option for <4 m peat, although cost of piling and temporary works that might be required are most likely to be the determining factor for whether piles are a potential option.

The group identified the need for closing out reports from EnvCoW/ECoWs, regarding the completion of the project and adaptive management, detailing the experience on site and how issues were resolved, to be part of planning conditions. There might be the opportunity to use local learning to support developers with information on historical sites, and knowledge of development sites to build more and a greater depth of policy guidance. It would be better to drive the requirement for an EnvCoW/ECoW and a CEMP (as examples) from the Local Development Plan guidance and not solely as NatureScot or SEPA guidance. Currently, the planners steer the developers to NatureScot and SEPA guidance, but it may be good to embed some local learning and experiences across some of the sites as described here. This is probably a useful way to start specifying in more detail what is required of developments so applicants have an early understanding of what is

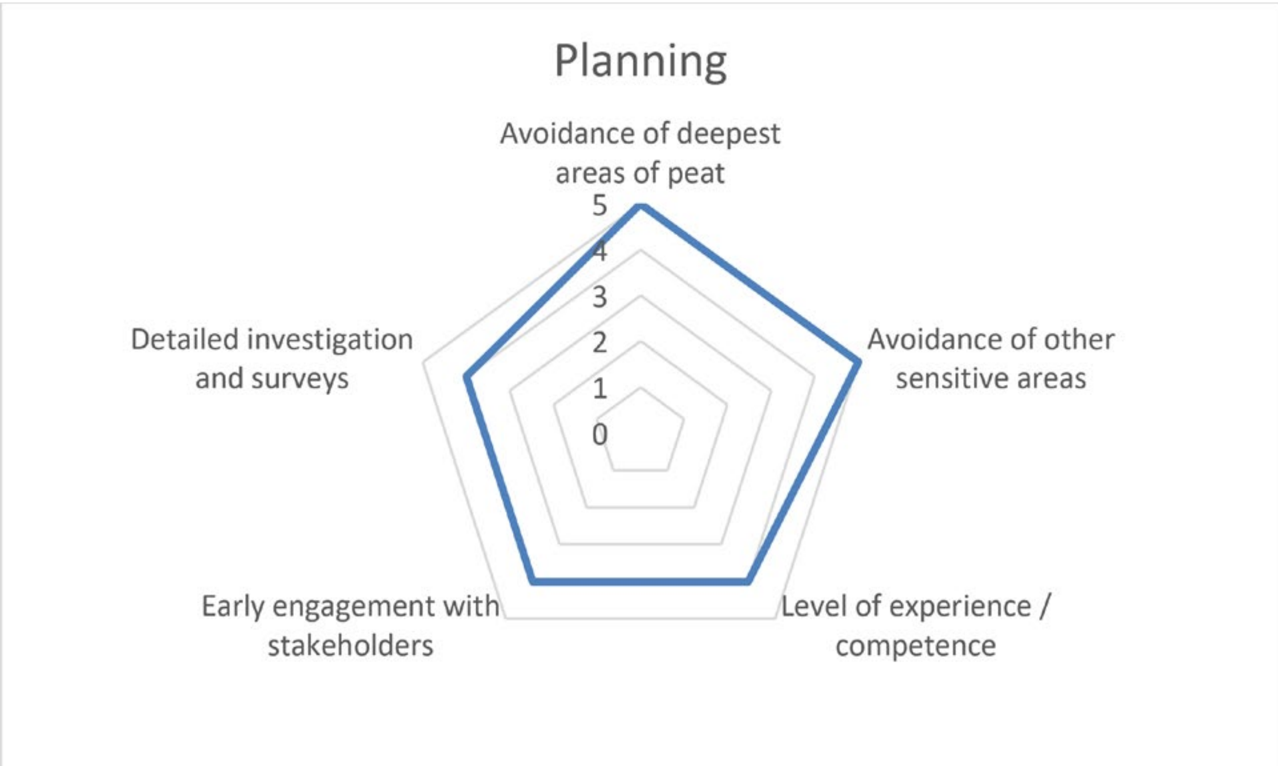

Figure B7. Planning evaluation matrix.

required and to avoid uncertainties prior to submitting applications. Thorough specification of these investigations, can help, in terms of, avoiding issues rather than react to them once construction has started.

H. Reinstatement of verges/tracks

The interviewees stated that verges should be 1 to 2 metres in width (as per guidance) and should tie with the adjacent landform. A wedge down to the shoulder of the road is created and it tapers down, whilst still trying to maintain the depth of peat, but not too thin so it doesn't dry out. No rule of thumb was given for minimum thickness to avoid drying out however, a rule was given for peat to be stored and reused within 6 weeks, preferably keeping the turves wet if required. One option presented was where the verge is laid with turves as a patchwork, if there is not enough material to have a complete coverage. It is anticipated that these patches will act like vegetative refugia for reseeding the other areas. If the track cuts across the slope, it is possible that there is a need for a shoulder on both sides or one side wider or deeper than the other, to conform with the landscape (and landscape guidance). The reinstatement is very much relying on the skills of the digger driver and contractors on site. Where there is enough peat for reinstatement on a slope, and if there is enough water to maintain hydrology, then there can be effective reinstatement (also depends on altitude). The experience on Shetland has shown that reinstatement tends to favour replacement of bog with dry heath habitat. There would need to be high rainfall and some barrier, to prevent free drainage, to provide the right hydrology for a bog mire habitat.

It can take longer, but in terms of slope, avoid any depth of peat and get advice from a geotechnical advisor, especially on deeper peat, as this is where it is more likely to get slope failure, or a peat slide.

When removing peat turves, separating the acrotelm and catotelm are obviously important, but the results can sometimes be mixed, depending on the skill of the excavator operator. It is also important to store turves where there isn't likely to be a large amount of silt run off, i.e., don't store near a watercourse. This should all be planned and marked out beforehand. Interviewees identified bad practice including stripping the turves but then placing the catotelm on top of it. It was recognised that it is difficult at times to spot where the acrotelm and catotelm layer are, given the thickness of the acrotelm in places. The interviewees found that it works best to explain to the groundworkers why removing the acrotelm separately makes it more likely to be successful. Communication of the best practices, and why they are important, make a big difference to the effectiveness. Spoil management tends to be more difficult with linear structures such as cut and fill roads. For effective reinstatement, rehydration is the challenge. This is done most effectively by keeping horizons separate, replacing them as quickly as possible and in reverse order (e.g., from top to bottom: vegetation layer, acrotelm and catotelm layers) and reduces cross contamination. Also, try not to mix layers or get gravel or clay in with the peat to reduce cross contamination and to reduce effects on the soil structure by returning it in the right order as quickly as possible. This will allow the vegetation to recover quicker to a pre-construction state/condition.

