Peatland Programme

Long-term monitoring network for UK peatlands

Technical Manual Version 2

May 2024

Contents

Cover image credit: Emma Hinchliffe

1. INTRODUCTION

1.1 Introduction to the 2nd edition

Following the release of the first edition of the Eyes on the Bog manual there has been widespread uptake of the methodology and, with that, much valuable feedback from early adopters of the methods. This highlighted a number of issues, mostly relating to implementation and interpretation of rust rods. This updated version of the manual includes a re-appraisal of the recommended methods, particularly focused on that aspect of the Eyes on the Bog procedures. **This edition does not seek to replace existing guidance but offers a wider range of approaches from which the most suitable can be adopted depending on local resources and capacity**. The original inert blue Noxyde paint is no longer readily available, so an alternative is suggested. We hope this new edition continues to stimulate monitoring activity on peat bog systems and we very much welcome further feedback from teams implementing the methods described here.

Given that the main changes in this edition are concerned with rust rods, the original order of topics has been changed so that revised methods are described first, thereby highlighting the nature of these changes. Consequently, methodologies for rust rod preparation, installation and interpretation are now described before presenting the largely unchanged methods for installing and interpreting surface-level rods and the use of photography.

It should perhaps also be re-emphasised that the Eyes on the Bog methodology was devised specifically for peat bog systems. Although certain parts of the methodology can be applied to fen peatlands, particularly low-growth moss-rich fens, rust rods and the von Post test are not generally suitable for tall-herb fen communities, particularly those in which there is considerable fluctuation of the water table and periods of surface flooding. Fixed point, 3600, stereo VR and aerial photography, as well as historical maps (sections 5 and 6) are all useful tools which can be applied in all peatland habitats. Surface-level rods are still usable in fens but may be difficult to locate where there is standing water or tall, dense vegetation.

1.2 The importance and potential of simple long-term monitoring

The science of peat bog research may seem beyond the scope of the interested public, but there is an important role for citizen science

International environmental treaties and national land use policies are devoting increasing attention to the benefits that peatlands provide to global society in terms of long-term carbon storage, ecosystem services and maintenance of biodiversity. The science underpinning this interest is often viewed as dauntingly technical, exclusive to academic researchers. It is therefore understandable that community groups wishing to engage in some useful way with their local peatland may feel there is little they can contribute in terms of gathering valuable scientific data and monitoring the health of the site.

By using a combination of simple methods and modern everyday technology, citizen groups can collect immensely valuable information about their local peatlands. Indeed, one of the world's longest-established peat bog monitoring projects can be regarded as a community science project.

The Holme Fen Post: one of the world's oldest community science projects

In 1848, an iron pillar from the Crystal Palace Exhibition was sunk to its cap in a raised bog called Holme Fen in Cambridgeshire, at the instigation of a Mr William Wells, because there was widespread concern about the rate of ground subsidence caused by drainage of the surrounding peat-dominated Fenlands. The cap of this pillar now stands more than 4 m above the ground surface because of peat shrinkage and oxidation, the pillar having been tended and maintained by the local community for much of the intervening period.

The Holme Fen Post is one of the oldest markers of peat shrinkage in the world and is particularly valuable because it provides an indisputable measure of change despite the relative simplicity of approach.


The Holme Fen Post in Cambridgeshire, demonstrating the remarkable peat loss that has taken place since 1848. Credit Richard Lindsay

Simple technology and modern everyday technology offer great opportunities

The Holme Fen Post provides an example of a straightforward approach to peatland monitoring which can be applied more widely. Modern everyday items now make it possible to extend the principle embodied by the Holme Fen Post to a suite of monitoring methods, having the capacity to generate valuable data for use by scientists, land managers and wider society.

Features readily amenable to monitoring

In the case of peat bogs and small-sedge fens, the range of features lending themselves to ready measurement or recording may come as something of a surprise (tall-sedge fen peatlands and sedge-fen swamps pose a different set of challenges which only some aspects of the methodology are suitable for). Using a combination of readily available materials and modern everyday technology, it is possible to gather useful monitoring information about:

- general behaviour of the water table;
- consequent surface subsidence or accumulation;
- associated carbon loss or carbon capture;
- condition of the peat soil;
- vegetation composition;
- surface structure/microtopography;
- historical context of change and possible current trajectories.

Do I need more than one Holme Fen Post?

With a single iron column, the Holme Fen Post starkly illustrates the long-term impact that drainage activity has had across this entire raised bog. In similar fashion, a single Eyes on the Bog plot, placed centrally, can provide evidence for what is happening on your site. As with any monitoring programme, however, the more locations that are monitored, the better and more fine scale the picture that will emerge.

Peat bogs consist of individual bog units, or ‘hydrological units’. A raised bog, such as Holme Fen, generally consists of a single domed unit, though occasionally two domed units may fuse together, as in Braehead Moss, SW Scotland. If you wish to obtain a picture of what the dome as a whole is doing, consider how many locations you might require to create a reasonable facsimile of the dome (or domes). With only three points the shape would be reduced to a crude triangle, but with five points it might be possible to create something approximating a cross-sectional profile. Another four points at right angles to the initial five then allows you to start creating a 3-dimensional picture of the dome. Further points will refine this shape, if needed. The same applies to individual bog units within a blanket bog landscape, although the variability in shape created by the underlying mineral landform may mean that more points are required simply to capture even a rough approximation of the shape. If there are particular features of concern or interest, such as a large drain, a series of drains, or an area of peat cuttings, you might consider setting up sets of points running across, and outwards to the unit centre, from such features in order to detect specific impacts arising from them.

In practice, the number of Eyes on the Bog survey points will be determined by the resources available to you. A single point in each bog hydrological unit within a vast and complex blanket bog site will still provide valuable information. A single point in a raised bog can be as revealing as the Holme Fen Post has proved to be. However, more points will give you more insight and allow for the possibility that rust rods (see **section 2**) may fail to rust in certain circumstances. The use of historical maps and photographs, as outlined in **section 6**, can also help in deciding useful Eyes on the Bog locations.

1.3 The role of water in peatland health and how to measure it

Waterlogging is the key to peat accumulation and carbon capture, or peat subsidence and carbon loss

Peat consists of semi-decomposed dead plant material which accumulates because it is waterlogged. Oxygen, needed for rapid decay, cannot penetrate effectively in waterlogged conditions. If the material were not waterlogged it would decay rapidly just like most dead plant material. Under conditions of waterlogging, carbon is captured by living plants and when those plants die, a proportion is preserved as semi-decayed plant matter that eventually becomes peat.

If a peatland is drained, the semi-decomposed plant material which comprises the peat soil will begin to decay, causing the soil itself to steadily disappear into the atmosphere as carbon dioxide, or be washed out of the system into local watercourses as various forms of dissolved or particulate organic carbon. This alone will cause the ground level to subside, but because peatlands are so waterlogged (peat typically contains less solids and more liquid by weight than milk), the matrix of peat particles is normally suspended within the volume of water held in the body of peat. Drainage causes some of this water to be lost, reducing the total volume of the peatland, causing the particles of peat to collapse more closely together and the ground surface to subside. These processes are illustrated in this video: Explaining the impacts of draining peatland on carbon emissions, hydrology & peat structure (youtube.com).

The determinants of this behaviour are the water table and associated moisture levels in the peat. One of the remarkable features of organic matter in soil is its capacity to hold and retain moisture – a feature observed most strikingly in sand dunes where the roots of marram grass tend to grow vertically down through the raw sand then spread laterally through, and only through, any organic-rich bands encountered within the body of the dune. Peat soils not only take this ability to retain moisture to extremes but are themselves created because of this retained moisture – none more so than peat formed from the remains of *Sphagnum* bog mosses.

The remarkable capacity of *Sphagnum* to maintain high moisture levels within the peat matrix comes from the fact that the bulk of the plant consists of large, dead, water-storage cells (hyaline cells), resulting in water-storage capacities within Sphagnum fragments having anything between two and five times the capacity of other peat particles. Water held within a peat soil thus consists of four broad types:

- freely-moving water held in large spaces between peat particles;
- more tightly-bound capillary water held in narrower spaces between peat particles;
- very tightly-bound water physically or chemically bound onto the surfaces of peat particles;
- water held within the peat particles themselves – most notably within the hyaline cells of *Sphagnum* fragments.

In the uppermost layer of a *Sphagnum*-rich bog, the peat volume may consist of around 74.5% external space, 24% internal storage space and 1.5% plant substance. However, at times when the water table is below this layer, the actual water content may consist almost entirely of internal storage and, most significantly, the proportion of internally stored water to the total peat volume may remain largely unchanged despite the lowered water table. This explains why *Sphagnum*-rich peat feels wet to the touch when a finger is pressed into the bog surface even though the water table may currently be tens of centimetres deeper within the peat. The high moisture content of peat above the water table at any given time also explains why it has proved necessary to amend the instructions given in the first edition of the manual concerning rust rods.

Water table behaviour

The water table difference between a healthy and a degrading peat bog mostly lies in the depth to which the water table frequently falls. A healthy 'active' bog will rarely see a water table fall as far as 30 cm, whereas a peat bog in hydrological difficulty will see falls of 40-50 cm or even more.

Monitoring of water table behaviour in a peat bog can be achieved using a variety of techniques. Some of these require specialist equipment and technical expertise to establish and interpret, while others require a significant and regular time commitment to collect sufficiently meaningful data.

Dip-wells

The most-used, simple method of water table recording has, until now, involved dip-wells. These consist of plastic pipes (typically standard plumbing downpipes) with a series of slots cut in them to allow water inflow and outflow, set into the peat. The water level in these pipes is measured on a regular basis to build up a picture of water table behaviour. One key disadvantage of this method is that the measurement can be affected by the weather immediately preceding or during the measurement. Another issue is that the number of readings obtained depends on the number of occasions that someone is willing to visit the dip-well array. Automated loggers overcome this issue but are expensive to install in large numbers.

Dipwells consist of a plastic pipe set into the peat.

Water level range gauges (WaLRaGs)

WaLRaGs provide a relatively simple method for recording the behaviour of the water table over longer time periods than is typically obtained for dip-well arrays. A WaLRaG consists of a long plastic drainpipe sunk into the peat, inside which is a float made from a drinks bottle. Attached to the float is a rod which forces two markers (often a piece of closed-cell foam) either up or down along a measuring tape fixed within some metal tracking. The lower marker indicates the lowest point reached by the water table between readings, the upper marker indicating the highest point reached by the water table.

A WaLRaG is relatively cheap to construct, though generally rather messy to install. It can be left to record between readings for as long as is convenient or interesting. It gives a good measure of the lowest and highest water tables experienced by the peatland and thus provides a valuable picture of the extremes – which is often of considerable value when assessing the condition of a peat bog.

The main restriction influencing the use of WaLRaGs is that even if a 'hedgehog' of spikes is added to the cap to prevent birds perching, they are still prominent features within the bog landscape and thus tend to attract attention from, and potential damage by, grazing animals or human passers-by. Installing large numbers of WaLRaGs is also a time-consuming process.

2. EYES ON THE BOG METHODS: RUST RODS

2.1 Monitoring water table behaviour

How rust rods work

In the same vein as a WaLRaG, but offering the potential to install a considerable number of recording devices across a site at relatively little cost and with limited effort, ‘rust rods’ make use of the fact that metal will undergo chemical changes within the zone of water table fluctuation but remain unchanged in the oxygen-free zone of permanent waterlogging. A one-metre-long metal rod is inserted into the peat down to the mineral layer beneath and left for at least three months to ensure rusting occurs. Few, if any, cases of peat bog drainage will lower the water table by more than 1 m, such is the water-holding capacity of peat, which is why a 1 m length should suffice for a rust rod. When the rod is removed, the presence of rust is used to determine the lowest depth to which the water table falls regularly. The rust can then be removed using sandpaper and the rod reinserted into the peat to repeat the process. If the rusting is too severe, the rod can be cheaply replaced.

Rust rods can reveal whole-site hydrology

The cheapness of rust rods, their relative ease of construction and installation, plus the fact that they can be left for a year or more to gather their patina of rust, means that they have the potential to help build up a whole-site-scale picture of water table behaviour within a modest budget of time and money.

