Managing Earthwork Monuments

A guidance manual for the care of archaeological earthworks under grassland management.

Compiled by Dr J N Rimmington 2004

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Part A: Introduction

A1 Introduction

A1.1 Introduction

This guidance manual has been prepared as part of the Proactive Earthwork Management Project on Hadrian's Wall World Heritage Site. This is an European Union Heritage Laboratory Project funded under their Raphael Programme and supported by English Heritage, The Countryside Agency, Cumbria County Council, The National Trust, and Northumberland National Park.

The project was born out of the recognition that unlike ruins and standing buildings, the philosophy and methodology of conservation for archaeological earthworks is poorly-developed and not well understood. Often practice has been reactive rather than proactive, leading to costly repairs only after irreversible damage to the archaeological resource has already occurred. It was recognised that if archaeological earthworks in grassland were to be effectively managed there was a need to develop proactive, low-cost, minimal intervention techniques to prevent the onset of erosion and archaeological damage, whilst accommodating other values such as nature conservation, agricultural use, aesthetic appeal and recreation.

In January 2000, the project commenced with the principal aims of;

- Assessing the condition of parts of the Hadrian's Wall World Heritage Site under grassland management,
- using Hadrian's Wall to develop methods of repairing damage,
- using Hadrian's Wall to develop methods of proactive management to prevent damage,
- and through this guidance manual and a series of seminars and bulletins disseminating that knowledge to a wider audience.

The production of this guidance manual has drawn from a wide range of sources. It has involved the review of good practice on Hadrian's Wall and at other World Heritage Sites and archaeological sites in the United Kingdom, as well as the discussion of techniques with individual experts and organisations. Available literature has been reviewed, principal works include the Lowland Grassland Management Handbook (Jefferson and Croft, 1999), Upland Grassland Management Handbook (English Nature, 2001), Historic Scotland's Technical Advice Notes and English Heritage's Landscape Advice Notes.

The manual has been developed with the support and input of a large number of organisations, companies and individuals. On behalf of the project I would like to thank them all for their assistance.

A1.2 Aims

The aims of the guidance manual can be summarised as follows:

- To help heritage managers, land managers and advisers to achieve best practice for archaeological earthwork preservation in a grassland management setting.
- To provide guidance on the various management options available to the manager and adviser.
- To assist in the choice between these options.
- To provide basic practical information about procedures, methods, equipment and the ways to achieve good management.

A1.3 Scope

This guidance manual covers the conservation and repair of archaeological earthworks in grassland management. Its focus is those grasslands that have remained largely undisturbed as unimproved or semi-improved permanent pasture. These are characteristic of the study area, Hadrian's Wall, where the best surviving archaeological earthworks tend to be in these land-uses. However, the methods described in the manual will be of use in other grassland situations.

The manual has been prepared with a review of methods in the United Kingdom and some of the advice is specific to this country (e.g. wildlife legislation). However, the guidance manual is relevant to the management of archaeological earthworks in grassland settings in similar climatic regions of north-west Europe and elsewhere in the World.

A1.4 Target Audience

This guidance manual is directed at organisations and individuals managing archaeological earthworks in grassland settings for their preservation and those responsible for advising them.

A1.5 Use

The partner organisations involved in the production of this guidance manual are eager to see the information disseminated as widely as possible so that archaeological earthworks are managed appropriately. For this reason they are content for users to copy parts of the handbook for educational purposes and progression of works for the conservation of archaeological earthworks provided the source is acknowledged.

References and Further Reading

English Nature 2001 Upland Grassland Management Handbook.

Jefferson, R G and Croft, A 1999 Lowland Grassland Management Handbook. 2nd edition.

A2 Archaeological Earthworks

A2.1 What are Archaeological Earthworks?

The term archaeological earthwork covers a vast range of ancient monuments. A simple definition of the term is an archaeological deposit that is expressed at the ground surface as a mound or hollow. This definition is necessarily broad as archaeological earthworks include ditches, earthen banks and grassed over or partially grassed over stone walls. The defining line between what is an archaeological earthwork and what is a ruined historic building is the clear presence of in situ building fabric above the present ground surface and no continuation of the ground surface over this fabric.

A2.2 Why are they Important?

Like all archaeological and historical remains, archaeological earthworks are a finite resource and any damage is irreversible and results in the loss of archaeological deposits, information and form.

But it is not just for their archaeological value that archaeological earthworks are important. They are also important (significant);

- for their contribution to the landscape,
- for recreational use,
- for their associations with people, memories, beliefs and events,
- and often for their ecology.

The concept of significance is one that is well developed for standing buildings (Clark, 2001) and is just as applicable to archaeological earthworks. It is only when we understand the significance of a monument that we can manage it effectively. Resources spent researching the significance values of a monument are always resources well spent as they can guide repair and proactive maintenance work, whilst ensuring that that work in itself does not compromise the other values of the monument.

A2.3 What makes them Vulnerable?

The vulnerability of an earthwork is partly dependent on the nature of the management issues affecting a monument (which are discussed in part C) and part on the nature of an earthwork and its environment.

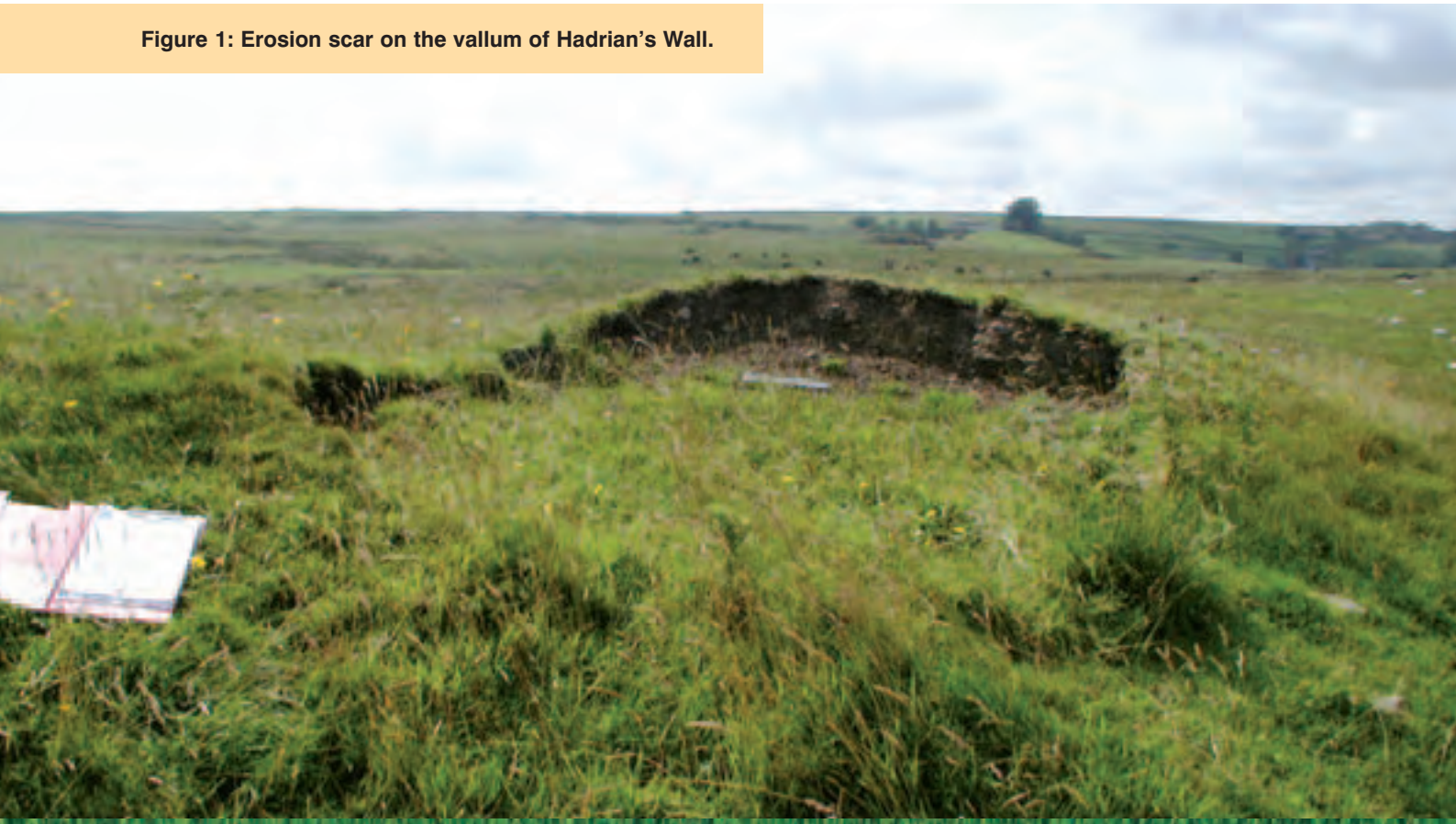
Nature of the earthwork

The key characteristics of an earthwork that affect its vulnerability are its;

- form
- composition
- and location

In many cases it is those archaeological earthworks that best survive, that are most vulnerable. This is because it is these earthworks that survive with the tallest and most steep sided banks that are most vulnerable if erosion begins. Observations on the earthworks of Hadrian's Wall (figure 1) suggest that a slope angle of 20° or less tends to be largely stable and any scars that develop tend to regenerate their grass cover if the erosion pressure is removed. However, slope angles greater than this tend to continue eroding until a stable angle is achieved. This angle reflects the cohesive nature of the boulder clay that much of the monument is composed of and would seem comparable to the Overton experimental earthwork project (figure 2) where the original angle changed little over the first 32 years of the project. On less stable soils such as sandy soils, a smaller angle may be required to achieve stability. The Wareham earthwork (figure 3), which had an initial slope angle of 14 degrees in 1964, had decreased to 7 degrees in 1980 (Bell, Fowler and Wilson, 1996).

Figure 1: Erosion scar on the vallum of Hadrian's Wall.



The Wareham and Overton experiments highlight how the composition of the archaeological earthwork affects its vulnerability. In general it can be said that sandy soils are most vulnerable and loams and clay loams are among the least vulnerable. The susceptibility to erosion of a soil is dependent on its infiltration capacity (affecting the amount and frequency of surface run-off) and its structural stability. More structurally stable soils, such as clay soils tend also to have lower infiltration capacities (Brady, 1990).

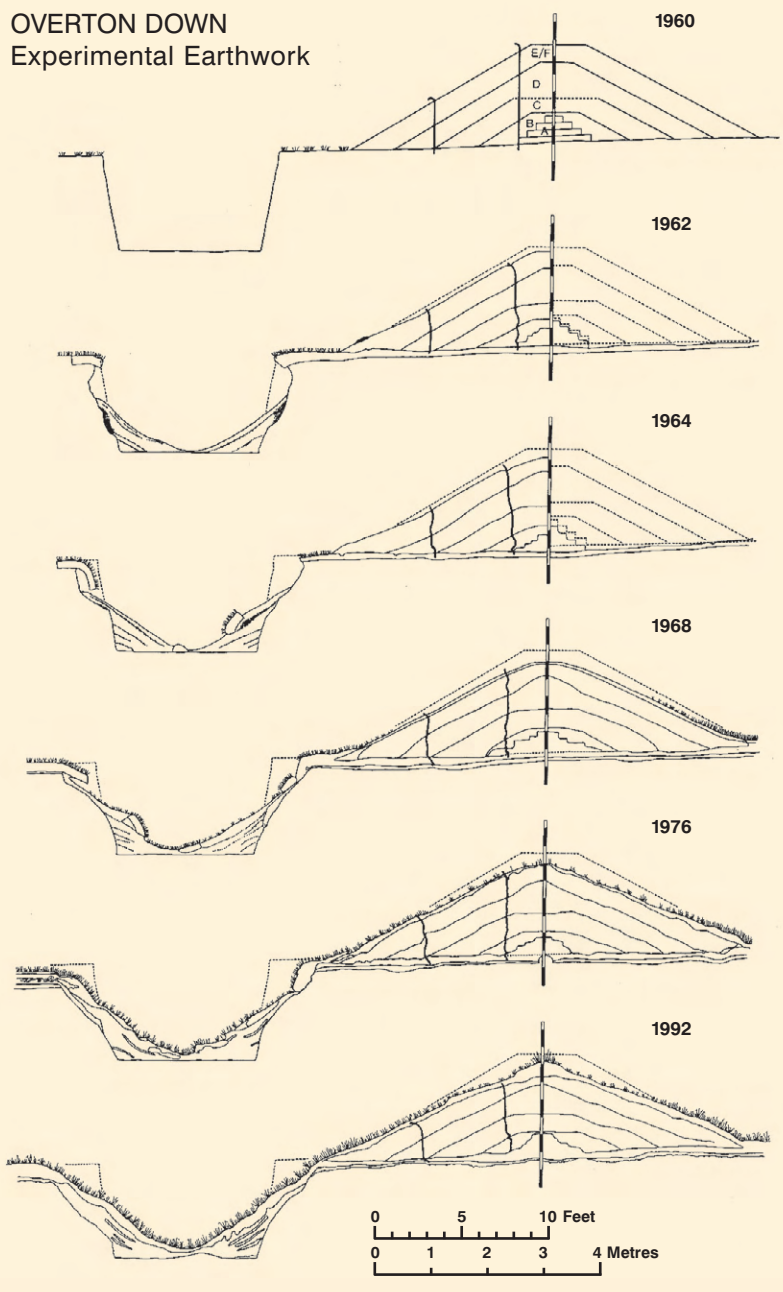


Figure 2: Overton profiles (from Bell, Fowler and Wilson, 1996)

The location of an archaeological earthwork will affect its vulnerability and ability to recover from damage. Key factors include the altitude, aspect, ground cover and surrounding vegetation and structures. Earthworks in exposed, upland sites where winds are stronger, temperatures are lower and growth of ground cover more limited are likely to be more vulnerable to wind and water erosion than those in sheltered lowland areas. Equally an earthwork surrounded by trees and hedges is more likely to be less vulnerable to prevailing weather conditions, although the shade and dry conditions created by the trees can lead to poor ground cover and high vulnerability.

Environmental conditions

The environmental conditions of the archaeological earthwork affect both the rate of recovery and the rate of erosion. The principal influences are temperature, precipitation and wind.

Temperature is an important influence on the rate of re-colonisation of any bare ground areas on a monument. Re-colonisation will only occur when plants are actively growing. The growing season in the United Kingdom typically extends from March until October, although this will vary according to geographical location and altitude. Temperature can also influence the wear resistance of grass as hot, drought conditions can lead to damage to the grass sward.

Precipitation has an important influence on the vulnerability of an earthwork, particularly where the soil surface has become exposed through natural slippage, land use or the action of burrowing animals. The degree of vulnerability is dependent on the amount, intensity and duration of precipitation and the character and soil moisture content of the soil. Precipitation has two particular impacts, displacement of soil particles through its ground impact and by run-off. The amount of run-off will depend on the moisture content of the soil and the amount of precipitation. In addition, prolonged periods of precipitation can leave soils saturated and more vulnerable to failure on slopes, leading to slumping.

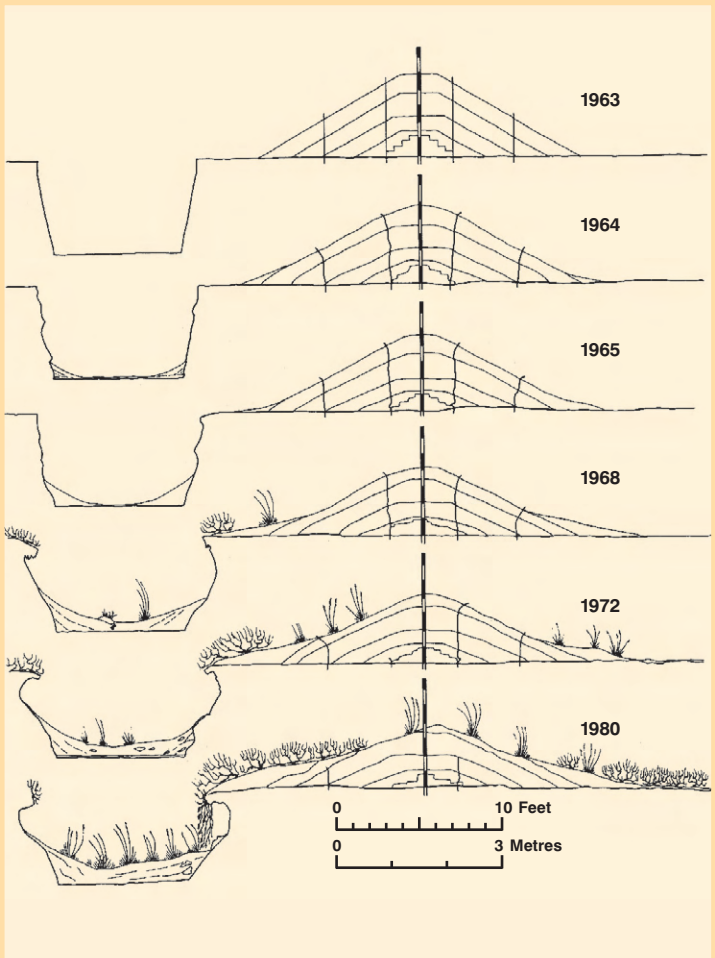


Figure 3: Wareham profiles
(from Bell, Fowler and Wilson, 1996)

Periods of dry weather combined with high temperatures will cause stress to the grass sward that makes it more vulnerable to damage and inhibits any re-growth in repaired sections.

The significance of wind to earthwork vulnerability will again vary with the soil character with sandy soils being the most vulnerable. It will also vary significantly with the level of exposure of the site to wind and in addition there can be a significant impact through the uprooting of trees.

A2.4 Why Manage Proactively?

Often the trigger for management action on archaeological earthworks is when a management problem has developed sufficiently to be readily identifiable and significant. This by nature means that there has been significant disturbance or loss of the archaeological deposits that form the earthwork. These deposits are a finite resource that once destroyed cannot be recreated.

Proactive management is about identifying management problems as early as possible and then putting in place monitoring and management actions that control the problem. In this way the loss from the resource can be kept to a minimum or prevented.

References and Further Reading

Bell, M. Fowler, P J and Hillson, S W (Editors) 1996 The experimental Earthwork Project 1960 – 1992. (CBA Research Report 100).

Brady, N C 1990 The Nature and Properties of Soils. (Macmillan Publishing Company, New York).

Clark, K 2001 Informed Conservation (English Heritage, London).

A3.1 Introduction

This sections gives a basic introduction to how grasses grow, how they are managed and improved, some of the common grasses and their resistance to wear and finally some of the ways in which wear can be reduced.

Grasslands are large open units of land dominated in their vegetation cover by grass species. The majority of grassland in the United Kingdom is used for agriculture, mainly to provide grazing for ruminant animals, with a smaller proportion managed to provide conserved fodder such as hay and silage.

In the United Kingdom about 30 % of all agricultural land is classed as permanent grassland, grassland that is not subject to rotation with an arable crop. A further 8% is classed as rotational grassland, which is rotated with an arable crop (Brockman, 1995). The Countryside Survey 2000, recorded that 24.7 % of the area of the United Kingdom is improved grassland. Unimproved or semi-improved grassland (neutral, acid and calcareous grasslands) cover some 8.6 % (Defra, 2001).

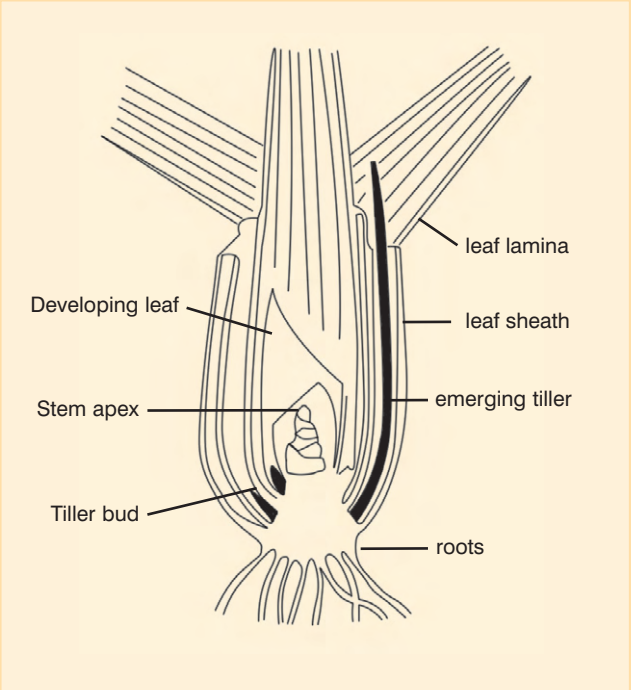


Figure 4: Diagram of a grass.

A3.2 How Does Grass Grow?

While individual grass plants are not flowering (also referred to as inflorescence development) then they grow from near ground level, at the stem apex (figure 4). This closeness to the ground surface protects the growing point from damage by grazing and mowing. The initial leaf grows from the stem apex and like all later leaves it is the cells at that base that divide to create new cells, so the youngest parts of the leaves are nearest the base and the oldest at its tip. As the grass develops new leaf buds (tiller buds) are formed around the stem apex. It is from these tiller buds that new leaves and new root systems develop allowing the grass to spread. The formation of tiller buds is promoted by regular cropping of the leaf tip.
In some grass species, specialised tiller buds develop with sharp points that can grow through surrounding leaves and then either along the ground surface or in the ground. These are known as stolons (on ground surface) and rhizomes (in the ground) and allow the plant to spread across bare areas of ground very rapidly. New plants develop at their nodes.

When the grass enters the flowering stage, growth is quite different. New tiller bud development is suppressed and all existing ones start to form flowers. The flower is a development of the stem apex and therefore if removed by mowing or grazing the remainder of the leaf is incapable of regrowth. In addition, after the removal of the flower or completion of flowering there is a delay

before the grass starts to grow again. This means that the grass is more susceptible to wear as it is not actively growing and therefore cannot replace damaged leaves.

Therefore, in terms of providing a dense sward, which is wear resistant, then regular cropping by grazing or mowing to prevent flowering and promote tillering is essential.

A3.3 How are Grasslands Managed?

The majority of grassland is managed for grazing by ruminant animals. There is however a variety of grazing systems that are used and the major methods are summarised below.

Continuous Systems

Continuous grazing systems are those where there is uncontrolled grazing on a land unit. The regular cropping promotes a dense, well-tillered sward with between 20,000 and 30,000 tillers per square metre. This method is normally used on large field units where the potential for overgrazing is minimized. It is sometimes employed with a buffer grazing area. This buffer can either be grazed while the main area recovers or if not required then it can be harvested as conserved forage.

Other continuous systems include the two sward system, set-stocking and three field system. The two sward system is where one field unit is grazed continuously and the other harvested for conserved forage. The set-stocking system defines a given number of livestock on a fixed area for the year and may include a period of the year when livestock are excluded from the field unit. This is a method that is often used in agri-environment schemes to achieve nature conservation aims, such as allowing rare or unimproved grasses to flower and seed.

The three field system divides the land unit into three equal parts. One part is grazed on a continuous basis for the first part of the season, whilst the other two parts are cut for conserved forage. Later in the season the conserved forage areas are grazed and the grazed area is cut for conserved forage. Towards the end of the growing season all the area is grazed.

Rotational Systems

Rotational grazing systems move stock through a series of land units. The sward is not as regularly cropped as continuous systems and therefore the sward is not as dense or well-tillered, commonly having between 5,000 and 15,000 tillers per square metre.

Examples of rotational systems are the block grazing system, the paddock grazing system and the strip grazing system. Each of these systems are managed similarly with livestock being moved into new grazing units on a regular basis allowing a period of rest for the grazed sward to recover before it is re-grazed. They differ only in the method they achieve this. The block grazing system achieves this by temporarily dividing the field unit into a series of blocks that are in turn grazed. The paddock system is a series of permanent small field units and the strip grazing system is where the field unit is temporarily divided up into strips for grazing.

Zero Grazing Systems

Zero grazing systems have no stock grazing the land unit. The grass is cut and transported to the stock for consumption on a daily basis. The grass can also be cut to provide conserved forage for later consumption. This later method is the production of silage, haylage (also refered to as big bale silage) or a hay crop. Grass is cut on a six-week cycle throughout the season to produce silage. This method will produce a sward that has a lower density of tillers than other continuous systems, as cropping is periodic rather than truly continuous.