Peatland Action do hag reprofiling, which is similar to rolling back the vegetative layer, but instead of the top side of a cut track, it is an eroded peat hag. So, if there is an erosion feature in a peatland, where there is a hag of peat, they have developed the technique where the top layer is removed, reprofile the slope, so that it retains more moisture, and then put the turf back on. In terms of removing catotelmic peat from underneath the acrotelm and spreading on verges etc., even years later it is still apparent where the catotelmic peat has been spread as there are black, cracked areas of bare peat which haven't revegetated or been restored. Unless the top layer is retained, it becomes extremely difficult to establish natural looking vegetation. Instead, soft rush occurs which have roots that transfer air into waterlogged soil, bringing oxygen into the peat layer and oxidising it.

The interviewees shared experience of success using native seeds for revegetation, i.e., spreading lime to stabilise the surface and then using seeds to revegetate. It is not likely that this would be in a wind farm development plan as, typically, the approach is to retain the turves, and that the catotelmic peat will be placed with the turves on top. There is no real 'plan B' if this isn't done carefully. It may be worth considering additional, stronger regulation so that contractors are more likely to make a greater effort to get it right first time. When turves are placed together with gentle compression, it does work well. A lot depends on the skill of the operator and the management of putting the most skilled people in the correct places. Further, it may be worth considering specialist contractors who have a lot of experience in peatland restoration and reinstatement. Also it may be worth considering training for excavator operators in using the techniques that have been shown to be successful. In the tender stage, it may be possible for contractors to have to provide examples of reinstatement work that they have done in the past etc. This would enable the client to be confident that the work will be carried out to the required standard.

An example of a verge revegetation study conducted at a site near Tain, nearly 600 m above sea level, found that these verges took almost 10 years to become 75% revegetated. Although, there were other issues with deer grazing on the vegetation. Additives such as geogrids, wood chips, fertiliser etc., were applied but did not make a significant difference. Seed availability is not a limiting factor, as there is usually a large number of seeds available. The problem is that excavated peat, that has been put back on the roads, is not the best growing medium. It is also very unstable and is normally piled above the water table, so that it dries out and oxidises. The peat is oxidising faster than the vegetation can grow – this can be worse in a particularly bad winter. Therefore, using more seed is not necessarily the best option to revegetate. Sometimes the best solution is have some material that binds the soil together. A lot also depends on the quality of the reinstatement, which comes down to the skill and experience of the contractor and to peat management i.e., where they can find places to store peat. It is possible to put peat in borrow pits, if they can be engineered to be a shape which can hold peat, as they naturally retain water. The peat tends to persist much better in borrow pits rather than in verges.

The interviewees noted when stripping turf and peat, where there is a good coverage of peat, stripped peat can be piled in blocks and looked after, but it is more difficult in variable depth peatland where peat can be mixed with other types of soil while being stripped. Most developments occur on variable depth peatland. For reinstatement, in areas where stripped peat could be preserved in blocks and replaced in shortest distances from the deposition site, the peat and plant structure remain in good shape and vegetation gets re-established quicker. In variable peat sections where stripped peat is accompanied by other types of soil, excavation results in breaking peat and vegetation structure and reinstatement usually is more difficult. Reinstatement on steep angled slopes is very difficult. Usually, to stop reinstated slopes being washed out, biodegradable material is used to cover the peat, in addition to seeding, to encourage vegetation growth. Choosing a suitable seed mix for a site remains an issue.

For recreation of habitat, re–seeding and tree planting are recommended. On organic soils, bog woodland is a potential habitat to create. However, most species of trees would not be suitable on blanket mire or raised bog. Re-seeding should continue every springtime until vegetation stabilises. Seed mixes should be selected carefully to be compatible to the surrounding environment and not to impose any risk to the existing species. Upon disturbance caused by construction, recreation of habitat would eventually happen as time is given for the land to regenerate (usually a few years).

Good contractors will take the turves off from the tops and lay them to one side, face up, keeping them moist, replacing them as soon as they possibly can, and they have a good reinstatement rate. Sphagnum propagules are used on site, as well as hydroseed, but general advice is to avoid peat. Also, to use peat appropriately along verges and for reinstatement and to prevent it from drying out. Micro siting is important to work around peat, rather than to work in a straight line.

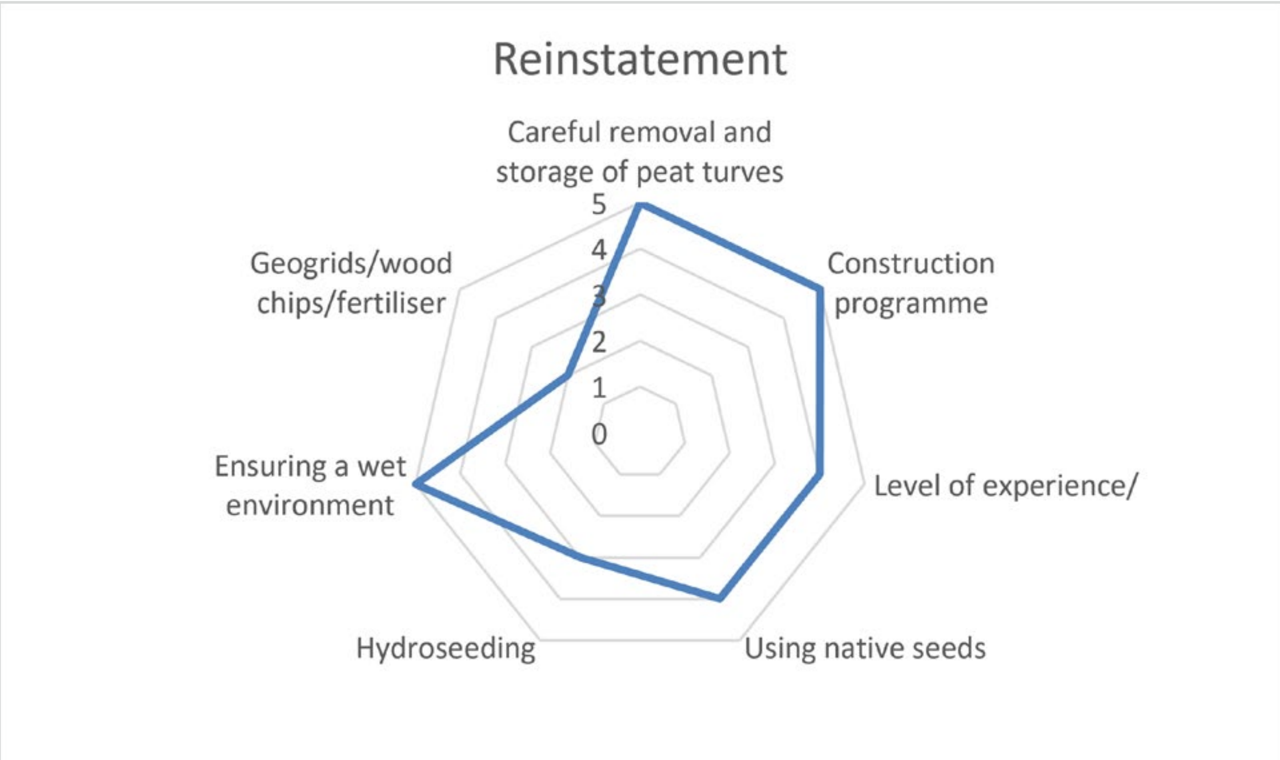

Figure B8. Reinstatement of verges and tracks evaluation matrix.