Rust rods are suitable for raised bogs and blankets bogs and have been well tested in these peatland types. They are not recommended for use in fens because the water regime and chemistry are very variable and poorly understood in terms of rusting behaviour, meaning it is not currently possible to provide clear guidance on rust rod behaviour and interpretation in those types of peatlands. Rust rods may work in some moss-dominated fen types but further research is needed, and we would be interested to hear from users who have trialled rust rods in these habitats.

The rust rod system is intended for use in peat. If the peat is less than 1 m deep it will be necessary to trim the rod to the depth of peat using a hacksaw or bolt cutters (a small plastic folding footstool can make a reasonably stable workbench for this). It is possible to drill into the mineral sub-soil and thus utilise the full 1 m length of the rust rod using a narrow soil auger, but often the sub-soil (typically glacial till) will be found to contain broken rock fragments, or may be solid rock, which makes coring a hole for the pipe exceptionally difficult or even impossible.

The first edition of the Eyes on the Bog manual described a single way of constructing rust rods using zinc-coated threaded steel with a flat surface ground along the length of the rod to create a bright face on which to record the rusting process. This approach is still valid, albeit with some possible modifications, but certain elements of the original construction method have proved challenging or time-consuming. Consequently some new approaches are offered in this second edition, including the use of unthreaded mild steel rods and plastic pipes in which to insert the rods.

2.1.1 Zinc-coated threaded steal rust rods

The first edition of the manual recommended that rust rods be assembled using zinc-coated threaded steel rods – specifically avoiding the alternative, and commonly available, stainless steel threaded rods because they are resistant to rusting. The advantage of threaded rods is that the top washer assembly is held firmly and permanently in place and will resist the effects of even the worst fires. The disadvantage is that they will be zinc-coated and will therefore require painting along their lengths to prevent leaching of the zinc and subsequent toxicity to sensitive species such as *Sphagnum*.

In order to produce a bright face on which to record the rusting process, an angle-grinder is used to grind a flat face along the length of the rod (use eye protectors, facemask and ear defenders). The aim should be to grind off the threads down one side of the rod to create a flat face but not grind away so much metal that the rod loses its rigidity.

Two issues have since emerged in relation to this process. Firstly, the recommended inert blue Noxyde paint is no longer available, and secondly the process of angle-grinding a series of such rods has proved challenging for many Eyes on the Bog teams because of the considerable noise created while grinding as well as the need to possess the skillset (and equipment) involved in using an angle grinder. However, with the use of Peganox paint instead of Noxyde (see below), this approach still remains an option.

Equipment:

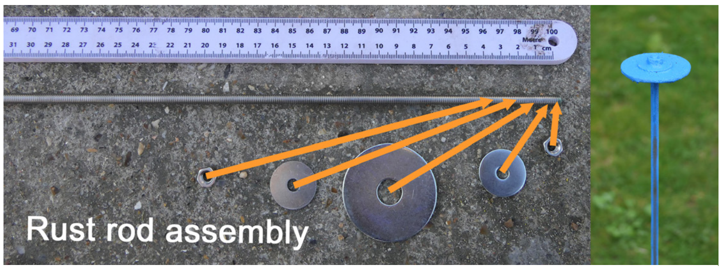
- Zinc-coated threaded steel rods (M6 x 1,000 mm)
- Threaded rod connecting nuts (M6)
- Large metal washers
- Medium metal washers
- Small metal washers
- ‘Peganox’ inert paint
- Push-fit plastic pipes (22 mm x 1,000 mm)

Tools:

- Paintbrush
- Plastic bottle with rubber grommet for applying paint (optional)
- Pallet for painting multiple rods (optional)
- Angle-grinder
- PPE (goggles, facemask and ear defenders)
- 1,250 mm x 25 mm metal curtain rod with the end capped off by a glued plumbing end-plug
- Bolt cutters/hacksaw for trimming rods/pipes where peat is less than 1000 mm deep
- Small folding footstool
- Moisture meter (see **section 2.2.4**)
- Metal detector
- Snowshoes
- Cloth and spray bottle for cleaning rods to measure rust zone
- Tape measure
- Red, blue or grey clipboard
- Camera
- Sandpaper to remove rust after measuring

Using a zinc-coated threaded steel rod rather than a stainless steel threaded rod, a 1 m length of M6 rod has an M6 nut fitted almost at the top of the rod. A washer assembly is then centred around a large 50 mm washer which, unfortunately, rarely comes with an M6 central hole. Consequently, a small washer is first placed on the nut already on the rod, then the large washer is added, then another small M6 washer is placed on top of this, and finally a further nut is screwed down tight onto the tip of the rod to hold the whole washer assembly in place. The entire assembly and length of rod are then painted with inert Peganox paint.

Threaded steel rod painted with inert paint and with a face ground down to create a bright surface on which rust will develop.



Nut and washer assembly demonstrating how to secure a large washer at the top of the rust rod to make it visible and easier to remove from the peat.

2.2 Updates to the 2nd edition

2.2.1 Drawn unthreaded mild steel rust rods

As an alternative to threaded steel rods, it is possible to use ‘drawn’ unthreaded mild steel rods. These are available as 6 mm diameter rods which can be supplied as 1 m lengths. The key advantage of mild steel is that it has no zinc coating so does not require painting or grinding. However, it is mid- to dark grey in colour and grinding a face will not create a brighter surface. The darker colour compared to ground threaded rods therefore poses some challenges when interpreting the rust pattern, as will be discussed later.

Equipment:
- Unthreaded mild steel rods (M6 x 1,000 mm)
- Large metal washers
- Medium metal washers
- Small metal washers
- ‘Peganox ’ inert paint for washer assembly only
- To secure washer assembly: either M6 dome nuts (if glueing washer assembly) OR M6 threaded rod connecting nuts (if using threading die) OR M6 shaft collars OR 6mm spring band/wire hose clips
- Push-fit plastic pipes (22 mm x 1,000 mm)

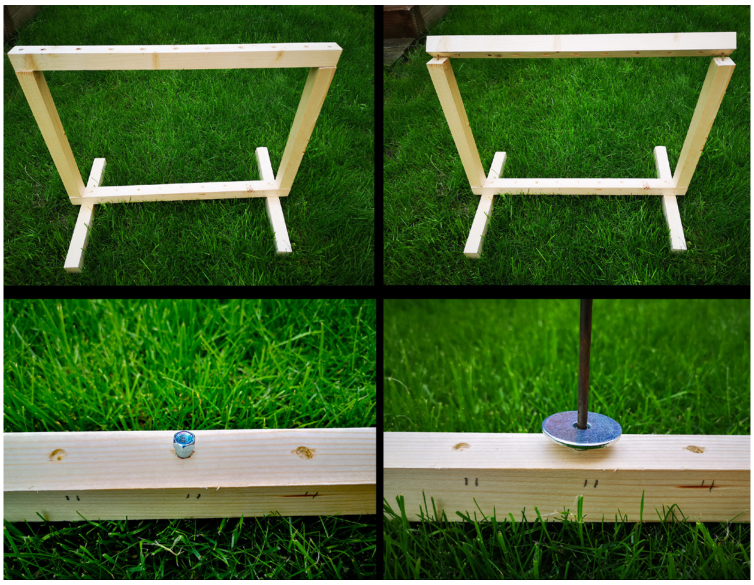
Tools:
- Paintbrush
- If glueing washer assembly: exterior-use epoxy-type glue and wooden frame (optional)
- 1,250 mm x 25 mm metal curtain rod with the end capped off by a glued plumbing end-plug
- Bolt cutters/hacksaw for trimming rods/pipes where peat is less than 1,000 mm deep
- Small folding footstool
- Moisture meter (see **section 2.2.4**)
- Metal detector
- Snowshoes
- Cloth and spray bottle for cleaning rods to measure rust zone
- Tape measure
- Red, blue or grey clipboard
- Camera
- Sandpaper to remove rust after measuring

Attaching washers to the top of mild steel rods

As mild steel rods are not threaded, there is no obvious way to attach the necessary washer(s) to the top. However, various options are available to solve this problem:

Exterior-use epoxy-type glue (e.g. Araldite)

An assembly can be glued in place at the top of the rod consisting of a ‘dome nut’ plus the small, large and small washers, as described above for threaded rod. A simple wooden frame can be constructed to hold several rods at once while the glue sets. Once glued, the washer assembly will need to be painted with Peganox because the washers will almost certainly be zinc-coated. A pallet drying rig as described for threaded rod can permit many rods to be drying at the same time. While glueing is suitable for assembling a relatively small number of rust rods, it is probably not feasible for assembly of large numbers. In addition, this method of fixing is not fire-proof so the washer assembly would probably fall apart in the event of a wildfire although at least the rod would likely remain in place.



A wooden frame can be used to hold several mild steel rods when gluing washers in place.

Top left: wooden frame with impressions made to hold the rods in place.

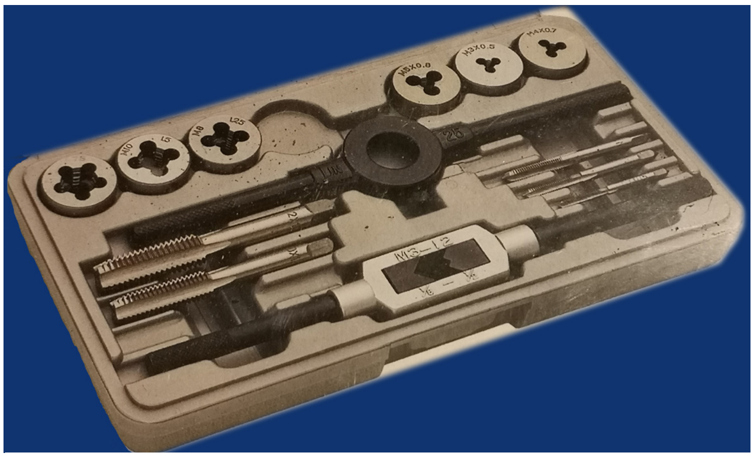
Top right: the top of the frame can be tilted so that the rods can be inserted and held securely in place while the glue dries.

Bottom left: a dome nut held in place at the bottom of the frame.

Bottom right: the washer assembly used for threaded steel rods is placed on top of the dome nut and glued in place. This will be at the top of the rod when inserted into the peat. These components are likely to contain zinc, so must be painted with Peganox prior to deployment.

Use a threading die to create threads

For the security of a threaded attachment, it is possible to use a threading die to add threads just to the top of the rod. Threading die kits are relatively inexpensive and would be a one-off purchase, capable of being used long into the future and also adaptable to differing rod diameters. Having created the threads, the process is as described for threaded rod above, though only requiring that the washer assembly be painted.



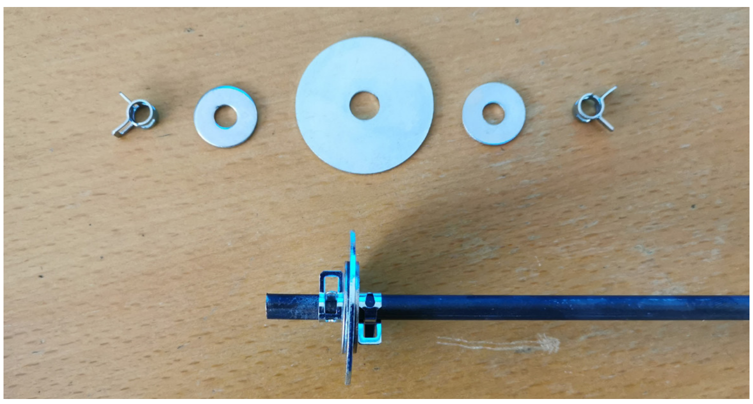
Threading die kit which can be used to add threads to the top of mild steel rods for attaching the washer assembly.

Shaft collars (6 mm bore)

These small metal rings slide onto the rod and are held in place by a grub screw. They take the place of the nuts in the description of assembly for threaded rods. Once the washer assembly is painted with Peganox the grub screws are unlikely to loosen. These are cheap and quick to attach. The only thing to be aware of is that drawn steel rods can vary in diameter by as much as 0.5 mm so if the rod that you purchase is slightly wider than 6 mm, then M6 shaft collars will not fit. It is therefore better to purchase the rod first, check its variability, then purchase suitable shaft collars.

Spring band/wire hose clips

Undoubtedly the quickest means of locking the washers in place, hose clips are half the price of shaft collars but arguably less robust in the long term if the thin wire from which they are constructed corrodes. A coating of Peganox should significantly reduce this possibility. Again, given that drawn mild steel rods may vary slightly in diameter, it should be recognized that these clips cannot be made to grip something thinner than their designed size so check the diameter of the delivered rod prior to ordering the clips.