A3.4 Improving Grassland

It is often in the interest of the agricultural landowner to improve the grassland in order to improve the productivity of the land in both its forage production and the condition of the grazing livestock. The methods available to the farmer are:

- Reseed – plough or chemically destroy the previous crop and seed
- Renovate – introduce new species into the old sward with or without partial chemical destruction
- Retain - improved defoliation technique through grazing and cutting, often with attention to drainage, pH and fertilisers

The main techniques used discussed below. These are;

- undersowing,
- seeding,
- direct drilling,
- slit seeding,
- and scatter and tread

Improving grassland by cultivation has the potential to damage archaeological earthworks by disturbing buried archaeological deposits and smoothing their form. It is desirable therefore to use the less intrusive methods of direct drilling, slit seeding and scatter and tread in any grass improvement works.

Undersowing

This is applicable to grasslands subject to periodic arable cultivation. The grass seed is sown along with a “nurse” crop such as spring cereals. The “nurse” crop is normally sown first to ensure that its removal is in the earlier stages of development of the grass and therefore does not overshadow the grass, which would result in a low density.

Seeding

Here the grass seed is sown as a crop in its own right without a “nurse” crop. Perennial ryegrass is normally used, as rapid establishment is required to minimise weed competition and the risk of erosion.

Direct Drilling

This technique sows the seed directly into the ground at a depth of 10-20mm. It is used as a method of re-seeding where the previous crop has been thoroughly killed off using a herbicide.

Slit-Seeding

This technique is used for sward renovation, the principal being that at least part of the original sward is kept. The machines available have a narrow disc that cuts into the old sward and then a seed-drill that deposits the grass seed into the slit.

Scatter and Tread

This is an opportunistic method of renovating grassland by simply scattering the seeds on the soil surface under moist conditions, normally followed by putting livestock on the area to tread in the seeds. Its success is dependent on the rapid treading in and a two-month period of moist ground conditions.

It is a cheap and good technique for patching worn areas of ground. Therefore it is a good technique for repairing bare areas on the slopes of archaeological earthworks, although it is recommended that a spiked roller or seed slotter be used rather than livestock which may exacerbate erosion. The spikes or slotter should penetrate the ground no more than 1-2cm; this is sufficient for the grass seed to have an ideal germination environment.

A3.5 Some Common Grasses

This section introduces some of the grasses the reader is likely to come across when dealing with agricultural land and management for amenity. The basic character and attributes are described. Further information on these grasses can be found in Grasses (Hubbard, 1984) and other publications listed at the end of this section.

Perennial Ryegrass (Lolium perenne)

Perennial ryegrass is the grass that the reader is most likely to come across. It is the main type of grass used when improving agricultural grassland due to its nutritive value, its growth response to manuring and its rapid establishment. In amenity situations it is extensively used, as it is extremely tolerant of wear.

It is a loosely to densely tufted perennial, 10-90cm high. It is one of the easiest grasses to identify in the field due to its leaf blades having glossy undersides.

It is an ideal grass for maintaining grass cover on footpaths due to its wear tolerance. However, it is reliant on fertile ground conditions or applications of artificial fertiliser to perform well. Its weaknesses are that it is vulnerable to drought and heat, and does not perform well on infertile ground. Ryegrass is constantly being hybridised and modern varieties have lessened its weaknesses.

Smooth-stalked meadow grass (Poa pratensis)

A very variable perennial, 10-90cm high, with slender creeping rhizomes, forming loose or compact tufts. This is widespread in the British Isles, though mainly occurring on well-drained sandy and loamy soils.

It is a particularly useful species of grass due to a number of its characteristics. Like perennial ryegrass it is tolerant of wear, but in addition it is able to cope with periods of drought and heat. These characteristics along with it being a rhizome grass species makes it particularly suited to erosion control on banks and thin soils.

Its only significant weakness is that it is slow and difficult to establish preferring to be sown when soil conditions are warm and therefore it is most effectively sown in June – July or under a germination blanket.

Red Fescue (Festuca rubra)

Three sub-species of this grass are commonly encountered in grass mixes;

- Chewings fescue (Festuca rubra ssp commutata)
- Slender Creeping Red Fescue (Festuca rubra ssp litoralis)
- Strong Creeping Red Fescue (Festuca rubra ssp rubra)

Chewings fescue is a densely tufted perennial, 20-90 cm high, without rhizomes. It is widely distributed in the British Isles particularly on well-drained chalk, gravely or sandy soils. It is another drought tolerant species.

Slender creeping fescue is a densely tufted or mat forming perennial, with short very slender rhizomes. It is found in marsh and upland environments and has good winter hardiness and sward density.

Strong creeping fescue is a dense to loosely tuft forming perennial with rhizomes. It is widespread in the British Isles and is used in fine lawn mixtures.

All the fescues have good drought tolerance due to their fine leaf structure and are reasonably fast to establish. This makes them useful in bank and thin soil situations. However, they are less resistant to wear than perennial ryegrass and smooth stalked meadow grass.

Creeping Bent (Agrostis stolonifera)

A tufted perennial, 8-40cm high, spreading by leafy stolons and forming a close turf. This is frequent to very common in the British Isles and is found in a wide range of situations from salt marsh to upland grassland and from light to heavy soils. It is reasonably drought and wear tolerant, but is most useful because of its ability to cope with a wide variety of situations.

Common Bent (Agrostis tenuis)

Also known as brown top, this is a tufted perennial, 10-70cm high, spreading by short rhizomes and stolons. It is widely distributed in the British Isles being present in grasslands from sea-level to 1200m and found on a wide range of soils, though especially prevalent on poor dry acid soils. It is another drought tolerant species, which like creeping bent is most useful because of its ability to cope with a wide variety of situations.

Timothy (Phleum pratense)

A loosely to densely tufted perennial, 40-150cm high. It is a shallow rooting species that performs best on moist soils, is winter hardy and wear tolerant. It is not perform well on dry soils or in grass swards subject to close mowing. Timothy is a common agricultural grass, being grown extensively for grazing and hay.

A3.6 Resistance to Wear

The trampling of grass affects their productivity by damaging the leaf structure, damaging the tiller buds and inhibiting photosynthesis by smearing soil over the leaf blades. Grass is most susceptible to damage when ground conditions are wet as the growing point of the grass can become exposed due to the compaction and displacement of soil around it.

In general types of grass that tiller profusely, such as intermediate and late perennial ryegrasses, are the most tolerant of trampling and have some ability to recover after poaching. The folded leaf structure of perennial ryegrass withstands the crushing pressure from feet and hooves better than grasses with a rolled leaf structure such as meadow fescue and timothy. Grasses with a creeping root system, by surface stolons or underground rhizomes, have the ability to regenerate from small pieces. Table A shows the reduction in yield of a number of grass species from stock trampling.

Table A. Comparison of livestock trampling on the yield of some common agricultural grass species. Percentage yield compared to an untrampled plot (from Charles, 1978)

Perennial Ryegrass	77
Smooth Stalked Meadow Grass	69
Common Bent	40
Timothy	38
Cocksfoot	20

Poached or heavily trampled ground is often colonised by annual meadow grass (Poa annua) or chickweed, which germinate readily from seed in

the soil. Annual meadow grass is wear tolerant, but dies back in the winter leaving the soil vulnerable to erosion. These areas are also colonised by prostrate rosette-forming plants (e.g. ribwort plantain) and deep tap-rooted perenials (e.g. dock) which can tolerate poaching by livestock, but are not wear tolerant of regular use by visitors. These are particularly useful species to note during summer field visits as they indicate areas subject to disturbance during winter months, which may look acceptable in the summer.

Trampling also damages the soil structure that is critical for good grass development. Trampling compacts the soil structure reducing the air spaces between soil particles in which the grass roots grow and respire. By reducing the air spaces it also reduces the ability of the soil to drain water away from the surface. This can lead to the air spaces becoming filled with water and standing surface water which reduces the wear tolerance of the grass by reducing its growth performance and increases its susceptibility to soil smear on its leaf blades.

A3.7 Methods of Reducing Wear

The methods available to reduce wear come primarily from agricultural and horticultural practices. The methods that could be employed are;

- ### The introduction of wear tolerant species

  Grasses such as perennial ryegrass and smooth stalked meadow grass can be incorporated into the sward to increase its ability to withstand wear. Even within these two grass species there is a wide variation in wear tolerance between the various cultivars. Information on the properties of commercially available cultivars can be found in Turfgrass Seed: the buyers guide to quality amenity turfgrasses, published jointly by the British Society of Plant Breeders limited (BSPB) and the Sports Turf Research Institute.

- ### The regular cutting or grazing of the grass

  The regular removal of the grass through cutting or grazing to a heigth of between 25mm and 75mm promotes a more dense and wear tolerant grass sward to develop through the stimulation of tiller development.

- ### The aeration of the soil

  Aeration actually does three things; it aerates the soil, improves drainage and reduces compaction. All are important for the promotion of a good grass sward. Aerating and improving the drainage of the ground achieves the right air and water balance for grass growth. A decompacted soil has more voids between the soil particles than a compacted soil. It is in these that the root system of the grass sward grows.

  There are a wide variety of tine types and sizes used to aerate the soil (figure 5). The main three types are the solid, the slit and the hollow tine. The solid tine punches into the soil, the slit tine slices through the soil and the hollow tine removes a core of soil.

Figure 5: A typical array of tines used on aeration machines.

- ### The application of fertilisers

  Fertilisers can be applied in the spring, summer and autumn. Spring and summer applications are high nitrogen fertilisers to encourage strong leaf growth. Autumn fertilisers are low in nitrogen, but high in phosphorus and potassium, which encourage root growth and hardier leaf growth for the winter. They should be applied only in appropriate weather conditions, when the soil is moist and rain is expected or can be replaced by irrigation.

  An alternative to fertiliser application is the inclusion of clover in the sward. Clover is a nitrogen fixing plant, which means it removes nitrogen from the atmosphere and makes it available to other plants in the soil.

- ### The application of a top-dressing

  Top-dressing helps to protect the growth point of the grass and can help alleviate soil compaction and improve drainage if combined with soil aeration. The range of materials is varied including blended soil/sand mixtures, composts and rubber crumb. Normally done in the autumn it can be incorporated with over-seeding to restore a full grass cover.

- ### Harrowing and scarifying

  Harrowing spreads molehills and wormcasts that can otherwise be smeared over the surrounding grass reducing its ability to photosynthesise and act as excellent seedbeds for the germination of weed species.

  Scarifying is carried out in the autumn. It is used to remove excess thatch that if left would suppress good grass development. The retention of a thin layer of thatch can be beneficial as it helps protect the growth point of the grass.

- ### Treatment of weeds

  Weeds, especially broad-leaved weeds are not normally tolerant of wear and can compete for nutrients and light with the grass. Removing weeds can be an effective means of improving sward vigour.

- ### Watering

  This is a strategy that can be used on sites with particularly thin soils, which can be prone to drought. Maintaining soil moisture is important when establishing turf or grass seed on repairs and if the prevailing weather conditions are not suitable then artificial watering may be necessary.

- ### Implementing repairs or resting the ground

  Carrying out repairs early is fundamental to preventing erosion. Often action is required by the time that the first surface indication of wear (the yellowing of the grass) is apparent. The yellowing is a reaction to the stress, which is often caused by the compaction where recreation is involved and programmes of repair and rest will be required.

Some of these methods may impact on the nature conservation value of a monument and it is important to consider this before action is taken. In cases where the monument is or is part of a designated site for nature conservation then it will be necessary to discuss with the appropriate organisation and obtain the necessary consent.

Managing Earthwork Monuments

A guidance manual for the care of archaeological earthworks under grassland management.

Compiled by Dr J N Rimmington 2004

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Part B: Condition Assessment and Monitoring

Part B: Condition Assessment and Monitoring

B1 Condition Assessment

B1.1 Introduction

Fundamental to all effective management of our archaeological earthworks are an accurate record of the present condition and how that condition is changing. The following section introduces what condition assessment is, what it aims to achieve and what to investigate before and during field assessment.

B1.1.1 What is Condition Assessment?

Condition assessment has been defined as a "point-in-time statement of circumstances appertaining to a particular site" (Monuments at Risk Survey, Darvill and Fulton, 1998, 99). This can be further defined as the recording of the present state of the monument, the evidence for change occurring to the monument and the prediction of how that change may affect the monument in the future.

B1.1.2 What does it aim to achieve?

By carrying out the above functions a condition assessment aims to inform on the priorities for present and future management of a monument in order to maintain it in a stable or improving condition. Often an assessment is used on a range of sites in a geographical area or a particular theme. In these circumstances the condition assessment will be able to provide an overview of the current state and influences on the sites and the priorities for funding of future management works, which can be an excellent guide to proactive management. By comparison the lack of that overview often means resources are directed into areas of perceived need, which are often reactive and costly.

B1.1.3 Scope of guidance

The following sections of the guidance manual present and discuss the potential sources of information available to the condition assessor. It has not been designed to be an exhaustive list of all possible sources of information and assessment techniques, but rather a checklist that the reader can use to prepare for a programme of work. The use and application of the information and techniques outlined will depend on the specific project requirements, which will be governed by available resources and required output of the assessment.

B1.2 Pre-Field Visit Assessment

B1.2.1 Introduction

The aim of the pre-field visit (or desktop assessment) is to develop an appreciation of the management issues and environmental factors relating to a monument and how they have affected the monument. The range of sources available to develop this is diverse and is discussed in the following section. It is not envisaged that every source of information should be investigated thoroughly prior to a visit, as some sources may be more usefully exploited after the field visit and some may provide little beneficial information. The reader should therefore treat the following section as a checklist when planning work.

B1.2.2 Sources of Information

The following sources of information are available to the assessor:

Free text reports may be held on individual county sites and monuments records (SMR) or may be available from national agencies or heritage conservation bodies. The information they provide will be highly variable, but is likely to provide valuable insight into the past state of preservation of the monument and also record potential vulnerabilities of the monument and existing management issues.

Photography, both ground based and aerial, can provide excellent information on the changing condition of monument and gives the assessor a very clear appreciation of the extent and nature of any management issues at the time the photograph was taken. Ground based photographs if repeated can give an appreciation of the level of change that is occurring on the monument, particularly if taken at the same time of year. Aerial photographs can also be used to provide quantitative data on how the monument is changing, particularly with issues such as scrub development.

Archaeological recording provides evidence of both the above ground preservation through field survey, and of below ground survival through archaeological excavation and development watching briefs. The information can be used both to assess the changing degree of preservation and the likely impact of any management issues on the site.

Antiquarian accounts, historical maps, paintings and photographs provide a longer history of the state of the monument than the sources detailed above. Photographs are the best sources as they accurately depict the state of preservation. Antiquarian accounts, as with map depictions and paintings, have to be used with care due to recorder biases (e.g. painters may have been commissioned by the landowner to depict the land in a favourable light, and therefore show extremely well improved land and emphasise landscape features, which may include historic features). Often the best source of these is the County Record Offices.

Oral accounts can provide information on the changing state of preservation of the monument and provide insight into management issues. This is particularly true in burrowing animal control and livestock management issues, where local information can give an indication of the reasons behind some disturbances to the monument.

Botanical and ecological surveys and natural environment designations provide information on the type of land-use, soil condition (acid or calcareous) and the presence of any important wildlife interests that may influence management actions for the conservation of the monument. Information of this nature can be found with English Nature, Local Wildlife Trusts and Local Authorities.

Soil and geology maps can be used to assess drainage characteristics of the land, which will influence the ability of the grass to withstand livestock, vehicle and recreational pressures. Soil information can also give an indication of the vulnerability of the monument to erosive forces if the vegetation cover is removed. Information on soils is available from the Soil Survey and Land Research Centre. Information on geology is available from the British Geological Survey.

Definitive Rights of Way maps indicate where damage from recreational pressure and maintenance may occur. These maps are held by all County Councils.
Visitor surveys where available can indicate how many visitors a monument will receive and how those people use the monument (e.g. whether there is a particular focus of activity close to a car park).

Management agreements if they are active or have been used for a site in the past can give an excellent indication of management issues on a site.

B1.2.3 What Next?

The information collated as part of the desktop assessment may be treated as purely an information gathering exercise before a field visit. Equally it can be used to assess the priority of making a field visit if the archaeological earthworks most at risk can be readily identified from the desktop study.

B1.3 Field Assessment

B1.3.1 Aim of the Field Assessment

The aim of the field assessment is principally to record the present state of the monument and any management issues. This should include the level of its survival, its overall condition, potential vulnerability, stability and any active damage.

In addition the field visit can be used to clarify the land use and to expand on it by recording the type and extent of vegetation present. This is particularly useful where the vegetation may cause future management issues, such as bracken and scrub.

The visit can also be used to provide baseline data for future monitoring visits such as a general photograph of the earthwork and fixed point photography of any management issues.

B1.3.2 What to Record

The field assessment should record the following key factors:

Survey detail: The date, name of surveyor, time spent on site, and weather conditions at time of visit are important information to record. The date allows future assessment to be made at a similar time of year or seasonal factors to be taken account of. The weather conditions and length of visit help indicate the level of detail that the surveyor will have recorded.

Environmental data: The ground conditions at time of visit, character of soil, vegetation cover and extent and agricultural land-use. If ground conditions are waterlogged at the time of the visit then this can be reflected in management problems such as ground disturbance from livestock, vehicles or recreation. Character of the soil will give an indication as to the vulnerability of the monument to various management problems.

General Monument Assessment: An assessment of the overall condition, survival (table B), stability and vulnerability of the monument. These should be done using a qualitative scoring system to enable them to be repeated and assessment made of change.

Specific Management Issue Assessment: An assessment of the degree of influence that various management issues are having on the monument at the time of visit. This as with the previous factor should be recorded using a qualitative scoring system that can be repeated. It should also record whether the management issue is active or inactive, where appropriate (e.g. burrowing animals). The following management issues are a sample checklist;

Table B: A simple qualitative scoring system for the survival of the vallum on Hadrian's Wall based on its components and height of components. The vallum had a central ditch and one mound on either side.

Score	Definition
0	No above ground evidence, below ground survival only
1	At least one component visible as a poor earthwork (less than 0.25m height)
2	All three components visible as medium earthworks (more than 0.25m height and less than 1m) or one component as a good earthwork (more than 1m)
3	All components visible as good earthworks (more than 1m)

- Livestock
- Recreational use
- Vehicular
- Scrub, tree or bracken
- Burrowing animal
- Mineral extraction
- Fencing
- Road construction
- Water action
- Vandalism (including metal detecting)

Table C Methods of scoring management issues

Score	Percentage method	Definition method
0	None	None
1	Less than 15% of area	Pressure from management issue in the area of the monument but not on the monument or minor impact on the less significant parts of the monument
2	15-60% of area	Management issue affecting large areas of the monument or having a minor impact on parts of the monument which have high significance
3	More than 60% of area	Management issue affecting majority of monument or management issue causing extensive damage to parts of the monument which have high significance

The scoring has and can be done in a number of ways. The two most common ways are by assessing the percentage of the monument affected by the management issue or by the defined significance of the management issue (table C).

Local Insight: Record oral evidence from landowners or tenants of the monument or adjacent land, which can help explain how and when a management issue has and does develop.

Recommendations: Recommendations should be made as to how to alleviate or remove any identified management issues and the timescale that this should be instigated on.

In addition the surveyor can make a photographic archive of the present management issues and carry out any necessary measuring of features to provide a baseline for future monitoring.

B2 Monitoring

B2.1 Introduction

Monitoring is essential to site management. It maintains a periodic assessment of specific management issues or the general state of the monument that enables the trend to be established. It is of particular importance as our understanding of management issues and techniques of management for archaeological earthworks is still in its infancy.

The length of time between monitoring visits will depend on the specifics of the management issue based on a variety of factors. Examples of these are how quickly the problem might develop (e.g. spread of scrub or bracken may be on a 5 year monitoring period) or how often it is at its worst extent (e.g. ground disturbance by livestock monitored on an annual basis).

Monitoring is also important in assessing the effectiveness of management techniques used and to detect whether further action is required.

B2.2 Methods of Monitoring

The following section presents a range of methods that can be used to monitor archaeological earthworks. These are:

- Visual assessment
- Qualitative scoring
- Semi-quantitative and quantitative scoring
- Photography
- Transect and quadrat surveys
- Measured survey

Visual assessment is the recording of key diagnostic features that assist in the clarification of management issues. These features are specific to the individual management issues (see individual management issue sections in Part C) for example for rabbit burrowing on a site the presence or absence of fresh soil scrapes, cobwebs over burrow entrances or presence of closely cropped grass sward around burrow entrances can help to define whether the burrow system is active or abandoned.

Qualitative scoring is outlined in the condition assessment section (section B1) and is a repeat of general monument assessment and specific management issue assessments. This can give a very rapid assessment of the trend in change, which in itself can be turned into a qualitative scoring such as this example below which combines condition and trend;

1 = Favourable and improving
2 = Favourable and stable
3 = Favourable but declining / Unfavourable but improving
4 = Unfavourable but stable
5 = Unfavourable and declining

Semi-quantitative or quan-titative scoring uses approximate measures to assess changes in pressure from a management issue. Two examples are presented below.

The approximate measurement of erosion scars can highlight any dramatic changes in the form of the erosion scar. This can simply be achieved by measuring the axes of the erosion scar at their longest points or by measuring from a fixed reference point or points.

Another example is the assessment of rabbit activity. A very rapid assessment but not reliable technique is the counting of rabbit identifying features (such as burrow entrances, runs, patches of droppings etc…) on a set length or area of the monument. This will give a rough guide to the level of activity. A more reliable method is to carry out night counts along a set length or area. This is purely a physical count of the number of rabbits observed an hour after dark using a lamping lamp (one million candle power). This second technique is particularly useful for assessing the impact of any rabbit control work.

Photography encompasses general, fixed-point, rectified and aerial photography. General photography is photography taken without any position referencing records or with only basic position referencing records (approximate position and general direction or compass bearing). This is a rapid method of monitoring the site and recording management issues. If the photographs from a previous site visit are taken on site then a fairly similar repeat photograph can be taken for the comparison of change.

Fixed-point photography (see monitoring case study) is photography that is taken from a known point and in a known direction. This technique permits the photograph to be repeated at a higher degree of accuracy than general photography. The fixed-point can be a survey peg, fence post, or landscape feature (e.g. boulder). A record of the fixed point including a photograph of it and grid reference should be made in order that re-identification is made easier. A handheld global positioning system (GPS) can be used to locate the position of the fixed-point, although some feature on the ground will still be required to repeat the photograph. A GPS is particularly useful in open, relatively featureless landscapes. Reference features should be noted in the frame of the photograph and if features such as trees on the horizon are used to locate the corners of the frame then the direction of the photograph will be more consistently accurate. A record of the direction of the photograph should be taken as a compass bearing.

Rectified photography is an expensive method to employ and will rarely be used in the monitoring of management issues on archaeological earthworks where other techniques can produce similar results. The advantage of rectified photography is that the information can be used to produce accurate two-dimensional measurements of features such as erosion scars.

Aerial photographs are particularly useful for the regular monitoring of area management issues including scrub or bracken cover of the monument, the extent of ground disturbance from livestock or farm vehicles or for natural erosion factors such as river or coastal erosion. Colour photography is best, particularly with bracken, which can be readily picked out from other vegetation in autumn and early winter by its rust-like colour.

Figure 6: Farm access track across the vallum of Hadrian's Wall in the winter (left) and in the summer (right).

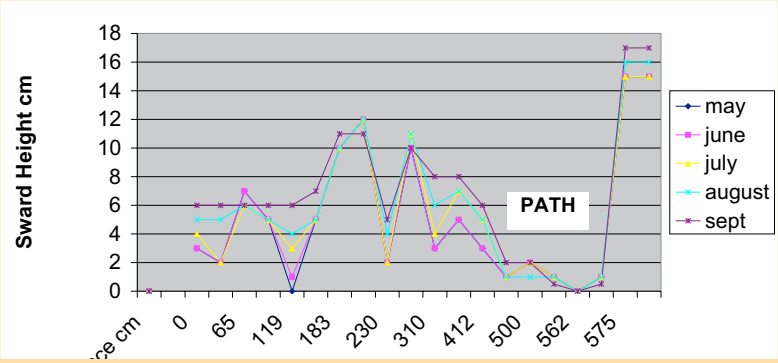
Critical to photography is to record the time of year the photograph was taken as the management issue can be significantly different in one season when compared to another. This is particularly the case with vehicle and livestock erosion, which are often very visible in winter months and not visible in summer months (figure 6).