I. Borrow pit and foundation reinstatement

The interviewees identified that, during borrow pit reinstatement, a lot depends on whether it can be covered with intact acrotelm, otherwise very soft spots of bare, black, cracked peat will occur. The reinstatement will work more successfully with peat turves placed on top. Also, making sure that existing good vegetation is not covered. Sometimes, additional vegetation around the edges may have to be stripped so that the borrow pit can be regraded properly with the good vegetation placed back on top. Using native seed would be best for borrow pit reinstatement; unless there is a significant seed base around the area, then the best way to proceed would be to allow natural regeneration to take place.

When reinstating foundations, it is often the case that the backfill is a mix of granular fill as well as peat. It is the same approach for the borrow pit, the most important part is the covering material. Around the turbine, it is normally stone covered for access. This can encourage non-native vegetation growth and there are no known options to mitigate against this. However, this is not necessarily a negative outcome since in the long-term, if the rest of the peat environment is restored, such non-native species won't thrive. The zone of influence will tend to be site specific and could also depend on the type of foundation used. Where cables are ducted through a trench, away from the foundation, this creates a preferential flow path for water and could generate a larger influence zone than if the cables were brought up to the surface at the foundation, through the actual pad foundation, and concreted in place. It can also depend on location of the crane pad, the access track and the drainage associated with the track.

On wind farm sites in bog areas, where vegetation has been stripped and reprofiled locally around turbine bases, this has worked effectively. Each turbine location is treated as a sub-site to minimise disruption. Rather than applying a generic approach, management techniques more specific to the particular sub-site can be adopted. It is also easier to address when mitigation techniques haven't worked so well, when considering localised areas around turbines.

An interviewee provided an experience where Hydroseeding was quite patchy, although the revegetation happened quite quickly. In this case, using material from adjacent areas was more effective over time but did take longer to revegetate. They noted with hydroseeding, pioneer species can thrive, but the second phase is more challenging because the conditions for the second stage to come through aren't captured using hydroseeding. If time allows, then solutions other than hydroseeding may be preferable. The time to revegetate would depend on the size and shape of the borrow pit. More linear borrow bits will probably revegetate quicker than round, bowl borrow pits because the distance from the edge to the centre of the borrow pit is shorter.

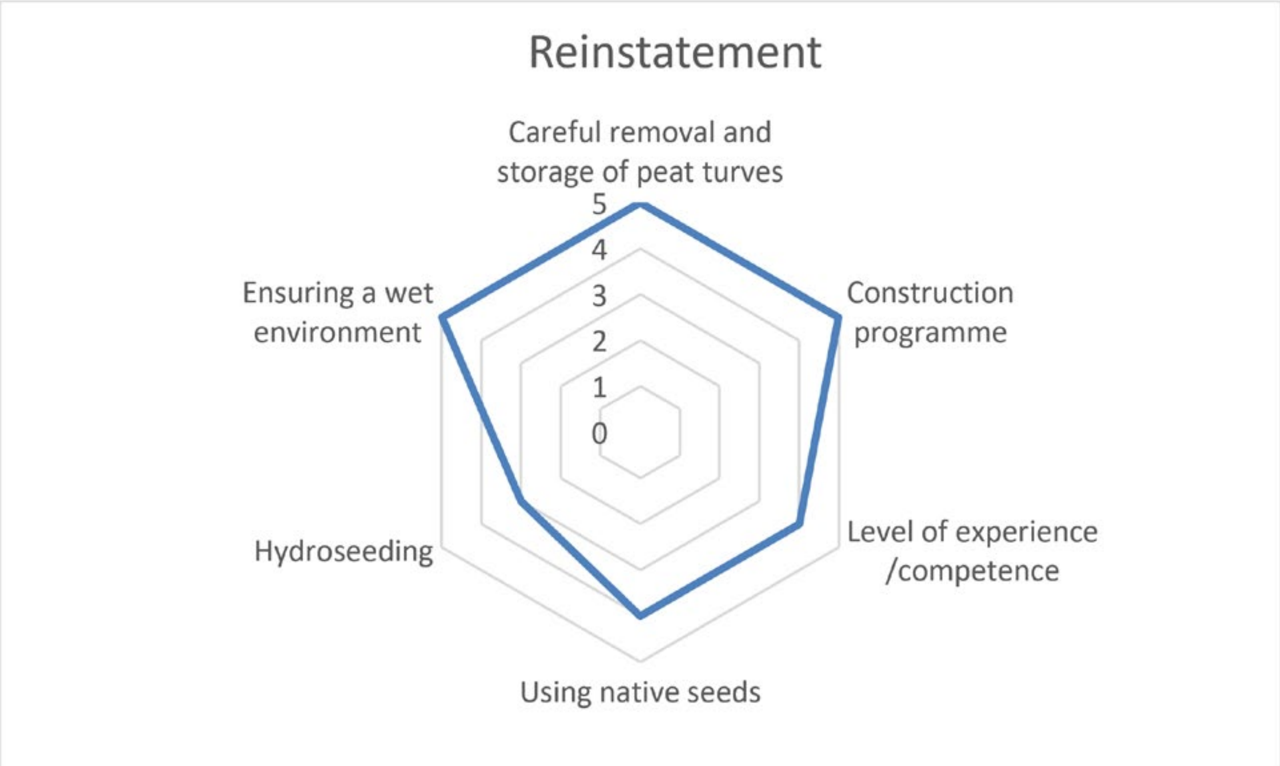

Figure B9. Reinstatement of borrow pit evaluation matrix.

J. Silt management

The interviewees identified that silt management is most effective when the contractor takes a pro-active approach, i.e., identifying where silt management will be required/what silt management technique should be adopted before any construction work takes place. For example, one contractor had installed silt fencing before any excavation work was carried out, and the groundworkers found it useful because it gave them a 'target' for where to place the excavated material. Maintenance of access routes etc., are sometimes in areas where there can be significant runoff, but it isn't always obvious to begin with that a silt fence might be required. Good, more experienced contractors will spot the less obvious areas where silt fencing is required and act accordingly before any work takes place. It is more difficult to put in silt management once runoff has already started. The interviewees noted that maintenance of silt traps is also crucial.

Explaining to the groundworkers how silt fencing works and why it is necessary is also crucial. There have been instances where silt fencing hasn't been in contact with the ground because groundworkers were not told how the fence works. It's important for groundworkers to understand that the reason why that silt trap is being put in the water course is that it is a mitigation measure in the first instance, and they need to avoid the silt getting into the water course. The same can be said for the CEMP, it is important that everyone on site understands the CEMP in its entirety and it should be the responsibility of the EnvCoW/ECoW to ensure this, so that all mitigation measures are implemented properly and, therefore, are more effective. Interviewees stated they often see silt traps that haven't been maintained. So, regular maintenance is key and they need to be well positioned.