The components needed for a washer assembly held in place by hose clips (top), and the completed assembly at the top of a mild steel rod.

2.2.2 Painting rods

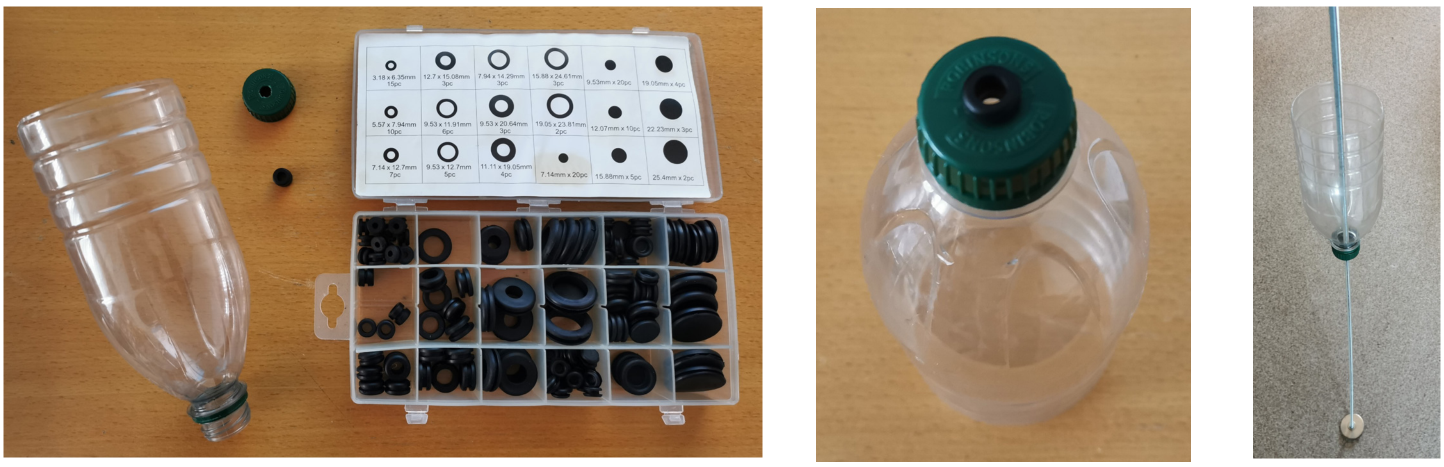
If using threaded steel rods, any parts of the rods that contain zinc, as well as the washer assembly, must be coated with an inert paint to prevent the zinc from leaching into the environment. Mild steel rods do not contain zinc, so only the washer assembly requires painting.

The blue Noxyde paint recommended in the first edition of the manual is no longer available in the UK. As an alternative, Peganox is an inert coating from the same manufacturing company. Although it is not available in blue, the offered colours are probably equally inert although green may be the optimal choice in terms of balancing minimal possibilities of leaching with ensuring that the rod is visible when searching for it.

Peganox is thinner than Noxyde so is easier to apply with a brush, although this is time-consuming when painting large numbers of rods. Alternatively, a plastic bottle can be used as a dispenser to apply paint more rapidly. A rubber grommet, with an inner dimension equivalent to the diameter of the rust rod, can be inserted into the lid of the bottle (after drilling an appropriate size hole). This creates a paint applicator that can be slid slowly down a bare rod adding a layer of paint several mm thick, and when slowly slid back up the rod, the applicator cleans and removes excess paint.

If an area of lawn is available and the weather is dry, the rods can be stuck into the lawn for painting, as long as they are dry before evening dewfall. When painting multiple rods, a wooden pallet can be used to construct and paint up to 70 rods at a time (see image below). The tops of the rods and washers can then be finished with a brush.

The purpose of the paint coating is to reduce to a reasonable degree any zinc leaching. Even a thin coating can achieve this, so it is not necessary to achieve as thick a coating with Peganox as was typical for the much thicker Noxyde paint.



Left: A plastic bottle with a rubber grommet fitted into a hole in the lid can be used as a paint applicator for rods with a zinc coating.
Middle: The grommet should have an inner diameter which matches that of the rods.
Right: The bottle and grommet can be used to apply a thin coating of paint which prevents zinc from the rods leaching into the environment.

A wooden pallet used to hold multiple rods for painting.

2.2.3 Plastic pipes for rust rods

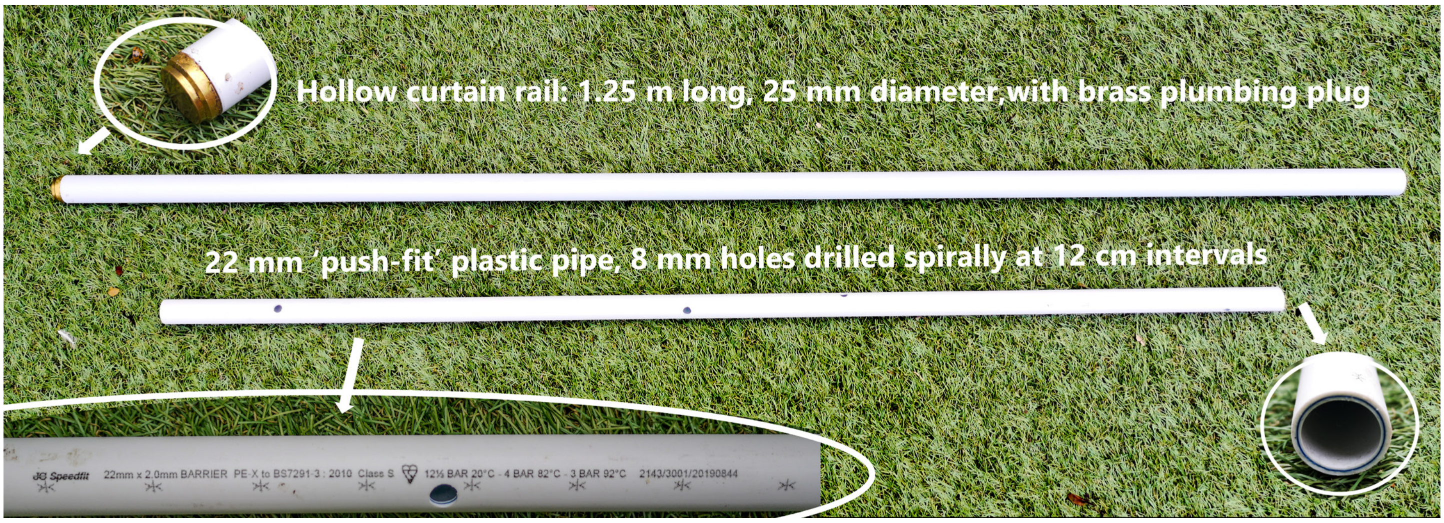
As discussed above, peat that is not directly affected by adjacent drainage features tends to retain a high degree of moisture even during periods of low water table. Where the peat is tightly packed round a rust rod, this degree of moisture can prevent rust from rapidly forming simply because the rod is not exposed to sufficient oxygen. Given enough time, rust will eventually form but it may take a year or more for this to occur. It is now therefore strongly recommended that instead of inserting the rod directly into the peat, a plastic pipe is inserted into the peat and the rod is then placed within the pipe. This permits better contact between air and rod, meaning rusting occurs more quickly and has the added advantage of enabling the rod to be more easily removed when taking a reading. Threaded rods with nuts and washers were originally recommended because removal of rods from some dense peats required considerable force on the washer and thus a secure threaded system was needed. Details of the recommended pipe assembly are provided below.

The objective of the plastic pipe housing is that it should provide sufficient access of air around the rust rod while not requiring a substantial effort to install the pipe. The pipe should also be relatively cheap, readily available and easy to work. The recommended piping is thus 22 mm ‘push-fit’ piping, cut to 1 m lengths and drilled with 8 mm holes in a spiral pattern at 12 cm intervals, with the top-most hole 4 cm from the top of the pipe. This number of holes should be regarded as a minimum, but too many holes would endanger the integrity of the pipe as it is pushed into the peat, so moderation in the number of holes is called for.

To install the pipe, we recommend a 1.25 m x 25 mm metal curtain rod with the end capped off by a glued plumbing end-plug. This will push into most peats and leave sufficient rod protruding to be able to pull the rail out again. The plastic piping is then pushed into the resulting hole until the top of the pipe is flush with the ground surface. In the case of a moss-covered surface, this would normally be the surface of the moss, although in some cases it will be found that vole-run cavities exist within the moss layer (though not usually if the moss is *Sphagnum*), in which case either a different location should be chosen or the pipe should be set at the floor of the cavity.

The rust rod is then dropped into the pipe so that the washer covers the pipe and prevents small mammals, reptiles, amphibians or large insects from falling into the pipe.

The ratio between the diameter of the rod used and the diameter of the pipe means that sufficient air can circulate round the section of rod above the water table. Consequently, it is not recommended that rod greater than 8 mm diameter is used with such piping. It is also possible for the holes in the pipe to become blocked by peat, preventing oxygen reaching the rod inside and consequent rusting. It is therefore advisable to install at least two or three rods at each location if possible, in case one rod fails to rust. Bottle cleaning brushes can be taken into the field to unblock any holes that have become clogged with peat.



Curtain rail (top) which can be used to make a hole in the peat in which to insert the plastic pipe (bottom). The rust rod is then inserted into the pipe, ensuring the top is covered to prevent small animals from falling in.

2.2.4 Rust rod placement and the importance of microtopography

The water table difference between a healthy and a degrading peat bog mostly lies in the depth to which the water table frequently falls. A healthy 'active' bog will rarely see a water table fall as far as 20-30 cm whereas a peat bog in hydrological difficulty will see falls of 40-50 cm or even more. However, it is important to consider the locality of the rod within the microtopography of the bog surface. If placed in the top of a hummock on a healthy bog, the water table will generally be some 20-30 cm below the summit of the hummock. It is therefore worth noting surface-pattern zone ('microtopography') in which each rod is placed. This can be done relatively easily using a simple and cheap moisture meter for domestic house plants. When the zone of high moisture is reached (above the water table itself) the needle will flick up to the start of the highest (blue) zone on the dial.

Moisture meter used to determine surface-pattern zone or 'tope' according to the depth at which high moisture is reached (blue colour on the dial).

Note the depth at which high moisture is reached and compare this with the following table (you can see the associated 'tope codes' in the image below):

Depth (cm)	'Tope' code	Description
40 +	T4	Top of erosion hagg
40-25	T3	Hummock
15-25	T2	High ridge
15-4	T1	Low ridge
0-4	T1/A1	Transition to aquatic zones

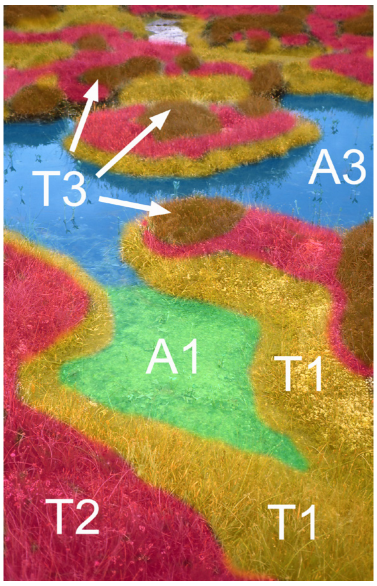
Four things should be noted:

1. Tussocks (Tk, not included in the table) will resist penetration by the moisture meter, so (a) do not install a rod in a tussock, and (b) do not damage your moisture meter trying to push it into a tussock;