Transect and quadrat surveys (figure 7) can be used to assess changes to ground cover over the monument. They are particularly useful in monitoring recreational pressures on the monument.

The use of a combination of transect, quadrat and photographic recording on sample lengths of the Hadrian's Wall Path National Trail enabled the monitoring of the impact of the Trail use on the archaeology. The transect and photographs on this page highlight this impact on a section of the Trail following the southern scarp of Hadrian's Wall ditch.

Trail route in June 2003

Soon after the opening of the Trail in May 2003 the favoured route (desire line) became apparent on this section as a trample line in the grass sward where the growth of the grass was suppressed (see photograph above) by the pressure of feet. This route then became self-reinforcing as the presence of a line encouraged most people to use this route and the lack of use around allowed the surrounding vegetation to increase in height thus further focusing the use of this narrow route. The transect data suggests that this route becomes narrow in late summer as the presence of thistles and other taller surrounding vegetation further narrows the route. The impact on the archaeology has been to alter the form of the slope as the use has formed a terrace by the action of erosion and compaction of the soil.



Low Teppermoor Sample Site 2 Transect Data

This information can guide future management. To alleviate this impact periodic mowing of a strip to widen the route and the placing of simple obstacles on the desire line to force a change in route could be implemented.

Trail route in September 2003

Figure 7 - Monitoring Hadrian's Wall Path National Trail

Transect surveys can be used to measure factors such as the trampled path width, worn path or bare width between two known points. These points can either be survey pegs or readily identifiable features such as a marker on a fence post. If the vertical position of the marker is stable then these can also be used to assess soil loss and entrenching of recreational routes.

Quadrat surveys can also be used to assess the impact of recreation on ground cover. Like the transect surveys an assessment can be made of the extent of vegetation loss and bare ground. However, their principal use is to assess changes in plant species caused by the use of the area as some species are more resistant to wear than others. In turn this method can also be used to quantify the effectiveness of any grassland management regime employed to alleviate the pressures of recreation.

Measured survey can be used to provide accurate records of management issues such as the extent and profile of erosion scars, extent of ground disturbance by livestock or the location and extent of burrowing animal burrows. These surveys can be repeated to provide an assessment of change.

B2.3 Putting it all together

Records from a single monitoring visit will rarely permit the surveyor to establish the change that is occurring on the site and therefore to establish what, if any, action is required, repeat visits will be necessary. The exception to this is where there is already a good site archive that illustrates the change that is occurring and the direction of that change. Repeat visiting will allow the surveyor to establish;

- what is changing and the trend in that change,
- why it is changing,
- what management action is required,
- and what future monitoring is required.

The monitoring information can be combined with other records such as people counts, meteorological data and information from the landowner or tenant to provide a better understanding of why and when an archaeological earthwork is vulnerable.

Case Study 1: Fixed-Point Photographs

Introduction

Fixed-point photographs are an essential part of monitoring. The record they provide can inform on the severity of a management issue and on the action, if any, that may be necessary to resolve the management issue.

Steel Rigg, situated 2½ miles west of Housesteads Roman Fort, is a popular stop-off point on Hadrian's Wall. It has a small car park that is used by both cars and coaches. Visitors often stop for only a short time, to walk the Hadrian's Wall Path National Trail for less than 200m to take one of the iconic views of Hadrian's Wall. In each of the months April, May and June 2003 the number of people counted passing along the footpath was consistently over 6000. This level of use has meant that at times of the year the grass growing on the thin soils has struggled to cope with the pressure, leaving the ground bare and susceptible to erosion, which is damaging to the setting of the monument and any archaeological deposits that survive buried in the soil. There is evidence around some of the geological outcrops that the soil level has dropped a few centimetres due to this pressure.

Figure 8: Iconic view of Hadrian's Wall from Steel Rigg.

In 2001 and the first part of 2002, the Foot and Mouth Outbreak meant that the site had a chance to recover and partially grass over. After this the site was once again open to the public, although it was not until the summer that visitors started to return in significant numbers. A monitoring regime of fixed-point photographs was set up to assess the impact of access on the ground cover. Photographs were taken prior to Easter 2002, then repeated at the end of the school summer holidays and at similar times the following year.

How to take Fixed Point Photographs

The following steps are a basic procedure for taking fixed-point photographs;

1. Walk over the site to assess where fixed-point photographs may be most usefully taken from. Make a note of the locations and any features that could be used to locate the fixed-point.

2. Stand in the chosen position and look through the viewfinder or if a digital camera the monitor on the back. Look for objects in the view that will help when repeating the picture (e.g. trees or buildings on the skyline, gates, rocks or archaeological features in the foreground).

3. Once satisfied, make a note of where you are standing (e.g. back is against third fencepost from corner, 10 paces along wall from gateway), the main reference features in the photograph and the compass bearing that it has been taken on. A handheld global positioning system (GPS) can be used to provide location information of the photograph. A GPS is particularly useful in open, relatively featureless landscapes. Now take the photograph.

4. Take a photograph of the position that you have taken the picture from for ease of re-identification.

5. If using a 35mm compact camera or single lens reflex (SLR) camera then make a note of the type of lens used (e.g. 50mm lens). This is always written on front of the lens. Most digital cameras record this with the image so there is no need to make a separate note.

Figure 9: Photographs from one of the ten fixed-points at Steel Rigg.
April 2002 (upper left), April 2003 (bottom left), July 2002 (upper right) and June 2003 (lower right).

Results at Steel Rigg

Two seasons of photographs have now been collected and the results suggest the level of wear is relatively stable (figure 9) and that no immediate action is required. However, the recent opening of the National Trail along Hadrian's Wall has raised its media profile and the number of visitors has probably increased, which may be sufficient to start the deterioration of the site. Therefore, monitoring should be continued at the site over the next few years to build up a long-term record of change.

Part C: Management Issues

Part C: Management Issues

C1 Management Issues

C1.1 Introduction

The following section deals with a range of management issues that are often encountered on archaeological earthworks in grassland management. They are dealt with separately, but it is recognised that sites often have multiple management issues that either act independently of each other or are inter-related. Therefore, the final management strategy for the earthwork may involve a tiered programme based on the impact that the management issue is having on its significance or based on the practicalities of carrying out the work. For example, an earthwork that is covered by dense scrub growth and subject to extensive rabbit burrowing will probably have to be subject to a programme of scrub clearance to permit access to the rabbit burrows for control even though the burrowing may be considered the more damaging influence.

As stated earlier (see section A2) an archaeological earthwork does not just have significance for the archaeological record it preserves or its archaeological interpretation. It may also possess significance for its landscape character value and nature conservation value. Management that focuses purely on the archaeological value may adversely affect the significance of the earthwork. Effective management comes from understanding the values of the earthworks and ensuring any action tries to balance the effects of any management action so that negative effects are minimised and positive effects are maximised. Throughout the following sections I have tried to highlight some of the impacts that managing for archaeological preservation may have on other values, in particular those for nature conservation.

Many of the management solutions involve some ground disturbance that may have an influence on buried archaeological remains, monument form or setting. The potential impact of this should be assessed on each specific site and the proposed management action either modified to account for potential impacts or if it goes ahead it must be deemed more beneficial as a whole to the monument than what may be lost. Appropriate archaeological action should be taken to ensure that wherever possible deposits are preserved in situ, or if this is not possible then they are preserved by record. On Scheduled Ancient Monuments it will be necessary to obtain scheduled monument consent from the Department for Culture, Media and Sport and discuss the works with English Heritage. On other archaeological sites the local authority archaeologist should be consulted.

C2.1 Recreational Management

1.1 Introduction

Recreational use of our rural landscape has increased in the last fifty years, particularly in the remoter areas of the United Kingdom. Much of this increase has been the direct result of our increased mobility, particularly through private car ownership. Many of these areas that are characterised by a greater proportion of permanent grassland and good archaeological earthwork survival.

Of equal importance is the seasonality of recreational use of the landscape. Improvements in outdoor clothing and footwear mean that there is more use in inclement weather when ground conditions make archaeological earthworks more vulnerable to erosion damage.

This section of the guide covers the monitoring and management actions that can be instigated to alleviate the negative influences of recreational use on archaeological earthworks.

1.2 The Issues

Recreational use of the landscape and its arch-aeological earthworks can lead to damage through erosion caused by the passage of pedestrian, horse or bicycle traffic. The wear is often limited to specific routes, known as desire lines where access is not restricted (figure 10) or to particular focal points (figure 11) that attract visitors and pinch points where there is a constriction in flow (e.g. a gateway). Most recreational use will only cause wear to the surface of the ground and therefore not cause significant damage to the archaeological integrity of the monument, although the setting of the monument may be damaged. However, on slopes or in areas of unmanaged long-lived wear, entrenching of the routes can occur and will damage the archaeological integrity of the monument through the direct erosion of archaeological deposits and changes to the profiles and setting of the earthworks. In addition the areas of bare ground created by recreational use can become prone to other management problems such as livestock erosion, colonisation by weeds and scrub or burrowing animals (although regular use will dissuade the latter).

Figure 10: Entrenched footpath desire line through Milecastle 38 on Hadrian's Wall.

1.3 Assessment and Monitoring

An initial rapid assessment using a simple scoring system (table D) should be carried out to assess the level of pressure from recreational activity. The initial assessment should preferably be carried out when the monument is likely to be under most pressure from recreational activity. This will tend to be in Spring or Autumn when wetter ground conditions combine with still significant numbers of users to create the disturbance signs of pressure. A visit at this time should present the worst case scenario for recreational pressure.

Where the initial assessment has identified that the earthwork is under or likely to come under pressure from recreational activity it may be necessary to carry out further assessment and monitoring works.

Figure 11: Interpretation panels in the open landscape can form a focal point for recreation. The combined action of recreation and livestock, the latter using the panel to rub against, causes the erosion of the surrounding ground.

Further assessment should evaluate the nature of pressure and make recommendations for monitoring and management. It should make use of previous surveys where available. The assessment should include:

- Background information on the site – climate, type of soils, type of grasses, nature of archaeological earthwork.
- Previous recreational surveys (where available).
- Identification of the principal areas of recreational pressure – desire lines, pinch points, nature of usage (pedestrian, horse, bicycles etc...)
- Recommendations for management – e.g. opportunities for relief or alternative access routes.
- Recommendations for monitoring – e.g. location of fixed photography points, people counters.

Monitoring will assist in the selection of appropriate management actions. This will be done by enabling a perspective to be developed as to when and where the recreational impact compromises the values of the archaeological earthwork. Possible monitoring techniques include:

- Regular qualitative or semi-quantitative condition scoring of recreational routes
- Quadrat or transect ground cover assessments
- Fixed point photography
- People counters
- Recreational surveys

Recreational condition scoring is a method that has been employed in the monitoring of National Trails. The National Trails Condition Survey Handbook employs both qualitative and semi-quantitative methods to assess path condition. A qualitative scoring is recommended for man-made paths as shown in Table D. Semi-quantitative methods (Table E) use a combination of path width or pattern and extent of worn bare areas to assess path condition.

Quadrat and transect surveys can provide quantitative data on the path condition and also the influence of use on the ground cover. Transects highlight the changing condition of the path between two known points. The assessment can be subdivided into the measured path width (trampled vegetation), measured width where there is >33 % vegetation loss, measured width where there is >66 % vegetation loss and measured width where there is bare ground and soil loss. Quadrats can be used to provide area measurement of ground conditions affected by recreation. As with transects the level of vegetation cover can be used to assess the condition. In addition a botanical survey of the quadrat can elucidate the influences of recreation on the ground cover vegetation.

Table D: Indicators of Stress from Recreation

Level	Score	Description	Photographic Example
None	0	No evidence of recreational pressure	
Low	1	Evidence of a small amount of recreational pressure in the vicinity of the monument and/or on non-sensitive parts of the monument. Characterised by pinch point erosion at site entrances or desire lines. Also evidence of incipient wear on sensitive pars of the monument characterised by yellowing or trampled grass.	
Medium	2	Recreational pressure visible on sensitive parts of the monument. Characterised by incised paths on archaeological features.	© Hadrian's Wall Coordination Unit
High	3	Significant recreational pressures on the monument resulting in extensive areas of wear and/or damage to key archaeological features. Extensive areas of wear are characterised by large bare areas, a number of incised paths or a wide incised path.	

Table E: Surface Class (from the National Trails Condition Survey Handbook, n.d.)

0 Manmade

1 No sign of path

2 Localised erosion <20m linear

3 Overall Path Width <2m

3/0 no or miminal vegetation loss (upto 5%)

3/1 up to 33% vegetation loss

3/2 33% to 66% vegetation loss

3/3 over 66% vegetation loss
(or any continuous bare strip within overall width, with <5cm soil loss)

3/4 soil loss 5-10cm depth on bare width

3/5 soil loss over 10cm depth on bare width

4 Overall Path Width between 2m and 5m

4/0 no or miminal vegetation loss (upto 5%)

4/1 up to 33% vegetation loss

4/2 33% to 66% vegetation loss

4/3 over 66% vegetation loss
(or any continuous bare strip within overall width, with <5cm soil loss)

4/4 soil loss 5-10cm depth on bare width

4/5 soil loss over 10cm depth on bare width

5 Overall Path Width >5m

5/0 no or miminal vegetation loss (upto 5%)

5/1 up to 33% vegetation loss

5/2 33% to 66% vegetation loss

5/3 over 66% vegetation loss
(or any continuous bare strip within overall width, with <5cm soil loss)

5/4 soil loss 5-10cm depth on bare width

5/5 soil loss over 10cm depth on bare width

6 Braided Paths >5m

6/0 Part worn width – mainly worn trods

6/1 Full worn width – mainly worn trods

6/2 Part worn width – mainly bare trods

6/3 Full worn width – mainly bare trods

Photography is an important method of monitoring recreational pressure. General or fixed-point photography can provide visual point-in-time assessments of the extent and degree of disturbance through recreational pressure and if repeated can give a good indication of change. Monitoring points should be set up for known areas that suffer pressure or those predicted to suffer (e.g. slopes, pinch points)

A wide range of people counting systems are available for assessing levels of use on recreational routes. The range has been developed for particular situations, traffic type and path structures (figure 12). Combined with other monitoring information these can give a good indication of the carrying capacity of a site before damage occurs through usage.

Recreational surveys (also known as visitor surveys) are targeted questionnaires designed to provide information on the use of recreational routes or areas. These have been particularly well used at “honey-pot” sites where it is often observed that the majority of use is limited to very short distances from a car park and therefore the areas nearest the car park tend to suffer greater deleterious effects from recreation.

The above information can be combined with meteorological information to achieve a coherent view of when damage is likely to occur.

Figure 12: People Counting Systems.

1.4 Methods of Repair

Methods of repair for monuments disturbed by recreational usage range from simple resting and reseeding techniques to the establishment of hard surface paths. The type of method used will depend on the particular circumstances of a site.

Resting involves the temporary removal of recreational use from an area. It can be achieved by erecting temporary fencing (figure 13), guide ropes or brashing to discourage use of a route. This technique is applicable where there is an alternative route that can be used while the temporary closure is in affect. It is likely that the resting of the route will need to be implemented at regular intervals.

A resting programme can be carried out in conjunction with a programme to decompact and aerate the surface of the soil of the area affected to encourage the regeneration of a grass sward. Re-seeding of the surface may be necessary if grass cover has been completely removed. Any resting

programme should be carried out in conjunction with information explaining why the normal route has been altered.

If small areas of entrenched and eroded routes have developed then these can be infilled either by adding soil and then re-seeding or re-turfing.

Larger areas of erosion may need to be revetted with sandbags, boarding or geotextile fabric to hold soil in place whilst ground vegetation cover re-establishes. This may be particularly relevant on sloped areas to minimise soil wash. The surface of any scars can be covered with a erosion control fabric.

Figure 13: Wooden barrier used to discourage use and allow worn area to recover.

Figure 14: Pitched paths have alleviated many of the recreational erosion problems on Hadrian's Wall.

If the resting of the surface is not practical and restoration using soil and re-seeding is deemed unlikely to be effective then a sacrificial layer may be used to prevent further ingress into the monument caused by recreational pressure. A sacrificial layer is one that will continue to be removed by the pressure or decay, but regular replenishment will mean that no significant erosion will occur on the site. The type of material used will depend on the site specifics, but options include wood or bark chippings, soil, turf or aggregate in keeping with the setting of the monument.

Where the above methods are not practical then the options are limited to the provision of permanently improved routes through the using of traditional or artificial materials.

Methods for the establishment of improved recreation routes using traditional materials involve the creation of aggregate paths, stone flag paths, or pitched paths. In all cases the materials used in the construction should be sympathetic and in keeping with the monument and its setting. Aggregate paths can be mixed with soil and grass seed to reduce the time for the path to blend in to the landscape.

Pitched paths (figure 14) deserve special mention as these have been used effectively within the central section of Hadrian's Wall to solve some long-term erosion problems.

Previous recreational routes on slopes in this area had followed the line of Hadrian's Wall and erosion had exposed it's foundations. The installation of worn natural stones angled (pitched) into the slope to form a path up the slopes away from the sensitive archaeology have significantly improved the preservation and setting of the monument. As with all hard surface paths they should only be used where a grass sward is unsustainable and all other management options have been tried or are inappropriate. The stone used in the path should be in keeping with the setting of the monument.

A range of artificial materials is available for creating improved routes. These include pavers, root-zone mesh reinforcement and geotextiles. Pavers (figure 15) have a cellular structure that protects the growing point of grasses and therefore allows a good grass sward to develop through the cells blending the paver with its environment. With use the cell of the paver will eventually fill up and need re-setting or cleaning out. There is a wide range of cell sizes, shapes and materials and it is important to consider the application and maintenance in the selection. The smaller cell sizes (1cm width) should be avoided as they more readily fill up and therefore will require regular maintenance. Slopes present another problem for this material because the smoothness of the surface means that they can become slippery. Some recent examples have overcome this problem as they have been made with a roughened surface.

Figure 15: Cellular plastic paver used at Housesteads Roman Fort (Before, on installation and after).

Root-zone mesh reinforcement is designed to relieve compaction of the soil and therefore aid the healthy growth of a grass sward. They often come pre-blended into a sandy root-zone mixture designed to be free draining. The success of these materials is reliant of the development of a healthy grass sward to prevent soil loss. If use of the area is high then the grass sward will be removed and the sandy soil will be easily eroded. This leaves the material exposed at the surface.

Geotextiles used near the surface are designed to spread the load of people passing and therefore reduce compaction of the soil. This in turn assists in the maintenance of a healthy grass sward that is able to withstand higher levels of use than without the textile. It is important to properly install these materials by ensuring they are sufficiently supported by good sub-bases that are also free-draining. One disadvantage of these materials is that standard grassland management techniques of aeration and scarification cannot be used with them.

1.5 Methods of Management

Methods of management for recreational use fall into two categories:

- Increasing sustainability
- Altering or influencing routes

Increasing sustainability involves the alteration of ground conditions and/or the grass sward to increase its ability to withstand the stress created by recreational use. This can involve changing the species composition of the grass sward, adding fertiliser to improve sward vigour, and increasing drainage to alleviate waterlogging or artificial watering to compensate for drought affects. Some of these methods may be subject to archaeological or nature conservation constraints and it may be necessary to obtain consents before implementing.

The sward species composition can be altered by seeding or by replacement with turf of higher wear resistant species, such as perennial rye grass (Lolium perenne) and the reduction in the sward of wear susceptible grasses and broad-leaved species. The influence of introduced species on the ecological value of the site must be considered. In some instances such as a SSSI designation for conservation of grass species it may be inappropriate to use introduced species. The appropriate party should be contacted (English Nature when the site is a SSSI) and they will be able to advise on the suitability of grass species.

Figure 16: A moveable interpretation panel at Housesteads Roman Fort which has been used effectively to reduce erosion on the site.

Other management actions that have a benefit to the sustainability of the grass sward include:

- the scarification of the surface to remove excessive thatch (dead plant material and mosses). It is important to maintain a thin layer of thatch as this can help reduce soil compaction and will protect the growth points of the grass.
- pest control and the removal of molehills before they spread out smothering surrounding grass and providing a seed-bed for competing weed species.
- weed-killing to remove broad-leaved weeds, which have a low wear tolerance.
- light harrowing to spread worm-casts and molehills reducing soil contamination of surrounding grasses (this reduces the grasses vigour through loss of photosynthesis) and to provide a better seed-bed for grass seeding.
- regular cutting or close grazing to encourage a low, dense sward.
- Surface or shallow depth aeration of the soil using solid, hollow or chisel type tines. This relieves compaction and increases air content of the soil.

Altering or influencing routes involves direct or indirect methods of changing access routes. Direct methods involve the physical alteration of the route normally by the erection of barriers such as guide ropes and timber barriers. Also routes can be mown to create a defined route or permanent paths can be used to steer users in a specific direction away from sensitive locations. An alternative

or reliever route can be used whilst the normal route is being rested or repaired. Indirect methods involve the influencing of access route direction by the use of focal features, such as fingerposts, stile and gate positions and information/ interpretation panels (figure 16). Moveable interpretation panels can be particularly useful as these can be regularly moved to change the alignment of the desire line.

The above methods are all on-site methods of managing recreation. It is also possible to influence the use of routes by the promotion of alternative routes when conditions are likely to lead to a deleterious effect on the monument. This can be done by marketing strategies, such as promoting other sites to visit or by educating the visitor in the impact they can have. It can also be influenced by controlling ease of access through the availability of transport to the site. Good bus provision can influence usage of a monument. On Hadrian's Wall visitors have been encouraged to do single direction walks, whereas in the past use of a car has encouraged visitors to use the same route on their return thus doubling wear on the ground. Seasonal closure of car parks to discourage access at vulnerable times of the year is also an option.

References and Further Reading

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Case Study 2: Creating a Relief Route: Hotbank Milecastle

Summary

A resting programme for a well-used section of the Hadrian's Wall Path National Trail through the use of an alternative route. The rest period will allow the repair and recovery of the grass sward through Milecastle 38 (Hotbank).

Figure 17: The soil around the stone of the east wall of the milecastle has been eroded making the stones vulnerable to displacement.

Introduction

Hotbank Milecastle is Milecastle 38 of the Hadrian's Wall system. It lies on a popular (40,000 people per annum were recorded in the late 1990s) section of footpath that has recently become part of the Hadrian's Wall Path National Trail. Despite the official route of the Hadrian's Wall Path National Trail going around the milecastle the used route follows Hadrian's Wall and cuts over the earthwork remains of the milecastle. The result has been the destruction of the grass sward over the milecastle, the gradual erosion of the soil and the displacement of the milecastle's fabric (figure 17). This erosion is most prominent in the west wall of the milecastle, which has become an entrenched route (figure 18) and serves to re-inforce the effects of erosion by concentrating walkers in a narrow corridor.

A number of solutions were put forward. Indeed the creation of the National Trail instigated one of the solutions, which was to divert the public right of way around the milecastle. However this diversion has never been implemented on the ground for a number of reasons.

- The wet ground conditions would have required some surfacing, either an aggregate path or stone flags. Both of these would have been intrusive to the setting of the monument.
- The presence of a fence directly adjacent to the earthwork meant that the diverted route was likely to cause new erosion on the monument.
- Also diverting people onto the diversion was a problem and it was felt that this would require some form of permanent barrier that would also be intrusive to the setting of the monument.

Figure 18: The route through the west wall of the milecastle has become entrenched.

The alternative route was initially created as a legal diversion to give adequate time for repairs to establish. In future years the

Figure 19: The alternative route along the military way. The milecastle is immediately in front of the farm house in the left of the picture.

route will be a voluntary diversion, which will mean no application for an official diversion will be required. Temporary barriers will be erected that will guide walkers onto the alternative route, but will not obstruct those who want to visit the milecastle

A further solution was made possible with the co-operation of the landowner, in this case The National Trust and the tenant farmer. An alternative route was proposed that diverted the National Trail onto the Roman Military Way for a 300m section around the milecastle. This proposal was implemented and is outlined below.

Alternative Route

At Milecastle 38 the Roman Military Way runs very close to the line of Hadrian's Wall. The Military Way is used as a public footpath in other nearby areas and due to its dry and firm ground conditions appears to provide a sustainable walking surface. It was felt that this would provide an alternative route that could be used periodically to allow the route through the milecastle to rest and be repaired, whilst also providing public access to a well-preserved section of the Military Way that had previously not been accessible.