Silt traps are an effective method to reduce contamination of water sources in wetland. However, heavy rainfall events can impact performance of silt traps, where they are incapable of dealing with large flows of water. To fix this, appropriate design to minimise runoff is an effective technique, including stopping trenches being preferential drainage pathway by building trenches in drier locations, if possible.

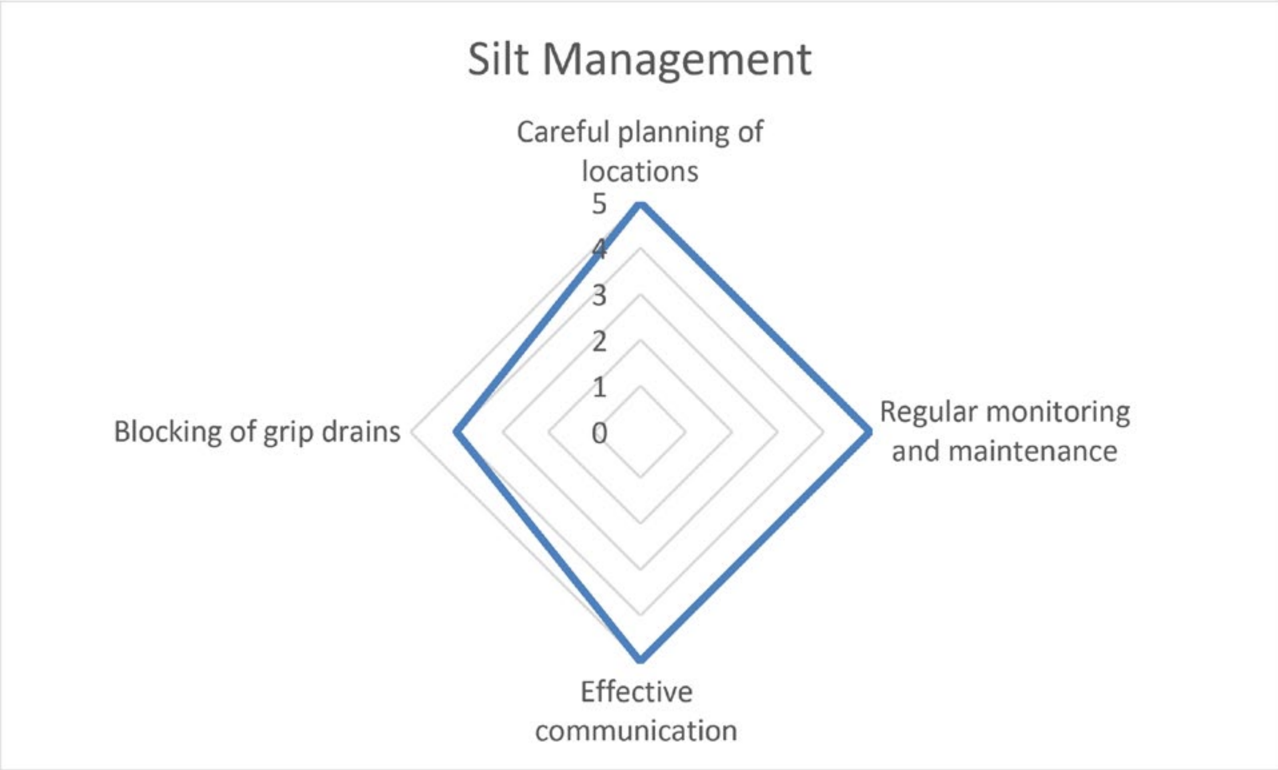

Figure B10. Silt management evaluation matrix.

K. Buffer zones

Interviewees noted that buffer zones between water courses and proposed construction activities are required by the guidelines. Marine Scotland Science normally support the 50-metre buffer zone. It is recommended to put in a shallow drain i.e., not cutting a metre-deep drain and getting a lot of subsurface water flow pulling into drain, to keep it as shallow as possible, therefore, trying to keep to a minimum depth. Typically, there would be a ditch or drain on the down slope of the track, usually at the shoulder, to catch the dirty water and that will feed off into sumps, silt trap ponds and small lagoons. Most sites use smaller lagoons as these are easy to manage. Sites that don't have space or have constraints must be more adaptive, potentially holding water in small lagoons (or set of small lagoons).

The interviewees advised that once the water has been cleaned, that the water is discharged naturally and not discharged straight to a watercourse. It is recommended to return the water as close to its natural source as possible to maintain its natural flow path. The water is discharged onto a vegetative surface close by, so water will then naturally flow back into the watercourse. For maintaining hydrology from one side of the track to the other, it is best to look at the natural lie of the land such as flushes, and maintain small pipes from one side to another that follow the flow path, which maintains the flow. These natural flow paths are maintained so that water is not removed from a potential GWDTE or peatland downslope. For culvert and other drainage features, design the crossing structure in a way that the structure does not restrict the channel flow in extreme conditions. Small pipes are used for this purpose or a group of small pipes depending on size if it is a watercourse or a flush; in a wide flush where there is not a defined edge/channel then a row of small pipes can be put in that go through the track from one side to the other. Pipes can be wrapped in geotextiles or small stones or some sort of permeable material. The stone and geotextiles may help filter out any fine-grained materials that you may get at these sites. Clay type bunds can be used to stop the floating track acting like a preferential flow path/drain. Sandbags are sometimes used, wrapped in terram, but contractors often prefer not to use materials not already on site.

For mitigation techniques on peat, contractor's appropriate machineries to cut culverts in peat could minimise disturbance significantly; turf cut for construction must be managed while piled in borrow pits as blocks, and very quickly reinstated after construction is completed. Delay in reinstatement is identified as a factor contributing to deterioration of peat quality/structure. Also, mixing peat layers stratigraphy during reinstatement destroys peat quality.

