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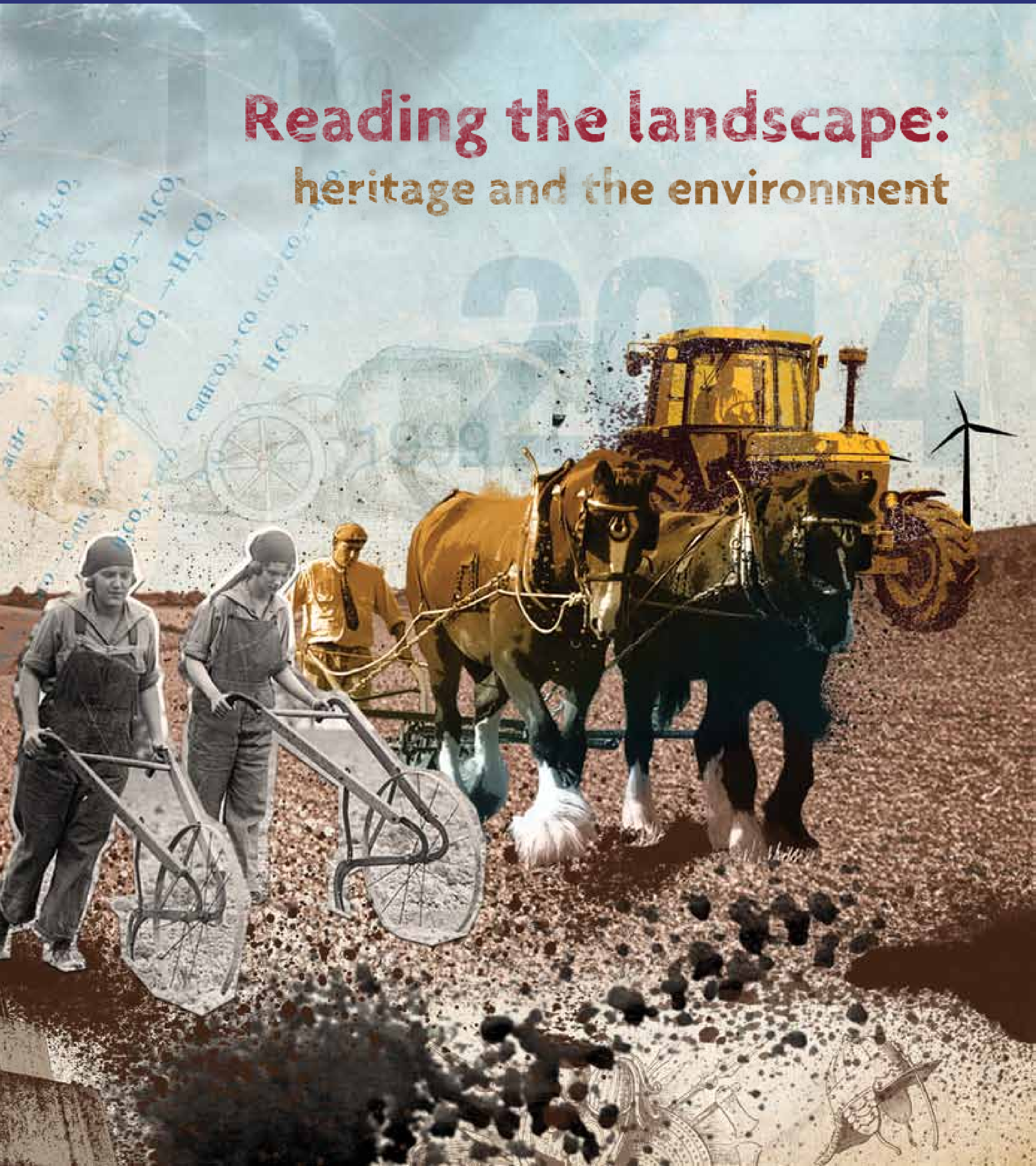
Reading the landscape: heritage and the environment



EDITORIAL

Heritage - from the past into the future

Heritage, in whatever form it takes, is made up of the remains of past generations. These may consist of tangible remains such as buildings or intangible remains such as the location of a battlefield. The diversity of material remains range from the flint and bone implements of early humans, to the monumental structures of Imperial Rome, or the traditionally built dwellings that characterise many villages. These provide for the variety and time depth of heritage that surrounds us.

Much of our heritage remains intangible, either in the form of buried archaeological remains or in the form of myths and legends associated with specific location, such as those surrounding Finn MacCool and the Giant's Causeway. The intangible heritage provides an additional perspective to the more traditional view of heritage as material remains.

Our understanding of heritage is advanced through a variety of methodologies, be they archaeological excavation, the investigation of historic building or academic research. These endeavours include not only heritage specialists but also other specialists from a range of environmental disciplines. They may contribute to the scientific analysis of artefacts or palaeo-environmental assemblages to, for instance, the identification and interpretation of macrofossils within sediments to provide information on past landscapes that cannot be gained from other sources. Other environmental specialists may be involved with the management of sites or landscapes where, for example, heritage and ecological issues may be intimately related, and therefore provide opportunities for the preservation of heritage assets and enhancement of natural habitats at the same time.

The articles in this issue of the environmental SCIENTIST provide insights into the range of challenges that are inherent in the heritage discipline in its broadest sense. The challenges that are faced by heritage professionals also include current significant issues, such as climate change, that are common to other environmental specialists outside of heritage.

The articles highlight that heritage is a broad discipline that draws together environmental specialists from a significant range of backgrounds. Environmental specialists have a significant role to play in preserving, enhancing and interpreting cultural heritage at every scale. It is hoped that this issue will inspire our colleagues outside the heritage profession to engage with this fascinating topic, and act as a springboard for future collaborations together.

Steve Haynes is a Senior Heritage Consultant with Arup and leads the Cultural Heritage Team. He has worked in professional archaeology for almost 30 years and has extensive experience of major infrastructure projects in a leadership role. He has a particular interest in the nature of major archaeological projects, especially their design and execution and the challenges that this brings within overall project programmes.

Steve is a Chartered Environmentalist, and a member of the Institute for Archaeologists and the Association for Project Management.

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The past: why do we want it?

Jennifer Blumhof explores our relationship with the objects, places and practices that make up our heritage.

The past is a foreign country:" begins L.P. Hartley's book *The Go-Between*, "they do things differently there"[1]. This thought-provoking start provides the title of David Lowenthal's 1980s book[2] that examines the distinction between history and heritage, and what has been termed the heritage industry. The heritage industry is where the past – or 'a past' – is preserved and packaged for sale as a commodity for visitors and the tourist industry. But, blurring the distinction between history and heritage, the past is always an interpreted view, and even subject to many interpretations or reinterpretations. As Winston Churchill said, "History will be kind to me for I intend to write it"[3].

And what has this all got to do with the environmental movement and environmentalists? Are we trying to protect and preserve scarce resources to pass them on to future generations to enjoy? Or are we trying to manufacture a sanitised past as grist for visitor centres or to sell in the myriad of museum shops? This has been done by replacing defunct industries such as coal mines or cotton mills with interpretive museums, re-enactments of rituals and the sale of folk handicrafts. And, to add another layer of complexity, this commodification of 'a past' is arguably making some communities more sustainable by giving employment.

If heritage is about preserving and protecting 'a past', the counter-argument is why keep anything old? Why not adopt a Futurists view and blow up the past, replacing it with shiny modernism? Why not live in the here-and-now? In fact, the Futurists drew something very like the Shard in London some 100 years ago, so even the new is an old idea.

WHAT IS HERITAGE?

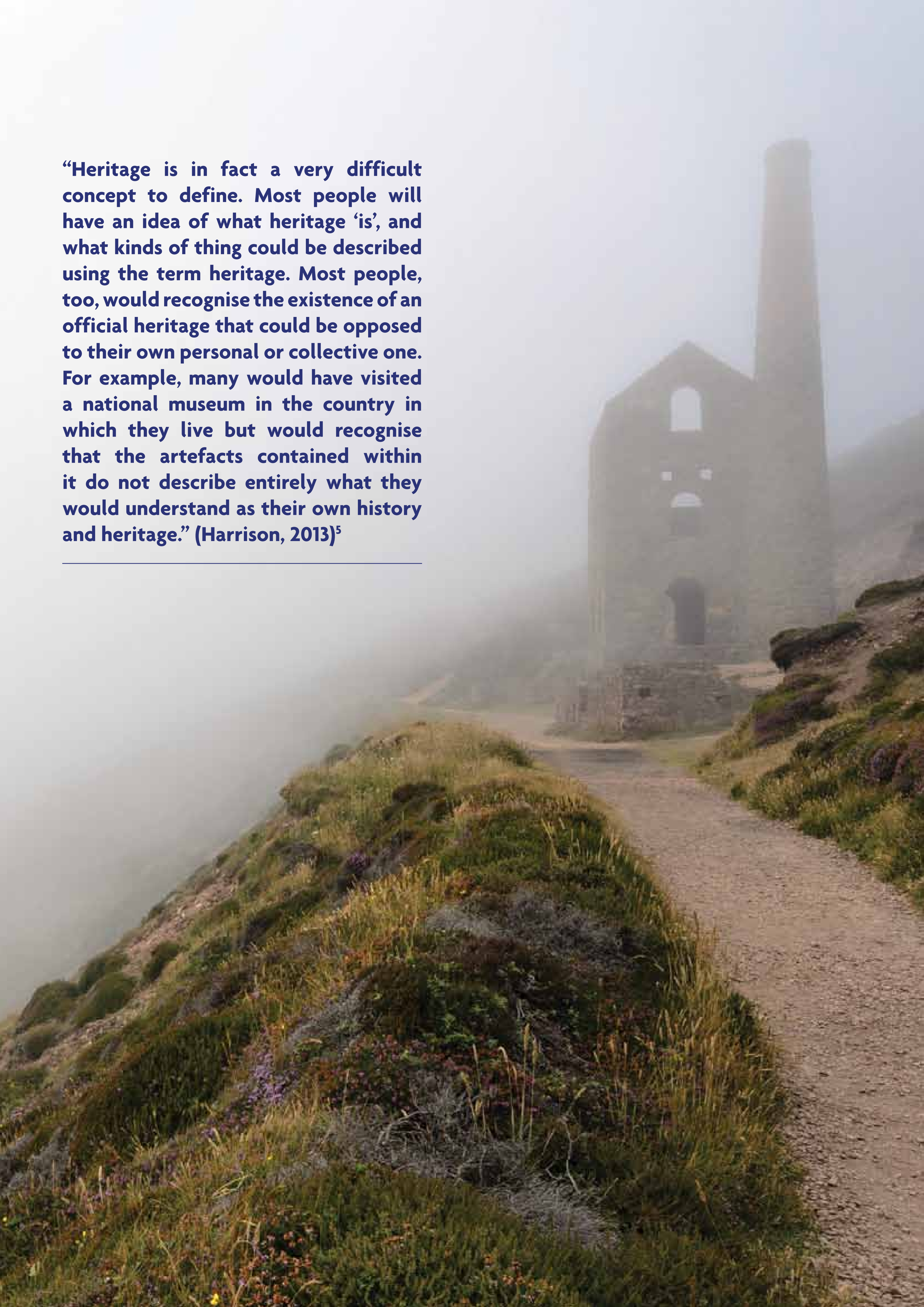
This introduction is not so much a carefully crafted argument for or against these ideas, but an exploration of them. Some are well thought through, others are at the fringes of thinking. But first, what do we mean by heritage and why is the past so important?