In its first year, the alternative route was to be used from September 2003 until August 2004 to allow the repairs to the monument to establish. In future years the route will be used between May and August as required to allow the route through the milecastle to rest and if necessary be aerated, re-seeded, and top-dressed. This period of use fitted in well with land management practice as it coincided with the absence of livestock from the alternative route as the land is managed as a hay meadow under the Countryside Stewardship Scheme.

The alternative route was initially created as a legal diversion. In future years the route will be a voluntary diversion, which will mean that no application for an official diversion will be required. Temporary barriers will guide walkers onto the alternative route, but will not obstruct those who want to visit the milecastle.

Figure 20: Repaired section through east wall of milecastle.

Repairs

Whilst the alternative route was in operation repairs were conducted on the monument. Mostly these consisted of the surface aeration of compacted ground, the filling of any desire lines with a soil/sand mix and grass seeding to re-establish a grass cover. On areas such as the east wall (figure 20) of the milecastle it was necessary to dress the bank over the wall with a greater amount of soil so that the stones were sufficiently reinforced to prevent their displacement. In addition by repairing this there was no obvious low point over the east wall and therefore no focus for future wear.

The entrenched route through the west wall was also re-profiled. Here, because a large amount of material was to be added, the present level of the path was defined using a geotextile membrane along its base before filling with soil to act as an interface between the *in situ* archaeological deposits and the fill material. The membrane was laid flat at the base of the repair and not laid up the sides or near the edges of the repair as this would have been prone to re-exposure if renewed erosion occurred. As with the east wall, reprofiling means that there is no obvious walked route and therefore it is hoped that wear will be spread.

Grassland Management Trials

In addition to the repairs, nine trial plots were established to assess the effectiveness of two simple grassland management regimes. The results of this trial will aid future management of this section of the National Trail by informing on the appropriate level of grassland management required to sustain grass cover. The nine trial plots were surface aerated and then given one of three treatments therefore giving three replicates of each treatment. The treatments were as follows;

- A control,
- an application of a top-dressing mix at a rate of 1kg/m^3 and overseeding at a rate of 10g/m^2 with DLF Perryfields PRO27 (Ecosward) grass seed,
- and an application of a top-dressing mix at a rate of 2kg/m^3 and overseeding at a rate of 10g/m^2 with DLF Perryfields PRO27 (Ecosward) grass seed.

The seed mixture used contained 10% small leaf clover, which fixes nitrogen and therefore should eliminate the need for fertilisers.

Conclusions

The opportunity to create an alternative route around the milecastle has allowed the aim of maintaining of the National Trail as a green sward to be achieved. In addition it has eliminated the need to install structures and surfacing that would have been detrimental to the setting of the monument, and prevented further damage to the monument.

The effectiveness of the use of this technique should be assessed after a number of years so that, if successful, it can be encouraged in other situations along Hadrian's Wall and elsewhere on archaeological earthworks.

Case Study 3: Restoring a Grassland Setting at Stonehenge

Summary

A programme of intensive grassland management at Stonehenge has maintained a grassland setting to the monument despite being probably the most visited field monument in the United Kingdom.

Introduction

Stonehenge is arguably the most well known ancient monument in the UK, possibly in the world and has long been the subject of 'tourist' visits. Gilbert White visiting in 1768 described it as 'that amazing work of antiquity' and early photographic records from c.1870 show top hatted visitors admiring the stones. However, in more recent times the visitor numbers have risen quite dramatically and by 1999 the annual figure had reached 870,000 visitors. This number of visitors on what is a remarkably small monument - the centre circle is only 30 metres in diameter and the surrounding ditch and bank only about 120 metres in diameter - cause enormous turfwear problems.

Figure 21: Aerial view of Stonehenge in 1986 showing the tarmac path and worn turf.
© English Heritage Photographic Library.

After access to the centre circle was stopped in 1978 all visitors were directed around the monument, initially on a tarmac path which leads from the tunnel exit and cuts across part of the site (figure 21). At the end of this path they were directed around the outside of the encircling ditch and bank, on the grass, to the fence by the heel stone and then, because the sensitive archaeology of the Avenue runs next to the heel stone, back again! This doubled the wear on an area of turf of only about 4,000 sq.m. Access over this area was unrestricted and by 1986 the area was markedly eroded (figure 22). Two years later the situation had become so bad that there were increasing calls for the tarmac path to be extended.

Figure 22: The worn path in 1988.
© A. Wimble.

For both archaeological and aesthetic reasons these calls were resisted and a decision was taken to re-turf the damaged area using more wear tolerant grass species, implement a programme of high intensity sportsfield maintenance and to

Figure 23: The "sportsfield" walkways in 1995. © A. Cathersides.

strictly manage the flow of visitors over the area. The success of this management regime was immediate and has remained successful to the present day. Figure 23 shows the area in 1995, five years after the introduction of the new maintenance regime.

The Grassland Management Regime

The sportsfield grassland management regime was introduced in 1990. The scheme had three key elements that meant it has been successful at preventing erosion at Stonehenge. These are;

1. **The use of wear tolerant grass species.** The whole area regularly used by visitors was re-turfed using 100% ryegrass. The area is regularly overseeded with ryegrass to maintain this homogeneous cover.
2. **Continuous maintenance.** The area is subject to a sportsfield style maintenance regime consisting of;

- regular cutting: to encourage a low, dense sward
- aeration: this is carried out regularly using a solid tine spiker to relieve compaction and improve aeration and drainage
- regular fertilising: carried out in spring and summer with high nitrogen fertilisers to encourage strong leaf growth and in autumn with low nitrogen, high phosphorus and potassium fertilisers to encourage root growth and slower, hardier leaf growth for the winter.
- light harrowing: carried out when necessary to disperse any worm casts or similar and prevent mud being smeared over the leaf surface.
- autumn restoration: this consists of scarifying to remove any thatch, followed by spiking, overseeding and topdressing, carried out over the whole area
- pest control: when necessary and especially removal of any molehills before these become spread out, covering grass and providing seed beds for weeds
- weedkilling: to remove broad-leaved weeds (which have very low wear tolerance) is carried out whenever necessary. It is interesting to note that all the preceding measures have served to maintain a very dense, healthy grass sward which has prevented weed establishment – no weedkilling has been necessary for the last 6 years.
- watering: the very thin soil at Stonehenge and the open, exposed nature of the site make it very susceptible to drying out – grass recovering from a period of wear is watered during dry spells – something of a problem on a site with very low water pressure. Because of the low water pressure at Stonehenge ordinary sprinklers are ineffective and soaker hoses are employed
- early repair: any wear is repaired as quickly as possible to prevent it spreading and becoming further eroded

3. **Management of visitor flow.** Individual walkways are marked out using unobtrusive low-level ropes and visitors are encouraged to keep within the designated walkway. There is room for approximately 10 individual walkways on the maintained area and these are alternated regularly, at the first sign of wear. This may be daily during peak periods or every 2-3 days off-peak.

Taken individually, all these measures will help to reduce wear on turf and delay the onset of erosion to some degree. The success at Stonehenge, with such high visitor numbers, is due to the combination of all three – on this site any measure taken in isolation would not suffice to control the wear.

Conclusions

The very nature of Stonehenge and the sheer numbers of visitors it attracts cause problems, but also help with some of the solutions. Staff are required on site to prevent misuse of or damage to this important monument and because such large numbers of people require a support infrastructure – having these site based staff allows us to ensure walkways are used properly and rotated regularly. Large numbers of visitors undoubtedly cause wear and tear on the turf, but their entrance fees help to ensure that funds are more readily available to carry out the intensive maintenance necessary to reduce this problem. However, every site, like every erosion problem, is different and the regime described above may not be physically or financially possible on other sites, or even desirable in some cases! So what general principles can be suggested for dealing with turf wear? The following are suggested:

- Always remember the basic requirements for good grass growth – good soil structure, undamaged roots/leaf blades and leaf blades not covered by mud.
- In areas of high wear, spread the wear wherever possible, giving some areas respite before wear becomes serious, carrying out repairs if necessary
- Where possible introduce more wear tolerant species of grass, such as ryegrass and reduce levels of wear susceptible grass and broad-leaved species. (The ecological value of the site in question must be considered here – in a SSSI, the introduction of sportsgrass cultivars might be unacceptable)
- Carry out as much 'sportsfield' maintenance as possible on susceptible areas
- Where funds are limited chose the most beneficial maintenance that can be afforded – as a guide spiking which relives compaction and improves aeration and drainage is by far the most beneficial operation.

Alan Cathersides, Senior Landscape Manager, English Heritage

C2.2 Livestock Management

2.1 Introduction

Grassland management for livestock pasture or mowing has ensured that many monuments have survived into the present day in a good state of preservation. This is particularly true in upland areas of the United Kingdom where land-use as permanent, unimproved pasture has ensured that archaeological earthworks survive as upstanding features in good condition and buried remains survive relatively undisturbed. Indeed, managing monuments for grazing is often seen as the ideal management for ensuring long-term preservation of the monument as it maintains the visibility of the monument and deters scrub growth. However, it is important to recognise that whilst grazing can be a highly beneficial form of management for archaeological conservation, it can also have a detrimental effect on the survival of the archaeological earthworks and their settings. Often this is due to local factors such as stocking levels, season of stocking, type of livestock, and presence of livestock focal points.

The goal of livestock management on archaeological monuments is to achieve the right balance of grazing for its long-term preservation. In its simplest definition, this lies between an over-grazed landscape with its characteristic areas of eroded bare earth and an under-grazed landscape that allows the regeneration of scrub. In reality, it is a far more complex subject that doesn't just relate to the level of grazing, but also the foci of livestock movement and the selectivity of grazing by the animals.

2.2 The Issues

As already mentioned, livestock grazed grassland management is highly beneficial to the long-term preservation of the archaeological resource. Despite this, livestock grazing can be a damaging activity. Damage can occur in two ways:

1. The use of an area by livestock above that which is sustainable for the soil and vegetation. This leads to areas being poached and/or eroded.
2. The under-use of areas for grazing or the use of grazing animals that are highly selective in what they graze. These areas can permit the establishment of root-penetrating vegetation such as scrub species and bracken.

Figure 24: Ground disturbance caused by livestock sheltering next to small plantation on Milecastle 34, Hadrian's Wall. The lower branches are used by livestock to rub against.

2.2.1 Poaching and Erosion

Poaching and erosion will occur where the use of the site is above sustainable levels for the type of vegetation and / or soil. Damage can occur through over-grazing in general over the site, resulting in the deterioration of the grass sward, exposure of the soil surface and leading to enhanced erosion. This tends to occur in the winter months when soils are more likely to be waterlogged and therefore more susceptible to poaching. However, it is more common to find specific areas affected by poaching or erosion, often associated with focal points such as;

- sheltered areas in the lee of trees, walls, ditches or slopes,
- feeding stations,
- movement pinch points,
- rubbing posts,
- water sources,
- exacerbation of bare areas created by burrowing activity or land slippage,

Figure 25: Ground disturbance caused by farm vehicles andby sheep feeding on the south mound of the vallum, Hadrian's Wall. © P. Austen

Sheltered areas in the lee of trees, field walls (figure 24) or slopes provide livestock with a protected environment from adverse weather conditions. The concentration of livestock in these areas leads to poaching of the ground surface which if on or close to the monument can cause damage.

Feeding stations (figure 25) are a particular problem on archaeological earthworks. These feeding stations are normally sited on the driest areas of the field, often the upstanding earthworks of a monument. If this is a regular location for the feeding station livestock will congregate prior to the feed being delivered in addition to feeding time and this can lead to significant poaching and erosion around this location. In addition the routes to a regular feeding station can also become significantly disturbed.

Pinch points lead to a concentration of moving stock and subsequent poaching and erosion. These pinch points tend to be associated with access routes, in particular farm gateways and with the presence of scrub.

Livestock will often use rubbing posts to scratch against. These can vary in nature from boulders (figure 26), low tree branches, the trunks of trees or scrub, fence posts or fence wire. Equally, the rubbing post can be part of an archaeological monument such as a standing stone or it can be an interpretation panel. Livestock tend to create poached or eroded ground around the feature.

Figure 26: Livestock poaching associated with an area of water in the ditch of the vallum, Hadrian's Wall. The boulder on the left shows the erosion associated with its use by livestock to rub against.

As with feeding stations, water sources, be they artificial (e.g. water trough) or natural (e.g. stream or pond), form a point of congregation for livestock. They are normally permanent in their location and therefore the poaching and erosion around them is cumulative. In addition the livestock will distribute the water over the surrounding area, which tends to make the soils around the source more vulnerable to damage from livestock activity.

Bare soil areas caused by land slippage or burrowing animal activity can form a congregation point for livestock. Livestock will lick bare areas for the minerals they contain, they will dust their bodies in them and will scrape them with their hooves. These actions therefore exacerbate the erosion caused by the original agent.

The above mentioned focal points should be the target of any management action and by their removal, re-siting of the focus or the permanent or temporary exclusion of livestock the right balance between grazing and conservation should be achievable.

2.2.2 Development of Damaging Vegetation

The establishment of vegetation that is damaging (development of trees, scrub and bracken) to the long-term preservation of the archaeological resource will occur if an inadequate grazing regime or alternative is employed in its management. Damaging vegetation includes species that will have a significant impact on the survival of buried archaeological remains through the disruptive activity of root development (see section C.2.5). The development of damaging vegetation occurs in three principle ways;

1. Insufficient intensity of grazing.
2. Insufficient variation in grazing animal to prevent areas becoming rank permitting the establishment of injurious vegetation.
3. Inappropriate timing of grazing when livestock do not graze injurious vegetation.

Insufficient grazing can occur through low stocking densities at the field or area level. At the field level this is normally due to an absence or lack of livestock. This is most common in areas where arable cultivation is the dominant land use and archaeological earthworks survive as islands of pasture. It can also occur where the archaeological earthwork is wholly or partly inaccessible to grazing, such as steep bank sides.

All animals, both wild and domesticated have different grazing pattern. Some animals favour certain types of vegetation that are eaten first while less desirable plants are left until last, or not grazed at all. The correct type and combination of grazing animal and the right timing and intensity of grazing are essential to overcome selective grazing. Sheep have narrow mouths, which enables them to be more selective in what they eat than species such as cattle, which are considered non-selective due to their broad mouths. Sheep produce a closely cropped grass sward, whereas cattle will graze the grass to a few centimetres in length. Therefore it is beneficial to have a mixed livestock practice as this helps achieve the best control of damaging vegetation. Cattle have the added benefit in that they trample bracken.
Timing of grazing can influence the development of injurious vegetation. Grazing animals will control scrub growth in spring or early summer, as the new growth is more palatable than later, when it becomes woody.

More information on the grazing attributes of different types of livestock can be found in The Breeds Profiles Handbook: a guide to the selection of livestock breeds for grazing wildlife sites (Tolhurst and Oates, 2003), which presents the results of the Grazing Animals Project. This can be viewed on the Forum for the Application of Conservation Techniques (FACT) Internet site (www.fact-group.org).

Table F: Indicators of Stress from Livestock

Level	Score	Description	Photographic Example
None	0	No evidence of livestock pressure	
Low	1	Evidence of a small amount of livestock pressure in the vicinity of the monument and/or on the monument in non-sensitive areas. The surface of the monument may have a pock-marked character from the action of the hooves of livestock, but will not have more extensive poaching of the ground or erosion.	
Medium	2	Evidence of livestock pressure on sensitive areas of the site. These will be visible as erosion scars on slopes or areas of minor poaching.	
High	3	Extensive lifestock pressure on the monument characterised by a large number of erosion scars or extensive areas of poached ground.	

2.3 Assessment and Monitoring

An initial rapid assessment using a simple scoring system (such as shown in Table F) should be carried out to assess the level of pressure from livestock activity. The initial assessment should preferably be carried out when the monument is likely to be under most pressure. This will tend to be in the winter season when deteriorating ground conditions make the surface of the monument more prone to disturbance from livestock activity.

Where the monument is identified as being under pressure from livestock activity further assessment should be used to highlight the causes of this pressure. The assessor should highlight any focal points for stock gathering and any worn routes to the focal point. They should consult with the landowner or tenant, as they will be able to provide local knowledge on why certain routes and certain locations are used by stock. They will also be able to explain what stocking regime is employed on the land unit and past land management.

Past land use is an important consideration in prioritising any conservation works, as an unimproved pasture is more likely to have significant archaeological deposits at shallower depths than improved pasture which may have been cultivated to 10-25cm depth.

Methods of monitoring livestock disturbance to a monument include:

- Fixed-point and general photography.
- Mapping and measurement of area of disturbed ground.
- Evidence from vegetation.

Photography provides a good point-in-time documentation of the extent and severity of any livestock disturbance to the monument. Fixed-point photography can be used to provide simple and effective visual assessments of whether the disturbance is developing or stationary. It is best to repeat photography in the same season of following years to assess changes in extent. Photography at other times of the year can help highlight how the extent changes in the year. This is particularly useful where the disturbance is caused by stock in the winter period, but is sustainable in the summer period as this can provide a basis to exclude livestock from the area for a short period of the year.

Mapping and measurement of the area of disturbance will provide exact information on the extent of the disturbance at a given point-in-time and can be repeated to assess change.

Vegetation can give a good indication of the area being disturbed even in the summer months when it can appear deceptively stable. The disturbed area will be characterised by weed species such as nettle and thistle, broad-leaved plants (e.g. docks and plantains) and annual grasses (e.g. annual meadow grass).

2.4 Management

The management of livestock on archaeological earthworks can be broken down into two main types based on whether the aim should be to control the grazing pressure on a site or to remove the focus of livestock activity.

2.4.1 Livestock Control

Livestock control can be introduced to reduce, alter, or increase grazing pressure. The aim is to achieve greater control over the intensity of grazing. This can be achieved through ascribing stocking levels for the field unit containing the monument and/or by agreeing seasonal restrictions on grazing. This is already a common method used in nature conservation, particularly in schemes such as Countryside Stewardship. For the conservation of archaeological remains a restriction on

winter grazing is the most common requirement. Livestock can either be removed or reduced to a level that does not cause significant ground disturbance. Guidance on the appropriate stocking level can be drawn from those already published (see appendix B) and these will help in establishing the initial programme. However, these are only a guide and therefore the situation should be monitored so that stocking levels can be adjusted to suit local circumstances.

Further control can be achieved by excluding the monument from the field unit by the erection of permanent or temporary fencing. This permits control of grazing on the monument itself by the mechanisms outlined above. The erection of fencing, particularly permanent fencing can cause damage to buried archaeology and has a significant impact on the setting of the monument and potentially to the wider landscape character. Therefore permanent fencing should only be used after other methods have failed to resolve a problem or where there is no practical alternative. Temporary fencing, such as electric fencing can effectively be used to exclude the monument or parts of the monument from grazing whilst the grass sward recovers or is re-seeded. This is similar to the agricultural practice of rotational grazing whereby the grazing area is divided into units, each of which is grazed in sequence. The units are rested from grazing for three to four weeks to allow the grass sward to recover, but not to give sufficient time for the sward to achieve flowering and therefore become less palatable grazing (Brockman, 1995).

Alternatively, where the area to be excluded is small, brashings of tree branches, wooden hurdles, or chain link attached to battens can be used to keep livestock off while the area recovers. This has the advantage that the control method is not as visible in the setting of the monument and although pegged down, this will be with tent pegs and will not create significant disturbance. Care should be taken, particularly with brashing that the cover does not encourage rabbit burrowing or exclude too much light thus slowing down re-growth.

2.4.2 Focus Removal

In order to alleviate pressure on a monument the focus of the livestock activity can be completely removed, moved, altered or an alternative focus can be provided off the monument. This section is dealt with by the type of management issue as outlined earlier (C2.2.1).

Shelter Areas

Removal or alteration can solve problems of livestock erosion associated with the presence of trees, either in the form of shelterbelts or individual trees. The removal of low branches that act as rubbing posts may be sufficient. In addition the canopy density and height can be reduced to promote greater light and air movement through the trees assisting in the development of a good grass sward beneath the canopy. In some cases where the proximity of a shelterbelt to a monument results in significant livestock erosion then part of the shelterbelt can be removed (see case study), though this decision will have to be balanced against the ecological, amenity, landscape and cultural value of the shelterbelt. With some sheltered areas such as buildings, walls, ditches and slopes it is not feasible to remove or alter them. In these cases it may be necessary to provide alternative shelter off the monument and restrict livestock access. This can take the form of modern mobile or fixed shelters, traditional stock shelters or planting of new shelterbelts.

Feeding Stations

It is often possible to re-site a feeding station or mineral lick off a monument. In other situations the ground conditions may make the siting of the feeding station off the monument impracticable (i.e. waterlogged ground conditions). In these cases moving the feeding station on a regular basis may reduce the impact of livestock congregation around a feeding station. Adequate time, usually three to four weeks in the growing season, should be allowed for the grass sward to recover before returning the feeding station to the same site. If neither of the above solutions is practical then the provision of a permanent feeding station on or off the monument may be necessary. It is preferable

to site these off the monument, but on occasions gravel over a separation membrane has been added to create a permanent feeding area on the monument whilst minimising the destruction of archaeological information. It is important to consider the likely movement of livestock towards feeding areas as preferred routes, particularly with sheep can start to develop and cause erosion.

Pinch Points

Removing or altering the causes can solve pinch-point erosion. Where the pinch-point has developed due to vegetation restricting livestock movement to a narrow corridor it is usually sufficient to enlarge the corridor by the removal of some vegetation. Where the movement of livestock through a gateway generates the pinch-point it may be possible to move the gateway to a less sensitive location. If this is not practical then the creation of a more sustainable surface through the gateway should be considered through the use of drainage, improving the soil, or adding a wearing course such as gravel.

Rubbing Posts

Rubbing posts can either be removed, the ground around them modified or livestock periodically excluded to prevent the formation of a doughnut of erosion around them. Removal is often appropriate and achievable for features such low branches, fences or tree trunks. In some cases the feature is not or not readily removable, such as a boulder that is considered part of the monument fabric or land ownership boundary fence. In these cases in situ management is necessary. Modification of the area around the rubbing post can be achieved through the addition of a wearing course of gravel or a surface of angular stone that discourages use by livestock.

Water Sources

Water sources such as troughs are moveable and can be re-sited off the monument or in less sensitive areas of the monument. If re-siting is impractical then the provision of a wearing course of gravel around the trough will prevent ground disturbance. Permanent water sources such as ponds and streams are not moveable and therefore they can only be managed by excluding livestock with fencing where acceptable to the landscape setting and providing an alternative watering point or by providing a wearing course over the archaeology.

Exacerbation of Erosion Scars

In some cases erosion by livestock can be an exacerbated by small land slippage or the development of disturbance around an animal burrow. In these cases it is normally sufficient to exclude stock temporarily and repair the erosion scar. Management of burrowing animals on monuments is discussed in section C2.4.

References and Further Reading

Brockman, J S 1995 Grassland. In Soffe, R J (editor) Primrose McConnell's The Agricultural Notebook, 19th edition (Blackwell Science)

DEFRA 2001 Controlling Soil Erosion: An advisory leaflet for preventing soil erosion in the uplands (DEFRA, London)

MAFF 1999 Controlling Soil Erosion: An advisory leaflet for preventing erosion caused by grazing livestock in lowland England (MAFF, London)

MAFF 1999 Controlling Soil Erosion: An advisory booklet for the management of agricultural land (MAFF, London)

Tolhurst, S and Oates, M (Eds.) 2003 The Breeds Profiles Handbook: a guide to the selection of livestock breeds for grazing wildlife sites. (Grazing Animals Project).

Case Study 4: Reducing Shelter at Four Laws

Summary

A shelterbelt adjacent to a set of well-preserved Roman barrows was reduced in size to remove the effects of livestock erosion from one of the barrows.

Figure 27: Erosion of a prominent Roman barrow due to cattle gathering in the lee of the shelterbelt

Introduction

Situated alongside the Roman strategic road known as the Stanegate is a collection of well-preserved Roman barrows. These are a particularly rare survival and although other Roman cemeteries are known to exist within the Hadrian's Wall World Heritage Site they are the only visible examples. Adjacent to the barrows is a shelterbelt of coniferous trees. The shelter provided by these trees had encouraged live-stock, principally cattle, to gather next to them, which was also on top of one of the most prominent barrows (figure 27). As a result the barrow was slowly being eroded.

It was decided that the partial removal of the shelterbelt would be a solution to the problem. A short section from the end of the shelterbelt was to be removed, which would allow livestrock to continue to shelter by the trees but off the sensitive upstanding earthworks.