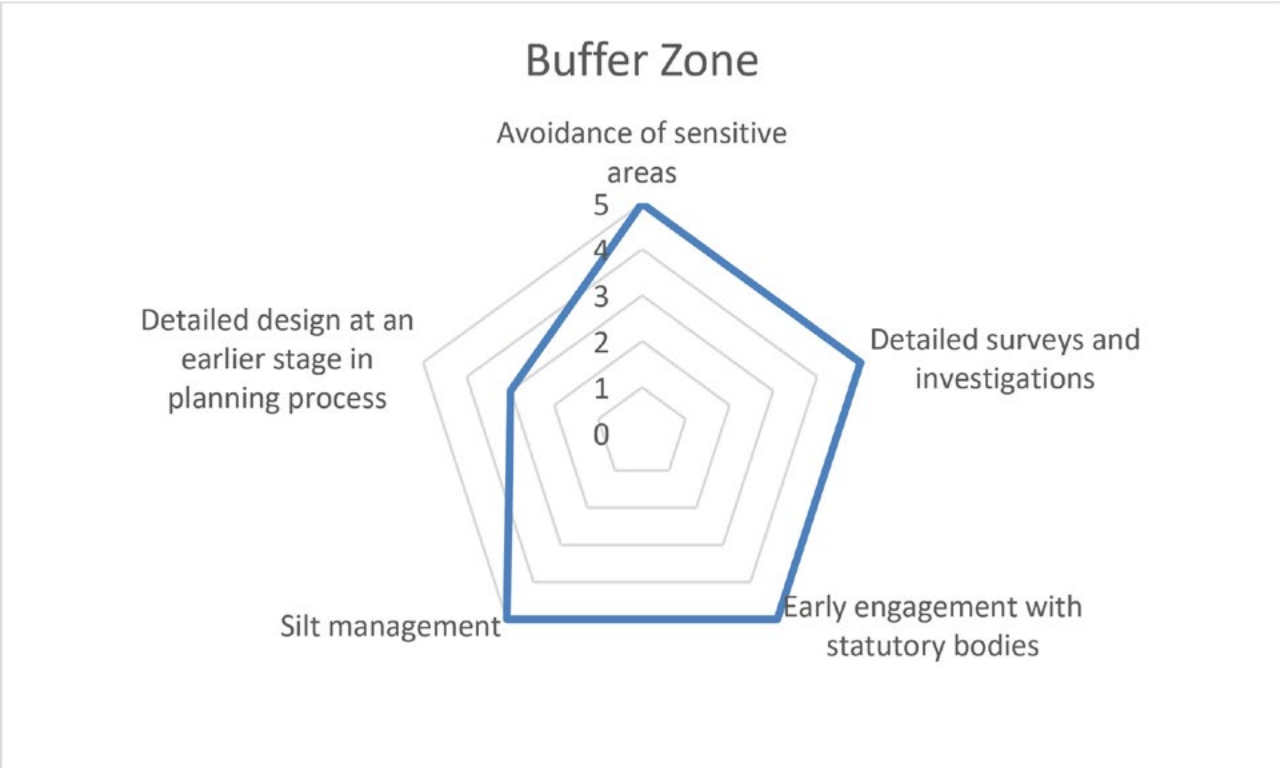

Figure B11. Buffer Zone evaluation matrix.

L. SuDS for re-directing water

The interviewees, particularly consultants, would certainly encourage the developer to consider SuDS as a form of mitigation measure and to put in a drainage system. The main aim is to keep the clean water from the dirty water and SuDS provides an approach to treat the dirty water prior to it going back into the water course. Enhancement of water retention by blocking of historical drains is a decision for landowners.

The best way to manage surface runoff, especially for quarries by the side of slopes, is to make sure there is a sufficiently-sized cut off drain to catch water and divert it outside of the quarry. Allowing water into excavation would result in instability of the excavated area, in addition to operational difficulty caused by accumulated water. Short-term monitoring shows effectiveness of this technique. Cross-drains, where water is drained across the surface of the road, worked well but there are issues with maintenance; whereas culverts constructed underneath the road require less maintenance and are relatively easy to manage so work very well. Interviewees tend to think of these techniques in a hierarchical system (culvert then cross drain) and would apply the technique based on a risk assessment of the effectiveness of the technique against the practical implementation.

Interviewees noted that if contractors are given information in advance, they can implement in the design early. For early drainage, when they are designed appropriately, the zone of influence on habitats is minimised. For stopping preferential path, one method is to stick cables close to existing roads or drains. Also, installing clay plugs at regular spacing along a path stops drainage significantly.

SuDS can be adapted to provide compensatory habitats. Biodiversity net gain is an initiative that is becoming more popular in projects to improve biodiversity around construction projects. SuDS could provide a bit of compensation, such as ponds and infiltration basins. Rather than lined basins, infiltration could put the water back to where it came from, replenishing groundwater.

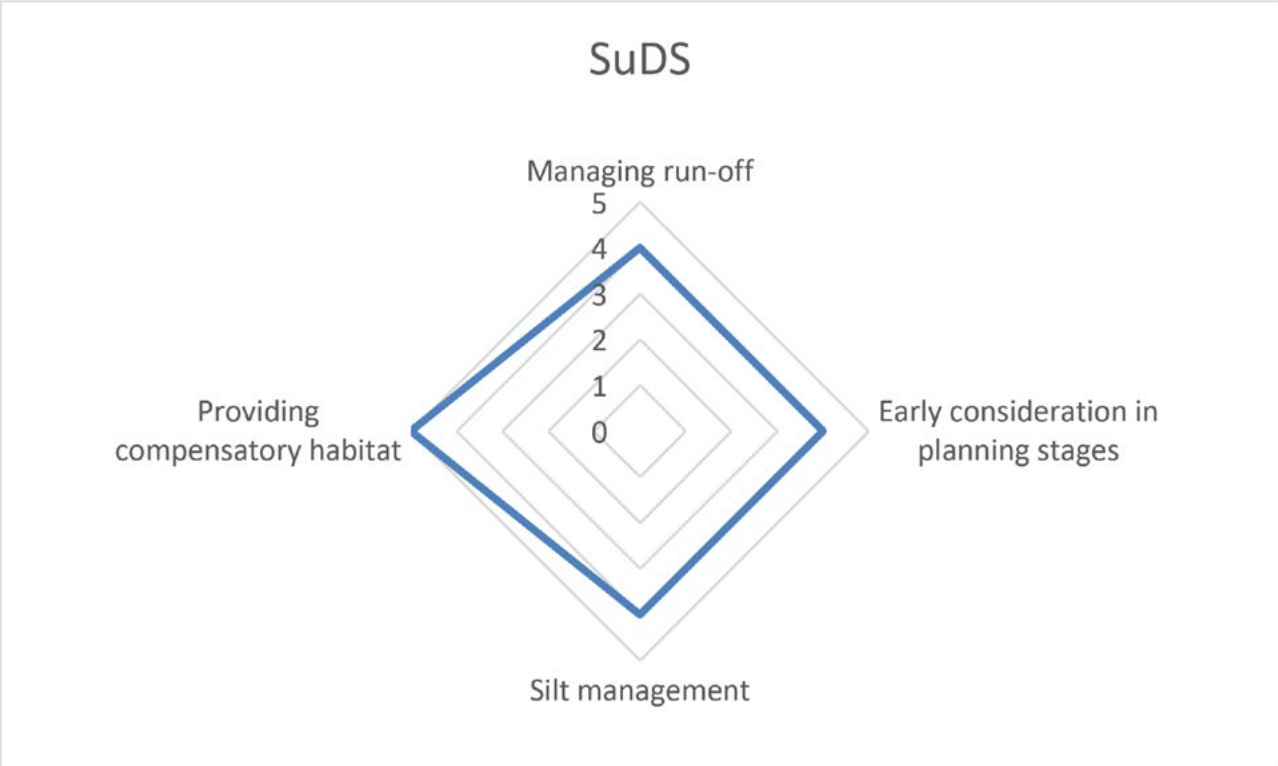

Figure B12. SuDS evaluation matrix.