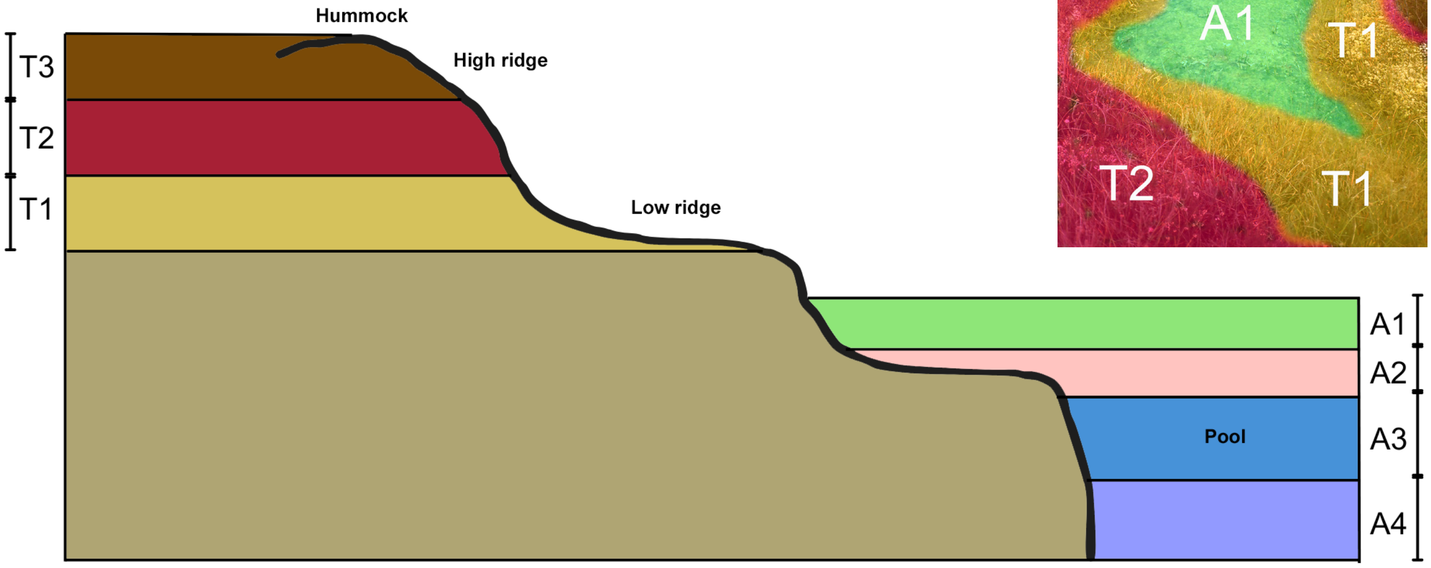
2. The needle will fade downwards quite quickly after inserting the probe (this is just a feature of the instrument) so look to spot the depth at which the needle first flicks up to the start of the blue zone;

3. These cheap probes are not designed to take a reading in water, so if your probe fails to indicate anything, check with your finger to see whether there is water immediately below the visible vegetation;

4. Where the vegetation is heather dominated, check to see whether there is a cavity beneath the (non-*Sphagnum*) moss layer or the dense tangle of heather stems and roots, because voles will often make runs beneath this layer; if you encounter a cavity, move the rod and the location of the moisture probe reading.



Top right: View of the bog surface with vertical microtopographic zones coloured. Credit Richard Lindsay. **Bottom left**: Small-scale vertical zonation diagram



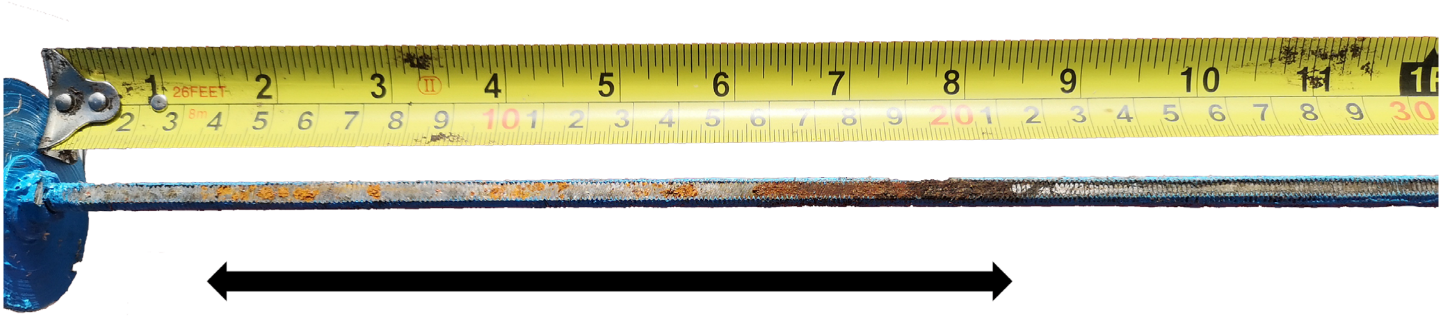
2.2.5 Interpreting rust rods

A minimum of a 3-month period will begin to show the average (mean) water table behaviour for that season

While a 3-month period of rusting will give a picture of the water table over a single season or a partial picture over two seasons, it must be borne in mind that a threaded rod appears to take longer to rust than a mild steel rod, so if using the former then it is better to plan readings at minimum intervals of 6 months. Placing the rods in plastic tubes accelerates the rusting process and is strongly recommended. However, the main purpose of the rust rod is to give a long-term reading of water table behaviour, so a full 12 months will give a better annual picture.

The pattern of observable chemical change is neither as simple, nor necessarily as quick to develop, as suggested in the first edition of the Eyes on the Bog manual. Specifically, there may be different zones of rust which reflect differing conditions of rusting and water table behaviour. If a section of rod has been beneath the water table but then the water table falls, it will develop oxidised red rust, but if some or all of this red rust zone is again submerged for any period of time, the oxidised red rust will be altered to a black, reduced form of rust.
The colour distinction between red oxidised rust, black reduced rust, and the zone of no alteration permanently below the water table, may not be clear on a wet rod just pulled from the peat. It is necessary to wipe the wet rod with kitchen towel or a cloth in order to dry it somewhat, and it may even be necessary to allow the rod to dry for five minutes or so for the colours to become more evident.

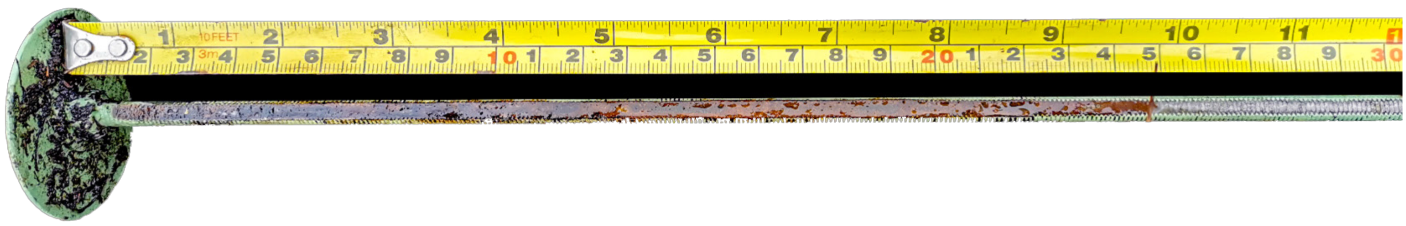
A typical pattern on a threaded steel rod can be seen below. The darker brown zone of rust indicates an area which has rusted and then been re-submerged, while the lighter orange rust indicates a zone which was, at the time of rod removal, above the water table and probably had been so for much of the time that the rod had been in place. The total zone of rusting indicates the main range of water table fluctuation, which is itself an indicator of condition – the water table of a degraded site will fluctuate more than the water table of a less damaged site.



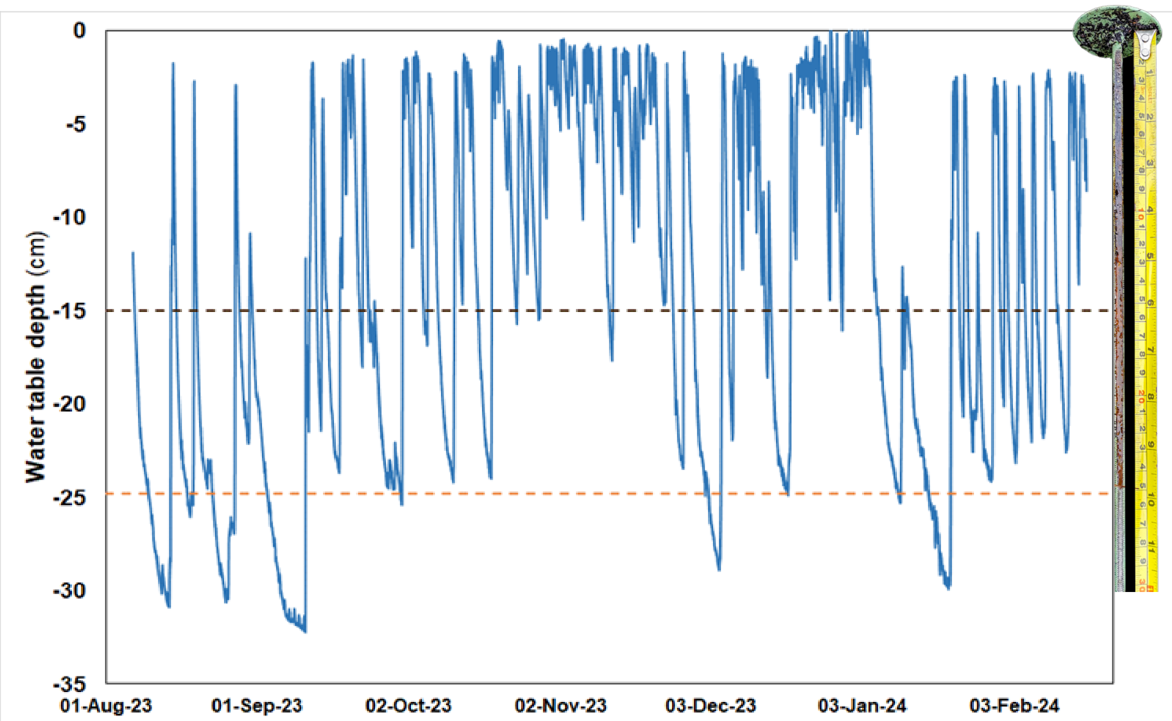
Threaded steel rod showing two zones of rust on the ground face: a brighter orange nearer the surface (left of the image) and a darker brown zone below. The most important measurement to record is the lowest point at which rusting occurs – in this case, -22 cm.

The most important measurement to record is the lowest point at which rusting occurs. This represents the maximum depth to which the water table falls, providing a clear indication of peatland condition. If other zones are visible and possible to interpret clearly, this additional information should also be noted. Taking a photograph of the rod next to a tape measure means data recorded in the field can be checked and different rods from the same area compared to help with interpreting more complex patterns of rust.

The rust rod shown below was installed directly into peat approximately 1 m distant from an erosion gully that is 4 m wide and 60-70 cm deep. An automated datalogger was placed in an adjacent dip-well and recorded the level of the water table over the period that the rust rod was in situ (approximately 6 months). There are two coloured zones of rust visible on the rod: a dark brown zone extends to around -12-15 cm, and a second lighter orange zone extends to around -25 cm. The location of these zones is shown in relation to the water table fluctuation recorded by the adjacent data logger in the graph below (dotted black and orange lines). The most important measurement to record is the lowest point at which rusting occurs, i.e., -25 cm in this case.