The Oxford English Dictionary has a broad range of definitions for heritage, both materialistic and non-materialistic, which include:

- property that is or may be inherited; an inheritance;
- valued objects and qualities such as historic buildings and cultural traditions that have been passed down from previous generations;
- denoting or relating to things of special architectural, historical or natural value that are preserved for the nation;
- denoting a traditional brand or product regarded as emblematic of fine craftsmanship; and
- denoting a breed of livestock or poultry that was once traditional to an area but is no longer farmed in large numbers[4].

From the definitions above it is clear that heritage can be both tangible and intangible, relating to objects, places and practices. But the distinctions are not clear cut; for example, cultural traditions might involve folk songs and dancing as well as clothes.

"Heritage is in fact a very difficult concept to define. Most people will have an idea of what heritage 'is', and what kinds of thing could be described using the term heritage. Most people, too, would recognise the existence of an official heritage that could be opposed to their own personal or collective one. For example, many would have visited a national museum in the country in which they live but would recognise that the artefacts contained within it do not describe entirely what they would understand as their own history and heritage." (Harrison, 2013)[5]



"With deliberate provocation," writes the editor of The Heritage Industry[6],

> "Robert Hewison's book sets out to protect the present and the future life in Britain from their most dangerous enemy a creeping takeover by the past. He sets today's obsession with yesterday in the context of a climate of social and political decline. The economic uncertainties and cultural convulsions of post war life have made the past seem a pleasanter and safer place. But how true is that image of the past and whose past is it anyway? Hewison questions the way that institutions like the National Trust are helping to create a past that never was. While the real economy crumbles, a new force is taking over: the Heritage Industry, a movement dedicated to turning the British Isles into one vast open-air museum." (Hewison, 1987)[6]

Has anything changed since Hewison's book came out in 1987? Has the growing acceptance of the concept of sustainability made us look at the present and forward and not forever back?

WHY DO WE CONSERVE THE PAST?

But what might drive us to value and conserve the past? A range of overlapping motivating forces have been suggested.These include the 'golden age syndrome', 'whole earth for whole people', 'collector's items', 'good housekeeping', 'all our yesterdays' and 'all their yesterdays'[7].

The 'golden age syndrome' refers to the idea that the past is often idealised, looked at with longing to a lost golden age often located in childhood, with childhood images. This concept carries with it an 'escalator back' effect as the golden age is always some era before. Dennis Hardy[7] suggests that this is a key motive for conservation. He states that there is a human tendency to cherish thoughts of the past, and the relics of the past acquire mystical meanings beyond themselves. The relics of the past therefore need to be guarded and preserved. The reality of the past, he notes, is far removed.

'Whole earth for whole people' as a motive for conserving refers to the idea that we might try to conserve in order to achieve an organic balance within ourselves. The argument runs that elements in our past give stabilising factors in a constantly changing and uncertain existence. Also, that the retention of wilderness and nature is essential for our own sanity and survival. Finally, there is a need to conserve ecological balance for the good of us as humans and on ecoethical grounds. Natural heritage is usually thought about in terms of landscapes and complex ecological systems. These can be valued for their contribution to ecological, biological and geological processes, the provision of natural habitats for the conservation of biodiversity and for aesthetic qualities. But they can also mean different things to different societies. For example, a mountain is sacred for some, for others, an exciting peak to be scaled.

'Collectors items' refers to conserving something because it is unique, scarce and non-renewable. The 'good housekeeping' motive refers to a wish to conserve things because they are usable or re-useable, such as new uses for old buildings. The 'all our yesterdays' motivation voices an increasingly popular desire to

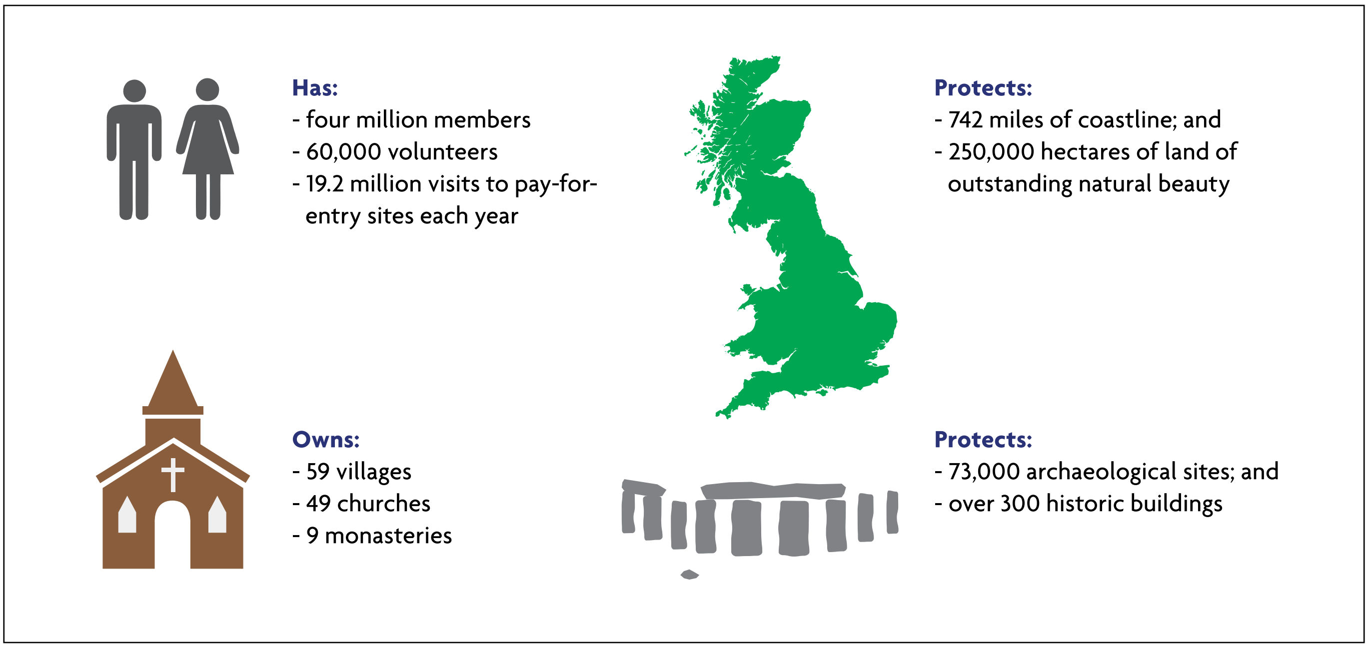
conserve a 'commonplace heritage'. A good example is the Ironbridge Gorge Museums in Shropshire. The 'all their yesterdays' is about conserving a 'national heritage' and this includes castles and country houses, *objets d'art*, landscapes and coastlines, ceremonies and traditions. This list illustrates the wide range of motivating forces for conserving the past and the seemingly powerful grip it has on the human psyche.

OUR NATIONAL TRUST

In Britain the largest, most powerful, and politically the most well-connected, of the conservation organisations is the National Trust, which protects, preserves and interprets our national past in its many forms[8].

The National Trust was founded in 1895, with the twin aims of the enjoyment of its properties and the preservation of our "cultural past". It could be argued that it has marketed a powerful brew of nationalism, monarchy and the rustic idyll. The question surfaces again: does this matter if we want to conserve resources and achieve "development that meets the needs of the present without compromising the ability of future generations to meet their own needs"[9].

"One aspect of understanding heritage is appreciating the enormous influence of governments in managing and selectively promoting as heritage certain aspects of the physical environment and particular intangible



▲ **The National Trust in numbers.**

practices associated with culture. One way in which governments are involved in heritage is through the maintenance, funding and promotion of certain places as tourist destination" (Harrison, accessed 23 October 2013)[5]

THE GLOBAL HERITAGE

Not only is heritage a powerful force in Britain, but it also has a place on the world stage. In 2002 during the United Nations Year for Cultural Heritage, the United Nations Educational Scientific and Cultural Organization (UNESCO) produced a long list of types of cultural heritage. As with the OED definition and the National Trust collection, the UNESCO list includes natural, built and cultural environments. Some examples are listed below.

- Cultural heritage sites (including archaeological sites, ruins, historic buildings);
- Historic cities (urban landscapes and their constituent parts as well as ruined cities);
- Cultural landscapes (including parks, gardens and other 'modified' landscapes such as pastoral lands and farms);
- Natural sacred sites (places that people revere or hold important but that have no evidence of human modification, for example sacred mountains);
- Underwater cultural heritage (for example shipwrecks);
- Museums (including cultural museums, art galleries and house museums);
- Movable cultural heritage (objects as diverse as paintings, tractors, stone tools and cameras, handicrafts;
- Documentary and digital heritage (the archives and objects deposited in libraries, including digital archives) and cinematographic heritage (movies and the ideas they convey);
- Oral traditions (stories, histories and traditions that are not written but passed from generation to generation), languages and literature;
- Festive events (festivals and carnivals and the traditions they embody), rites and beliefs (rituals, traditions and religious beliefs), music and song;
- Traditional medicine and culinary traditions; and
- Traditional sports and games[10].