M. Monitoring

Construction stage monitoring is short-term, that is, a snapshot and there are many factors which can affect the vegetation and the hydrology on a site. Most monitoring is carried out during construction on GWDTEs. The drive for this is mostly by SEPA planning conditions. This is done by vegetation monitoring using quadrats, before development and during development. But vegetative monitoring is not hugely beneficial as the effects on the hydrology would take a long time to manifest. Often, all that is observed is a little story of growth and decay over the growing season, so it is not known if the development has had an effect or not. The impression is that this may not be the optimal method for this type of monitoring on GWDTEs, or hydrology, as it can take so long to see the effects. It's hard to pick out any themes or threads to determine if the construction has had an impact. SEPA planning condition doesn't always state what type of monitoring needs to be done and it's rare that dip wells are asked for, so vegetative monitoring is more common.

Long-term monitoring is required to 1) cover a sufficient timescale to detect changes in vegetation community structure in response to the project (including mitigations measures) and 2) establish whether the effectiveness of the mitigation measures is maintained or declines over a period of years. Interviewees identified the importance of 1) conducting a baseline monitoring programme for at least 12 months prior to construction starting, to provide comparable data for the pre-construction phase and capture natural fluctuations, and 2) use of control sites to differentiate between natural fluctuations and potential impacts associated with the development during construction. It allows investigation of the sort of layering hierarchy that is important in the likes of silt traps and other mitigation measures.

Post-construction monitoring is absolutely crucial to ensure practices are evidence-based. There's little post-construction monitoring; it is usually done during construction. However, developments can have a habitat management plan where they do hag re-profiling and ditch blocking and restoring hydrology, they will also do vegetative monitoring and some dip wells, to monitor hydrology. The monitoring of any habitat restoration that is undertaken is not a replacement for the monitoring of the effectiveness of mitigation/re-instatement measures as both are required. Monitoring techniques should be quite simple and pragmatic to encourage clients to adopt more monitoring. Sometimes clients may be concerned about the cost of monitoring. Effective monitoring is crucial, it must be worthwhile to avoid a 'tick box' approach. Interviewees reflected that if consultants make sure monitoring is proportionate it will encourage clients to do it more. Monitoring can also identify possible alternatives for mitigation that may be more straightforward, that can be presented to clients, instead of expenditure on techniques where the efficacy is uncertain.

Post-completion monitoring is crucial as time is required to reinstate and the success is unknown until this later stage. Also, is must be ascertained if the method hasn't worked so that it can be rectified, which can only be accomplished by monitoring. The monitoring must be fit for purpose; there are many monitoring procedures that fail to answer questions because they haven't been set up correctly or because the experimental design hasn't been considered enough. Interviewees noted that there is often 'tick box' monitoring which isn't fit for purpose because there are no useful data from it. Monitoring should be sufficiently robust to achieve the right data. There should be a focus on what the important features really are and to put monitoring in place for these features. Also, monitoring of post-completion state is crucial. Occasionally, designs fail to consider changes throughout the year; experience in the past has involved design changes on site because seasonal changes weren't considered during design stage.

There is very little enforcement of post-completion of restoration conditions or monitoring conditions. Post-completion monitoring is often specified but there isn't a reward system in place to ensure it is satisfactory. Part of the problem is that monitoring is not actively enforced. Better guidance on monitoring is required in the longer term to raise awareness among practitioners of what type of monitoring is most effective.

Previously, monitoring experience of peat hydrology has faced difficulty with standpipes that were installed for groundwater monitoring, which moved with peat, providing inaccurate readings. In the first instance, the sensitive site must be identified and silt traps implemented and regularly monitored, such that its effectiveness can be maintained throughout the construction activity next to the respective water course.

Aftercare monitoring plans could be useful with reports written at one, three and five years after implementation, and an ecological visit every year to establish what the mitigating factors might be, how the regeneration is proceeding and what further steps could be taken to deliver enhancement.

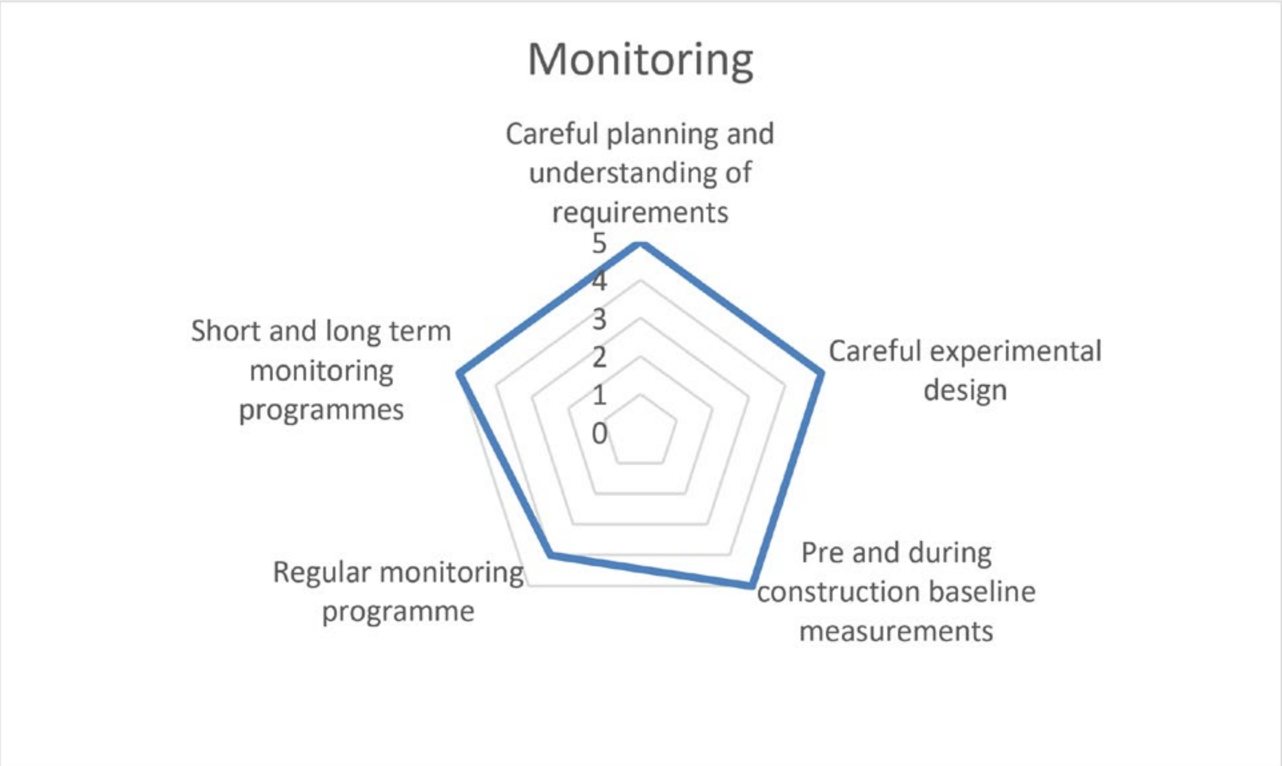

Figure B13. Monitoring evaluation matrix.