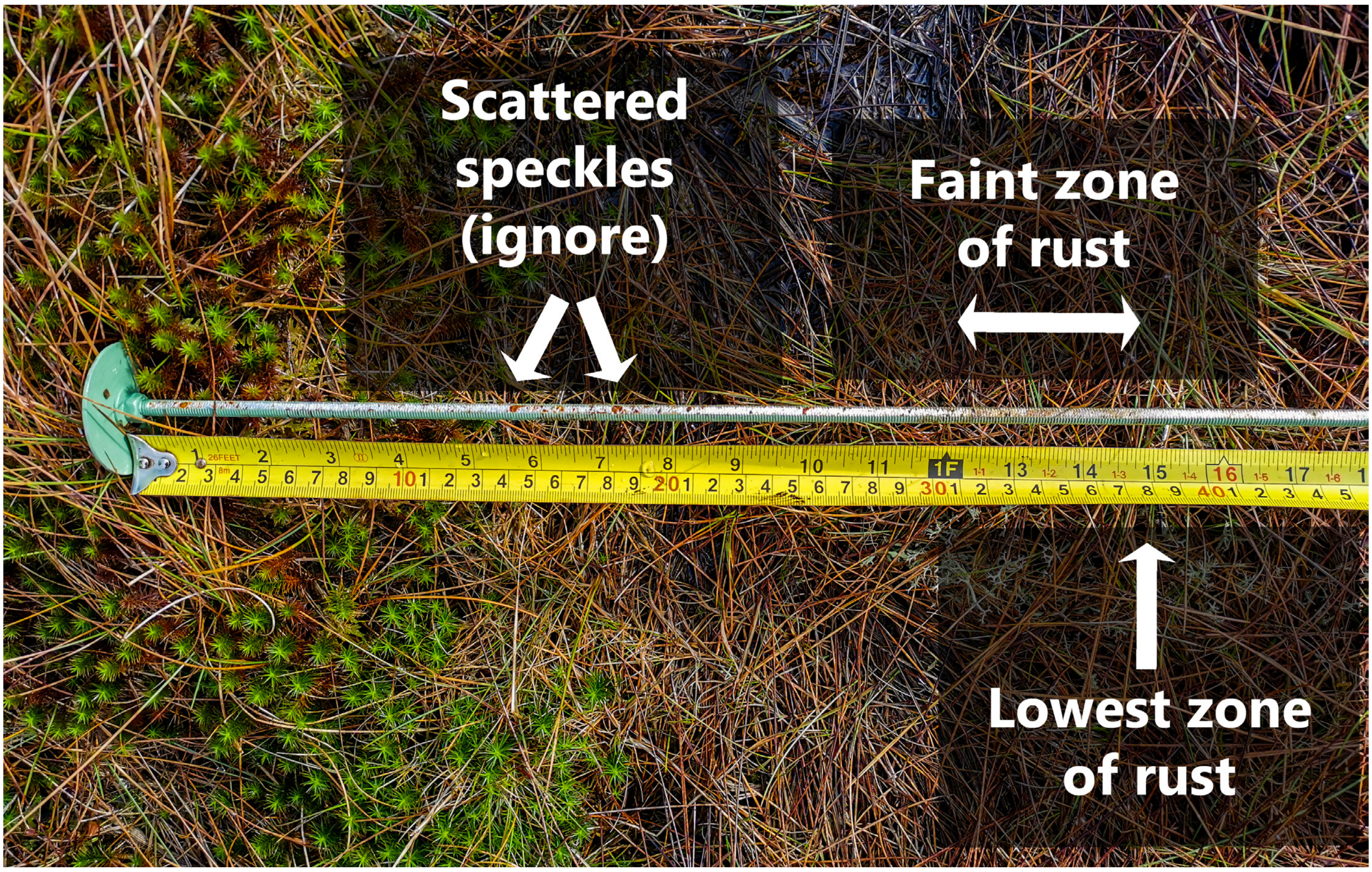


Threaded steel rod showing two zones of the rust on the ground surface: a dark brown zone which extends to 12-15 cm below the surface (difficult to see) and a lighter orange zone which extends to 25 cm below the surface. The dark brown zone (left of the image) indicates the area that is most frequently exposed as the water table fluctuates, and the brighter orange zone indicates the lowest depth that the water table drops to frequently. Below this, the rod was mostly covered by water and no rusting has occurred. The most important measurement to take is the lowest point of the rust zone, i.e., - 25 cm.



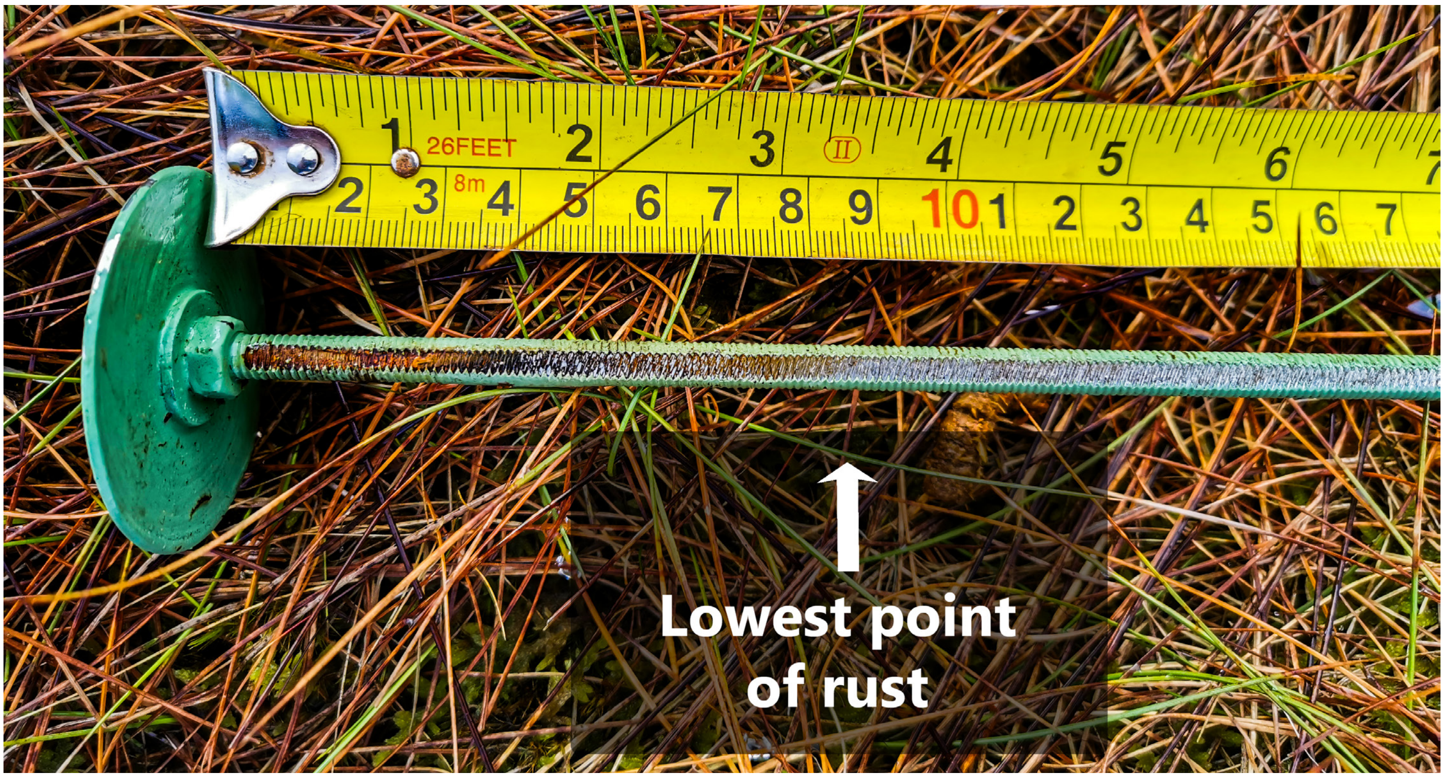
Water table readings from an automated datalogger adjacent to the rust rod. The dotted black line indicates the lowest extent of the dark brown zone on the rust rod, and the dotted orange line indicates the lowest extent of the brighter orange zone on the rust rod.

Sometimes the zone of rusting is very faint, with seemingly random but clearer speckles of rust at various points, as in the example below. In this case, ignore the speckles and measure the lowest point of the faint zone of rust.



Sometimes the band of rust can be very faint, with speckles of rust above it. Cleaning the rod carefully should reveal any faint zones of rust. Using a plain background with the correct exposure when taking a photograph can help make the rods easier to interpret (see below).

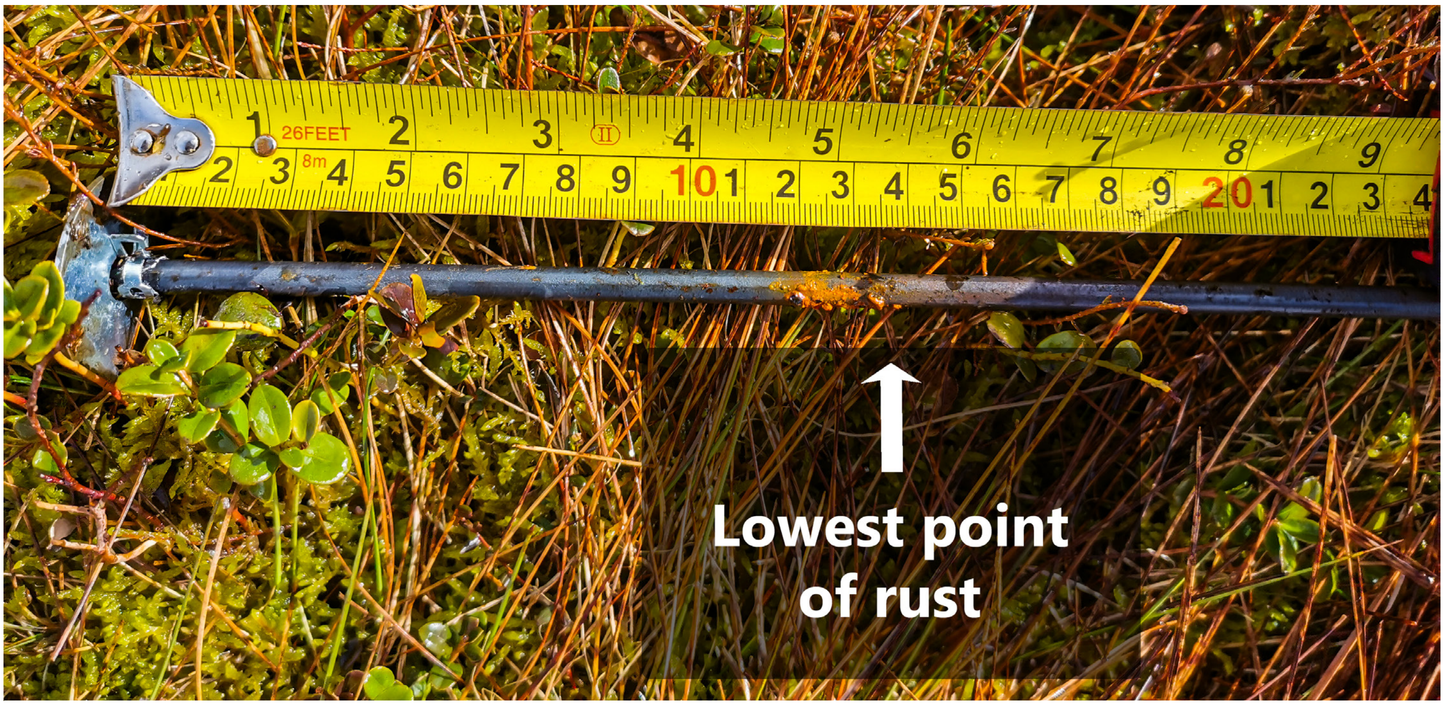
The band of rust may also be darker further up the rod, as in the example below. Again, ensure the rod is cleaned properly and measure the lowest point of rust.



In this example, the band of rusting is clearer at the top of the rod. To avoid missing the lowest point of rust, ensure the rod is cleaned properly before taking a measurement.

Rust zones on drawn mild steel rods

The dark colouration of mild steel rods means that the rust zonation may be more difficult to see. Again, ensure the rod is clean before taking a measurement.