This long lists begs a question: is there anything that isn't heritage or potentially heritage? And how old does heritage have to be?

THE GLOBAL LIST

UNESCO has also compiled a World Heritage list. The list encompasses 981 properties forming part of the cultural and natural heritage that the World Heritage Committee considers as having outstanding universal

value. These include 759 cultural, 193 natural and 29 mixed properties in 160 states as of September 2012[10].

According to UNESCO:

> *"Twenty-two years after the adoption of the 1972 Convention concerning the Protection of the World Cultural and Natural Heritage, the World Heritage List lacked balance in the type of inscribed properties and in the geographical areas of the world that were represented. Of the 410 properties, 304 were cultural sites and only 90 were natural and 16 mixed, while the vast majority is located in developed regions of the world, notably Europe.*
> *…*
> *By adopting the Global Strategy, the World Heritage Committee wanted to broaden the definition of World Heritage to better reflect the full spectrum of our world's cultural and natural treasures and to provide comprehensive framework and operational methodology for implementing the World Heritage Convention.*
> *This new vision goes beyond the narrow definitions of heritage and strives to recognize and protect sites that are outstanding demonstrations of human coexistence with the land as well as human interactions, cultural coexistence, spirituality and creative expression.*
>
> *Crucial to the Global Strategy are efforts to encourage countries to become States Parties to the Convention, to prepare Tentative Lists and to prepare nominations of properties from categories and regions currently not well-represented on the World Heritage List."* (UNESCO, Global Strategy, accessed October 2013)[10]

From the UNESCO quote above, it can be seen that not only is the definition of heritage expanding, but so is its global reach. Its power should not be underestimated, but what we are conserving and why, who bears the costs and who benefits should be constantly questioned.

ES

Jenny Blumhof graduated in Contemporary Studies at the University of Hertfordshire before obtaining an MA in Conservation Policy and a PGCE in secondary education from University of London Institute of Education. Nationally she was a member of the Benchmarking Panel for Earth Science, Environmental Science and Environmental Studies and advisor to the Benchmarking Panel for Geography.

In 2012 Jenny was elected Vice President of the IES in recognition of her sustained and substantial contribution to the running of the IES.

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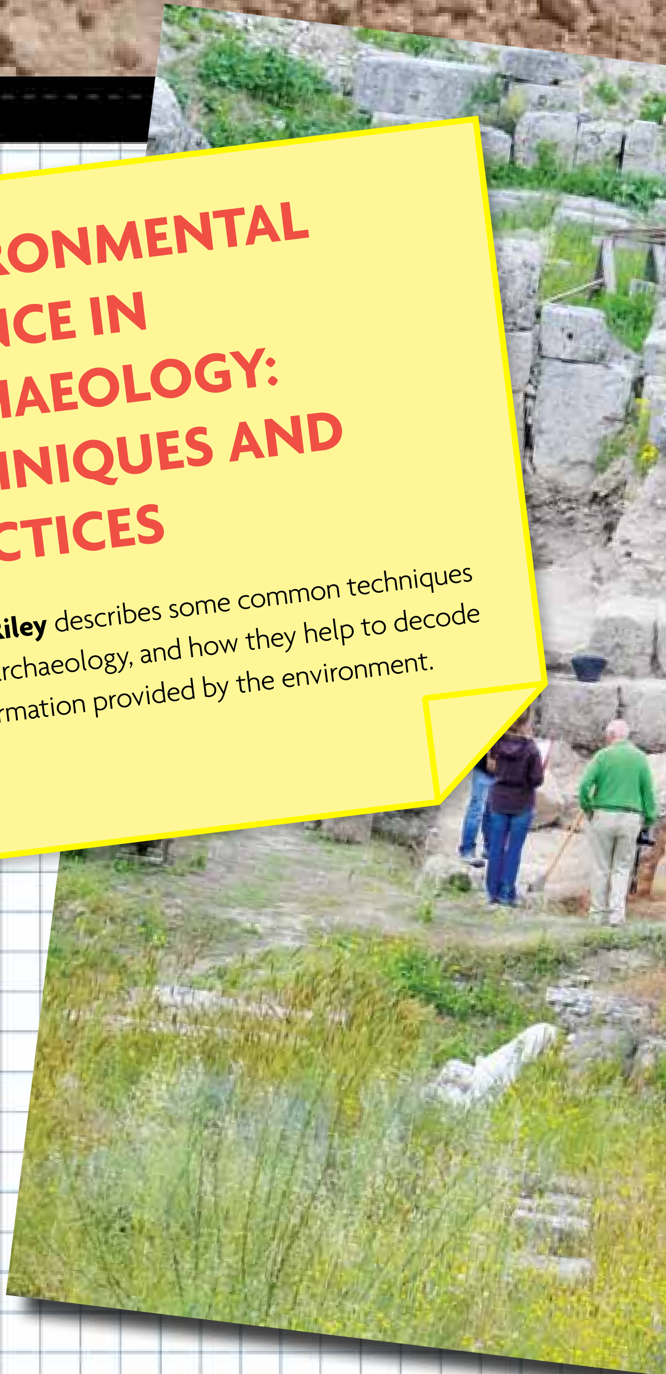
ENVIRONMENTAL SCIENCE IN ARCHAEOLOGY: TECHNIQUES AND PRACTICES

Maddy Riley describes some common techniques used in archaeology, and how they help to decode the information provided by the environment.



As scientific techniques become ever more sophisticated, the field of archaeology is changing our understanding of how the environment has changed and been changed by our interaction with it. The availability of new analytical processes has shone light on archaeological mysteries and allowed researchers to better understand how our cultural and geographical heritage has been shaped by those who have gone before us.

SITE SURVEYING

The first step in identifying a potential archaeological site is to do a site survey. There are many different ways to do this: through maps, historical documents, field walking, measuring resistivity, magnetometry, metal detection and sample excavations. Any of these methods can be used, and often several are used to understand where to excavate, as excavation is neither time nor cost effective. By looking for unusual aspects in the topography – best seen using aerial photography – it is possible to see which areas are most likely to contain settlement remains. Furthermore, unusual or thick vegetation can suggest a particularly rich soil substrate with animal or plant remains, indicating a good site to excavate, but can equally suggest the soil has been more disturbed in that area.

STRATIGRAPHY

Soil and other matter such as human debris are deposited in layers that are called 'strata'. These layers are normally only visible during excavations, and can easily be identified visually or during analysis, as strata often look different and each stratum is characterised by individual chemical and elemental compositions. This identification gives an understanding of the chronology of the study site.

In general, the further down you dig, the older the strata and objects are likely to be. If there are datable objects in a particular stratum, it is generally inferred that that stratum and all the objects it in are likely to be of a similar age. This is not always the case, as ploughing can disturb the object chronology closer to the surface. Therefore when a site has been developed the usable chronological sequence typically available from soil strata is rendered useless.

TREE-RING DATING

Tree-ring dating (dendrochronology) is a method by which the age of a tree or a piece of wood can be established by its rings. Tree rings vary in thickness due either to the increasing age of the tree or the weather during the tree's lifetime. For example, in a year with more rain than normal, a tree ring will be especially wide. The varying weather over a number of years therefore leads to a particular pattern of wide and narrow rings in all the trees in a particular area. This enables tree rings in different trees to be compared, creating a distinctive chronology of the tree rings. Therefore, any trees, as well as and logs or beams from houses, can be dated by matching their tree-ring pattern to the chronology.
Tree ring data also provide a greater understanding of the historic weather conditions in the area where the tree grew.

3D SCANNING

Photographing surfaces to create 3D detailed images of objects and sites allows the study of the minute details undetectable to the human eye. Sophisticated computing software allows detailed analysis of particular features of objects or sites. For example, using different lighting techniques and angles on ancient texts can allow the detection of writing that is invisible to the naked eye, including that which has been erased or lost because of weathering to the material.

Scanning Electron Microscopy (SEM) allows much higher levels of magnification than traditional microscopy and is used for high resolution study of the surface of artefacts.

ISOTOPIC ANALYSIS

Isotopic analysis is used to determine the precise proportion of different elements and their isotopes in an object. This is done because organisms from different geographic areas are made up of slightly different proportions of elements. Therefore, depending on the accuracy and precision of the instruments used for measurement, it is sometimes possible to provenance a material. By knowing the type and provenance of a material, it is possible to begin to understand the journey it has gone through, for example whether it is found near its origin, or whether it has been carried a long way. This can provide useful information on the movements of populations and occasionally provide insight into therelative cultural importance of different materials.

RADIOACTIVE CARBON DATING

Radioactive dating is a process that enables the approximate age of organic materials (such as wood, leather or bone) to be identified using measurements of its carbon isotopes. Isotopes are different forms of the same element, and the difference lies in the number of particles called neutrons in the nucleus. Carbon has three common isotopes that exist in known proportions to each other: carbon-12, carbon-13 and carbon-14; the first two are stable, but carbon-14 is radioactive and therefore decays at a known rate (its half-life). Once an organism dies, its regular carbon intake stops, and the amount of carbon-14 starts to decrease. The proportion of carbon-14 left in an organic material is measured, and from this its age is calculated. Carbon dating can give the age of organic materials up to about 60,000 years old.

BONE CHEMICAL ANALYSIS

By calculating the nitrogen, fluorine and uranium content in bones, their approximate age can be established. The amount of nitrogen in the protein content of bones decreases over time – a live bone contains approximately four per cent nitrogen. The speed of the decrease in the nitrogen content depends on the surrounding soil conditions (such as acidity and temperature). These properties also affect fluorine and uranium content, as buried bones absorb fluorine and uranium over time.