An alternative management option would have been to erect a single strand barbed wire fence around the barrows to exclude cattle from them, but maintain sheep grazing. It was felt that this would be intrusive to the setting of the monuments and potentially through its erection and maintenance cause disturbance to buried archaeological deposits.

Preparation

The first stage, after permission from the landowner was obtained, was to determine whether any consents were required to remove the trees and what impact partial removal may have on the rest of the shelterbelt.

Trees may benefit from a Tree Protection Order (TPO), which should always be confirmed with the local authority. Depending on the amount of timber being removed a felling licence from the Forestry Commission may be required. In this instance, the shelterbelt was a modern plantation of coniferous trees and was not covered by a TPO. A felling licence was not required due to the small amount being removed.

Figure 28: Works on completion

The removal of trees from the edge of shelterbelts can cause further loss, as the newly exposed trees will be less resistant to windthrow. As this shelterbelt was relatively small it was felt that the removal would not significantly increase the risk of windthrow above that which was already occurring. However, this needs careful consideration where falling trees may cause further damage to the archaeological site.

Method

The following method was employed in the works:

1. The trees were felled. Smaller branches were shredded. Larger branches and the trunk were cut up into manageable sections. In this case all materials were removed from site, but in some cases it may be possible to leave some wood to rot down on site and enhance the wildlife value of the site. However, this may encourage greater burrowing activity by providing cover.
2. The stumps were ground down to just below the ground surface and covered with soil.
3. The area was raked over to provide a fine tilth and re-seeded with grass seed. The re-seeded area was not fenced as it was felt the stocking rate was sufficiently low to allow recovery of the grass cover.
4. A new stock proof fence was erected around the modified shelterbelt.

Conclusion

The removal of a section of the shelterbelt has solved the damage being caused to one of the most prominent barrows on the site. Although more expensive in the short-term than erecting a fence around the site it is a better solution for the setting of the monument. It will in the long-term be less expensive as the fencing would have required continued maintenance.

This method could be applied to the wholesale removal of a shelterbelt, where provision of alternative shelter away from the site could be incorporated into the scheme.

C2.3 Management of Vehicular Erosion

3.1 Introduction

Vehicle access on monuments largely occurs as part of the necessary, everyday agricultural management of the landscape, but in some cases it also occurs for recreation. The latter includes the use of off-road motorbikes and cars, which can have significant impact on monuments particularly where these are located near urban areas. The study area of Hadrian's Wall used in the development of this manual does not suffer from recreational vehicle use and therefore this aspect has not been included in the manual. Future revision of the manual may allow for management techniques to be included.

The passage of vehicles can in some instances cause disturbance to the ground surface and therefore can have a significant impact on the preservation of archaeological earthworks, in addition to leaving unsightly scars in the setting of the monument. This section of the guidance manual discusses the problems that can occur through the use of vehicles on earthworks and the possible management options.

3.2 The Issues

Vehicles can have a significant impact on the preservation of archaeological earthworks. Damage from vehicular use occurs in two ways, through the displacement of the soil by the downward pressure of the vehicle wheels and the erosion of the ground surface by soil shear across the surface through the traction of the vehicle wheels (figure 29). In both cases the severity of damage is likely to be greatest when soils are waterlogged. This is most likely during the winter months. With its protective grass sward removed by vehicle damage, the monument is prone to further damage from natural erosion processes and from the invasion of scrub and weed species. Damage to archaeological earthworks is particularly likely to occur in areas where soils are characterised by seasonal waterlogging. In waterlogged conditions the upstanding earthworks often provide the most firm and dry ground in the area and therefore damage is likely to occur as they present the best ground to drive a vehicle across.

Figure 29: Farm vehicle disturbance across Hadrian's Wall Ditch

3.3 Assessment and Monitoring

An initial rapid assessment using a simple scoring system (table G) should be carried out to assess the level of pressure from vehicular activity. The initial assessment should preferably be carried out when the monument is likely to be under most pressure. This will tend to be in the winter season when deteriorating ground conditions make the surface of the monument more prone to disturbance from vehicle use.

Table G: Indicators of Stress for Vehicular Erosion

Level	Score	Description	Photographic Example
None	0	No evidence of vehicular erosion.	
Low	1	Evidence of some vehicle erosion on the monument, but not causing significant disturbance or evidence in the vicinity of the monument that may impact on the monument periodically.	
Medium	2	Evidence of vehicle erosion causing significant disturbance over parts of the monument (generally less than 25% of the area of visible earthworks affected by vehicle erosion).	
High	3	Extensive vehicle erosion over much of the monument (Over 25% of the area of visible earthworks being affected by vehicle erosion).	

Where the monument is identified as being under pressure from vehicle activity further assessment should be used to highlight when vehicles are causing disturbance, reasons for using the route, alternative routes, contributing factors and additional threats (e.g. presence of scrub, invasive weed species, presence of livestock feeding areas).

Vehicles may not cause damage all the year round and their passage is often sustainable during drier periods. The period in which the route shows disturbance should be established through discussion with the landowner and other available information. This can be enhanced by further monitoring visits throughout the year.

The reason for using the route will assist in developing the management response. Some routes are primary routes on the farm and have to remain in use throughout the year. Other routes are for access to feed stock and therefore are used seasonally when livestock are on the land. These routes present a greater opportunity for reducing pressure.

The presence of alternative routes or the opportunity to use a wider zone for access may assist in preventing damage. The assessment should identify where the route for vehicle use could be varied so that the route can be changed when the indicator of pressure has reached its limit of acceptability.

The presence of contributing factors will affect the sustainability of the route. These factors include soil drainage, the presence of stock, and the presence of scrub, bracken or other invasive weed species. Poor soil drainage will increase the vulnerability of the monument as the soil becomes more easily displaced when waterlogged. The presence of stock will add to the amount of disturbance. The presence of scrub, bracken, or other weed species in the vicinity increases the vulnerability of the monument as they may become established in the disturbed ground causing further damage.

Monitoring should be carried out to enhance knowledge before and after any management action is taken. This should be targeted at identifying the amount of disturbance and its impact, which can be done in a number of ways:

- visual assessment or fixed point photography to make a rapid and easily repeatable monitoring system.
- ground condition survey to accurately record the area and depth being disturbed.
- botanical observations to identify whether the influence of vehicle damage is limited to the observed disturbed area or whether the surrounding area is subject to periodic disturbance as indicated by the presence of species that characterise disturbed ground such as annual meadow grass and broad-leaved weed species.

3.4 Management

The aim of management is to remove the pressure causing the damage or reduce it to acceptable and manageable levels. The options for management can be grouped into two types. Those that alter the usage of the route (indirect methods) and those that alter the surface of the route to make it more sustainable for the use (direct methods).

Indirect methods

Indirect methods involve the alteration of the pattern of use for the route. This can be done in a number of ways that include:

- reducing the load
- changing the route
- altering the time of use

If the access is limited to a single route then the use of vehicles that have less impact on the ground surface is an option. These are vehicles that either are physically lighter (e.g. All Terrain Vehicles) or have a greater spread of their weight (e.g. tractors with larger load dispersing tyres fitted). The applicability of this management technique will depend on the vehicle requirements of the land use and the availability of the appropriate equipment.

Changing the route means that either the existing route is closed to vehicle use or it is periodically rested to allow recovery. Closure of an existing access route is feasible where an alternative, more sustainable route over less sensitive ground has been identified. Resting the route will depend on the availability of at least two access routes that can be alternated or a wide strip in which the access route can be altered. In both cases once there is evidence of sward deterioration (areas of bare ground development) or ground disturbance the access route should be moved to allow recovery.

The ground is most susceptible to damage from vehicle use when it is waterlogged. Restricting use during this period will assist in preventing any damage. Limiting the use is best done over a specified period (e.g. October – March) when damage is likely to occur and when natural recovery through grass sward re-growth would not occur.

Direct methods

Direct methods involve the alteration of the surface of the route to provide a surface that can sustain the level of use. This can be achieved in the following ways:

- provision of hard surfacing
- provision of improved soft surfacing (e.g. re-inforcing the rootzone, improving ground cover)
- improving ground conditions (e.g. improving drainage)

Hard surfacing is the most durable surface for vehicle use. However, its installation can in its own right have a significant impact on the preservation of the monument and its presence can be an intrusion into the setting and appearance of the monument. The traditional options are tarmacadam or gravel. Alternative synthetic surfaces are available as a loose material to apply in the same way as gravel (e.g. shredded car tyres) or others as a paver. Some pavers are constructed as a cellular moulding allowing either additional material (e.g. gravel) to be added in the cells or for grass to grow through it. All methods require the preparation of the ground surface prior to application (e.g. the excavation of a tray) and therefore may require archaeological works prior to or during works (see section C.1).

Soft surfacing improvements include the addition of biodegradable materials, the reinforcement of the grass sward or the addition of a wearing course into the surface. In woodland pasture settings the use of wood-chips as a renewable, biodegradable surface may be appropriate. Re-enforcement of a grass sward can be achieved through the introduction of synthetic materials that relieve compaction. Most common is the use of a plastic mesh that gives the soil elasticity thus preventing wheel rutting and soil compaction. A wearing course of gravel worked into the surface of the ground can increase its ability to cope with traffic and if a large aggregate size (75mm) is used will assist with drainage. The addition of materials in conjunction with the movement of vehicles can lead to the added material migrating deeper into the soil profile and potentially into buried archaeological deposits. It is therefore appropriate to use this technique in archaeologically non-sensitive areas or lay a geotextile membrane to separate the added material from underlying archaeological deposits.

Damage from vehicles often occurs due to the soils being waterlogged. Therefore improving drainage and aeration of the soil to reduce the moisture level of the soil may make the surface more sustainable for vehicle use. This can be achieved through a programme of grassland management similar to that used in recreational management (section C2.1). This involves the spiking of the ground to improve aeration, addition of sharp sand to improve drainage and the application of fertilisers to encourage growth of the grass sward. In addition harder wearing grass species may be introduced to improve sustainability of the route. Other initiatives to improve the drainage include ensuring any existing land drainage is functional and effective and the installation of new land drainage (see section C2.6). Both of these latter options will require significant disturbance in archaeologically sensitive areas and therefore will require archaeological works prior to or during implementation.

Case Study 5: Blackcarts Farm Access

Summary

The traditional improvement of an access track across the vallum of Hadrian's Wall to facilitate farm access on a single route and to restrict access to other previously used parts of this well preserved section.

Figure 30: The upper of the two crossing points showing the vehicle ruts across the monument and along the berm, and also the erosion caused by feeding livestock. © P. Austen

Introduction

The vallum at Blackcarts is an extremely well preserved section of vallum and was being damaged through farm vehicle use and livestock activity. The problem was that the vallum acted as a barrier to farm traffic accessing a large field unit and a regularly used agricultural building from the modern road. In addition ground conditions during winter months were extremely poor and although the vallum could be crossed in two places allowing the farmer to alternate their use, both had regularly become severely rutted (figure 30). The severest rutting was occurring as the vehicles left the vallum and entered the field. At times it was impossible to get a vehicle onto the field through these routes and the farmer was using the berm of the vallum and driving over its south mound causing further disturbance in order to access the field and barn.

In addition to this, because of the problems of accessing the field the farmer was feeding his livestock on the south mound of the vallum causing further disturbance.

The Solution

Through a management agreement between the Northumberland National Park and the landowner an improved aggregate track was laid under archaeological supervision from the modern road to the barn (figure 31). Provision was also made for access to feed livestock away from the monument. Through the management agreement restrictions were placed on the farmer not to use farm vehicles or feed livestock on the monument. In addition the gateway that gave access to the other crossing point was reduced in size to only permit pedestrian and bridleway use.

Figure 31: The lower crossing point with new access track installed. © P. Austen

Conclusions

The creation of a single well-drained access track that provides both access across the monument to the barn and facilitates the feeding of livestock away from the monument has had a significant benefit to the monument. The previously disturbed ground is beginning to recover with the annual grass species and weed species being replaced by perenial grass species (figure 32). It demonstrates the benefits of working with the landowner to create good effective farm access that minimises disturbance to archaeological earthworks.

Figure 32: The upper crossing point one year on (2003).

Case Study 6: Grindon Farm Access

Summary

A farm access route across Hadrian's Wall was improved using an expanding plastic cellular fabric part filled with aggregate and finished with soil and grass seed. The cellular material will prevent further damage to the archaeological significance of the monument by bearing the weight of farm vehicles. The finishing of the route with a grass cover will improve the setting of the monument.

Introduction

Grindon is the local name given to the site of Milecastle 34 of Hadrian's Wall. About 100m east of the site a farm access route crosses the line of Hadrian's Wall, its northern ditch and counterscarp mound. The regular use of this route by farm vehicles and livestock had resulted in the route becoming entrenched over time. The erosion of the route had been exacerbated by the flow of surface water. In addition the combined effects of natural erosion and livestock were causing disturbance to the well-preserved remains on either side of the route (figure 33).

Figure 33: The farm track prior to works.

The route was situated in unimproved grassland and it was felt that an aggregate track would be intrusive to the landscape setting. Therefore, it was proposed to create a sustainable access route within the existing entrenched route and to re-establish a grass cover that would maintain the setting of the monument.

Repair Method

The repair was carried out as follows:

1. A 100mm deep trench, 300mm wide was excavated down the centre of the route under an archaeological watching brief. The trench and base of the route were lined with a geotextile membrane.
2. A drainage pipe was laid in the base of the trench to remove any standing water from the finished surface of the route. This will prevent future erosion damage to the ground surface by farm vehicles and livestock.

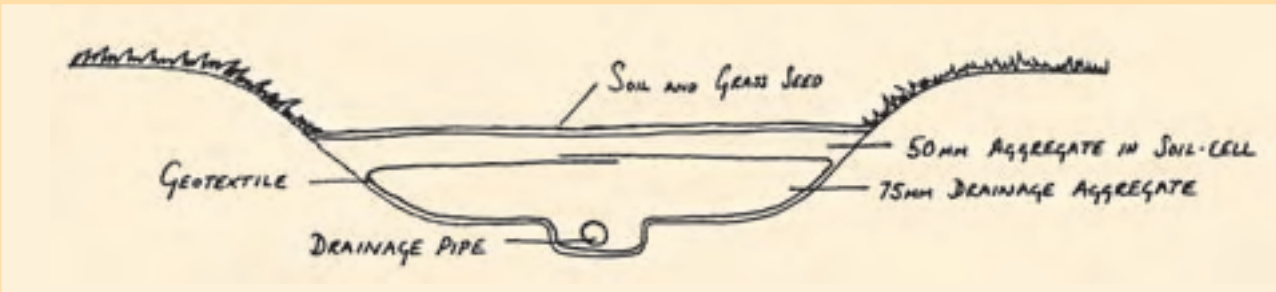

Figure 34: Plan of method.

3. The trench was backfilled with 75mm clean drainage aggregate and the same size aggregate was used to form a 100mm deep base for the expanding cellular fabric, called “Soil-cell” to rest on.
4. The geotextile mem-brane was wrapped around this aggregate.
5. The “Soil-cell” (75mm- depth specifi-cation) was laid over the route and pegged down using 700mm long steel “J” pins. The pins were driven in at 1m intervals down the centre of the route and at either side.
6. The “Soil-cell” was filled to a depth of 50mm with a 50mm size aggregate to increase its rigidity. A smaller aggregate was used at this stage to assist with retaining moisture near the surface of the route to promote good grass growth.
7. The remaining 25mm of the “Soil-cell” was infilled with soil and an additional 25mm laid over the surface of the route before seeding with an appropriate grass seed mixture to match the surrounding vegetation.
8. Livestock were kept off the repaired route until a grass sward had established.

Conclusions

A sustainable farm access route across the monument has been created. The method employed will re-establish a grass cover on the route that improves the setting of the monument by blending the farm access with its surrounding landscape. It is best used where a 200mm tray can be excavated or an existing entrenched route can be used. This is so that the finished result does not alter the field characteristics of the monument.

Although it is predicted that this will be a durable farm access route, as no other known examples exist then this remains to be seen. It will be interesting to re-visit the site in the future and assess its success.

Figure 35: Farm track after completion of works.

C2.4 Burrowing Animals

4.1 Introduction

Burrowing animals have been recognised as a major cause of damage to the archaeological resource. Their damaging impact is the effect of their tunnelling activities, which can disfigure the surface expression of the monument, destroy stratigraphy and result in the redistribution of artefacts and the loss of information.

This guide covers those burrowing animal species that are most likely to be encountered in a grassland management setting and have been recognised as causing significant damage to archaeological deposits. These include the rabbit, badger and mole. The impact of fox, rat, puffin and shearwater has been assessed in the Historic Scotland Technical Advice Note 16, Burrowing Animals and Archaeology (Dunwell and Trout, 1999) and is not dealt with under this guidance manual.

Despite the potential severity of their impact there has until recently, been very little intensive research into their archaeological impacts and the effectiveness of control methods in archaeological settings. The Historic Scotland Technical Advice Note formed the first synthesis of the available information and the excavations at Brown Caterthun provided the first investigations into the impact of rabbit burrow systems on buried archaeology. Therefore, much of the information used in this guidance manual has been derived from the fields of nature conservation and agriculture where the management of burrowing animals has a longer and more developed history.

In addition to the Historic Scotland Technical Advice Note this section has principally been drawn from the following texts; The Lowland Grassland Management Handbook (Jefferson and Croft, 1999), The Handbook of British Mammals (Corbet and Harris, 1991) and Badgers on Historic Sites (English Heritage Landscape Advice Note 16, 2000). These texts contain additional information that the reader may find useful.

4.2 Issues

As the title of this section suggests, it is the burrow or tunnel system that is the principal damaging impact of these animals. With the exception of moles, these tunnels will be excavated preferentially into soft and sloping ground, both for ease of digging and to provide well-drained refuges. Archaeological earthworks, which are often earthen banks are therefore a particularly attractive habitat for burrowing animals. The tunnelling activities of burrowing animals can cause damage to archaeological earthworks in a number of ways.

Figure 36: Disfigurement of a turf wall section of Hadrian's Wall by a badger sett.

Disfigurement – The collapse of tunnel systems and the spread of excavated material from tunnel entrances is apparent on the surface as a disfigurement in the field characteristics of the earthwork (figure 36). This is detrimental to its visitor appreciation and its research potential by field survey.

Figure 37: Rabbit burrows have exploited the softer buried soil horizon at the base of the counterscrap mound of Hadrian's Wall

Destabilisation – The creation of tunnels destabilises the earthwork and the exposure of bare surfaces through the collapse of the tunnel systems can leave the monument prone to further degradation from other influences, such as livestock erosion, wind and water erosion.

Information loss – The disturbance and, in extreme cases, destruction of buried remains, and the loss of field characteristics entail irretrievable loss of archaeological information (figure 37).

The aim of this section of the guidance manual is to provide the reader with sufficient information to effectively manage burrowing animals and limit their negative impacts on archaeological earthworks.

4.3 Important Features of Burrowing Species

To understand the likely impact to archaeological earthworks and the appropriate management regimes it is necessary to understand something of the ecology of these animals. The remainder of this section and the following section deals with important features of their ecology and nature conservation interest.

Rabbit

Rabbits can form dense permanent colonies of up to 30 individuals, and therefore increases in population are mirrored by an increase in the amount of burrowing activity and burrow holes. Burrow systems are favoured on soft, well-drained soils and are particularly prevalent on sloping ground with warmer facing slopes (east- and south-facing). These preferences make archaeological earthworks particularly susceptible to damage by rabbits.

The most suitable habitat is areas of short grass with secure refuge (e.g. scrub, bracken, hedgerows or woodland) in proximity to feeding areas. Rabbits graze a territory of 0.3-3ha (equivalent to a circle with a radius of 30-100m), but typically maintain a short-cropped area of 50m radius around the burrow system. Rabbits eat a wide range of herbage, but favour young succulent leaves and shoots. The suitability of the habitat is enhanced by the presence of adequate vantage points (old tree stumps, grass hummocks, ruined walls and archaeological earthworks) to monitor for predators.

Rabbits can produce litters of between 3-7 young at 30-day intervals between January and August. Typically each breeding doe can produce 10-11 offspring per year.

Rabbits create burrows for breeding (February to August) and for refuge during the day, often under bushes and trees for cover but also in open flat or sloping ground. Short breeding burrows, known as stops may be made by subordinate rabbits emigrating from the original focus of the local population; these then become enlarged and more elaborate. The entrances to burrow systems are commonly between 8 and 20cm, though they can be as large as 50cm.

The warren structure is variable according to soil/subsoil characteristics but may have 5-250m of tunnel, typically 0.1-0.15m in diameter and reaching 0.75-4.5m below the ground surface. Estimates for the volume of warrens also vary widely; perhaps 2.5-8m of burrow per hole and 0.02-0.14 cubic metres of soil removed per hole (greater in soft, easily excavated deposits). A guide to the extent of excavation can be determined from the frequency of burrows and the amount of spoil outside (except where rabbits are living in cracks in hard ground e.g. rock).

Badger

Badgers are widespread in the United Kingdom, only being largely absent from high altitude regions (above 500m) and urban areas. Woodland or scrub, sloped ground and more easily dug soils are the favoured habitats (Neal and Roper, 1991), although they also occur in open moorland. They are most common in south-west England. The badger population has increased significantly in recent years with a recorded rise from 200,000 in 1988 to 310,000 in 1997 (The Mammal Society, 2001).

Figure 38: Spoil heap outside badger tunnel entrance in counterscarp mound of Hadrian's Wall.

Badgers live in social groups, known as clans of around 6 (range 2-23) in elaborate tunnel systems known as setts. The setts can be divided into five types according to their size and importance.

Main sett: large sett, continuously occupied, more than 3 entrances, used for breeding.

Annex sett: smaller than main sett, usually occupied, and connected to main sett by well-worn pathways.

Subsidiary sett: seasonally occupied and some distance from main sett.

Outliers: often single holes, only used occasionally as a sleeping site or as refuge during feeding.

Day nests: above ground, usually in dense vegetation, used as temporary shelters.

The tunnels can extend up to 100m, but are typically 10-20m long. Excavated examples suggest that tunnel systems are largely two-dimensional, rarely exceeding 2m below the entrance hole. Badger setts can be distinguished from other burrows by the size and shape of the entrance holes, which are typically 25cm in diameter and oval (wider than they are high). Large spoil heaps can be found outside sett entrances containing plant material used for bedding. Foxes produce similar spoil heaps known as earths, but these lack any plant material. Tunnel systems can be used by other mammals such as rabbits and foxes.

The presence of elder, nettle and blackberry (blackberry replaced by raspberry in northern Britain) can be an indication of the presence of a badger sett as these form a major element of their diet (Neal and Roper, 1991).

Badger clans are territorial. Under optimal conditions a badger territory is about 30ha, but under marginal conditions it can be as large as 150ha. The majority of badger latrines are located on the boundaries of the territories.

Badgers mate mainly in February and March producing 1-4 young in the following February, which emerge from the sett in April. Badgers can live for up to 11 years, but more commonly only live to 6 years old.

Mole

Moles are present in most habitats where the soil is sufficiently deep to allow tunnel construction and thrive in land that is in pasture management. They are uncommon on moorland and sand dune areas due to a lack of prey (soil invertebrates, especially earthworms). They spend most of their lives in extensive and elaborate system of tunnels. These vary in depth from just below the surface to well over a metre down and are characterised by the molehills created from the spoil of excavating the tunnel system.

Moles live solitary for most of the year and occupy largely exclusive territories. A single territory normally covers between 0.13 and 0.28ha, which is equivalent to a circle of a radius between 20 and 30m. During the short spring breeding season (March – June) male territories can increase to around 0.73ha (equivalent to a radius of 50m) to find receptive females.

Population growth is more rapid in southern England where two litters of 3-4 moles can commonly be raised each year. Only one litter is raised in other parts of the United Kingdom.

4.4 Nature Conservation Value

Burrowing animals can be of nature conservation value either in their own right as a valued or endangered species or by virtue of the ecosystem they are part of and assist in maintaining.