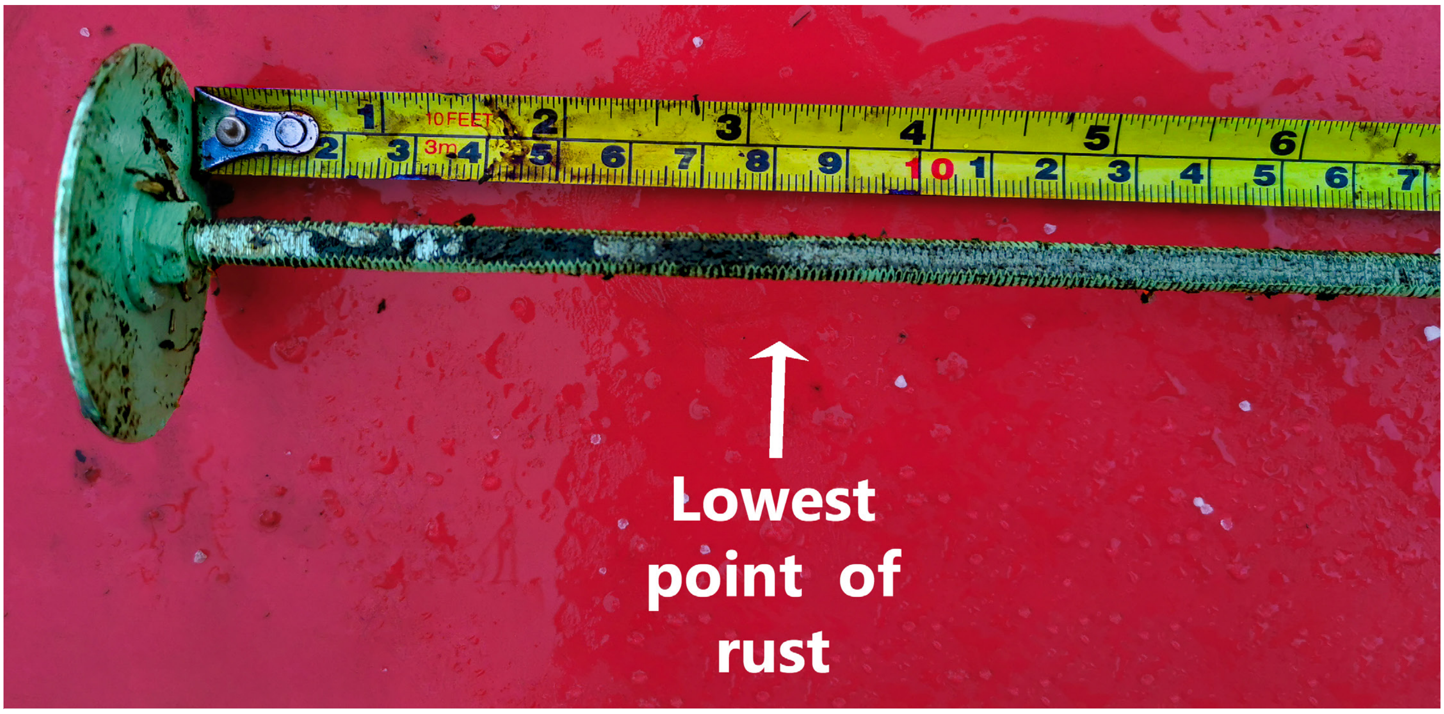


Interpreting rust on mild steel rods can be difficult due to their dark colour. Inserting the rods in a plastic tube, as seen in the image above, makes the rods easier to clean and interpret.

2.2.6 Recording data

The measurements recorded may depend on the type of rods being used and the level of rusting that has occurred, as well as the amount of information sought. If taking the rod home before reading, wrap it in cling-film to keep it wet, otherwise the whole rod may rust before the reading is obtained. Remove any peat from the rod using a cloth (this is less likely to be present if the rod was inside a plastic tube).

Take a photograph of the rod with a tape measure next to it, ensuring the location of the rod is recorded in the photograph. Rusting is easier to interpret if the rod is placed on a plain background, such as the back of a coloured clipboard when taking the photograph, ensuring that the exposure level is suitable. Avoid over- or under-exposure by using a colour such as grey, red or blue and do not use a black or white background.



Clean the rod and take a photograph next to a tape measure on a plain background, ensuring the image is not over- or under-exposed. A red, medium/light blue or grey clipboard works well, but avoid a white or black background.

All rust rod readings should be recorded in centimetres as negative numbers, as they represent a decrease in the height of the water table relative to the surface.

As a minimum, measure down from the top of the rod to the bottom of the lower zone of water table fluctuation (where the non-rusted zone starts) and record this. This may be the only zone which can be clearly distinguished and reliably measured. It represents the depth to which the water table regularly falls and will rarely be more than -30 cm in a healthy ‘active’ bog. This is the most important reading to take. Be careful if using mild steel rods, where a black band of reduced rust may be difficult to distinguish (drying the rod as described above should help).

If there are other zones or bands of rust visible, make a note of these as they may be useful in understanding the zone of water table fluctuation, particularly when comparing adjacent rods or those placed in relation to different microtopographic or erosion features.

3. EYES ON THE BOG METHODS: SURFACE-LEVEL RODS

3.1 Monitoring peat depth

The cap of the Holme Fen Post now sits more than 4 m above the present peat surface because of three processes: rapid primary consolidation where freely mobile water was lost from large pore spaces, slow secondary compression where the weight of drained peat squeezes out water from smaller pore spaces, and oxygen-driven decomposition, which causes peat material to be lost to the atmosphere. Primary consolidation will have occurred whenever the surrounding drainage ditches were cleaned out and deepened, while secondary compression and decomposition continue all the while that the peat is not waterlogged. The method of monitoring these effects, adopted back in 1848 at Holme Fen, points to an approach which can be adapted simply and cheaply to the modern recording of such phenomena using what we term ‘surface-level rods’.

Importance of surface-level rods

Surface-level rods are important because they indicate the condition of a peatland – is it accumulating peat as a natural ‘active’ peatland, or is it degraded and losing carbon? In relation to this latter question, surface-level rods are particularly important because the effect of drainage on a peatland is two-fold. Drainage lowers the water table to an extent, but it also results in surface subsidence, and it is the combination of these phenomena which can result in widespread impacts across a peatland. Traditional hydrology focuses only on measuring the effect of drainage on the water table, not the effect on the peat surface, but **it is essential to measure both water table and surface movement for a full picture of drainage effects on a peatland.**

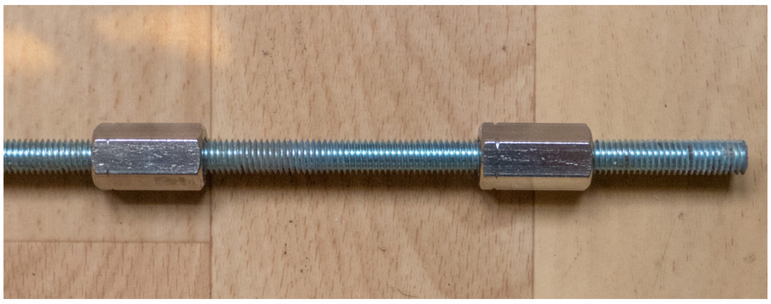
Equipment:
- Zinc plate or stainless steel threaded rods (M6 x 1000 mm)
- Threaded rod connecting nuts (M6)
- Large metal washers
- Medium metal washers
- Small metal washers
- Bare steel (not copper) wire
- ‘Peganox’ inert paint

Tools:
- Paintbrush
- Bolt cutters or hacksaw
- Small folding footstool
- Metal detector
- Snowshoes

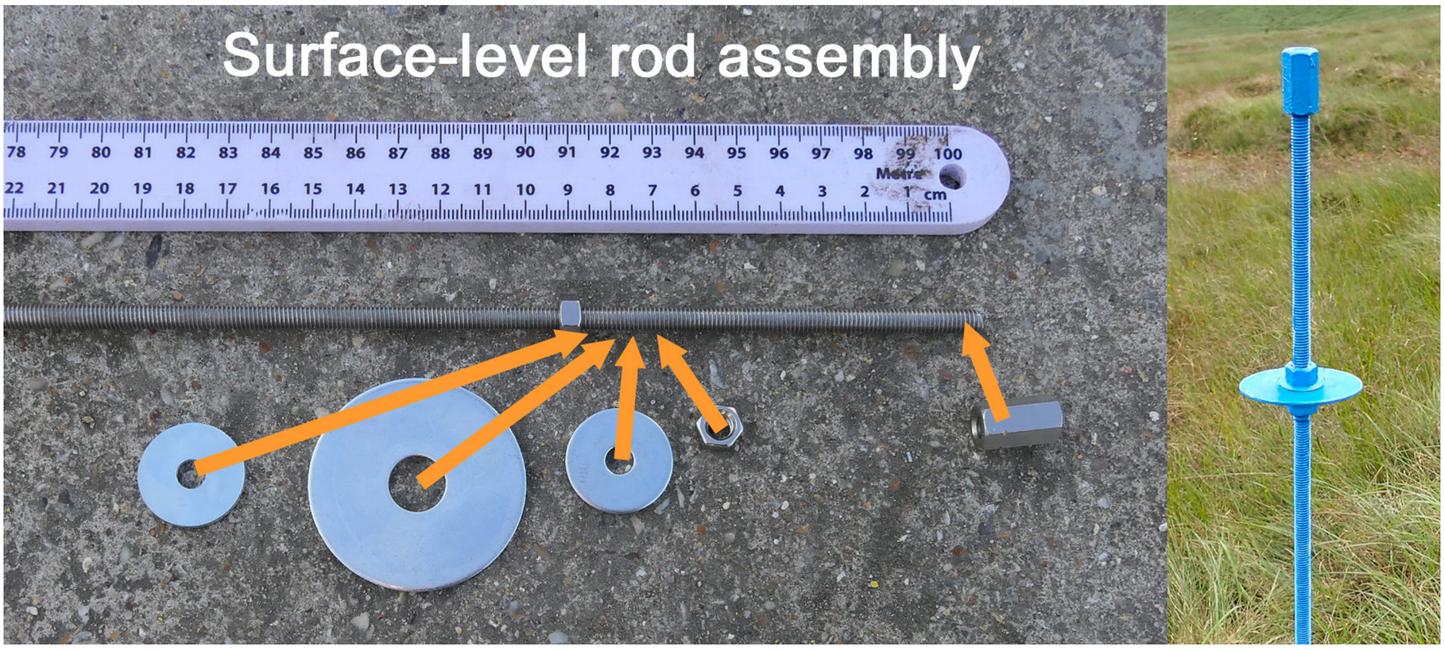
3.2 Preparing surface-level rods

In lieu of a pillar from the Crystal Palace Exhibition, threaded steel rods of various diameters and lengths are relatively cheap and widely available. In the first edition of the manual, it was suggested that zinc-coated rods would be the most suitable choice as they could be used for both surface-level rods and rust rods. If threaded rods are to be used for rust rods, then to avoid confusion between rods during construction, it is probably best to purchase zinc-coated rods for both purposes and accept that the whole of the rust rod will need to be painted and that the uppermost 1 m of the surface-level rod will also need to be painted. If, on the other hand, drawn mild steel is used for rust rods, it is possible to use stainless steel threaded rods for surface-level rods to distinguish them from rust rods and because multiple rods must often be connected together in order to plumb the full depth of peat.

Steel rods typically comes in 0.5 m or 1 m lengths and are often coded as M6 or M8 meaning that they are 6 mm or 8 mm in diameter respectively. Stainless steel connectors are used to join lengths of rod together and are also fairly readily available and inexpensive. The M6 diameter rods are sufficiently stiff to push easily through most peat soils, though M8 is less prone to bending when inserted into dense peat.


Threaded steel rod with stainless steel connectors.

In advance of going out on site, the top-most section of rod can be prepared. An M6 nut is positioned approximately 10 cm from one end of a 1 m length of M6 rod (or two connected 0.5 m lengths). A medium-sized metal washer is then slid down the rod until it is prevented from further travel by the nut. The largest possible off-the-shelf washer is then slid down the rod until it sits on top of the medium washer. A further medium washer is then slid down the rod to sit on top of the large washer, and the whole thing is then locked in place by threading another nut down onto the washer assembly. Finally, another connector is added at the very top of the rod. The whole rod is then painted with inert Peganox paint leaving some 2-3 cm unpainted at the bottom of the rod to allow an M6 connector to be added. This pre-painted assembly is then taken out to the site.



Surface-level rod showing nuts, washers and connector assembly.

Use of inert paint

Blue Noxyde paint was specifically manufactured to be biologically non-toxic, highly weather resistant and quick-drying. Standard paint will not suffice because it will leach metal ions into the surroundings, while the blue version of Noxyde was the most inert of the colours available. Unfortunately, the blue version of Noxyde is no longer available, but the closely-related Peganox is available and can be obtained in 'Resda green' which is probably the safest option in terms of any potential long-term leaching of pigments, though leaching from such paint is highly unlikely. Peganox is thinner than the original blue Noxyde and is specifically designed to be applied using a brush (amongst other application methods).

The purpose of the coating is to reduce as far as possible (not necessarily completely) any leaching of ions potentially toxic to *Sphagnum*, so a single brush-applied coating should be sufficient. An old palette drilled at regular intervals can provide a useful painting and drying stand for as many as 50 rods at a time. The thinner nature of the paint means that the uppermost part can be dipped in the tin, then spun to remove excess, before painting the remainder of the rod.

3.3 Installing surface-level rods

Having decided on a location within the site for inserting a surface-level rod, the first step involves determination of the peat depth at the precise location where the rod will be positioned. Threaded rods ('depthing rods') are inserted into the peat, length upon length, until the mineral soil or bedrock beneath the peat is reached. At this point, either solid or markedly increased resistance is encountered. The depth of peat will thus have been determined but can be confirmed if desired by using a peat corer should one be available (local universities, peat partnerships or statutory environmental agencies may provide one). The 'surface' should be taken either as the top-most surface of a moss layer, if present, or the level of the solid peat surface if no moss layer is present (i.e. push aside any overhanging leaves of vascular plants such as cotton grass, purple moor grass or heather to reveal the peat surface).