This technique can only ever give a very approximate age as it is so dependent on soil content and status. Therefore it is only used for relative dating, such as for the comparison of bones on the same site to establish their ages relative to each other.

STONEHENGE: ENVIRONMENTAL TECHNIQUES IN PRATICE

Stonehenge is one of the most iconic archaeological sites in the world and its purpose remains a hotly disputed mystery. It is therefore a perfect example of how newer techniques have shone light on different aspects of its history.

SITE SURVEYING

Site surveying Stonehenge is useful for visualising the site as a whole. Whilst Stonehenge was originally considered a solitary monument, by analysing its location – close to the River Avon and therefore easily accessible – and its position with respect to other sites, it has been suggested that Stonehenge is strongly linked to other sites nearby. Its proximity to the Avon means that it would be possible for people to travel to the site from greater distances and reinforces the isotopic evidence demonstrating the range of geographic origin discovered amongst the remains onsite.

For example, the nearby Durrington walls site was inhabited for around 35 years, and in this time housed approximately 4,000 people. It is possible, because of its proximity to Stonehenge, that these inhabitants were the builders of Stonehenge.

PHOTOGRAPHIC 3D RECORDS

Photographic imaging has allowed the stones to be explored from different angles and in different lighting. By modifying the images it is easier to identify unusual features and understand more about the stoneworking techniques used in their extraction and modification. For example, laser scanning led to the discovery of rock art and carvings on the stones.

The types of grooves left from working the stone give hints as to what type of tool may have been used, and how. From the imaging it seems likely that hammerstones were prominent in the shaping and polishing of the stones.

CARBON DATING

Antlers are known to have been used elsewhere as digging tools, and those found at Stonehenge were likely used for this purpose as well. Carbon dating shows that the antlers found on site vary in age. However, this does not mean that they were used at different times, simply that the deer died or shed their antlers at different times.

ISOTOPIC ANALYSIS

Isotope analysis has been used to determine the provenance of the domestic animal remains on site at Stonehenge as it can be carried out on tooth enamel using isotopes of oxygen, strontium and sulphur.

The isotopic analysis of animal remains at Stonehenge provided an additional level of mystery, as many of the

animals came from as far as Scotland. With isotopic evidence demonstrating mass-gatherings of people from across the British Isles, the theory evolved to suggest that the site held a religious significance, meaning that people flocked to Stonehenge for the summer and winter solstices. Given the age and provenance of the various animal remains it is likely that the animals were brought with groups of people visiting the site rather than as a result of regular trade at Stonehenge itself.

Analysis of sulphur isotopes was also used to disprove a prevailing theory about a nearby population called the Beaker people. Originally it was proposed that this population had travelled across Europe to reach Britain. However, sulphur isotope analysis showed that around half of the bodies analysed proved to be from people who grew up near Stonehenge, and very few who may have grown up outside Britain. **ES**

Maddy Riley is a student at the Institute of Archaeology, University College London, studying Archaeology. She aims to specialize further in the scientific aspects of archaeological discovery.

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Archaeology as part of the environment

Jim Keyte highlights the way that archaeology is integral to our surroundings.

When one mentions archaeology to a non-archaeologist, the discussion will invariably move rapidly to *Time Team*, and "that chap with the long hair". That *is* archaeology for most people, including those involved in environmental disciplines; truth be told, many archaeologists would contend that archaeology can and should fit into this neat box as well. However, as always, the reality is somewhat richer – archaeology *is* trowels, mud and old pottery, but archaeology and heritage also contribute in a wider sense to our shared environment. There is also the point that changes to that environment will affect archaeological remains, and therefore our ability to study the past and learn lessons from those who have gone before.

WHAT ACTUALLY IS ARCHAEOLOGY?

A common definition is "the study of changes to human society through its material remains", and this clearly encompasses the traditional image of archaeology, but also casts itself more widely to include almost anything you can think of: if humans have made it, then it is archaeology (or, at least, archaeology in the making). Even the landscape in which we live is archaeology – for example, the majority of the woodland clearance that has taken place since the British Isles were recolonised after the last Ice Age occurred during the Neolithic Period between 4000 and 2500 BC. And therefore many of our most valued habitats for wildlife, such as heathlands and bogs, are a direct result of this human intervention in landscape.

As well as this wider archaeological origin of our day-to-day environment, many early archaeological sites serve to highlight humans' relationship with the environment in the past. Monuments such as Stonehenge or Avebury are rather obvious examples, but good ones nevertheless. Internationally famous, Stonehenge for many people is the quintessential archaeological site: enigmatic evidence of the ability of humankind to mould nature, quarrying vast stones and transporting them many miles without the benefit or knowledge of the wheel. However, it is not the physical achievement of moving the stones that is most significant, rather it is how they were arranged that tells us more about the actual people who built Stonehenge, and their relationship with their environment.

It is well known that the stones of Stonehenge are aligned to the movements of the Sun, and this article will not attempt to discuss the many competing theories on this – the detail is less important than the overall lesson that can be drawn from the site; that the movement of the Sun is intrinsically linked to the seasons, and that the seasons had a profound importance for the population of Britain at this time. The predictability of the seasons was a vital consideration for our ancestors, as it remained until relatively recent times. The majority of the population were subsistence farmers, utterly dependant on the success of their crops; natural changes to the climate

or weather conditions could lead to failed crops one year, and often the desertion of entire settlements if conditions were unfavourable for a prolonged period.

PRESERVED OR DESTROYED BY THE CLIMATE

It is an easy step to draw comparisons between the evidence from the past for how humans were affected by climate change, and the changes currently taking place to our modern environment, with the attendant impacts upon the wider natural environment. These impacts are, rightly, high on the agenda for environmentalists throughout the world, and they also have implications for archaeology. There is a significant risk, if not a certainty, that our shared cultural heritage will be permanently affected.

Many of the world's most important archaeological sites now exist only due to having been preserved by the prevailing environmental conditions; sites such as those of Ancient Egypt are perhaps the most widely known examples. The structures, bright painted murals, and objects made from organic materials such as cloth or wood are preserved because of the arid conditions. If one considers the difference compared to sites in northern Europe where thousands of years of rain have destroyed much of the physical evidence of the past, leaving only buried pits, ditches or foundations as our principal evidence, it is easy to see how our archaeological inheritance in areas that are currently dry could be vulnerable to long-term changes in the weather conditions.

But this is only the most obvious example: the vast majority of the world's archaeological remains are buried beneath the ground. Far from being protected from environmental changes, it is the buried archaeology that is likely to experience the most widespread and rapid damage. Changes to the climate will dictate changes to existing farming practices: land currently shallow-ploughed or used as pasture may be turned over to more intensive agriculture, which results in buried archaeology being damaged by deep ploughing or more extensive root systems. Beet, grown for biofuel, is one crop that has been identified as resulting in increased damage to buried archaeology.

Archaeological remains are our main avenue for understanding human successes and failures in coexisting with and managing our environment. Archaeologists in general are not well integrated with other environmental disciplines, and our voice is currently a quiet one. This cannot continue, and it is hoped that by beginning to highlight these issues in journals such as this one, things will begin to change. And change they must – humankind has not shown itself particularly adept at learning lessons from the past and if, through inaction, we lose our shared archaeology, we may never get the chance. **ES**

Jim Keyte is a Senior Consultant at Arup's Midlands Campus. He specialises in consulting on archaeology and the historic environment, as well as environmental and social monitoring and auditing, particularly in Eastern Europe.

How heritage and archaeology fit within the EIA framework

Steve Haynes explores the issues involed in preserving archaeological assets.

Archaeology, together with other environmental disciplines, is firmly placed within the environmental impact assessment (EIA) process as defined in the Environmental Impact Directive 85/337/EEC and its amendments. Archaeology may be a standalone EIA topic but is more often considered under the wider remit of the historic environment or cultural heritage, which includes, for example, historic buildings and historic landscapes. It is from this perspective that archaeology forms part of a significantly broader understanding of the development of the landscape.

Some archaeological elements are clearly visible as earthworks, but many are buried remains. As such, archaeological assets have inevitable linkages with other environmental disciplines within the EIA process. The clearest is the relationship between archaeology and landscape and visual impact assessment, specifically in the consideration of the historic landscape where both disciplines consider it as part of their respective assessment methodologies. This brings with it the need to work collaboratively to understand the whole historic landscape from the perspective of the different disciplines.

INTEGRATED ARCHAEOLOGY

Archaeology should preferably be involved in the design process of a development from the earliest stages. This, in effect, means that archaeology influences scheme design. A mix of approaches may be used to meet the requirements of the development and the significance of the archaeological assets. Avoidance of archaeological remains is the principal aim, to ensure that these assets are not disturbed. Where this is not feasible the approaches to mitigation are detailed in Planning Policy Guidance 16: Archaeology and Planning (PPG16, 1990). On the basis that archaeological assets are fragile and non-renewable, the preferred option for mitigation is preservation *in situ* whereby the archaeological remains are preserved within or as part of the development.

Archaeological investigation and recording, which may take a variety of forms, is less popular. This approach was taken forward in Planning Policy Statement 5: Planning for the Historic Environment (PPS5, 2010) and the most current guidance National Planning Policy Framework (NPPF, 2012), Section 12, supported by the PPS5 Practice Guide. In addition, local planning authorities have policies that define their approach to archaeology areas that are of particular importance.

MITIGATION STRATEGIES

Where preservation or physical intervention are chosen, the implementation of mitigation strategies requires careful consideration and extensive consultation with project consultees. These may include the archaeological officers of the local planning authority and English Heritage if Scheduled Monuments are involved. In addition the involvement of the scheme design team and client is fundamental to the successful design and implementation of mitigation strategies.

This can be a complex undertaking. The development of mitigation options also requires consideration of other factors. This includes, for example, ecological constraints where the presence of protected species may have a significant bearing on the extent of archaeological works that can be undertaken in support of an EIA. This can include limitations on the extent of trial trenches and the exclusion of areas for ground contamination.