Rabbits are not normally considered of nature conservation value and in high population densities can lead to the degradation of the conservation value of important semi-natural grasslands. However, in areas where there is insufficient or unreliable grazing then rabbit grazing can be important for nature conservation by maintaining a mosaic of grass heights.
Badgers are not usually of high nature conservation value as they are generally common. However, in some areas such as urban, upland, intensively farmed or low-lying areas badgers may still be uncommon, and a sett may be of high local importance. Due to their history of persecution they are legally protected, primarily under the Protection to Badgers Act 1992, which makes it an offence to kill, injure, capture or cruelly ill-treat a badger or interfere with a badger sett except by licence. If badgers are present on an archaeological earthwork it is essential to consult with the relevant government departments and nature conservation organisations and obtain the appropriate licence before any action is taken, as an offence may otherwise be committed under the act.

Moles are a native component of grassland ecosystems and therefore requests to control them should be limited to where there is a justified archaeological conservation need.

4.5 Assessment and Monitoring

Assessment and monitoring are key to the accurate evaluation of the present and changing risk to an earthwork, and to the review of the effectiveness of management regimes. They should be repeatable and relatively simple to allow rapid appraisal. This phase can be carried out at most times of year, however it is easiest in late winter or early spring when burrowing animals are becoming active as they enter their breeding seasons and vegetation is at its lowest making observation of burrow holes easier. For badgers, September can also be a good time to observe the level of activity as this is a peak time for burrow digging (Woods, 1995).

The initial phase of the assessment of burrowing activity on and in the vicinity of archaeological earthworks should be a rapid survey of the level of pressure the monument is under. The aim of this type of assessment is to establish the present condition of, and risk to, the monument by recording the level and presence of burrowing activity on and in the vicinity of the monument. Table H provides an example of a suitable assessment system.

It is the recognition of the early signs of evidence that is a problem for the surveyor. Therefore it is often not until burrow entrances are visible and damage is occurring to the monument that the evidence is easy to recognise. The surveyor should look for evidence such as droppings, scrapes, and tracks.

Where the earthwork is under active damage from burrowing animals or is likely to become damaged from burrowing animals due to their presence in the vicinity of the monument it may be necessary to carry out more detailed assessment.This additional assessment can include the following;

Level of activity – An assessment of the level of the burrowing animal activity in the area. The area being the ground on and around the earthwork where colonisation of the earthwork is most likely to come from (e.g. for rabbits this is an area 100m around the archaeological earthwork). This can be done by estimating the percentage of activity on or around the monument (e.g. 25% of the monument area shows evidence of activity), counting holes or identifying individual burrow systems.

Status of activity – An assessment of whether the burrow systems are active or inactive. Indicators of inactive burrow systems include the presence of cobwebs over burrow entrances, vegetation growing over spoil, lack of tracks going from the burrow entrance and no evidence of fresh droppings or rabbit grazing. Indicators of active burrows include fresh scrapes and droppings, rabbit grazed areas, and tracks. Inactive burrow entrances can be blocked with turf to confirm absence before any further management activity is taken, though this will need to be done under licence for badgers.

Presence of exacerbating factors – An assessment of the presence of habitat favourable to the burrowing species (e.g. for rabbits the presence of a short grass sward that makes suitable grazing, burrow sites and cover) and the presence of factors that would exacerbate any destabilisation of the monument (e.g. livestock presence).

Present management or population limiting factors – An assessment of any existing management of burrowing animal populations and their effectiveness. Presence of disease in burrowing animal population (e.g. myxomatosis).

Significance of impact – An assessment of the impact on the significance of the archaeological earthwork. Recording the amount of disfigurement (e.g. loss of form in the monument and therefore its value as a landscape feature and ease of interpretation by visitors) and evidence of significant information loss in burrow spoil (e.g. presence of artefacts, charcoal, variations in soil matrix colour

Table H: Indicators of Stress for Burrowing Activity

Level	Score	Description	Photographic Example
None	0	No evidence of burrowing animal pressure.	
Low	1	Evidence of rabbit activity (droppings, tracks, scrapes) on the site, but no burrows. Burrows may be present in the adjacent area.	
Medium	2	Evidence of rabbit activity on the monument, including burrows. The burrows only occupy a small area and have not resulted in disfigurement to the monument.	
High	3	Extensive burrowing activity over much of the monument. The monument shows evidence with the exception of badger setts entrances. Inactive badger sett entrances can only be blocked once disuse of sett has been confirmed and agreed by the appropriate licensing body.	

and texture, which all indicate disturbed stratification). Also, an assessment of the key components of the archaeological earthwork for preservation (e.g. parts of the monument that give key stratigraphic information) to highlight the potential impact of an incursion by burrowing animals.

Monitoring should be carried out at suitable time intervals to assess the changing condition and risk to the monument and to assess the effectiveness of any management actions taken. It should review earlier assessments, particularly the level and location of any activity and the archaeological impact. Fixed point photographs should be taken to show the change in the monument condition due to active management or to assess the developing impact if no action is taken.

4.6 Management

The use of chemicals to control burrowing animals will require adherence to COSHH regulations and other regulations relating to the use of pesticides.

Rabbit Control

Under Section 1 of the Pests Act 1954, the occupier of any land has a continuing obligation to kill or take rabbits on their land to prevent damage being caused by them. Damage as defined under this act can include archaeological earthworks. Where an occupier is failing to meet their obligation, agriculture ministers have powers, under section 98 of the Agriculture Act 1947 to require occupiers of land to take action against rabbits.

Rabbits can be controlled by a variety of means including exclusion and removal. These methods can be used in conjunction with habitat alteration to reduce recolonisation pressure.

Exclusion Methods

Methods for excluding rabbits from archaeological earthworks involve the creation of barriers. The barrier can either be created as a fence surrounding the monument or by laying the barrier on the ground over the monument. In both situations the wire netting should comply with British Standard 1722 and should have a hexagonal mesh of at least 18 gauge, 31mm (1.25").

Netting for fencing areas should be a minimum width of 900mm. The netting should be erected so that 750mm is erected vertically and the bottom 150mm is lapped on the surface of the ground away from the area being excluded of rabbits. Turves of grass should be placed on the lapped netting at 1m intervals and pegged securely down; after a year vegetation should grow through the mesh to hold the netting firmly in place. Two straining wires should be attached to the lapped netting side of the fence (one at the top and one at the base of the fence) and the netting attached using connectors. Fence stakes can be placed at 15m intervals if high tensile spring straining wire is used or 4m intervals if mild steel is used. Stakes should be 1.7m long and 50-75mm in diameter. Straining posts should be 2.1m long and 100-120mm in diameter.

Where the netting is laid over the surface of the archaeological earthwork the netting should extend for a minimum of 300mm beyond the limit of the earthwork's slope. Where more than one width of netting is required the widths should be overlapped. The netting should be pegged down at regular intervals. After about a year vegetation should grow through the mesh and hold it firmly in place. Where it is important to maintain the aesthetics of the monument the netting can be covered with turves or soil.

It is necessary to monitor the excluded area for burrowing activity. In particular, where rabbit populations are at high-density exclusion methods will eventually be breached and therefore it will probably be necessary to use the above methods in conjunction with removal methods. Where fencing is used multi-catch drop box traps set in the fence-line can be an effective form of control.

The netting will have a finite lifespan and will therefore need periodic repair and replacement. In addition the installation of metal wire meshes means that some geophysical prospection methods are not usable and therefore should be carried out prior to installation if appropriate. Also, if lain over the surface it will limit the options if the grass is cut by machine, as the netting has the potential to become caught up in the machinery causing it and the netting damage.

Removal Methods

Removal methods include fumigation, shooting and trapping. The methods vary in their efficacy. Fumigation is the most effective method if eradication of the population is necessary, with an

average population reduction of 70% following a single treatment. Repeat treatments can increase efficacy to 90% (CSL, 2000). More traditional methods of management such as ferreting and shooting achieve 30-50% reductions (Corbett and Harris, 1991). The optimum time to carry out all these methods is between November and March when the population is at its lowest and before the breeding season begins.

Fumigation products are based on aluminium phosphide (e.g. Talunex, Phostek and Phostoxin). These are permitted under the Control of Pesticides Regulations 1986 and are subject to the Poisons Act 1972 and the Poisons Rules 1982. They are applied to the rabbit burrows and rely on a reaction with soil moisture to release a toxic gas. The burrow holes are blocked with turf, earth or sand. Care should be taken to chose a material that does not alter the burial environment of the archaeological deposits. It is recommended that at least one repeat fumigation is necessary, four to seven days later to achieve optimum reduction. These compounds are extremely toxic to humans and animals and should only be used by trained professionals.

Shooting using a shotgun or .22 rifle is a widely used method. Night shooting with lights is the most effective method but is restricted to authorised persons (owners, occupiers and tenants who possess shooting rights) under the Ground Game Act 1880. A game licence may be required to shoot rabbits if the person effecting control is not the owner, occupier or tenant. Further advice on shooting can be found in Parkes 1991 and Parkes & Thornley 1994.

Trapping can be used to kill or capture rabbits. Traps include snares, spring traps, drop traps and cage traps. Snares and spring traps are not considered particularly effective or humane and can result in other animals, including pets, being caught. Therefore they are not recommended for use in rabbit control, particularly on sites open or accessible to the public.

Drop traps are used in conjunction with fencing. The traps consist of a tunnel, trap-door and box. When set, the rabbits fall through the trap-door of the tunnel into the box to await humane disposal. The trap-door in the tunnel can be left set or not, which allows the periodic harvesting of the rabbit population. When set the trap should be inspected daily.

Cage traps are wire mesh cages that are normally baited with carrots. These traps are sited in rabbit grazed areas in winter when the lack of grazing increases the effectiveness of this type of control. These traps should be inspected twice a day. When in use livestock should be removed from the area as they, particularly sheep can become caught up in the trap.

Other methods include ferreting and long netting. Ferreting involves the introduction of ferrets into the burrow system as a means of bolting the rabbits either into nets or to be shot as they emerge. It is common practice to dig out ferrets if they get stuck and therefore this is not a suitable technique for archaeological earthworks. Long netting involves the driving of rabbits into a net by dogs. Again dogs may enter burrows, get stuck and require digging out and therefore the method is not highly suited to archaeological earthworks.

After a phase of removal, burrows should be blocked with turf, earth, sand or gravel. This will allow an assessment of the effectiveness of the removal and the rate of recolonisation at a future monitoring visit by the number of re-opened holes. The use of PFA grout in a plastic sleeve to backfill burrow systems after removal has been shown to be an effective alternative means of control as the hard substrate discourages re-excavation of burrow systems (Cowan, pers. comm.)
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Habitat Alteration

The success of a rabbit colony is dependent on the availability of the right habitat. Alteration of these factors may assist in rabbit control. The important elements of the habitat are;

- suitable sloping ground for the creation of the burrow system,
- availability of existing burrows, particularly nesting chambers,
- cover from natural predators,
- suitable feeding areas of short grass,
- and vantage points to watch for predators.

Although no known example exists for rabbit control, the creation of an artificial burrow mound may be a method that could assist in rabbit control. The artificial mound should be located at the furthest point from the archaeological earthwork where rabbits currently burrow, but within the home feeding range (30-100m). Equally, non-archaeological sloping ground may be enhanced for burrow provision by providing cover and suitable short grass grazing nearby to distract activity away from the archaeological earthwork. The construction of an artificial mound will be expensive, may be considered detrimental to the setting of the monument and potentially confuse interpretation of the monument. Therefore, it would rarely be an appropriate form of management.

Burrow destruction through ploughing is a method that has been used effectively to produce long-term reductions in rabbit activity (McKillop and Dendy, 1999). This reduces the availability of burrows and therefore the ability of rabbit populations to recover after reduction. This method is not appropriate for archaeological earthworks, but recent research (Cowan, pers. comm.) has shown that back-filling the burrow system with a hard material such as grout can have a similar long-term effect on rabbit numbers and therefore rabbit burrowing.

Removal of cover will enhance predator activity and reduce the suitability of the burrow system to recolonisation. This can be combined with the enhancement of cover off the monument to provide an alternative colony site.

Creating feeding areas of short grass sward away from the earthworks where the rabbits can be controlled by shooting.

Altering the grazing regime on the land to favour the development of a long sward (removal of livestock grazing between February and July) may help in reducing rabbit activity. The long grass has three effects; it reduces the availability of suitable grazing for the rabbit colony, it increases infant rabbit mortality and reduces the effectiveness of vantage points for predator monitoring. However, care should be taken to prevent the development of scrub vegetation on the earthwork, which will encourage rabbit burrowing.

General Management

Rabbit burrow entrances should be blocked as described earlier, after rabbit removal or if disused to prevent re-use by other burrowing species. Bare areas of ground should be restored to an appropriate grass sward to prevent secondary management problems such as the establishment of damaging vegetation species and livestock erosion.

Badger Control

Badgers are a protected species under the Wildlife and Countryside Act 1981. This act consolidated earlier legislation and has in turn been reinforced by the Badgers Act 1992, which makes it an offence to kill, injure or take a badger or to interfere with a sett except by licence. The act makes provision under schedule 10 for licences to be granted 'for the purpose of the preservation, or archaeological investigation, of a monument scheduled under section 1 of the Ancient Monuments and Archaeological Areas Act 1979, to interfere with a badger sett within an area specified in the licence by any means so specified' (section 10.1.e). It also makes provision

under section 10.2.b for a licence to be granted 'for the purpose of preventing serious damage to land, crops, poultry or any other form of property, to kill or take badgers, or to interfere with a badger sett, within an area specified in the licence by any means so specified'. The definition of property extends to ancient monuments.

Due to these laws it is necessary that advice be sought from suitable organisations if badger control is necessary for the preservation of the archaeological earthwork or if preservation works affect a badger. Two organisations issue licences; DEFRA and English Nature. Under present guidance DEFRA can issue licences for the purpose of preventing damage by badgers to archaeological earthworks. English Nature can issue licences to interfere with badger setts for the purpose of the preservation or archaeological investigation of a scheduled archaeological earthwork. The distinction between the two aims may at times become blurred and it is always recommended practice to discuss with these organisations to confirm the appropriateness of the licence being sought.

The first stage of any management is to assess the situation. This may involve the commissioning of a badger study. The study should include some or all of the following;

- an assessment of the type of sett on the earthwork,
- the relationship between the use of this sett and the use of the rest of the badger clan's territory,
- the suitability of the habitat on the earthwork for sett use and expansion,
- and an assessment of the available options for management of the badger activity.

Badgers can be controlled by methods that include exclusion and removal. The methods permitted to be used for this purpose are restricted to those specified in the Wildlife and Countryside Act, 1981 and should be carried out by experienced contractors. Habitat alteration may also be an option.

Removal

Under badger licensing legislation it is possible to remove badgers from an archaeological monument by interference with the sett. This can be achieved by installing a badger gate in the sett entrance or badger proof fence surrounding the sett. This permits the badger to leave the sett but not to re-enter. Works for the removal of a badger sett can only be carried out outside the breeding season (July to October).

Exclusion

Badgers can be excluded from a monument by creating a physical barrier to the excavation of setts. This can either be done by the laying of wire mesh over the upstanding earthworks or by erecting a badger proof fence around the monument. Chain link or welded mesh should be used in both cases. Some geophysical survey techniques are affected by the presence of metal and where appropriate should be caried out prior to installation.

Where the wire mesh is applied to the surface of the monument then the sections should be overlapped and it should extend at least 0.5m beyond the upstanding feature to prevent badgers digging underneath.

If used as a fence then it should be at least 1.25m high and either buried to a depth of 0.6m or lapped outwards for 0.5m to prevent badgers from digging underneath it (MAFF, 1999).

Electric fencing has also been shown to be an effective method of exclusion. However, its continued maintenance means that it is a costly method of exclusion.

Renardine, a bone-oil repellent can also be used to deter badger activity.

Habitat Alteration

The suitability for badger activity of the habitat on an archaeological earthwork can be altered. For example the removal of scrub and bracken from the earthwork reduces the cover for the sett and the availability of suitable bedding material. Combined with the enhancement of habitats away from the earthwork this may be an effective means of reducing damage by badgers.

General Management

If a badger sett is removed from an archaeological earthwork or a sett is identified as unused then the sett entrances should be blocked as for rabbit burrows to discourage re-use by badgers or other burrowing species. Any bare ground around them should be restored to grass to prevent secondary management problems such as the invasion of damaging vegetation species and livestock erosion.

Mole Control

Methods

Mole populations can be controlled by chemical or physical means. The methods include:

- poisoning using strychnine hydrochloride treated worms,
- fumigation using aluminium phosphide tablets,
- trapping,
- and non-lethal repellents.

Both the chemical controls, strychnine hydrochloride worms and aluminium phosphide tablets, are highly toxic. They are subject to the Poison Rules 1982 and Poisons Act 1972 and should only be used by licenced, trained operators familiar with the necessary precautionary measures.

Worms treated with Strychnine hydrochloride powder are a widely used and effective method of mole control. The treated worms are inserted into the mole tunnels by means of a small (2cm) diameter hole. The worms should be placed in tunnels at depth to minimise the risk to non-target organisms.

Aluminium phosphide tablets are used by locating a mole tunnel between molehills with a metal probe. A small hole is then pierced, the tablet is inserted and the hole plugged. The gas is created by the reaction of the tablet with the moisture in the soil. This needs to be repeated at sufficient points to ensure the entire tunnel system is gassed. The need to create a number of holes in otherwise undisturbed archaeological earthworks in order to locate tunnels and insert the tablet makes the method less suitable for use on archaeological monuments. An additional disadvantage of this method is that it only works well in damp soil conditions.

Mole traps are a readily available control method and can be performed without the need for specialist training. However, their use entails digging and therefore they are unsuitable for use on archaeological monuments. They can be effectively used in conjunction with other control methods as they can be used in the vicinity of archaeological monuments to create a buffer zone.

Non-lethal repellents are available and include ultrasound and bone-oil. The effectiveness of these repellent methods is not conclusive. However, bone-oil formulation (Renardine) repels moles for at least 28 days (Atkinson and Macdonald, 1994) and may be used as a realistic alternative to poisoning and fumigation on archaeological earthworks. The moles once repelled from the monument may then be controlled by conventional trapping methods. Further information on the mole as an agricultural pest and available control methods can be found in Atkinson, Macdonald and Johnson (1994).

General Management

Molehills should be removed by raking or harrowing as they can cause secondary management problems. These include providing a seed bed for the establishment of weed, invasive scrub and other potentially damaging plant species, and if compacted they can reduce the grass swards' ability to withstand recreational, vehicle and livestock pressures.

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Case Study 7: Reducing Rabbit Burrowing Activity at Brampton Roman Fort

Summary

The rabbit population from a section of Roman fort rampart was eradicated and the burrows back-filled with a grout to prevent re-excavation and to suppress recovery of rabbit population. This study will assess this method as a long-term means of reducing rabbit damage to archaeological earthworks.

Introduction

The reduction of rabbit burrowing on archaeological earthworks is a desire of archaeological earthwork management. Traditional methods of rabbit control techniques such as fumigation, trapping and shooting are an on-going commitment. Exclusion methods such as rabbit fencing need periodic maintenance and replacement. The aim therefore is to find a management technique that can reduce or remove rabbit burrowing activity on a monument with the minimum of long-term commitment.

Figure 39: Rabbit and livestock damage to the rampart of Brampton Old Church Roman Fort.

Recent research (Cowan, pers.comm.) has shown that by filling the rabbit burrow with a hard material that cannot be re-excavated by rabbits then a significant reduction in the rabbit activity can be achieved. The theory behind the technique is that only a finite number of suitable burrow sites (most particularly for the construction of nesting chambers) are available in the landscape. Even in the most suitable circumstances that archaeological earthworks often provide there will only be a number of sites where the right conditions combine. By back filling the burrow system these sites are unavailable to the local rabbit population and as a result rabbit populations are reduced as is burrowing activity on the monument.

The method was tested at Brampton Old Church Roman Fort. This is a Roman fort on the Stanegate, the strategic frontier road between the Roman forts at Corbridge and Carlisle. Excavation has shown that there is a wealth of buried archaeological evidence at this site. However, only the south and part of the east rampart are still readily visible as an archaeological earthwork. Rabbit burrowing activity has been causing the erosion and disfigurement of parts of this rampart (figure 39).

It was felt that the site presented a good trial for the technique, as there are significant populations of rabbits in the area and it would demonstrate the effectiveness of the technique in an area of high re-colonisation pressure.

Preparations

Prior to the back filling of the burrow system the burrow entrances were recorded as part of an archaeological survey. This allowed the assessment of the location of the burrows in relation to other factors such as cover and it also permits the re-assessment in five years time to assess its effectiveness as a management technique. The re-assessment will record any new burrow entrances, which can then be related to old locations to determine whether any new excavation is into the old burrow system or previously undisturbed archaeological material. It will also indicate the level of re-colonisation, which it is believed, will be significantly lower.

After recording the burrows were fumigated with phostoxin to eradicate the rabbit population. This was repeated on the day of back filling to eradicate any rabbits that had re-entered the burrow system.

Burrow Blocking

The burrows were lined with plastic sleeving, 180mm diameter and 450 micron thickness. To do this the length of burrow was assessed using a drain rod with a brass wheel attachment to facilitate manoeuvring of the rods around tunnel bends. The corresponding length of plastic sleeve was then cut off the roll and a knot tied in one end to form a bag. The grout was inserted under low pressure using a grouting machine. The surplus plastic sleeve was cut off and the remainder folded over the end of the fill.

After the burrows were blocked they, along with their associated scars were given a top dressing of soil and then finished off with turf to restore the setting of the monument.

Conclusion

At this stage of the study no conclusions can be drawn. However, on the basis of recent research it is expected that this method will significantly reduce the future level of burrowing activity on the monument and therefore minimise future disturbance to archaeological deposits. In addition it will prevent the collapse and resulting disfigurement of this, the last remaining visible section of fort rampart at this site.

Case Study 8: Surveying Badger Activity Along Offa's Dyke

Summary

A desktop and sample field survey was undertaken along Offa's Dyke to develop a detailed understanding of patterns of badger activity along the monument, to assess the extent of badger burrowing damage to the earthwork, and to devise practical management responses.

Introduction

Offa's Dyke is a remarkable 80 mile long 8th century boundary earthwork in the Welsh Borders. It typically consists of a massive bank and western ditch, and parts of it today serve as the England/Wales border and the line of the Offa's Dyke Path (a National Trail). The dyke mainly occupies a pastoral context, with substantial lengths also under woodland and scrub, and some urban sections. Despite Scheduled Ancient Monument protection, management problems range from recreational pressure to agricultural practices and the action of burrowing animals, and since 1999 English Heritage and Cadw: Welsh Historic Monuments have funded the post of Offa's Dyke Archaeological Management Officer (based with the Clwyd-Powys Archaeological Trust) to develop improved practical care of the earthwork.

Erosion associated with badger burrowing had long been noted on Offa's Dyke, but little detailed information was available on the scale and patterning of activity, or, indeed, the true extent of the threat to the monument. An introductory 'Badgers on Offa's Dyke' meeting in 2000 with interested parties (including the Welsh and English natural and historic environment agencies, DEFRA and county badger groups) emphasised the different perceptions of the issue held by particular groups, and the need for systematic research before any management approaches could be developed or collectively agreed. Accordingly English Heritage and Cadw: Welsh Historic Monuments jointly funded a survey project undertaken by a specialist badger consultant.

Objectives

- Determine the scale and nature of badger activity on Offa's Dyke
- Analyse dynamics of badger activity within selected localities
- Suggest practical management approaches against this background

Method

Part 1 – Whole Dyke Desktop Analysis

Existing data were used to attempt a generalised assessment of the overall incidence of badger activity along the whole 80 mile length of the monument. Sources were sett records maintained by county badger groups, and data gathered during archaeological management surveys variously undertaken in the 1990s by English Heritage, Cadw and Gloucestershire County Council.

Part 2 – Sample Field Survey

Badger setts were surveyed along a 13.5 km sample section of Offa's Dyke north and south of Knighton, Powys (6 km English northern section, 7.5 km Welsh southern section). Each sett was photographed and sketched, and data recorded on the number of entrances, level of entrance

activity, status (main/annexe/subsidiary/outlier), surrounding habitat and structural condition. Assessment was also made of dyke size, completeness and apparent severity of ongoing burrowing damage. Additional records were made of landscape and habitat within the wider dyke corridor.

Results

Part 1 – Whole Dyke Desktop Analysis:

- Information was not available/supplied for all areas, and there were significant questions of consistency and completeness within and between the data sets obtained. Consequently no firm conclusions could be drawn.