In the case of solid resistance from the mineral base, the sound is often important. A harsh 'metal-on-stone' sound indicates that bedrock or hard sediments have been encountered. A hollow 'wooden' sound may indicate that a buried tree-stump has been encountered and it may therefore be advisable to move 1-2 m away from this initial point before testing the depth again. In the case of increased resistance rather than a dead stop, a sandy base sends a 'gritty' vibration back up the rods and will soon resist further penetration. Soft clay, on the other hand, will simply provide increasing resistance. In this case, when the rods are removed it is generally possible to determine how far the basal rod penetrated the clay because clay particles will be caught and retained in the thread.

Two useful tips when measuring the depth of peat in this way:

1. Never pull the rods out of the ground as a single connected length because they will bend, distort and subsequently be unusable. Disconnect the rods as they come out of the ground, ensuring that the last lengths are held firmly so that they do not slip back down the hole to be lost forever.

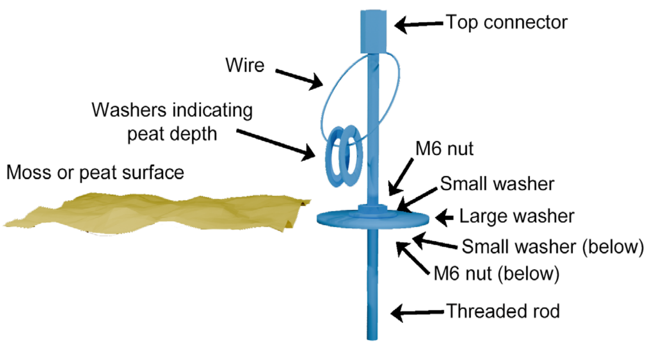
2. Never count the rods as they go into the peat because it is easy to lose count. As the rods come out of the ground, disconnect them and lay them side-by-side on the ground. Only when the last rod has emerged and been disconnected should the rods be counted and the depth of peat calculated.

Having established the depth of peat at this precise location (peat depths can vary significantly less than 50 cm away from a given point), it is necessary to calculate the number of rods that must be added below the top-most rod that was prepared off-site earlier, such that when the entire assembly is sunk into the peat, the large washer will sit at the bog surface. Usually this means that the bottom-most length of rod must be cut to length using bolt cutters or using a small hacksaw (a small plastic folding footstool can make a reasonably stable workbench for this). The entire assembly is then constructed length upon length, starting with the bottom-most rod, steadily inserting the rods into the peat until the large washer sits flush with the bog surface.

Robust means of recording peat depth

It is important to record the depth of peat below the washer in a robust way that will resist the passage of time and events such as fire. Metal tags for gardening and horticulture use offer one option, with the peat depth punched into the label using a set of metal number punches. These tags are, however, generally aluminium and could be lost in the event of a fire.

A better option to ensure there is a permanent record of the original depth involves preparing a number of large, medium and small washers beforehand by coating them with Peganox



Surface-level rod components, including washer assembly which sits level with the surface, and a set of depth washers to provide a permanent record of the peat depth which is resistant to fire. The top connector protects the top-most threads.

paint. Wind a length of general-purpose galvanised wire (approximately 1 mm in diameter), that has previously been dipped in Peganox paint, round the rod just beneath the washer assembly, then slide a number of the pre-painted washers onto the wire – the largest washer representing metres, the medium washer representing tens of centimetres and the smallest washer representing centimetres. Finally, the loose end of the wire is wrapped around the rod again to form a large loop holding the washers in place. The 'peat-depth washers' on their wire loop can be buried in a small slit made alongside the washer assembly and finally a rubber gardening 'cane-cap' is slipped onto the uppermost connector to provide added protection and reduce the possibility of damage to the hooves of deer or other passing animals. The position of the surface-level rod is recorded using a GPS.

Avoiding perching birds

The rod extends only 10 cm above the surface in order not to encourage perching birds, who would add seeds and guano to the immediate area. The top-most connector is added simply as protector to the top-most threads.

Installation of a rust rod and a surface-level rod pair

Once constructed, it is a simple matter of inserting the rods into the peat until the washer assemblies sit flush with the moss/peat surface. Ideally every surface-level rod should have a rust rod adjacent so that the combined picture of water level and surface movement is obtained, but the rust rods can be distributed much more widely across a site if desired because they are cheap and easy to install. It may well be that these markers become overgrown with vegetation, or even peat, over time, but with a GPS record of their position and use of a metal detector they should be relatively easy to find even under these conditions.

Surface-level rod (left) with adjacent rust rod (right)

3.4 Recording surface-level change

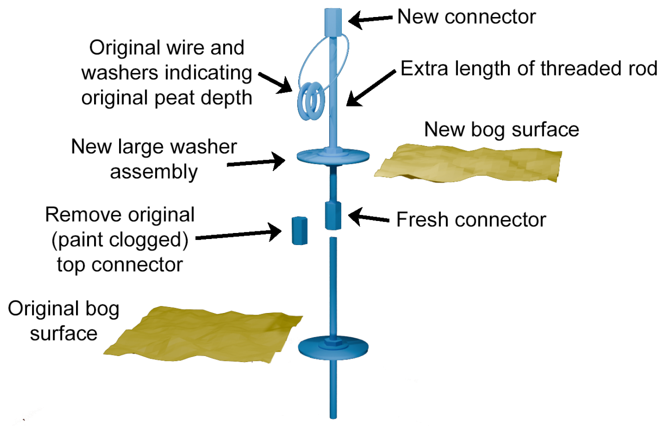
3.4.1 If the surface-level rod is buried – i.e. there has been carbon capture

In subsequent visits, the first challenge might be finding the surface-level rod as it may have become buried beneath vegetation or even fresh peat. Enlisting the help of a local metal-detectorist may be worth considering, though £100 will purchase a perfectly serviceable metal detector. If the surface-level marker is not obvious, the immediate vicinity of the GPS position should be searched by only one person using a metal detector in order to minimise trampling damage. The combination of metal rod, level-washer and depth-washers should give a sufficiently strong signal to ensure that finding the assembly is an easy task. Should they be available, snowshoes are useful in minimising trampling damage. In fen peatlands with standing water and/or tall dense vegetation, metal detectors do not work well, making rods difficult to locate without a high-accuracy GPS device.

Locating surface-level rods with a metal detector.

The level of the moss or peat layer is then noted in relation to the large surface-level washer. If this washer is deeply buried, gently expose the top-most connector and slide a length of threaded rod down alongside the buried rod until it hits the large washer. Note the depth of burial.

If the top connector is buried by more than 4-5 cm or so, remove it using two pairs of pliers – one on the connector, one on the rod below to stop the rod unscrewing from lower connectors – in order to expose clean thread at the top of the rod.



Adding a new washer assembly and depth washers to a surface-level rod that is buried by more than 4-5 cm.

Prepare a short section of rod having a length that, once attached to the top of the existing surface-level rod, will stand proud of the present bog surface by around 10 cm. Attach a connector to one end; this will be screwed onto the tip of the existing surface-level rod. Using M6 nuts above and below to lock them in place, position two small washers and a large washer between them at the position that will mark the new bog surface once the assembly is attached to the existing surface-level rod. Attach this assembly to the existing surface-level rod, then add a connector to the top of the new assembly. Attach the depth-washers with wire to the rod just beneath the top-most connector. Paint everything with Peganox paint. If necessary, gently press the moss/peat layer back around the rod without lowering the new moss/peat surface once the paint is dry (1 – 2 hours).

3.4.2 If the surface has subsided – i.e. there has been at least some carbon loss

If the peatland surface has subsided in the manner of Holme Fen, the surface-level marker will be standing proud of the surface and may attract perching birds or the attention of grazing animals or other passers-by. It will then be necessary to note the height of the surface-level washer above the present moss/peat surface, then detach the 'depth-washers'. Remove the whole original rod but immediately place a spare length of rod into the vacant hole, with a large washer attached to prevent the rod from being lost down the hole, thereby temporarily marking the exact location of the original rod. A whole new surface-level rod should be constructed as above and inserted into the peat down the original hole, attaching the original depth washers as a record of the former peat depth.

4. EYES ON THE BOG METHODS: THE VON POST FIELD TEST FOR PEAT SOIL CONDITION

The more degraded a bog becomes, the smaller the fibres of semi-decomposed plant material become. In a healthy 'active' peat bog dominated by Sphagnum bog moss, the peat will be extremely fibrous and 'springy'. However, in a highly degraded bog, the plant material will have decomposed much more, the fibres will therefore be small (more 'humified'), and the peat will squeeze through small gaps. This is the basis of a long-established field test for peat soils known as the von Post test (see image below). The von Post test is not suitable for use in fen peatlands because of the variability of fen peat, which is often characterised by very large vascular plant fibres which prevent the test from being meaningful or even possible.

The test is very simple. Dig wrist deep into the peat and take a sample of peat somewhat larger than a golf ball. Squeeze it hard in a clenched fist. The amount of material squeezing out between the fingers and the amount remaining when the palm is opened, gives a value of H0 to H10 on the von Post scale. For those interested in using the full range of the scale it is possible to find many versions of this test on the internet. For a very quick and approximate assessment of peat condition, however, it is possible to divide the scale into a simple 3-point version:

- no material, only brown water, squeezes out between the fingers (H0-H4)
- around half squeezes out and half remains in the palm (H5-H7)
- most of the peat squeezes out between the fingers (H8-H10)



Conducting a von Post test.
Left: collect a sample of peat at wrist depth approximately the size of a golf ball. **Middle**: squeeze the sample hard in a clenched fist.
Right: Assess the amount of peat remaining when the palm is opened and assign a von Post value.

The higher the von Post value (usually) the more degraded the peat

If the peat falls in the H0-H4 range then the bog is likely to be fairly healthy, at least at that point on the site. If the peat is H8-H10 then the peat at that location on the site is likely to be highly degraded.

A word of caution: if the bog consists of ridges of peat consistently giving von Post values of H0-H4 and there are pools or hollows which cannot be safely trodden on also distributed across the bog, the soft peat in these pools or hollows will tend to give high von Post values simply because peat in pools tends naturally to be more decomposed ('humified') than the peat of ridges and hummocks.

On the other hand, if the whole base of what looks like a bare-peat 'hollow' is solid and gives a von Post value of H8-H10, this is unlikely to be a true hollow and is more likely an erosion gully, or micro-erosion gully running between hard tussocks of cotton grass, deer grass or purple moor grass.
A picture of von Post values obtained from across a site will help to give a valuable picture of the condition of a bog over time, particularly if this can be aligned with data obtained from rust rods and surface-level rods.

5. EYES ON THE BOG METHODS: SMARTPHONE PHOTOGRAPHY AND VIRTUAL REALITY

5.1 Smartphones

Photography is more than 150 years old so can hardly be described as ‘modern’, but the fact remains that a photograph is a moment frozen in time, recording fairly objectively whatever is captured in the frame. Modern smartphones are the equal of many cameras nowadays, being quite capable of producing high-resolution images of the general vegetation at a particular location, and also for close-ups of any moss layer and other associated plant species. Some smartphones will even take panorama photographs, giving a 180-degree or 360-degree view of the site from that particular spot. Importantly, many smartphones with GPS technology can now geo-tag the location of a photograph so that the exact location can be pinned to social media or on websites such as Google Maps and Google Earth.

Value of time-stamping and geo-tagging

The value of such photographs should not be under-estimated. Being time-stamped and geo-tagged, they hold a record of what exactly was at a particular location on a particular date. The quality of the photographs is now so high that a specialist can often subsequently determine with a degree of certainty the precise species in the photograph, even if they include one of the more ‘difficult’ mosses such as *Sphagnum*.

Species identification via smartphone

Many plant species of peat bogs are considered difficult to identify, particularly the *Sphagnum* ‘bog mosses’ but also the various ‘feather mosses’ which may be found particularly on drier, somewhat damaged bogs. Technology, however, can replace specialist knowledge to a useful degree, and increasingly so with modern technology.



Smartphone photographs allowing identification of (L-R) *Sphagnum magellanicum*, *S. fuscum*, great sundew and bog asphodel at specific locations on a site on a specific date, being geo-tagged and date-stamped.