Mitigation strategies need a detailed baseline, provided by information in the county-based Historic Environmental Records, archive sources and, depending on project circumstances, sometimes surveys and other studies maybe used. These are used to characterise the likely archaeological assets present. It is then normal practice to undertake geophysical survey or trial trenching to provide physical information as to the nature, extent and significance of any archaeological assets. The techniques to be adopted will be driven by project-specific circumstances. The methodologies for a deeply stratified urban site, with a sequence of archaeological deposits that may span millennia, would be very different to those for a rural development or where there are deep sequences of alluvial deposits.

Other forms of data capture and prediction are also used, such as deposit modelling in urban contexts, which uses data from a number of sources to build a model of the likely depth and spatial extent of archaeological assets. On spatially extensive projects, such as roads and railways, that may cross different archaeological landscapes, predictive modelling may be used to formulate mitigation strategies. This may include remote sensing techniques such as aerial photography and LiDAR analysis.

AT A GLANCE: LIDAR ANALYSIS

LiDAR is a remote sensing method that uses a pulsed laser — generally mounted on an aircraft — to measure the distance from the aircraft to the Earth. These light pulses—combined with other data recorded by the system— generate precise, three-dimensional information about the shape of the Earth and its surface characteristics. [NOAA (2013, oceanservice.noaa.gov/facts/lidar.html)]

ARCHAEOLOGY AND CONSTRUCTION

Based on the data collected during the research and any additional studies, a programme of archaeological work will be formulated and undertaken in advance of or during construction. The design of the programme of archaeological works is detailed in a Written Scheme of Investigation (WSI), which will be based on a brief prepared by the Local Planning Authority Archaeologist, who also approve the WSI as part of the discharge of archaeological planning conditions. This programme could be phased, so that data can be collected to inform subsequent stages. Archaeological excavation in advance of construction is the most common form of archaeological mitigation.

However, in urban areas, excavation is often a closely integrated part of the site development process. The methodologies that are adopted depend on the significance of the archaeological assets found and the nature of the impacts from construction.

Preservation *in situ* requires consideration of a range of potentially conflicting issues so that the archaeological assets are integrated into the new development. The location of buildings, site piling layouts or basement design as well as their internal arrangement all need to be carefully considered.

In other instances, where earthworks are used for preservation, their implementation for landscape planning requires careful consideration. The adoption of a planting scheme that includes, for example, trees that have a deep and extensive root ball, will potentially harm the assets that are being preserved, in effect rendering the preservation ineffective.

These considerations ensure that the archaeology is actually preserved. For this, specific methodologies and monitoring are likely to be required during construction to ensure conditions under which archaeological assets survive, and that no deterioration of the assets takes place. Under certain circumstances preservation may be used to protect archaeological remains during temporary construction activities, to ensure that restoration does not result in damage to, or as a worst case, destruction of the archaeological assets on the site..

FIELDWORK LEGACY

The post-fieldwork activities are also an intrinsic part of the mitigation process and comprise a phased programme. This critically assesses the nature and significance of the findings of the fieldwork to identify that part of the excavated material that can contribute to an understanding of the archaeological assets investigated. This may be at a site-specific level as well as regionally, nationally and sometimes internationally.

Where archaeological excavation has been adapted as the mitigation method, the final product is a report detailing the findings of the fieldwork. The form of these reports depends on the nature and significance of the findings as well as the expected audience. Academic reports provide the principal method of communicating project results to a technical audience and contribute to academic research, whilst those aimed at a popular audience provide the findings in a readily understandable format. Other media, and in particular the internet, are increasingly common for the public and academic dissemination of the results of archaeological projects. A project archive of the data collected during the fieldwork is a critical element of the outputs from archaeological fieldwork. This archive forms the primary material that researchers will use for future studies based the data collected.

The preservation *in situ* or the excavation of archaeological assets can provide a positive contribution to a new development. They provide a linkage to former uses of the site and enable the public to be better informed about and therefore value their local environment.

ES

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Steve is a Chartered Environmentalist, and a member of the Institute for Archaeologists and the Association for Project Management.

FEATURE

National Character Areas: an integrated framework

Chris Mayes and **Jeremy Lake** describe how the NCAs are using the past to help the understanding, analysis and management of the environment.

"*[England] has a flavour of its own. Moreover it is continuous, it stretches into the future and the past, there is something that persists, as in a living creature.*" George Orwell, 1941[1]

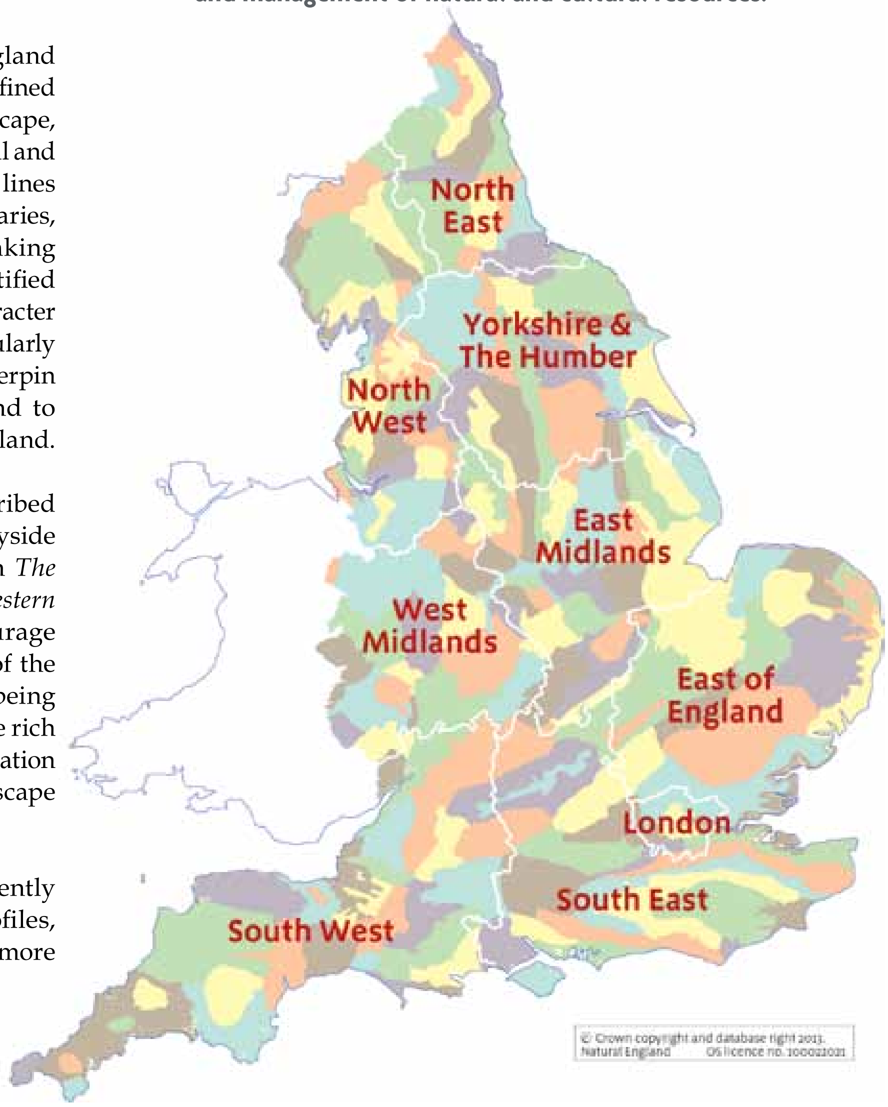
THE NATIONAL CHARACTER AREA FRAMEWORK

National Character Areas[2] (NCAs) divide England into 159 distinct areas (see **Figure 1**). Each is defined by a unique combination of past and present landscape, biodiversity and geodiversity, and historical, cultural and economic activity. Their boundaries follow natural lines in the landscape rather than administrative boundaries, making them a powerful, integrated decision-making framework for the environment. Originally identified and published in the late 1990s as Countryside Character Areas, the framework has been widely used, particularly by the landscape sector, as baseline evidence to underpin management decisions affecting landscape and to monitor change in the landscape character of England.

These distinct areas were first mapped and described through the Countryside Commission's Countryside Character Initiative using a method piloted in *The New Map of England: a Celebration of the South Western Landscape* (1994). The approach aimed to encourage greater understanding and active management of the whole countryside as well as areas designated as being of national importance. This work highlighted the rich diversity of England's landscapes, laying the foundation for a character-based approach to national landscape conservation and enhancement.

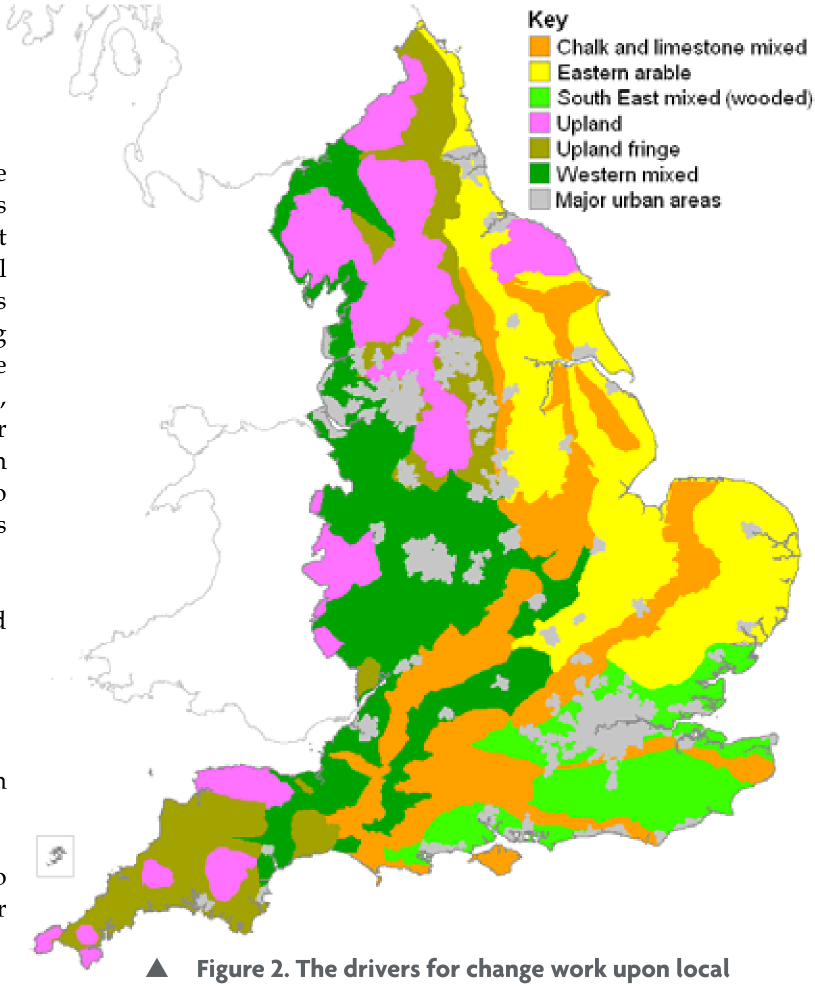
The Character Area descriptions were subsequently matched to English Nature's Natural Area[3] profiles, signalling a growing awareness of the need for a more