Part 2 – Sample Field Survey:

- Northern Section: 35 setts (7 main) affecting 83% of dyke, average number of sett entrances 27. Setts found across range of habitat types, with scrub (15.5% of dyke) supporting 28.5% of recorded setts. 94% of setts occupy sections of dyke with the bank above 1.5 metres in height (98% of the dyke in this sector).
- Southern Section: 20 setts (4 main) affecting 15% of dyke, average number of entrances 13. Woodland (41% of dyke) supported 85% of setts. 95% of setts occupy sections of dyke with bank above 1.5 metres in height (52% of the dyke in this sector).

General Observations

- Levels of badger activity along the surveyed sections of Offa's Dyke are generally very high. This is true both in terms of the incidence of setts and sett size (one 60 entrance main sett spread over 130 metres of dyke is among the biggest recorded anywhere in Britain).
- Setts almost exclusively occupy the best preserved sections of earthwork, and are focused on the bank crest which is also one of the most archaeologically and cosmetically sensitive parts of the structure.
- Access to setts by stock (especially cattle) is exacerbating erosion, burrowing activity and sett size as the badgers seek to replace burrows repeatedly damaged by poaching.
- A key factor influencing location of setts on the dyke is availability of alternative habitat in the surrounding locality. The particularly high concentration in the northern survey sector reflects the dearth of suitable habitat elsewhere in that area, and it seems likely that sett density will increase along the dyke hereabouts until a maximum threshold of a main sett approximately every 550 metres is reached. In the southern sector, greater availability of alternative off dyke badger habitat reflects the more selective presence of badgers on the dyke only at the most preferred woodland/high dyke locations.
- In practical terms, management can at best aim to limit existing badger activity on the monument, and prevent expansion to currently untouched areas of high dyke.

Management Proposals

Reduce and limit sett numbers:

- Licensed badger exclusion and closure of selected setts (excluding main setts) using exclusion gates and electric fencing or chainlink mat.
- Reduce areas of scrub/bracken/woodland cover on high dyke.
- Monitor sett free areas for preliminary evidence of new burrowing/scrapes and use chainlink mat to deter further activity.
- In the long term, develop additional habitat on land surrounding dyke to reduce badger pressure on the monument (multi-agency approach linking with agri-environment schemes).

Reduce and limit sett size:

- Licensed closure and infilling of disused sections of setts.
- In areas of setts, reinforce crest of dyke with combination of chainlink wire and geo-jute membrane and/or exclude stock from dyke area.
- Use chainlink mat at peripheries of existing setts to limit expansion.

Conclusions

Badger activity is a significant cause of localised erosion on Offa's Dyke and poses the most pressing threat to some of the best preserved sections of the monument. An important insight has been that the dynamics and scale of damage closely reflect wider environmental and land-use patterns in the landscapes surrounding the dyke, and management must address these broader issues as well as direct measures for control of sett increase and new sett establishment. The research has also generated reliable badger sett record data in the survey areas which will be used as a comparative base for future monitoring.

The suggested management strategy focuses on stabilising patterns of badger activity on the dyke. While this approach reflects the particular circumstances of Offa's Dyke (not least its sheer size), it may nevertheless be appropriate for other monuments where total exclusion is either difficult or not archaeologically justified. It has also been possible to build some degree of consensus between different interest groups in support of this strategy, although issues of persuasion do remain – such as gaining the support of landowners to create new badger habitat elsewhere on their land, or indeed to actively 'protect' existing setts. As yet it is too soon to report on implementation and results, but the research has generated a way forward with a management issue that had previously seemed entirely insoluble.

5.1 Introduction

Trees, scrub, bracken and some other types of vegetation have the potential to be prejudicial to the long-term preservation of archaeological earthworks, through direct (e.g. root and rhizome action) and indirect (e.g. competition with grass sward, uptake of water) mechanisms. This section of the guide covers the presence of trees, scrub and bracken on archaeological earthworks managed as grassland. Although many of the issues are similar, the guide does not cover the management of woodland on archaeological earthworks. Guidance can be found in the Forests and Archaeology Guidelines (Forestry Commission 1995). Other work on woodland management and archaeology is in preparation by the Forestry Commission including *The Influence of Soils and Species on Tree Root Depth* (Forestry Commission, forthcoming). The recently published *Scrub Management Handbook* (English Nature, 2003) will contain valuable information for the heritage manager. This section of the guide does not cover other potentially damaging vegetation (e.g. nettle, thistle and reed), information on the management of these and other grassland weed species can be found in *Lowland Grassland Management Handbook* (Jefferson and Crofts, 1999).

Figure 40: Root distuturbance associated with different types of deposit. © English Heritage.

In addition to the work being prepared by the Forestry Commission, this section of the guidance manual has been drawn from the Historic Scotland Technical Advice Note on *Bracken and Archaeology* (Rees and Mills, 1999), *Bracken Control* (The Southern Uplands Partnership, 2001) and from the *Lowland Grassland Management Handbook* (Jefferson and Crofts, 1999). Other sources are referenced in the text and included in the bibliography.

5.2 Issues

The presence of certain types of vegetation can be prejudicial to the long-term preservation of archaeological earthworks through direct and indirect mechanisms. The principle mechanisms for damage are:

Direct: Root and rhizome penetration
Wind-throw

Indirect: Reduction in light to grass sward
Competition (bracken)
Focal point of activity for livestock and recreational activity

The root and rhizome penetration of trees, scrub and bracken can have a significant impact on archaeological deposits. Disturbance mainly varies according to environmental conditions such as soil type, moisture and amount of air, but also with plant type. The development of roots is enhanced under favourable conditions such as where the soil is less compact and has a better balance between air and water. Therefore the type of archaeological deposit will affect the amount

Figure 41: Normal form of tree and root system (from Biddle, 1998).

of disturbance, with compacted soil or stone structures providing greater resistance to roots than a less compacted soil earthwork (figure 40). They will deform around objects that impede them and take the path of least resistance (Biddle, 1998). Tree and scrub roots can essentially be divided into two types, structural and fine, moisture absorbing roots. The relationship of the root system as a whole to the above ground form of the tree is represented in Figure 41. Typically the radial spread of the roots is about equal to the height of the tree and that the majority of roots are within 0.5m of the surface. The majority of these roots are the fine, moisture absorbing ones. Most of the archaeological impact of roots is associated with the disturbance caused by the larger structural roots. These are normally limited to within 2m of the trunk and are unlikely to penetrate below 1m depth (Biddle, 1998).

Wind-throw is an issue mainly associated with trees, although it can also occur with mature scrub species where there has been disturbance to the root system. Wind-throw is the uprooting and felling of trees by the natural action of wind. The area damaged is dependent on the volume of soil occupied by the larger structural roots (figure 42). As stated above this in turn is dependent on the environmental conditions and type of tree. However, as structural roots are limited in their spread or depth penetration this is unlikely to be more than to a depth of 1m or a radius of 2-3m. This type of damage can cause significant damage to the archaeological earthwork and in addition may result in the initiation of other damaging impacts, such as enhanced natural erosion, burrowing activity, and exposure of fresh surfaces to livestock activity.

Figure 42: Wind-thrown Beech tree on the north mound of the vallum.

5.3 Nature Conservation Value

The following is a brief summary of the nature conservation value of the different types of vegetation. When considering the management strategy to be implemented it is important to consider whether any management actions and whether any changes are acceptable will affect this value. It is recommended that consultation should take place to consider the nature conservation value of a site prior to the implementation of works.

Trees: Trees, particularly native species, are an important nature conservation resource, not just in their own right but in the wealth of other flora and fauna species they support. This is especially

true of veteran trees, which can be present in the land boundaries of grassland managed areas. In addition trees form an important aesthetic element of our landscape and for these reasons any management for archaeological benefit should be assessed against its impact on the nature conservation and environmental value of the tree(s). Information on veteran tree management can be found in *Veteran Trees: a guide to good management* (Read, 2000).

Scrub: In terms of botanical conservation, many scrub types are considered to have low intrinsic value, as they are commonplace, have low species-richness, are often of recent origin and are easily created. Additionally, scrub has often been seen as a threat to the integrity of more valuable vegetation types including semi-natural grassland, which it can replace in the absence of management. However, scrub can be an important habitat for birds and invertebrates and its presence in association with grassland can enhance the nature conservation value of a site. In addition, some scrub types are of particular conservation value (e.g. juniper) in that they are rare, support uncommon shrub species or are relatively rich in woody species.

Bracken: In comparison to the nature conservation value of the habitats it is replacing such as heather moorland and semi-improved grassland, bracken is poorer. Generally, plant communities associated with bracken are floristically poor due to its vigorously competitive rhizome system, it's dense above ground growth and consequent shading out of smaller plants. However, in certain situations it does have a nature conservation interest that should be considered in any proposed management. Within habitat mosaics it can be important for many forms of wildlife including invertebrates, small mammals, some plant species and birds such as whinchat, tree pipit, yellow hammer and nightjar. Patchy stands can support several rare fritillary butterflies which depend on violets and cow-wheat (often growing under bracken) as their sole food plants and bracken can support a woodland ground flora in areas that were once tree-covered (The Southern Uplands Partnership, 2001).

5.4 Assessment and Monitoring

An initial rapid assessment using a simple scoring system (Table I) should be carried out to assess the level of pressure from damaging vegetation. This can be carried out at most times of the year, but is easiest when both the earthwork and vegetation are visible. Therefore, areas affected by trees and scrub are best visited in winter and those affected by bracken in early summer.

Where an archaeological earthwork has been identified as being under pressure from damaging vegetation then further assessment can be carried out. This additional assessment should review the susceptibility of the monument to damage from the vegetation, any associated factors and the longevity of the pressure.

As stated in 6.2, the development of the root system is dependent on environmental conditions with roots exploiting softer deposits or lines of weakness. Therefore, an assessment should be made of the likelihood that important archaeological features are going to be affected by root development. At most risk are those earthworks composed of un-compacted soil and the interfaces between deposits as these act as lines of weakness. At least risk are those earthworks that have stonework at their core, particularly if that stonework is mortared.
In addition the type of vegetation influences the threat to the monument. Bracken is a relatively rapid colonizer of ground and has a more destructive root system than scrub and trees, which are slow to develop. Therefore sites under pressure from bracken are at greater risk than those from scrub and trees.

The length of time that the vegetation has been on the site is important in making a management

decision. If the site has only recently been invaded by damaging vegetation then damage is likely to be fairly limited and removal or reduction is an appropriate management strategy. Where the damaging vegetation has been long established and damage is likely to be extensive then management to maintain the present extent and prevent secondary impacts (e.g. providing cover for burrowing animals, encouraging livestock poaching or wind-throw) is appropriate as an initial management objective, with reduction in extent being the long-term objective. Maps, aerial and ground photography, previous site visit reports and ecological surveys are all methods of identifying the length of time that damaging vegetation has been on a monument.

An assessment of the associated problems or potential problems connected with the presence of the vegetation should also be made. This should include the use of the vegetation for cover by burrowing animals, the presence of ground disturbance by livestock using the vegetation for shelter (figure C.2.5.4), browsing or rubbing and the threat of wind-throw.

Table I: Indicators of Stress from Tree, Scrub and Bracken

Level	Score	Description	Photographic Example
None	0	No evidence of vegitation pressure.	
Low	1	Small amount of potentially damaging vegetation on the monument or the presence of damaging vegetation in the vicinity of the monument causing secondary impacts or root disturbance.	
Medium	2	Patches of established potentially damaging vegetation on the monument and/or encroachment over the rest of the monument.	
High	3	The monument is mostly covered with vegetation that may have a damaging impact on its long-term preservation.	

The threat of wind-throw is based on the exposure of the tree to wind both at the present time and in its development, and the nature of the medium into which the tree has developed its structural roots. Trees most at risk of wind-throw are those rooted in soft sediments that have developed in a sheltered environment but are now exposed to greater wind strengths (e.g. trees adjacent to where a shelterbelt of trees has been removed).

Monitoring of the site should be directed to evaluating the changing spread, density and maturity of the vegetation. The spread can be evaluated from aerial photographs, whereas density and maturity will need field assessment. Monitoring should also review the associated threats to a site as indicated in the above paragraphs.

Figure 43: Trees can provide a source for associated damage by other agents. Here livestock is disturbing a Roman barrow cemetery.

5.5 Management

Trees:

The management of trees on archaeological earthworks involves their removal, the management of their canopy or, in the event of wind-throw, the restoration of the earthwork.

Removal is the complete removal of the tree from the monument. The tree can be felled as a whole or felled in sections. This type of management will have advantages, as the monument will be more visible, root damage and secondary management issues such as disturbance from sheltering livestock will cease or be reduced. The removal of a tree from an archaeological earthwork can cause significant disturbance and therefore to minimize this the tree should be sectioned on site and removed when ground conditions permit. The remaining stump and root system should remain in place, but should be ground down or reduced to as close to ground level as possible. The presence of a stump can continue to act as a focus for livestock and provides a good vantage point for rabbits. All cut stumps of tree species that may re-grow should be treated with a suitable herbicide immediately after cutting. A notch should be cut close to the bark, which will enable the herbicide to get into the cambium cells of the tree and will also allow those that have been treated to be easily identified.

An alternative to removal is the management of the canopy. This involves actions such as the raising of the canopy, reducing crown height and thinning of branch density. Each of these actions has a specific management objective. The raising of the canopy removes the focus for livestock of low branches for rubbing and their use for shelter. Both raising and thinning the canopy improve the amount of light reaching the ground and therefore improve ground conditions for vegetation growth. Reduction in crown height reduces the threat of wind-throw.

Scrub:

It is normal when discussing scrub management on archaeological earthworks to prescribe its removal or reduction. However, in some case where the scrub is of nature conservation value, enhancement of this value may be an option by removing scrub from archaeologically sensitive areas and increasing the scrub margin, which is the most biodiversely rich part of the habitat.

Removal and reduction is achieved by cutting with follow-up treatment. The follow-up treatment is an essential part of scrub control as cutting can increase vigour and stimulate re-growth. Cutting should be carried out during the winter and should concentrate on scrub with stems over 1 cm thick, cutting as near to the base as possible. A high percentage of smaller stemmed bushes will die naturally and if they survive they can be treated in follow-up works. Cutting can be carried out using hand tools (either powered or not) or by using vehicle mounted machinery such as tractor mounted flails and swipes, reciprocating knife mowers (often referred to as Allen scythes), forage harvesters or a JCB mounted root fork (known as a drott) or stump lifter. Both the root fork and the stump lifter cause soil disturbance and are not suited to archaeological earthworks. Use of vehicles can also cause disturbance to the soil, and if they are necessary, should only be used when ground conditions permit. All cut stumps should be treated with a suitable herbicide immediately after cutting.

Follow up treatment can also include annual cutting of re-growth. This will kill off scrub in about five years if no herbicide is used. Grazing during the spring and early summer can be employed to reduce re-growth and to kill off seedlings. Application of herbicide as a foliar spray or using a weed wipe can be used on scrub less than 1.5 m tall.

Bracken:

A range of techniques that can be broadly grouped into physical and chemical methods can control bracken. No technique will eradicate a bracken stand in a single treatment and therefore it is important to have a sustained and planned programme of control if a significant reduction or eradication is desired.

Physical control methods work by damaging or disturbing the bracken frond or root. Ones that damage the rhizome involve pulling or cultivation and are therefore not recommended for archaeological earthworks under grassland management. Cutting and crushing is an effective method of controlling small areas of bracken. The fronds should be cut around the middle of June and then again six weeks later for at least three consecutive years. Crushing is best carried out in the early growth (June and July) period when the stems are still brittle. Hand cutting is the preferred option as it avoids significant disturbance to the monument and any important flora and fauna.

Physical control can also be carried out using the trampling effect of stock, burning and establishing tree cover. However, all three of these techniques can have adverse affects on earthworks and their buried archaeology. A sufficient stocking density to control the bracken may lead to ground disturbance. Burning leaves the ground bare and therefore vulnerable to a range of factors including natural erosion. Establishing tree cover is inappropriate on archaeological earthworks.

Physical control rarely achieves eradication, but a noticeable reduction in density can be achieved. It can also be effectively used as a follow-up treatment to chemical control.

Chemical control methods involve the application of a herbicide. Two are available for use in controlling bracken infestation; Asulam and Glyphosate. Both of these are applied to the bracken fronds and are systemic herbicides, which means they are translocated from the frond into all parts of the plant.

Asulam is the recommended treatment as it is reasonably specific to bracken and ferns. However, it cannot be used where rare ferns are present. Asulam has no effect in the year of application but will cause a 98% reduction in the number of fronds in the following year. The remaining 2% will re-emerge and without follow up management can re-infest the land within five years.

Glyphosate is a broad-spectrum herbicide, this means it affects most forms of vegetation and consequently it should not be used where it may affect non-target species of importance. It is best applied by hand using weed wipe so the impact on other vegetation can be minimized. Glyphosate has a larger window of application than Asulam and causes fronds to brown, which makes assessment of application easier.

The herbicides can be applied by hand application, vehicle-mounted application or by aerial spraying. In all cases the environmental implications should be carefully considered. The site should be visited prior to the application and possible impacts on ferns and other flora, danger of stock consuming treated bracken, impact on watercourses and groundwater and the need to exclude people and stock during treatment should be considered.

Hand application can be carried out using knapsack sprayers, ultra-low volume drift sprayers or weed wipes (or weed glove). Knapsack sprayers are a useful method for small areas and follow-up treatment. The herbicide can be applied through a lance or boom and can be applied with a marker die to assist in even and targeted application. A buffer zone of 10 m from a watercourse and 2 m from a site of ecological importance should be maintained. Ultra-low volume drift spraying is extremely useful where the treatment of a large open area of bracken is required. The technique requires low wind speeds to avoid excessive drift and the bracken stand is walked in 3 m wide swathes. Due to the greater risk of drift with this technique it is recommended that a buffer zone of 100 m be maintained from watercourses and sites of ecological importance. Weed wipers or gloves are excellent in situations where spot treatment is required to avoid damage to important species.

Vehicle-mounted application can be carried out using a boom sprayer or by use of weed wipes. The impact of the vehicle on the archaeological monument should be an additional consideration before implementing this method. Both boom sprayers and weed wipes can be mounted on or trailed behind a tractor or ATV. A 100 m buffer zone should be maintained with boom spraying.

Aerial spraying is carried out by a boom sprayer mounted on a helicopter. It is best suited for treating large uniform areas of uninterrupted bracken cover. The technique greatly increases the risk of spray drift and consequently appropriate buffer zones should be used (250m for ecological sites and 160m for watercourses). It is essential that the area to be sprayed is clearly marked with ground markers and the application should only be carried out in low wind speeds. Aerial spraying is only feasible for large area application and therefore is only suitable for extensive archaeological sites or sites within an area being treated as part of a larger bracken control programme.

References and Further Reading

Biddle, P.G. 1998 *Tree Root Damage to Buildings: Volume 1 Causes, Diagnosis and Remedy* (Willowmead Publishing Ltd., Wantage).

English Nature 2003 *Scrub Management Handbook* (English Nature).

Forestry Commission 1995 *Forests and Archaeology Guidelines* (Forestry Commission).

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Read, H 2000 *Veteran Trees: a guide to good management* (English Nature, Peterborough).

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The Southern Uplands Trust 2001 Bracken Control (The Southern Uplands Trust, Galashiels)

Case Study 9: Low Teppermoor Gorse Scrub Clearance

Figure 44: General view of gorse in the ditch of Hadrian's Wall and associated erosion by livestock.

Summary

Gorse scrub on Hadrian's Wall and its northern ditch was removed to reduce root disturbance to buried archaeological deposits and improve the visibility of the monument. In addition it has removed cover for rabbit burrows and removed pinch points for livestock and people movement.

Introduction

This section of Hadrian's Wall has been consolidated and as a Guardianship monument is in the care of the state. The archaeological earthworks surrounding it are well preserved and include further remains of Hadrian's Wall, its northern ditch and the counterscarp mound (the upcast from the ditch). The encroachment of gorse scrub had a number of impacts on the monument. It;

- decreased the visibility of the monument (figure 44),
- encouraged rabbit burrowing by providing cover,
- caused root disturbance to the archaeological deposits,
- encouraged erosion by livestock by creating shelter and constrictions to movement,
- encouraged erosion by visitors by constricting movement (figure 45).

It was proposed that the gorse scrub should be removed from the monument, but retained where off the monument. There were three reasons why the gorse off the monument was retained;

- it provided continued cover for rabbit burrows, thus encouraging burrowing off the monument and it was felt that if completely removed the rabbits might have moved into the next best habitat (the archaeological earth-works),
- it provided a potential nature conservation habitat by providing nesting cover for a number of small bird species such as the linnet, yellowhammer and dunnock,
- and it is considered by some, to possess considerable aesthetic value in the landscape, especially when in flower.

Figure 45: Gorse bushes on the berm of Hadrian's Wall causing erosion by constricting visitor movement.

Method of Gorse Removal

The following method of work was employed.

1. Top growth was removed.
2. Stumps were cut down to ground level and treated with an appropriate herbicide.
3. Both top growth and stumps were removed from the monument and burnt.
4. The litter layer under the gorse bushes, consisting of gorse needles and dormant gorse seeds, was raked up and removed. This was done as the needles would have suppressed the re-establishment of grass and the gorse seeds would have germinated.

Figure 46: Repeat general view after gorse removal.

5. The areas were then re-seeded with an appropriate grass seed mix.
6. Any re-growth can be controlled by either repeat cutting and herbicide treatment or by foliar herbicide treatment prior to cutting.

Conclusion

The removal of the gorse has improved the visibility of the monument and removed the main causes of erosion by reducing the suitability of the habitat for rabbit burrowing, removing shelter for livestock and removing constrictions to livestock and visitor movements. It has also permitted access for the repair of erosion scars and to carry out rabbit control on the site.

Figure 47: Removal of gorse bush on berm has removed contstriction to visitor movement.

By retention of the gorse off the monument the aesthetic value and nature conservation value have to a degree been retained on the site. The retention has also altered the focus of rabbit burrowing on the site. Initial observations almost a year after works indicate the majority of rabbit burrowing activity on the site is now located in this retained gorse rather than being spread across the monument, as was the case prior to the works.

C2.6 Land Drainage

6.1 Introduction

Land drainage is an important element of grassland management as it assists in maintaining good grass yields. Insufficient drainage can lead to waterlogging of the soil with the result that there is a loss in grazing through poor grass growth and poaching by livestock. The later can have a negative effect on the preservation of the monument and its setting. Therefore sufficient drainage can be of benefit to monument conservation.

However, the creation and maintenance of drainage systems can also have a damaging impact on the preservation of archaeological remains as it will disturb below ground deposits and may also alter the monuments field characteristics. This section discusses the implications relevant to land drainage in a grassland management regime.

6.2 Issues

Land drainage can have a damaging impact on the preservation of archaeological remains in a number of ways:

- The installation of new drainage
- The maintenance of existing drainage
- The form of the drainage
- The lack of maintenance of existing drainage

The installation of new drainage on an archaeological monument will cause damage to the archaeological remains and alternatives should be encouraged wherever possible. Installation will normally mean the creation of an open-cut drain or the excavation of a trench to lay clay tile or plastic pipe drainage. In both cases this means the physical destruction of archaeological remains. In addition the upcast material from the trench will modify the field characteristics of the monument and the modification of the groundwater regime may adversely influence the preservation of organic remains. However, in some cases the installation of new drainage may have conservation benefits such as a reduction in poaching. In these cases the beneficial effect must outweigh any potential adverse effect.

Figure 48: Maintenance of an open-cut drain can cause damage to the monument and removed material can modify the form of the monument.

Maintenance of existing drains on an archaeological monument is also likely to cause damage. The clearing out of open-cut drains or the unblocking of pipe drainage requires below ground disturbance. Clearing out of open-cut drains will produce spoil that may modify the field characteristics of the monument and over-cutting will intrude into the buried remains of the

Figure 49: Investigations for tile drains at the base of the vallum ditch.

monument (figure 48). Unblocking of pipe drainage normally entails the relocation of the course of the drain through excavation at intervals sufficient to allow clearance through rodding or sluicing (figure 49).

Both of the forms of drainage have as discussed above, an installation and maintenance impact. In addition the open-cut form of drainage as a source of drinking water provides a focus for livestock activity that can lead to poaching and enhanced erosion.