N. Effective communication between developers, designers, EnvCoW/ECoWs and contractors

The contractors are asked to do a job and they want to carry it out, but they need to be mindful of the mitigation measures and why they are being implemented. The understanding of the techniques by contractors, as well as designers, is important. The significance of ensuring each approach is site specific, and that CEMP are entirely project specific and that techniques that have been used previously might not be suitable for another project. When you have right people and the right kit on site, it is likely that the wider environment is enhanced and habitat management becomes an integral part of the construction process. If this is in place, then implementing the process on the ground will kick start habitat restoration. Developers are aware and have learnt lessons quickly for cognisance of deep peat and the understanding of that environment. Good examples of restorative programmes as part of development "provide betterment" to the developers plans. Good practice identified is to ensure high level engagement with the habitat management plan, value the engagement of statutory consultees and their knowledge, and recognise the value that they bring to the project team. It is the responsibility of designers to recommend good practice measures like silt traps and store turfs to side, they in turn, rely on the contractors to have the skill to deliver.

Construction schedules are created but often bad weather isn't factored in, so the programme becomes very 'tight'. Often the simplest and easiest schedules to follow are the most effective because they can be done correctly. The role of the EnvCoW/ECoWs can be seen as quite difficult in theory as they are on site, acting as a mediator between the developer's consultant and the contractor; with good communication knowledge is passed to the respective contractors. The EnvCoW/ECoW is employed by the developer and yet must be independent. Many local planning authorities are appointing Marine Management Organisation (MMO) to provide advice for pre-application enquiries.

Occasionally, in the past, there has been a breakdown in communication at the stage where a contractor is appointed because the method statements attached with the tender don't match with the documents produced by the client. More time must be allowed for a thorough review of all the documentation by suitably qualified people. This documentation

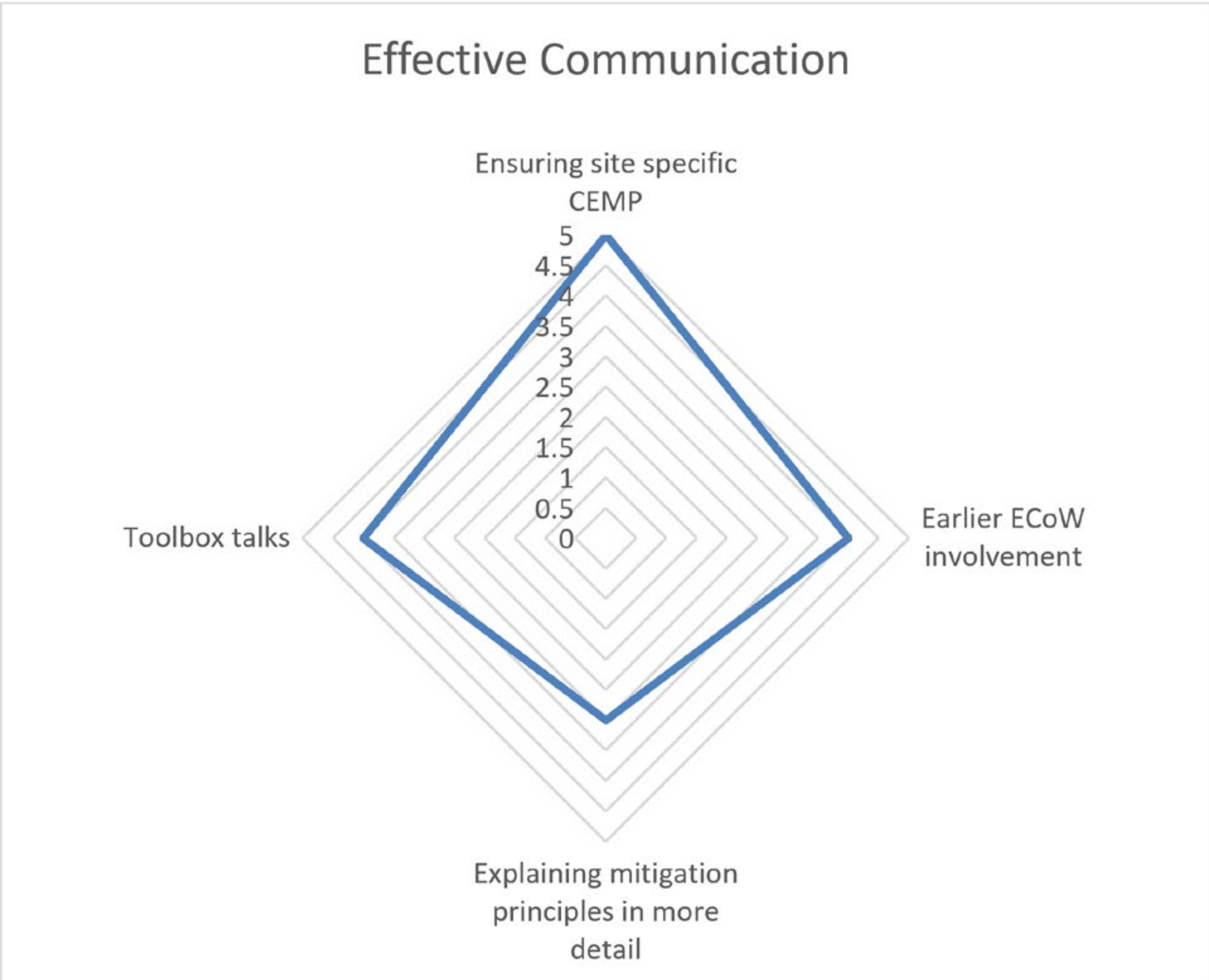

Figure B14. Effective communication evaluation matrix.

should be reviewed months in advance, rather than when the work is starting on site. Even having an EnvCoW/ECoW more involved in the design process might reduce the likelihood of mishaps on site.

It's important to consider the various mitigation techniques prior to the diggers going onto site and to have the sort of pre-application, pre-construction talks, that considers all these factors, and that information is relayed to the contractors on the ground. Also, there is a need to be clearer on definitions, to start thinking about GWDTEs sooner in the design process, and identify areas that are critically dependent on groundwater.

O. Cost considerations

The interviewees stated that cost considerations against environmental considerations can vary significantly depending on the client. Larger clients, especially in terms of larger infrastructure projects, are now more environmentally driven rather than commercially driven. The best way to reduce costs is to properly plan, rather than bring an EnvCoW/ECoW or similar on site once work has already started and when the budget has not been made available in the first place. The best approach to ensure the contractor does the optimum mitigation, is to get their 'buy-in' early in the process.

Cost, against environmental impact, is probably second only to the experience of the operators. As contractors bid on a certain price, they may not wish to include additional pipes for maintaining flow, if conditions are slightly different from the initial bid. One way to encourage contractors to do proper mitigation may be to offer an incentive, or reward, based on the quality of the reinstatement work or mitigation.