▼ **Figure 1. England's National Character Areas define and describe 159 distinct landscapes, providing a spatial framework that informs our understanding and management of natural and cultural resources.**



integrated approach to managing and enhancing the environment as a whole. A historical dimension was added by English Heritage and the resultant Joint Character Areas (JCAs) began the process of full integration and comprehensive application. It was the use of the JCAs as a framework for monitoring landscape change that first identified the need to update the descriptions into more comprehensive profiles, and the vesting of Natural England in 2006 together with the UK becoming a signatory to the European Landscape Convention (ELC) provided the impetus to begin developing the JCAs into the NCA profiles. This process sought to:

- encapsulate the character assessment and trend analysis already undertaken;
- integrate the principles of the ELC[4];
- incorporate the aims of the UK Geodiversity Action Plan[5];
- introduce an ecosystem services approach[6] to assessing assets and resources; and help to deliver positive change at a local and national level.



▲ **Figure 2. The drivers for change work upon local and historically - conditioned variations in landscape character. This map shows the five Agricultural Landscape Types into which the National Character Areas have been grouped by Natural England and Defra, in order to scope the options for future change and measure the effectiveness of agri-environment schemes.**

NATIONAL CHARACTER AREA PROFILES

In June 2011, Natural England was commissioned by Defra to deliver two landscape commitments in the Natural Environment White Paper (2011)[7]: to update and improve the consistency of the NCA profiles and integrate information on the ecosystem goods and services they provide, and to work with local communities in a number of areas throughout England

AT A GLANCE: AGRICULTURAL LANDSCAPE TYPES

All these areas reflect broad differences in terms of soil type, farming practice and other fundamental historic distinctions that extend into the medieval period and beyond. In summary:

- **Chalk and Limestone Mixed**. Some of the largest holdings and estates in Europe have developed on the free-draining alkaline soils and chalk or limestone geology of these plateau landscapes, and large-scale arable farming is likely to expand in the future.
- **Eastern Arable**. Large corn-producing farms developed across these areas from the 18th century, transforming earlier landscapes, and it is expected that the land area (now 80per cent) devoted to crops will intensify in the future.
- **South East Mixed**. It is predicted that this agriculturally diverse area will witness the expansion and intensification of arable production, in tandem with the growth of hobby farms and other smallholdings (already 19per cent of all holdings) which are concentrated in surviving wood pasture and heathland.
- **Western Mixed**. This developed as an area of mixed farming, where there is a trend towards larger farms which are involved in arable production in combination with sheep and beef, rather than dairying.
- **Uplands and Upland Fringe**. These areas retain the highest proportion of surviving traditional farmsteads within landscapes that retain exceptionally clear evidence for land use and settlement dating from the medieval period and earlier. Grassland for stock rearing is now the dominant land use and many upland farmers are now more economically disadvantaged for modern farming than other parts of England, and increasingly dependant on diversification and other sources of income. These areas, especially within National Parks, have seen a high uptake of agri-environment scheme grants for the maintenance and conservation repair of traditional farm buildings.

to support local engagement in landscape planning. Using landscape as the framework to integrate social, environmental, economic and cultural factors, the new NCA profiles are guidance documents that will help to achieve a more sustainable future for people, places and natural and cultural resources, protecting and building on the diverse and distinctive landscapes of England.

At the heart of the NCA profiles, amongst many other environmental themes, is an enhanced understanding and analysis of how landscapes have evolved, the drivers of those changes, and the current sense of history that people associate with landscapes, making them fundamental contributors to human identity and wellbeing. While each NCA can be seen as a distinct cultural landscape – the product of natural processes and human activities – all are dynamic, constantly interacting and offering "both high heritage values and (relatively) stable ecosystem functions"[8]. The intention is a spatial understanding of the historical elements in the environment, rather than presenting the 'historic environment' as if it were separate from ecology, geodiversity, land use and settlement, and other aspects of the landscape (see **Figure 2**).

Through a synthesis of a wide range of evidence about the natural environment (including historical land use and settlement, the most recent climate change implications and the influences of current human and natural processes) Statements of Environmental Opportunity are presented that indicate the potential actions that are most likely to achieve sustainable benefits for current and future generations.

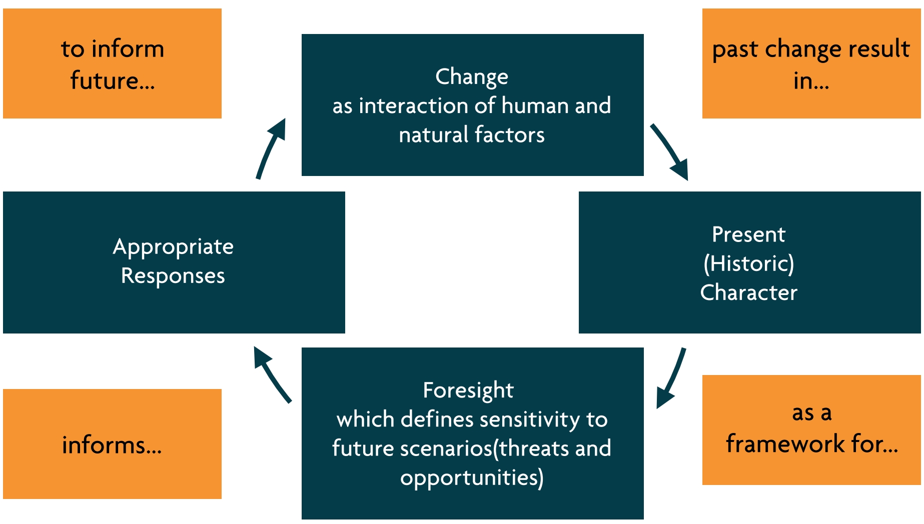
CHARACTERISATION FOR ASSESSMENT AND ANALYSIS

The process of holistically assessing and analysing the landscape has many strands and points of origin. By the 1970s various thinkers – one of the foremost in the UK being Nan Fairbrother[10] – were voicing the need to address the totality of landscape character and change. The need for more multi-disciplinary approaches, including the critical contribution of archaeologists to the debate on past and future change, was heightened by the development of agri-environment schemes across Europe, some of which, such as the Environmentally Sensitive Areas introduced across the United Kingdom in 1986, began to use landscape (through landscape character assessment) as a framework for directing funds towards conserving landscape, wildlife and historical features.

Those involved in managing and protecting the historic environment were also highlighting the need for more integrated and proactive means of gathering evidence about change, for example through the thematic surveys of a range of archaeological sites and historic buildings[10]. Others working at a large scale stressed that conservation priorities could not be plucked out of their social, economic and environmental context[11]. Ecological research was also stressing the positive contribution that species-rich landscapes can play in agricultural production and the importance of a whole range of anthropogenic processes to nature conservation, while acknowledging that approaches to sustainable food production must be forward-looking[12].

For English Heritage and its partners, the idea of identifying further 'special landscapes' had by the early

▼ **Figure 3. Rather than seeing the present landscape as fixed in time, a historical perspective can enable the present landscape, and local character, to be understood as the result of past change and the framework for identifying their sensitivity to future scenarios for change.**



1990s been jettisoned in favour of creating and using top-down tools for informing change at a strategic scale above that of individual sites and designated areas[13].

Foremost among these is Historic Landscape Characterisation (HLC), which has been implemented by English Heritage with its county and local partners and now nears completion. It has used the techniques of geographical information systems (GIS) mapping to plot change over time in the landscape, through the analysis and identification of field patterns and other elements, and the identification of distinct historic landscape types, such as woodland, fields and rough ground (the latter including moorland and heathland). This is now informing a broad range of conservation and enhancement strategies, strategic land-use planning and similar initiatives[14].

The idea of working through the concept of the cultural landscape is now well-established, notably in the ELC's definition of landscape as "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors"[15]. Landscapes are thus cultural both in terms of reflecting millennia of human activity and development and also in providing a framework for individual and collective perceptions that shift as our understanding of those landscapes develops.

The commitments embodied in the ELC were already being implemented as a result of the UK Government's Rural White Paper (2000), which highlighted the need for a better understanding of the state of the countryside, how it was being transformed and how it mattered to people. It stressed the need for future monitoring and made a commitment to publish an indicator of change in countryside quality that would take account of biodiversity, tranquillity, heritage, and overall landscape character. In response the Countryside Agency's Countryside Quality Counts (CQC) project, with expert input from Nottingham University, constructed an indicator of change in countryside quality using the JCAs as a spatial framework for reporting change over the period 1990–2003, the characterisation forming the basis for analysis[16].

The 1990–1998 analysis for CQC was based on an assessment of change in the countryside relative to the descriptions written for the JCAs. A subsequent pilot project, carried out across Hampshire in January 2004, demonstrated that it was possible to go beyond a single 'historical features' topic heading as used in the 1990–1998 analysis. As a result the historical dimension for the second round of CQC analysis (1998–2003) was developed for all the profile themes, using HLC and other data throughout, in much the same way that the issue of biodiversity runs through them.