The lack of maintenance of existing drainage will lead to the increase in the water content of the soil and can lead to waterlogging and the presence of standing water. This increase makes the grass sward more prone to poaching from recreational, vehicular or livestock activity. In addition the presence of standing water can act as a focal point for livestock activity and thus concentrate their poaching activity. Poaching results in the alteration of the field characteristics of the monument, and causes damage to buried remains by direct disturbance and enhanced erosion due to exposure of the ground surface.

6.3 Assessment and Monitoring

Assessment and monitoring are key to the accurate evaluation of the present and changing risk to an earthwork, and to the review of effectiveness of management regimes. They should be repeatable and relatively simple to allow rapid appraisal. They can be carried out at most times of year, however a winter visit when ground conditions are normally at their most waterlogged should present the worst case situation.

The initial phase of the assessment of land drainage on and in the vicinity of archaeological earthworks should be a rapid survey of the level of pressure the monument is under. The aim of this type of assessment is to establish the present condition of and risk to the monument by recording the presence of land drainage and assessing it's present impact on the monument. Table J provides an example of a suitable assessment system.

Monitoring will provide information on the changing state of the impact. Monitoring is limited to observation on the ground surface and therefore to the presence of excess water on the surface, amount of poaching from livestock, vehicles and people and to the amount of erosion. The monitoring period should be sufficiently regular to observe whether the impact is relatively static or whether it is developing. For example where the impact is poaching then a repeat visit at the same time the following year should highlight whether the area under effect is increasing or not.

Table J: Indicators of Stress from Land Drainage

Level	Score	Description	Photographic Example
None	0	No land drainage on monument.	
Low	1	Some land drainage on the monument, affects only a small area and there are no plans to renew.	
Medium	2	Some land drainage on the monument, affect a significant area and is regularly maintained but not on sensitive areas of the monument. Poor maintenance is causing limited disturbance to the monument.	
High	3	The monument has a significant amount of land drainage that is regularly maintained and is on sensitive areas of the monument. Poor maintenance is causing significant disturbance to the monument.	

6.4 Management

The installation of new drainage on the monument as a management solution should be avoided wherever possible unless there is a significant conservation benefit. Where it is unavoidable or of significant benefit then a buried pipe drain is preferred as this does not provide a focal point for livestock activity and does not modify the field characteristics of the monument. The method of construction should allow for future maintenance with minimal disturbance by providing easily identifiable and accessible entry points for unblocking.

New drainage outside the monument that replaces drainage on the monument can be of significant benefit, as it will remove any need for future disturbance on the monument. Consideration should be given to the impact of the new drainage on the burial environment of the monument. If the monument is characterised by naturally waterlogged ground conditions that would be removed by the new drainage then it is inadvisable to proceed as important waterlogged deposits may be disturbed.

Where drainage is in existence its management can be improved by various means. As with the installation of new pipe drainage, old pipe drainage can be modified to provide easy access points for maintenance.

Open-cut drains can be converted to pipe drains by laying the pipe in the open-cut as for a new pipe drain and covering over. Other options involve the retention of the open-cut, whilst mitigating the negative impacts which are principally the re-cutting and the presence of livestock activity. Lining of the sides of the open-cut will prevent over-cutting of the trench and will prevent the collapse of the sides through livestock activity. A reduction in livestock activity through the limitation of access to the open-cut can be achieved by fencing along its course or the establishment of vegetation that discourages access. Both of these measures need to be balanced against the negative impacts that they may have.

In some situations the deterioration of drainage and the subsequent increase in soil moisture may be desirable (e.g. in nature conservation the restoration of water meadow). In these situations the land management practice will need to change to take account of this (e.g. reduction in stocking density and season of use).

Case Study 10: East Bog Vallum Drainage

Summary

The installation of drainage access points to facilitate future maintenance of a tile drain at the base of the vallum ditch and therefore eliminate the need to carry out speculative excavation to access the drain, which could damage archaeological deposits and spoil the setting of the monument.

Introduction

The ditches associated with Hadrian's Wall and its vallum are often exploited for land drainage. At times this is as an open-cut, but more frequently it is a buried tile drain. The renewal and maintenance of tile drains requires excavation, which can have an impact both on the preservation of archaeological deposits and the setting of the monument. The vallum ditch at East Bog is no exception (figure 50). It is utilised to drain water from the nearby fell, from the adjacent B-road and from the adjacent houses. The main drain is a 19th century 3-inch tile drain. In 2002 it was recognised that the drain was not working adequately as the vallum ditch was at times flooded. This had resulted in the some livestock being drowned and it was causing the loss of monument definition through the gradual silting up of the ditch profile. This silting was being enhanced by the presence of an old silage bale and some building rubble that had been dumped in the ditch and was acting as a dam to water flowing along the ditch.

Figure 50: General view of the vallum at East Bog showing initial non-archaelogical excavation down to drain.

It was decided that it was appropriate both for agricultural purposes and the preservation of monument visibility that the drainage should be investigated, repaired if possible or renewed and the dumped materials removed. It was also utilised as an opportunity to install access points (known as rodding points) into the tile drain to facilitate future maintenance and eliminate the need for future excavation unless the drain fails.

Archaeological Evaluation

It was recognised that the repair of the drain or the installation of a new drain could have an impact on the buried archaeological deposits, including palaeoenvironmental evidence. Therefore, two archaeological evaluation trenches were excavated across the vallum to assess the potential.
The results of the evaluation (see figure 51) confirmed that below a depth of topsoil 30cm thick (context 1) there were deposits of archaeological significance with excellent preservation of waterlogged plant remains, pollen and materials suitable for radiocarbon dating. These deposits could provide significant information about the importance of the vallum in the landscape after its original construction and the changing environmental conditions of the area. It also confirmed that there was a distinctive cut for the tile drain (contexts 2 and 3) that could be excavated to permit repair of the old drain.

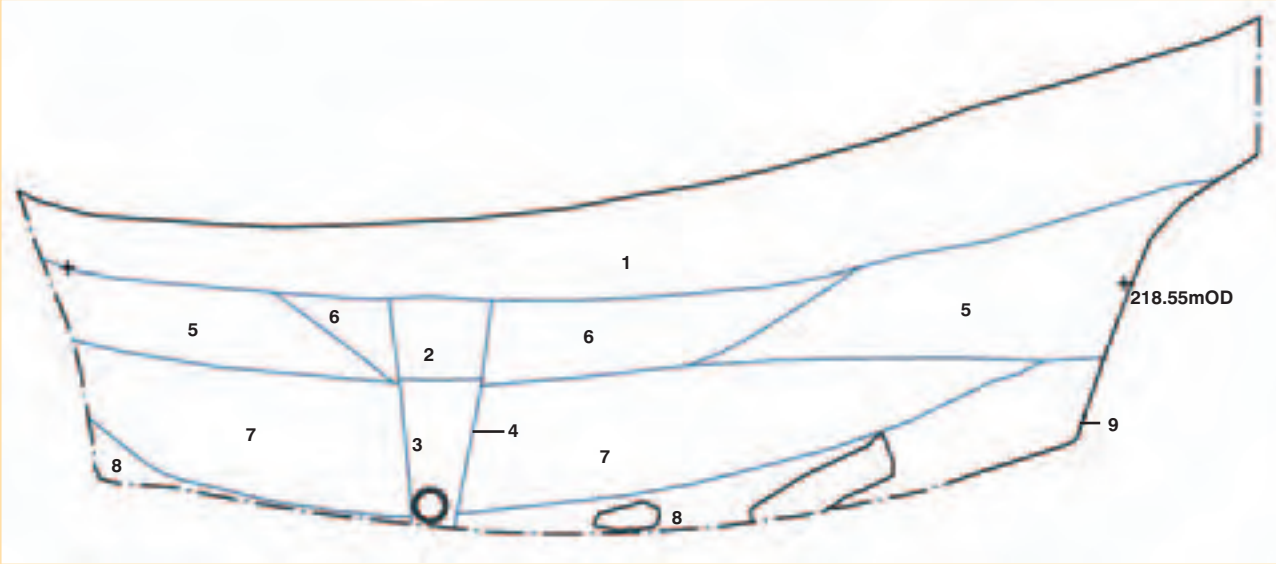


Figure 51: Trench 1 of the archaeological evaluation (courtesy of Oxford Archaeology North).

Based on this assessment it was recognised that installing a new drain may destroy important archaeological remains and adversely affect the survival of palaeoenvironmental evidence. However, as there was a distinctive cut for the tile drain and the palaeoenvironmental remains had survived the tile drain when it was in effective use it was decided that in addition to removing the dumped materials it would be possible to install access points on the tile drain and repair it where it had failed.

Method

Access points come in two types. The most common type are the manhole type. These being fairly large structures can only be inserted into areas where it is known that the archaeology has already been significantly destroyed. In the case of East Bog it was possible to install this type of access point near the B-road where disturbance probably from the construction of the road had destroyed the archaeological deposits.

The second type of access point is a capping to the end of a pipe and is therefore minimal in its disturbance. It comes in diameters of 110mm and 160mm. At East Bog it was possible to install this type into the tile drainage cut of the well-preserved section of vallum near to trench 1 of the archaeological evaluation.

Conclusions

The installation of access points will facilitate future maintenance at this site and therefore will eliminate the need for speculative excavation to locate and repair tile drainage that is so often responsible for damage to the archaeological resource. Even when the drain fails it should be possible to accurately locate the point of failure by measuring from the access point.

However, the findings of the archaeological evaluation highlight how sensitive the repair and maintenance of these tile drains can be when they are located within archaeological monuments. The evidence highlights the need to maintain the status quo in the drainage quality and effectiveness or to investigate ways of removing the drainage from the monument without altering the burial environment and thus adversely affecting the survival of important palaeoenvironmental remains.

Appendix A - Repairing Erosion Scars

Introduction

One of the most common tasks to be carried out on archeological earthworks in grassland management is the repair of erosion scars. These are often the result of natural slippage or borrowing animal scrapes being exacerbated by livestock erosion. If left to develop they can become significant scars disfiguring the monument and resulting in the continued loss of archeological information. It is therefore important to stabilise the scar and restore a grass sward.

Method of Repair

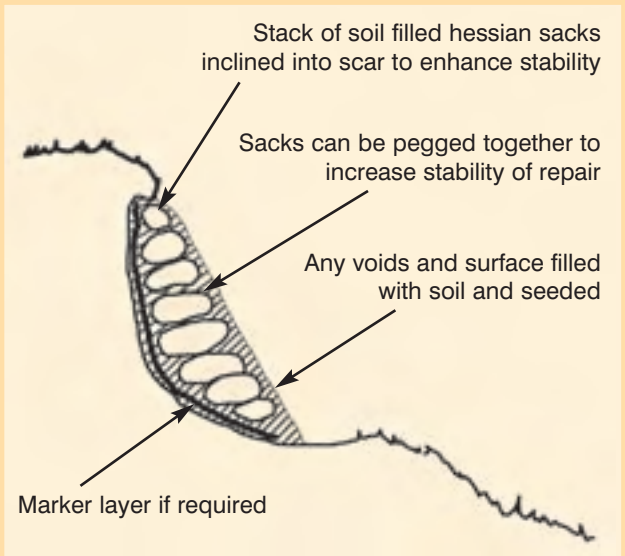
There are a variety of methods available for the repair of erosion scars. There are;

- Soil infill
- Undercut lip of scar and natural recovery or soil infill
- Turf stack or soil filled sack sack

Soil fill can only be used where the erosion scars are minor and shallow, as greater depths are relatively unstable and will be prone to slippage and settlement that may permit the erosion to restart. The technique is best applied to areas where there are a large number of minor scars or the scar is too shallow for any other method. The soil is added as a spread over the scars and re-seed with an appropriate grass seed mix.

Undercutting the lip of an erosion scar lessens the steepness of the scar and therefore aids its stability and ability to recover. The scar can either then be re-seeded if the angle is sufficiently stable or infilled with soil and then re-seeded if not. The disadvantage of this method is that it does necessitate further damage to the monument to achieve stability, which rarely acceptable and therefore this method should only be used where other solutions are impractical or inappropriate.

Turf or stacks are very effective repair methods. The stack is built up at a slight angle so the layers recline slightly into the erosion scar increasing the repair stability. Any voids are filled to reduce settlements and the surface seeded with a suitable grass seed mix.



Section through a hessian sack stack repair.

This method of repair has the advantage that it does not necessarily aim to restore the original profile of the monument, rather it aims to achieve the minimum repair to achieve the stability of the movement.

Therefore it is often easy to recognise that damage has occurred at the site even after the repair has established. The other advantages of the method are that it is very stable and in the case of turf stacks, very quick to establish.

Turf stack repair being constructed.

A variation of the soil infill is the revetment infill. Here a variety of materials are available to create a revetment that then supports the infill behind. This method of repair is best suited to areas of gully erosion where commonly a timber or hessian sack revetment pegged or wedged into the gully is used. The infill materials can then build up behind and re-seeded.

Is a marker layer needed?

A marker layer is only required where there is the potential to confuse in future assessment the repair with the in situ archeological remains. An example of this would be where the monument is a bank that has been created between two turf stacks. A turf stack repair would therefore have the potential to be confused with the archaeology.

If a marker layer is required then this will need to be a layer of material that is easily distinguished from the archaeology, eg. sand, gravel or geotextile. If the sand or gravel is used then care will need to be taken to ensure that the materials does not alter the burial environment.

Aftercare

With all repair work there will need to be some aftercare work to ensure successful establishment of the repair. The most common operations to consider are;

- Watering: during periods of drought it may be necessary to artificially water to ensure successful germination and establishment of a grass sward on the repair.

- Over-seeding and adding soil may be necessary as there will commonly be some settlement in any repair and germination of grass seed may not always be successful

- Fencing out livestock is one of the critical considerations. If cattle or high stock rates of sheep are present then it will be necessary to exclude livestock by fencing off the repair while it establishes. Fencing is less critical where low stocking rates of sheep are present as any damage to the repair will be minor and can be adding soil and over-seeding.

- Control of scrub growth may be required as the removal of grazing and the presence of bare ground will provide the potential for scrub vegetation to establish.

Preventing Future Erosion

Fundamental to management of the earthwork is the prevention of future erosion scars developing. Ideally action needs to be taken as soon as a new scar starts to develop.

At this point it will be sufficient to dress the developing scar with soil, re-seed and exclude livestock for a couple of months with some form of temporary barrier. However, this level of management needs regular monitoring of the monument that is not always practical.

An alternative method is to reduce or remove livestock when the monument is most vulnerable, normally in winter and carry out an annual programme of minor repair to prevent erosion developing.

Turf stack repair on completion

Turf stack repair two months later

Appendix B - A Guide to Stocking Levels for Lowland Grassland

No. of grazing weeks per year	Calcareous Grassland		Neutral Grassland		Acidic Grassland		Wet/Marshy Grassland	
	S	C	S	C	S	C	S	C
2	60	15	100	25	50	12	50	12
4	30	8	50	12.5	25	6	25	6
6	20	5	33	8	16	4	16	4
8	15	4	25	6	12	3	12	3
10	12	3	20	5	10	2.5	10	2.5
12	10	2.5	17	4	8	2	8	2
14	8.5	2	14	3.5	7	1.5	7	2
16	7.5	2	12.5	3	6	1.5	6	1.5
20	6	1.5	10	2.5	5	1	5	1
24	5	1	8	2	4	1	4	
36	3.5	1	5.5	1.5	3	0.5	3	
52	2.5	0.5	4	0.5	2	0.4	2	
Annual Stocking Rate LU/ha/yr	0.25		0.5		0.2		0.2	

Numbers of animals per hectare

S = sheep (c60kg) c = cattle (c250kg LW)

Source: Jefferson and Croft 1999.

Appendix C - List of Suppliers

The following is a list of suppliers and manufacturers that the author has encountered through this project and a review of the companies listed in Berry and Brown (1994).

ABG LIMITED
E7, Meltham Mills Road, Meltham,
Holmfirth, West Yorkshire, HD9 4DS
Tel: 01484 852096, Fax: 01484 851562
Website: www.abg-geosynthetics.com
Email: geo@abg-geosynthetics.com
Producer of geotextiles including geotextile membranes, drainage membranes, cellular pavers and erosion control matting.

ADVANTA SEEDS UK LTD
Sleaford, Lincolnshire, NG34 7HA
Tel: 01529 304511, Fax: 01529 413137
Website: www.advantaseeds.co.uk
Email: amenity@advanta seeds.co.uk
Grass seed supply company

BARENBURG UK LTD
33 Perkins Road, Rougham, Bury St.Edmunds, Suffolk, IP30 9ND
Tel: 01359272000, Fax: 01359 272001
Website: www.barenburg.co.uk
Email: info@baruk.co.uk
Grass seed supply company

BRITISH SEED HOUSES LTD
Camp Road, Withan St.Hughs, Lincoln, LN6 9QJ
Tel: 01522 868714, Fax: 01522 868382
Website: www.britishseedhouses.com
Email: seeds@bshlincoln.co.uk
Grass seed supply company

CEBECO SEEDS
The Old Wood South, Skellingthorpe, Lincoln, LN6 5UA
Tel: 01522 507300, Fax: 01522 507319
Grass seed supply company

COMPLETE WEED CONTROL
Hackling House, Bouton Industrial Park, Bourton-on-the-Water, Gloucestershire, GL54 2EN.
Tel: 01451 822897, Fax: 01451 822587
Website: www.completeweedcontrol.co.uk
Email: cwc.ho@completeweedcontrol.co.uk
Weed control service.

COOPER CLARKE GROUP LTD
Bloomfield Road, Farnworth, Bolton, BL4 9LP
Tel: 01204 862222, Fax: 01204 793856
Website: www.cooperclarke.com
Email: groundeng@cooperclarke.co.uk
Produce a heavy-duty cellular paver called ecoblock. Suitable for car park projects, particularly used by larger vehicles.

DJ TURFCARE EQUIPMENT LTD
MJF Yard, Chiddingfold, Dunsfold, nr. Goldaming,
Surrey, GU8 4PB
Tel: 01483 200976, Fax: 01483 200983
Email: sales@djturfcare.co.uk
Supplier of turfcare equipment including seed slotters, spikers, and germination blankets.

Coir Matting used to stabilise a section of Hadrian's Wall ditch

DEKOWE
Schurholz, Teppichfabrik GmbH, Marienstr 51-53, D-46286 Dorsten, Germany
Tel: +49 2362 600164, Fax: +49 2362 600186
Email: info@dekowe.de
Manufacturer of range of bidegradeable coir fibre erosion control fabrics including matting and fencing (Recultex). Greenfix supply Recultex in the UK.

DLF PERRYFIELDS LTD/JOHNSONS
Thorn Farm, Inkberrow, Worcestershire, WR7 4LJ
Tel: 01386 793135, Fax: 01386 792715
Website: www.perryfields.co.uk
Email: amenity@perryfields.co.uk
Grass seed supply company

GEOFABRICS LTD
PO Box 7, Wellington Mills, Huddersfield Road, Liversedge, West Yorkshire, WF15 7XA
Tel: 01924 412477, Fax: 01924 412375
Website: www.geofabrics.com
Email: info@geofabrics.co.uk
Manufacturer of a range of geotextiles for ground reinforcement, drainage, erosion protection and separation.

GREENFIX
Laverham House, 77 St.George's Place, Cheltenham, Gloucestershire. GL50 3PP.
Tel: 01242 700094, Fax: 01242 700093
Website: www.greenfix.co.uk
Email: cheltenham@greenfix.co.uk
Manufacturer of a wide range of materials including biodegradeable coir and jute erosion control matting for various situations. Also produce an expandable plastic cellular material for retaining materials on slopes.

GREENKEEPER LTD
Shelford Manor, Shelford, Nottingham, NG12 1ER
Tel: 01949 21144
Website: www.greenkeeperltd.co.uk
Supplier of a range of turf products including turf carpet and rubber crumb turf.

GREEN-TECH
Sweethills Park, Nun Monkton, York, YO26 8ET
Tel: 01423 332100, Fax: 01423 332101
Website: www.green-tech.co.uk
Email: sales@green-tech.co.uk
General supplies, including cellular pavers, ground stabilising mesh, erosion control matting, geotextile membranes, bark mulches, soils, top-dressings, fertilisers, seed mixtures and pesticides.

GROUNDSMAN INDUSTRIES
30 Ballybrakes Road, Ballymoney, County Antrim, Northern Ireland, BT53 6LG
Tel: +28 276 67049, Fax: +28 276 66855
Website: www.groundsmanindustries.co.uk
Manufacturer of mechanical aerators.

HOOFMARK (UK) LTD
First Floor, Unit 24, Philadelphia Complex, Philadelphia, Houghton-le-Spring, Tyne & Wear, DH4 4UG
Tel: 0191 584 5556, Fax: 0191 584 5577
Website: www.hoofmark.co.uk
Email: info@hoofmark.co.uk
Supplier of cellular pavers.

LOTRAK GEOTEXTILES
Don & Low Ltd., Newfordpark House, Glamis Road, Forfar, Angus, DD8 1FR
Tel: 01307 452200, Fax: 01307 452300
Website: www.lotrak.com
Email: lotrak@donlow.co.uk
Manufacturer of a range of geotextiles for ground reinforcement, drainage, erosion protection and separation.

LAUDERDALE ENGINEERING
Whitlaw Road Industrial Estate, Lauder, Berwickshire, TD2 6PA
Tel: 01578 718718, Fax: 01578 718719
Manufacturers of the Leader Rabbit Trap, a drop box trap.

MICRON SPRAYERS LIMITED
Bromyard Industrial Estate, Bromyard, Herefordshire, HR7 4HS
Tel: 01885 482397, Fax: 01885 483043
Website: www.micron.co.uk
Email: micron@micron.co.uk
Manufacturer of weedwipers and sprayers for the control of weeds and bracken.

NETLON TURF SYSTEMS
New Wellington Street, Blackburn, Lancashire, BB2 4P3
Tel: 01254 266833, Fax: 01254 266868
Website: www.netlon.co.uk
Email: turf@netlon.co.uk
Manufacturer of a range of cellular pavers and advanced turf (soil with plastic mesh mixed into it).

NOTTS SPORT
Premier House, 18 Mandervell Road, Oadby, Leicester, LE2 5LQ
Tel: 0116 272 0222, Fax: 0116 272 0617
Website: www.nottssport.com
Email: info@nottssport.co.uk
Manufacturer of a grass reinforcement fabric.

POWERSEEDS (UK) LTD
Honeybourne Trading Estate, Honeybourne, Evesham, Worcestershire, WR11 7QF
Tel: 01386 832000, Fax: 01386 834343
Website: www.powerseeds.co.uk
Grass seed supply company

RIGBY TAYLOR LTD
Rigby Taylor House, Garside Street, Bolton, Lancashire, BL1 4AE
Tel: 01204 377777, Fax: 01204 377715
Website: www.rigbytaylor.com
Grass seed supply company

Expandable cellular mesh used to provide vehicle access across Hadrian's Wall Ditch

SOMMERFELD FLEXBOARD LIMITED
New Works Lane, Arleston Hill, Wellington, Telford, Shropshire, TF1 2JY
Tel: 01952 503737, Fax: 01952 630132
Website: www.somerfeld.co.uk
Suppliers and hirers of portable roadways.

SOURCE CONTROL SYSTEMS LIMITED
5 Horninglow Street, Burton upon Trent, Staffordshire, DE14 1NG
Tel: 01283 509021, Fax: 01283 562941
Website: www.sourcecontrol.co.uk
Email: mail@sourcecontrol.co.uk
Manufacturer of cellular pavers designed for wet environments and storm water management blocks.

TENAX UK LIMITED
Ash Road, Wrexham Industrial Estate, Wrexham, LL13 9JT
Tel: 01978 664667, Fax: 01978 664748
Website: www.tenax.co.uk
Email: info@tenax.co.uk
Manufacturer of a grass protection systems, ground stabilising mesh and cellular retaining fabrics.

TERRAM LIMITED
Mamhilad, Pontypool, Gwent, NP4 0YR
Tel: 01495 757722, Fax: 01495 762383
Website: www.terram.com
Email: info@terram.co.uk
Manufacturer of a range of geotextiles for ground reinforcement, drainage, erosion protection and separation.

TOPGREEN
c/o Nickerson (UK) Ltd, Rothwell, Market Rasen, Lincolnshire, LN7 6DT
Tel: 01472 371471, Fax: 01472 371195
Grass seed supply company

TURF SEED EUROPE LTD
17 Earlsfort Terrace, Dublin 2, Republic of Ireland
Tel: +39 348 4760940, Fax: +39 011 9723420
Website: www.turf-seed.com
Grass seed supply company