If guidance from the design team is that, rather than reinstate at the end of the work, the contractor should reinstate throughout, the contractor will plan, programme and cost works accordingly. As with other changes on site, increased cost will be incurred if changes are made to the design once starting on site. Costs relate to flow of information, the earlier the better, where cost can be made and programmed in. This approach is not typical and the mitigation would be easier to include if this were the case. Previously, cost was the main factor in mitigation measures but environmental benefit is becoming the most important factor though cost remains an important factor. At the EIA stage, it is not known for a client to state that mitigation measures are too expensive since there is value in achieving planning consent that outweighs the possible mitigation techniques.

The interviewees noted there is an economic balance to be struck by developers and contractors when they are developing a proposal from the paper exercise, and about how much site investigation is required to realistically deliver that proposal on the ground. It is a cost-benefit analysis; 'how much site investigation do we do in order to obtain planning permission, if we do too much site investigation and then end up possibly not achieving the planning permission or the CAR licence' etc., so

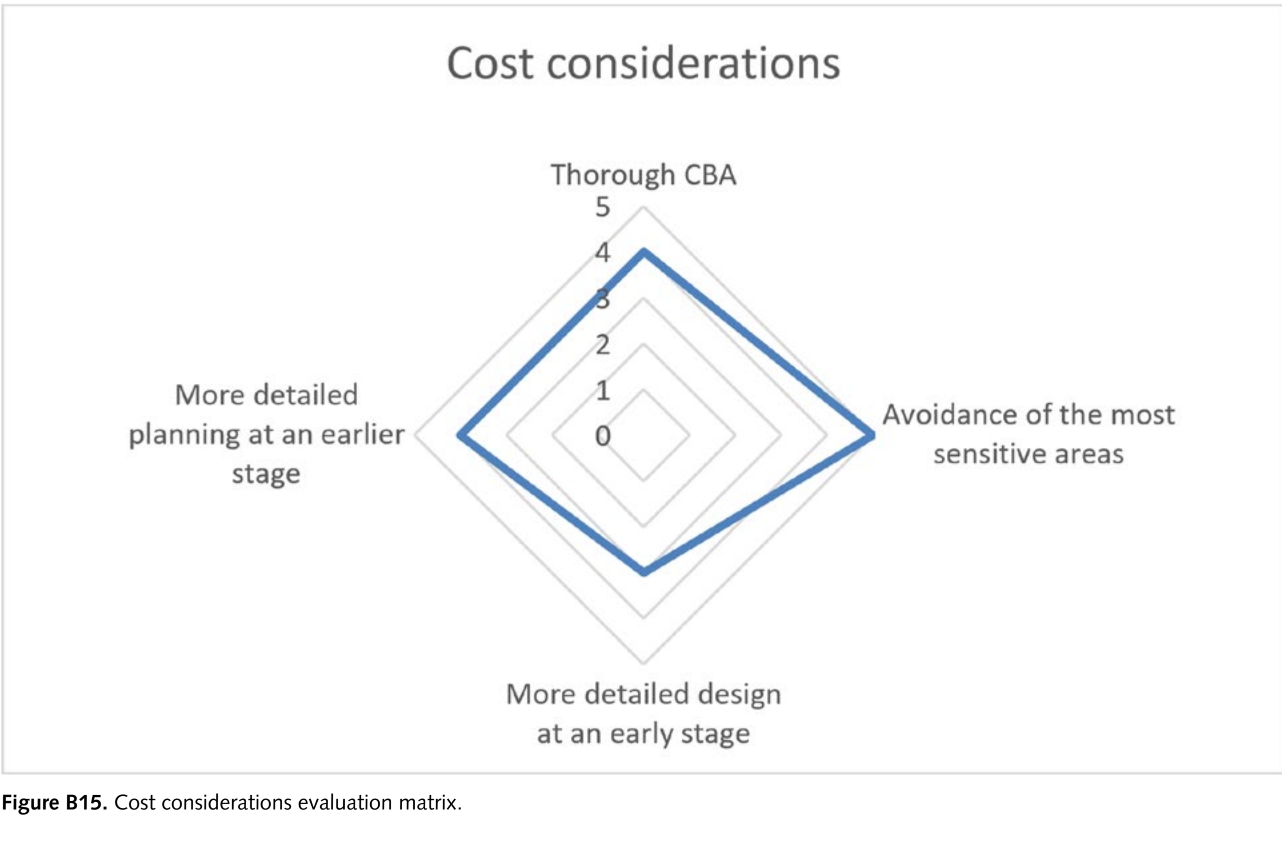

Figure B15. Cost considerations evaluation matrix.

there is a tendency to do the minimum required. In such cases, there isn't enough authority in the planning system to then get the information necessary to give a more rounded picture for the development proposal because of economic concerns.

One of the issues, or restrictions, of planning is the cost of the red line site boundary (i.e., size of the development) and so developers try and make that as tight as possible, leaving little ability to microsite. Microsites may only occur within the red line boundary, so keeping the red line boundary small/tight is inherent in the industry and there needs to be another approach to assess this. Additionally, interviewees noted that the planning fee structure is too stringent, and a larger red line boundary should be allowed to adjust design and microsite.

B.1.2 Findings

The interviewees identified some of the key issues relevant to the effectiveness of construction techniques on peatlands and wetlands in terms of impact on groundwater and on habitat. The interviews covered both the impact of construction techniques and experience of mitigation. Combining these interrelated discussions, several key issues arose frequently. Table B1 presents the combined key issues related to the effectiveness of construction and mitigation. The number shown in the column is the number of times these are identified as key to effectiveness in interviews.

Table B1 shows that detailed design and careful planning in implementation were emphasised through the interviews. Detailed surveys of the site are required to enable effective planning. The level of experience of the contractor and the competence of the operative were identified as key for the effectiveness of implemented approaches. Communication between all the stakeholders was considered important, together with early engagement of all stakeholders through the process. This sharing of knowledge and engagement of the key parties early, ensured that expertise was applied at the best time to be most effective.

Avoidance of deep peat and sensitive communities and habitats was identified as a key part of the design process. This involved a full understanding of the site location to determine orientation, location, access and borrow pit location. Careful removal, storage and replacement of turves was identified as key for successful reinstatement of vegetation. These techniques alongside water management and silt management were all discussed and emphasised as important factors for effectiveness by the participants.

Table B1. Key issues related to the effectiveness of construction and mitigation.

	Key issues related to the effectiveness of construction and mitigation (total number[1])	Q1 What impact do construction techniques have on peatlands and wetlands? (number)	Q2 What is your experience with the following mitigation techniques? (number)
Detailed design plans and careful planning	12	5	7
Detailed Surveys	9	6	3
Level of experience/competence	8	5	3
Communication	7	3	4
Careful removal of Turves	7	4	3
Avoidance	7	3	4
Early Engagement with stakeholders	5		5
Silt management	4		4
Construction Programme	4	2	2
Regular Monitoring	4		4

[1] number of times identified as key to effectiveness

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The Centre is funded by the Scottish Government.