APPLICATIONS

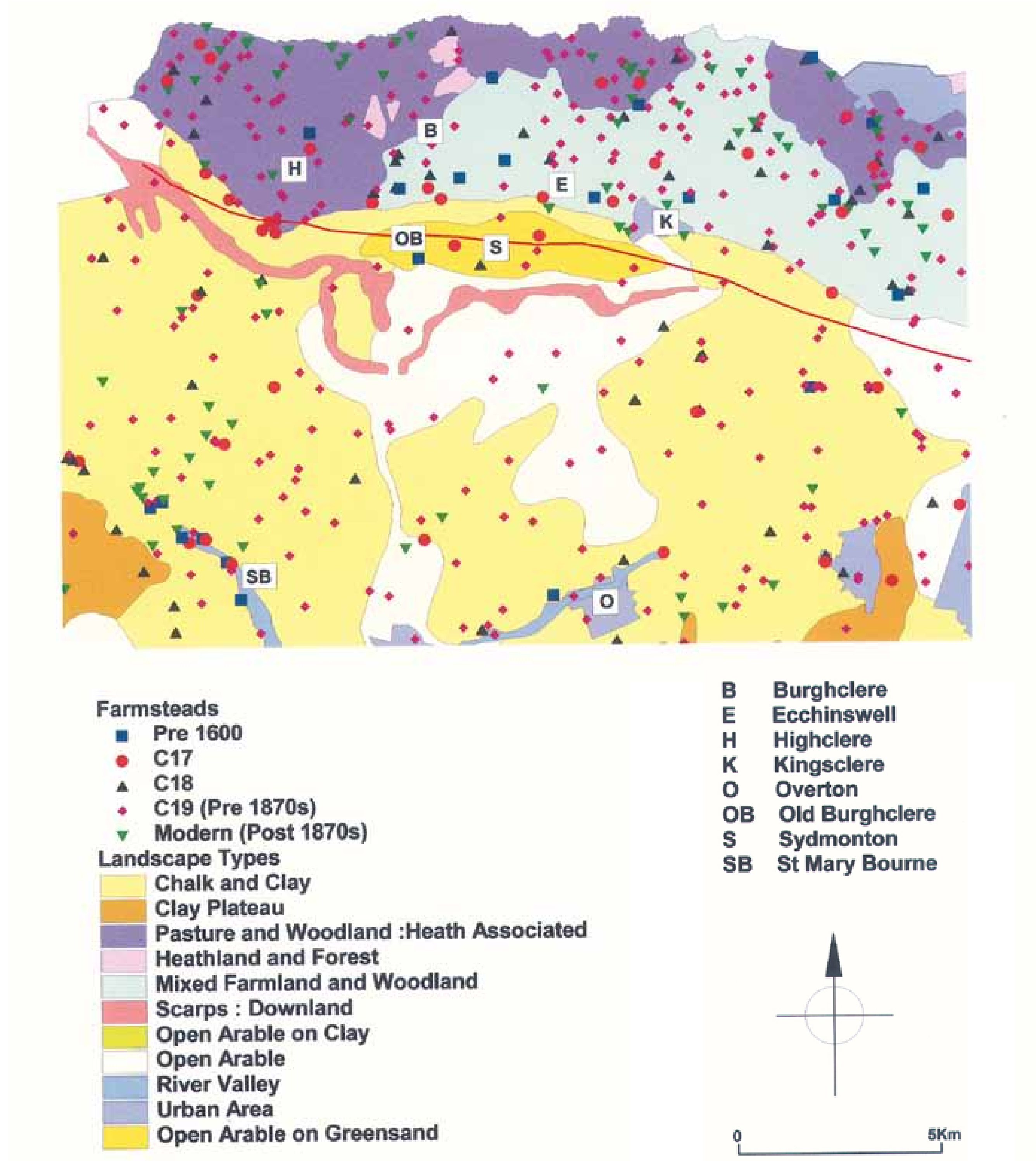
This process of historic characterisation, already used for CQC and being used to inform the NCA profiles, provides a context for further mapping and analysis of heritage features, such as ancient monuments and historic farmsteads[17], and the time-depth of modern settlement as mapped by the modern Rural–Urban Classification developed by the government18. Much of this work is using the NCAs as a framework for developing guidance for the identification and management of patterns of fields, farmsteads and settlement, for example through illustrated Farmstead and Landscape Statements (which will be completed by the end of 2014), analysis of the survival of parkland, and the Fieldscapes of England project, which is using GIS-based analysis to characterise and assess the complexity and extent of fieldscapes in the English landscape. It is also, critically, enabling us to take a strategic and long-term view of the drivers for change, and the extent to which these reinforce or diverge from patterns of land use that have shaped the present landscape.

CHALK AND CLAY

For example, an analysis of the historic character and survival of traditional farmsteads across an area of southern England has revealed profound differences between the development of the large-scale courtyard farmsteads and arable fields of the downlands and the high densities of small-scale courtyard farmsteads, distinctive dispersed layouts and pre-17th century buildings in wood pasture areas such as the High Weald and parts of the Thames Basin Heaths (see **Figure 3).**

The NCAs highlight distinctions between the chalk downlands and the clay lowlands that reflect the result of medieval and earlier land management. Downland fields and farms are large, reflecting the piecemeal and planned enclosure of farmland and downland from the medieval period. Chalkland farms commonly exceeded 200 ha by the early 19th century, whereas farms on the clay lowlands developed within a more intimate landscape of medieval enclosed farmland and were smaller, commonly 20–40 ha and occasionally less than 5 ha. The occupants of the smallest farms were sustained by the availability of other employment such as coppicing, carting or brick-making. This supplemented a more mixed agricultural economy than that found on the chalk with, for example, pockets of dairying, although easy access to major markets did support a similar, albeit smaller-scale, arable-based system[19].

The Hampshire Downs comprise one of a series of NCAs which have been grouped together as the same Chalk and Limestone Agricultural Landscape Type (see **Figure 2**) [20]. Large holdings and estates, often more than 2,000 ha in size, developed on the free-draining alkaline soils and chalk or limestone geology of these plateau landscapes.



▲ **Figure 4. The dating of farmsteads using listed-building data shows that farmsteads retaining buildings from before 1600 are concentrated in areas of predominantly dispersed settlement that were anciently enclosed, in particular the High Weald and Low Weald, but also in the other wood–pasture landscapes of the south-east of England. This map demonstrates how the boundary (shown as a red line) between the Hampshire Downs to the south, including the white open arable areas characterised by late 18th and 19th enclosure with straight thorn hedges and few farmsteads, and the wood pasture and heathland landscapes of the Thames Basin Heaths to its north. This map is based on Ordnance Survey material with the permission of Ordnance Survey on behalf of the Controller of Her Majesty's Stationery Office © Crown Copyright 2013, 100019238.**

The importance of arable farming has fluctuated in these areas, grassland becoming more significant in the 1880–1940 period and arable farming sharply increasing in the second half of the 20th century, and expected to further intensify in future. CQC data indicates that between 1999 and 2003 there was a continuing loss of permanent and rough grassland, and a decline in mixed farming, in all of these areas. **Figure 5** shows the distribution of scheduled ancient monuments under threat from arable activity. In 2012 nearly 39 per cent of those on the 'at risk' register were directly threatened by cultivation and a further 5.4 per cent by arable clipping (where cultivation is gradually encroaching upon the monument).

Natural England's analysis of trend data for the NCAs shows a clear shift to agricultural contractors in these landscapes with (as recently noted in Dorset Downs and Cranborne Chase) a decline in agricultural workers and increase in farm managers. Large-scale courtyard farmsteads and large fields show that large wheat-producing farms developed from the 15th to 17th centuries in parts of the southern downs and the Cotswolds, but not until the late 18th and early 19th century in the Lincolnshire and Yorkshire Wolds. Two-thirds of the area is taken up by arable farms, which together with those in the Eastern Arable ALC include some of the most specialised and largest farms in Europe.

VULNERABLE MONUMENTS

Evident from the map of protected ancient monuments vulnerable to arable ploughing and clipping are the high risks that such practices bring to heritage features in the landscape. The NCAs classified as Eastern Arable, where arable agriculture has intensified over the last 200 years, have also sustained the development of increasingly large-scale arable enterprises, but also evident from the map are other areas where high numbers of medium-risk monuments are in declining condition. Particularly clear in the north-west are the Solway Plain and Eden Valley, where there has been a 30 per cent increase in arable farming since 2000. Another notable area, in an NCA, is the central saddle of the Cornish Killas where large-scale estate farms, which have shaped much of the historic character of the landscape, provide the framework for increased risk through arable ploughing.

CONCLUSION

The NCA profiles assist an understanding of how landscapes have evolved and, together, they provide a national spatial framework for considering the options for influencing and responding to future change. For example, it is now widely predicted that the future development of farming landscapes will reflect both the aspiration to align UK agriculture with world markets and reduce carbon emissions through biomass and energy crops alongside the desire to conserve and enhance those of the most highly valued landscapes that are better suited to smaller-scale, diverse and high-value production.