Potential to create ‘big-data’ archives

Such photographs can be taken in a moment, without unduly disturbing other activities, and can help to build up an immensely valuable record over time – assembling ‘big data’ archives. Indeed, there is a strong argument to say that site managers could be building up just such an archive of data during their normal rounds of a site without taking any significant time from their normal activities.

Clear evidence of change over 11-year interval

The value of a photographic record over time, whether of individual species, vertical shots of the immediate vegetation, or panoramic views, can be illustrated by the pair of photographs shown below. They are of exactly the same view but 11 years apart. It can be seen that the heather stimulated by drainage of this small-sedge fen has almost completely vanished and been replaced by purple moor grass and other more typical fen species. It took less than 10 seconds to photograph each view, the only additional requirement being that a permanent marker (it could have been a rust-rod or a surface-level rod) was in place to provide a consistent location from which to take the photograph.

Views of the same location taken 11 years apart. **Left**: heather dominance due to drainage. **Right**: purple moor grass and other fen species following rewetting.

5.2 Virtual reality

The rise of Virtual Reality (VR) has also provided new opportunities to record the vegetation and, to some extent, the surface morphology, of a peatland. Cameras costing between £300 and £400 can now take 360-degree views of entire scenes which, when viewed in even cheap devices such as Google Cardboard, can give a sense of standing in the middle of the peatland, allowing the viewer to look at the vegetation immediately at their feet or to view everything to the far horizon. Such views are, to repeat, irreplaceable records of a specific place at a specific time and can be used in years to come as a wholly objective record of what once existed at that location.

Stereo VR

A further opportunity now being offered by the latest technology is the ability to record the surface morphology – often referred to, albeit somewhat incorrectly, as ‘hummock-hollow topography’ – of a peatland. The technique goes back as far as the beginnings of photography but only now is it becoming re-invented through developments in modern technology. Stereo (3D) photographs were all the rage in Victorian times but fell out of fashion with the rise in popularity of the mono (2D) Box Brownie camera and its descendants. Virtual Reality headsets are now introducing a whole new generation to the possibilities offered by stereo photography.

Importance of stereo for recording surface morphology

The importance of stereo views to the monitoring of peat bog systems cannot be over-stated because the surface morphology of a peat bog is one of its most characteristic features and one of the most useful means of judging its condition. This morphology is almost completely invisible in a 2D photograph but becomes immediately evident in a 3D image. In fen peatlands, where non-stereo images can make the vegetation appear as a visual ‘wall’ of green, stereo images make it possible to distinguish the density and height of the sedge sward.

VR cameras offering 180-degree stereo views are already on the market for little more than £300. As the market develops and viewers become less cumbersome it can be expected that such cameras will become even cheaper and enter the mainstream – with even smartphones offering true 3D stereo. The opportunities for everyday monitoring using stereo VR video will then become truly remarkable.

The ‘trampling issue’ – extreme sensitivity of peatlands to trampling

The regular or semi-regular visiting of fixed-points on a peatland raises the issue of trampling, which can be a significant problem for the vegetation, and the more natural the vegetation the more sensitive it becomes to trampling. Even yearly visits can eventually create a path to, and a patch of bare peat around, a fixed marker point. Flat-plate snowshoes (rather than the ‘tennis-racquet’ type) are helpful in the absence of a fixed, raised boardwalk. In the absence of either, a temporary boardwalk may be placed beside a marker to be measured. In the case of photographs, if fixed-point photography is used it may be sufficient simply to stand in the same general vicinity of the fixed point rather than at exactly the fixed point each time.

Some peatland nature reserves have boardwalks, allowing for fixed point locations to be created along the boardwalk where people can record their photographs and perhaps be shown examples of previous views on information signs. QR codes are small and can be regularly updated on signage, allowing visitors access to previous views via their smartphones.

6. MONITORING 'BACK' AS WELL AS FORWARDS

The term 'monitoring' is most often understood to mean monitoring forward in time, but technology is also making it increasingly possible to monitor back in time, putting a site into the context of its trajectory of change over the past half-century or so. This context is important because present-day management interventions may or may not result in expected changes, and observed change may instead occur because the site was already on a trajectory of change that was established 30, 40 or 100 years ago.

6.1 Use of historical maps and photographs

Various information sources can shed light on past conditions, allowing us to 'monitor back in time'. In the UK, the First Edition 6" Ordnance Survey maps contain a wealth of detail, including the original extent of many lowland bogs, plus drains cutting across these systems, while subsequent OS map series reveal the nature of at least some of the changes to which these sites have been subject. Such historical maps are increasingly available via the internet, providing the opportunity to map at least the changes in mappable features over time.

Aerial photography

The development of aerial photography during World War I and its increasingly sophisticated development during World War II, combined with the desire to photograph large areas for military purposes, generated a large archive of aerial photography for many parts of the globe. This strategic mapping by aerial photography continued after WWII and many countries now have a rolling programme of aerial survey which underpins the updating of national cartographic maps.

Internet-based map resources

A further recent development has been the addition of aerial imagery to online resources such as Google Maps, Google Earth, Bing Maps and What3Words. At full zoom, the 'satellite' view is predominantly very high ground resolution (12.5 – 50 cm) aerial photography or pansharpened satellite imagery. There are still a few areas of the globe where these data are not available for a variety of reasons, and lower resolution (10 – 30 m) Landsat or Sentinel satellite data are presented there. Significantly, where high resolution imagery is available, Google Earth is beginning to present historical imagery for as far back as the 1940s, though this typically only goes back two or three decades, and, for example, is not available for everywhere in the UK.

Aerial-photo archives

Focusing on the UK, extensive national archives of historical aerial imagery are managed by Historic England, Historic Environment Scotland (HES), The Royal Commission on the Ancient and Historical Monuments of Wales (RCAHMW) and The Public Record Office of Northern Ireland (PRONI). All archives contain a range of both military and commercial photography and are continually expanding. There is some overlap between the archives and, of wider interest, the National Collection of Aerial Photography (NCAP) run by HES is one of the largest international collections, reported to hold over 26 million aerial photographs covering places throughout the world.

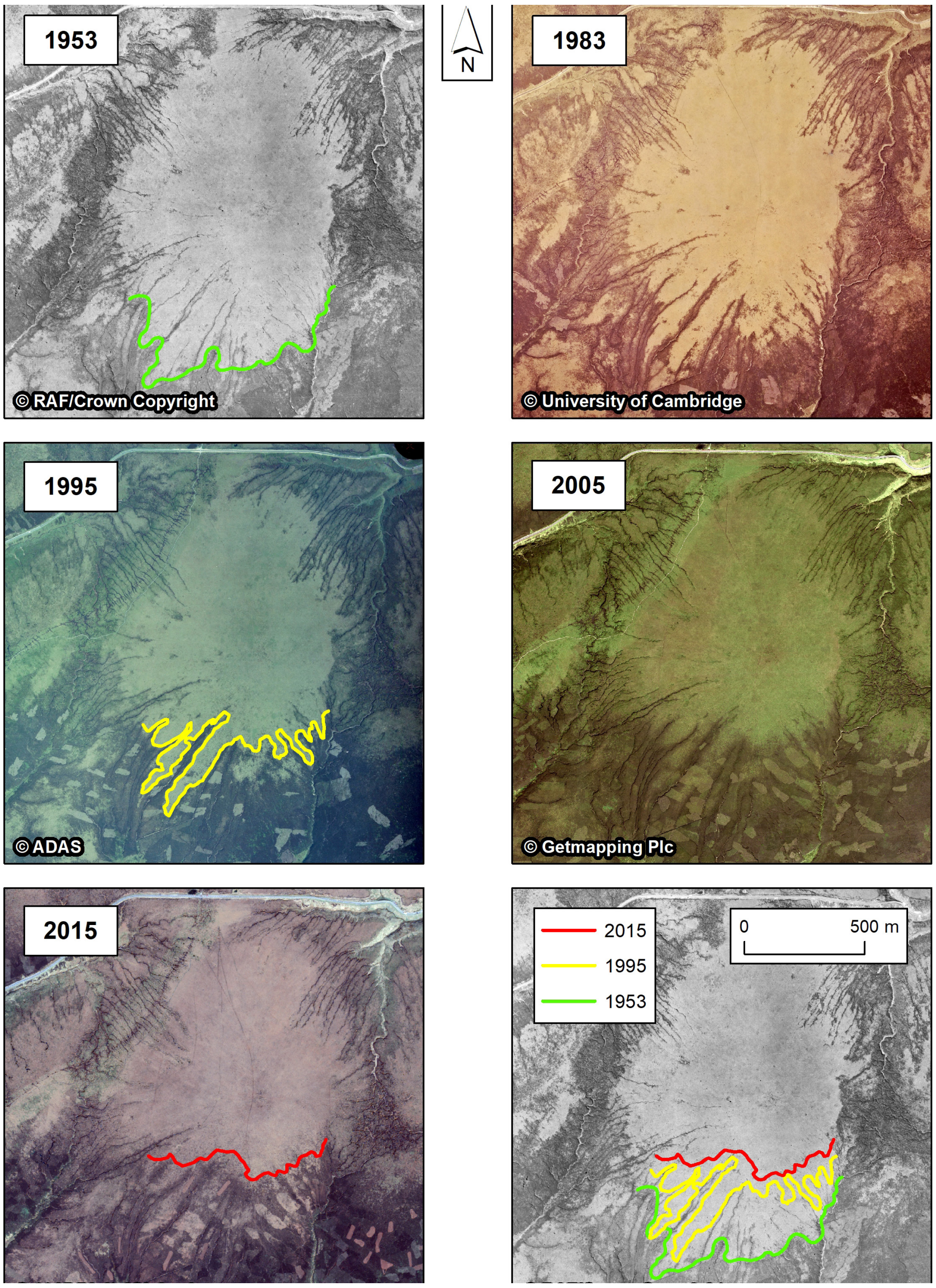
Methods of accessing aerial photo archives

Image archives are making increasing use of computer mapping (Geographical Information Systems or GIS) to facilitate image searches and all archives noted here have online search tools. Scans of images are continually being added to the GIS databases and it is possible to view low resolution 'quickviews' for many images online. Advanced searches can be performed by the archive curators to reveal the full record available for an area, often at no cost. Purchase of imagery is simple and the dominant form of image delivery is in digital format made available for download. High resolution scans of individual frames from national archives range from £25-50, although if image quality or cloud cover is uncertain, some archives, such as Historic England, can provide a photocopy.

6.2 'Monitoring back' at Featherbed Top - a worked example

The benefits of using historical aerial imagery as part of a monitoring programme are highlighted here for Featherbed Top, a dome of blanket bog in the Peak District National Park. Erosion gullies are visible on all sides of the dome and have the potential to compromise the integrity of the peat body, reduce the height of the water table in the bog and ultimately influence surface vegetation. The historical appearance of the bog has been reconstructed using aerial imagery dating from 1953. A high-resolution scan of an aerial photograph captured by the RAF in 1953 was purchased from Historic England.

The ground resolution (i.e. pixel size) is c.25 cm, equivalent to the resolution of the majority of colour aerial photography today. The image highlights that at this time the majority of the peat dome was covered by cotton grass-dominated vegetation and that heather dominated vegetation was present on the lower slopes on the south side.



Aerial imagery of Featherbed Top in the Peak District National Park, demonstrating historical change in vegetation cover that has the potential to be used in assessing the success of restoration interventions.

The reconstruction of Featherbed Top from historical imagery demonstrates that since 1953 the heather on the south side of the dome has increased in extent by at least 100 m upslope and in places by over 300 m.

From the historical data the rate of spread of heather (and perhaps an indication of drying of the peat moss) can be determined, thereby allowing prediction of where the heather may be in 30 years' time. If, in 30 years, heather has not increased as predicted (i.e. the rate of change has slowed or even begun retreating), this may indicate that blocking of erosion gullies on the south side of the dome undertaken by the National Trust in the early 2000s is having a positive impact beyond the area of intervention. Such overall trajectories of change can only be identified through the use of 'monitoring backwards' as well as conventional monitoring forwards.

7. FURTHER READING

This document has been produced following a major process of review and comment building on an original document: Lindsay, R. ‘*Peatbogs and Carbon: a Critical Synthesis*’. University of East London. 2010. Published by RSPB, Sandy.

More information on Eyes on the Bog is available on the IUCN UK Peatland Programme’s Eyes on the Bog webpage.

Version Date: May 2024

EYES ON THE BOG

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