This understanding is deepened by the parallel process of historic characterisation, so that the options for future change can at least be knowingly considered on the basis of understanding whether the trajectory for future change will be consistent with or divergent from the patterns of land use that have created and change our diversity of landscapes. Arable intensification in landscapes where large-scale farms have developed will demand a more flexible approach to the location of new boundaries, banks and buffer strips, aimed at restoring biodiversity and mitigating soil loss and cross-land water flow. This will need to be achieved in ways that work 'with the grain' of historic field patterns and that are also functionally consistent with the requirements of modern agriculture. The effects of plough damage on sites of national and international significance need to be mitigated where possible and desirable, but there will also be opportunities to reveal the historic development of pre-medieval landscapes stripped bare by the plough. New landscapes will therefore be created, along with an adjustment in people's perceptions of their value. As agricultural historian Joan Thirsk has observed, in an overview of her well-known mapping of agricultural regions, that the value of such a generalised and high-level approach "lies in clarifying the direction of large changes, and encouraging further investigation of the small ones"[21]. ES

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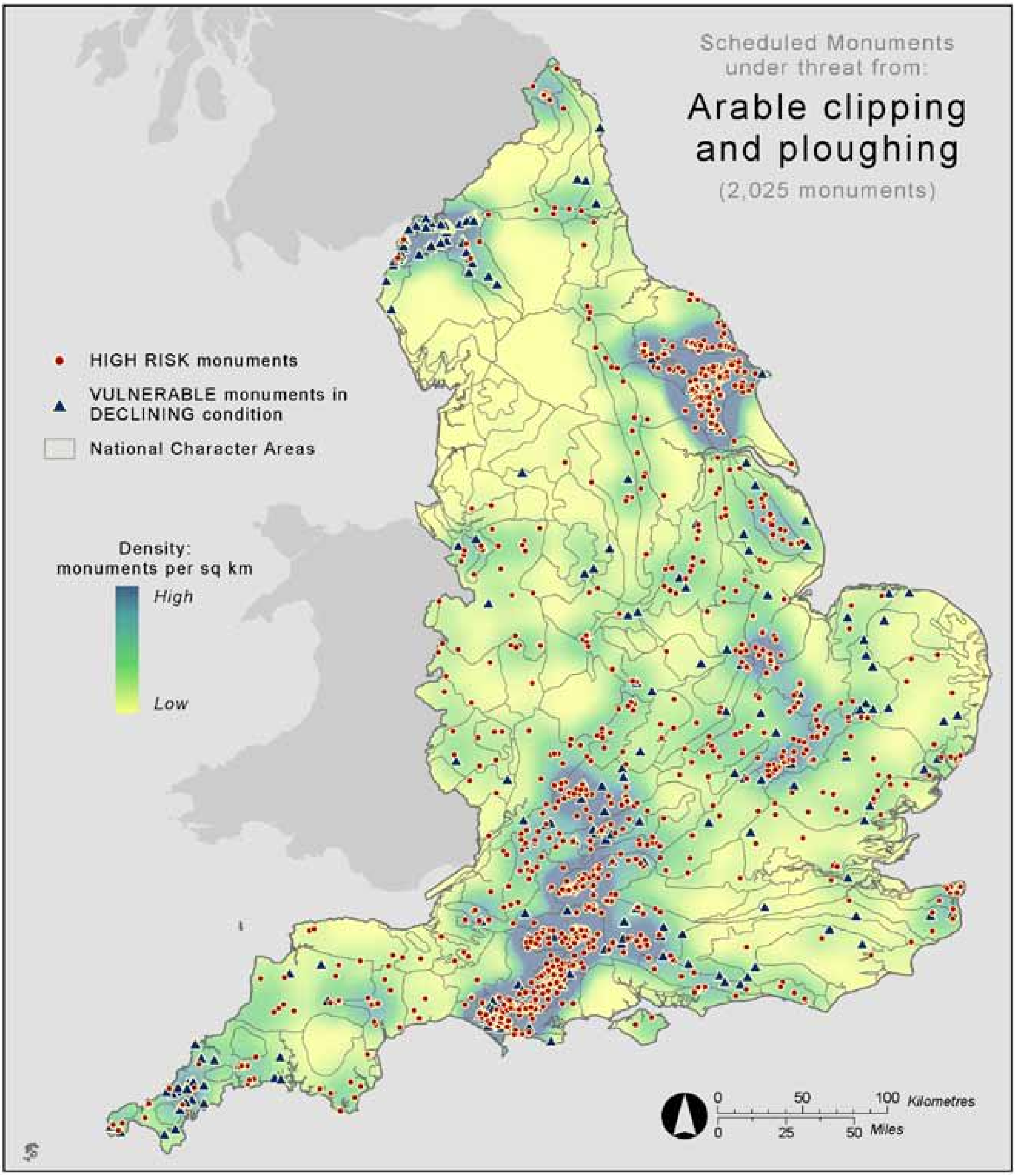
Jeremy Lake is the Historic Environment Intelligence Analyst for Resource and Landscape Exploitation across England, with long experience in vernacular architecture, archaeology and historic environment research, both with the National Trust and in private practice. Since 1988 he has worked with English Heritage, and plays the lead role in contributing to Natural England's revision of the National Character Areas. He has published extensively on a range of subjects, from chapels and military sites to farmsteads and rural settlement. He serves on the Methodist Church Listed Buildings Advisory Group and the committee of the Historic Farm Buildings Group, the Society for Landscape Studies and the Medieval Settlement and Research Group.



▲ **Figure 5. Evident from the map of protected ancient monuments vulnerable to plough damage (11.5 per cent of those at risk) are the high risks that such practices bring to heritage features in the landscape, particularly in areas subject to more intense arable cropping and continuing loss of permanent and rough grassland. Natural England's analysis of trend data for the NCAs shows a clear shift to agricultural contractors in the Chalk and Limestone landscapes (see Figure 2) with (as recently noted in the Dorset Downs and Cranborne Chase NCA) a decline in agricultural workers and increase in farm managers. The NCAs classified as Eastern Arable, where arable agriculture has intensified over the last 200 years, have also sustained the development of increasingly large-scale arable enterprises. Also evident from the map are other areas where high numbers of medium-risk monuments are in declining condition. Particularly clear in the north-west are the Solway Basin and Eden Valley, where there has been a 30 per cent increase in arable farming since 2000.**

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17. Now completed for Hampshire, Sussex, Kent, the West Midlands (Herefordshire, Worcestershire, Shropshire, Staffordshire and Warwickshire), the North Pennines, the Derbyshire Peak District and Wiltshire. Underway in Lincolnshire and other priority areas at the time of writing. Mapping the historic character and use of all traditional farmsteads is finding strong local variations in survival and is returning similar figures for the proportion of surviving sites in agricultural use (around one - third) and the difficulty of finding commercial uses for them (around 10per cent). Upland NCAs retain the highest proportion of traditional farmsteads and buildings still in agricultural use, but in all areas there is a high incidence of home-based businesses associated with the residential use (sometimes entailing the conversion of agricultural buildings to domestic use) of farmsteads (see for example www.english-heritage.org.uk/wmidlandsfarmsteads for a study of nearly 30,000 farmsteads across the West Midlands).
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CASE STUDY

Learning from our ancestors: the challenges of climate change and water management in the Peruvian Andes

Robert Early explains how the extraordinarily successful Andean agricultural systems can be used today.

The populations that live in the Andean highlands today face huge challenges, as did their pre-Inca and Inca ancestors. The threat of climate change looms ever larger, and the Intergovernmental Panel on Climate Change (IPCC) has recently brought to the world's attention the significance of tropical glaciers as key indicators of recent climate change, due in large to their particular sensitivity to temperature change. The tropical Andes host 99 per cent of all tropical glaciers in the world, most of them in Peru.

The expected effects of climate change on both the water cycle and agricultural production in the Andes will become increasingly problematic for glacierised mountain catchments, and a response is now needed by the international scientific community to mitigate the local, national and international risk of significant water shortages. In Peru, unexpectedly, experts are becoming increasingly interested in the ancient technologies of their ancestors and have begun to contemplate the rehabilitation, on a massive scale, of Inca terraces and irrigation systems.


Rehabilitated irrigation canal © Cusichaca Trust

▼ Irrigation canal restoration © Cusichaca Trust

APPLIED ARCHAEOLOGY

The Cusichaca Trust, founded and led by Dr Ann Kendall, is a rural development NGO that has operated in Peru for four decades. The Trust has combined detailed archaeological and environmental investigations focused on the agricultural infrastructure of the Incas and their predecessors. Initial archaeological research was carried out in the Cusichaca and Huallancay side-valleys of the Urbamba Valley in Cuzco, and over the last 25 years the archaeological data collected has been applied and fed back into rural development programmes in the Cuzco, Apurímac and Ayacucho Regions. These programmes have been incredibly successful and it is estimated that 30 km of canals and 600 ha of terracing have been restored to full productivity for the benefit of the local communities. This applied archaeological approach is now being recognised more widely as a way of solving contemporary problems.

THE LOST ART AND SCIENCE OF TERRACING

Tourists visiting the Sacred Valley of the Incas and the World Heritage Site of Machu Picchu will be familiar with the impressive staircases of terraces that can be viewed throughout the valley and beyond. These 500-year-old Inca agricultural systems are a common feature of the Andean landscape that was much more intensively utilised in the past than it is today. Although some of these systems, particularly those associated with Inca cities and fortresses, had a monumental or defensive aspect, the majority were constructed to prevent soil erosion and to extend the area of land available for cultivation.

However, most of these terrace systems were abandoned after the Spanish conquest: some were sporadically farmed by privately owned estates, but poor investment, resulting in depopulation, brought about a major decline in traditional agricultural practices and the techniques of terrace construction, maintenance and management. Local indigenous farmers had neither the time nor the inclination to maintain the agricultural infrastructure of land they no longer owned.

▲ Rebuilding an irrigation canal © Cusichaca Trust

The Peruvian government implemented a series of agrarian reforms in the 1960s and 1970s, and as a result large tracts of land were returned from the estates to local indigenous communities. The impact of these reforms was very slow, and a majority of communities continued to operate a system of subsistence agriculture.

In the Cusichaca valley, initial attempts by local communities to reuse Inca irrigation systems relied on modern materials (such as cement, which was both unsuitable and costly) and systems of farming using modern techniques and machinery that were inefficient and unsustainable within such extreme environments. It was clear to the Cusichaca Trust that there was a need to understand more fully the agricultural processes and techniques of the Inca. Thus the Trust's archaeological and agricultural research began, and for over 35 years has informed capacity-building programmes that share ancient technological knowledge with current Andean communities.

TERRACING AND IRRIGATION

Archaeological excavation and architectural studies provide evidence that terrace systems were carefully constructed and engineered, and were linked to vast and complex irrigation systems. These were fed from corries (moraine-dammed lakes at high altitude) or purposely constructed reservoirs known as *cochas*. Rain and glacial meltwater were sometimes diverted into natural underground caverns known as *almunas*, from where they emerged once more along Andean hillsides as springs that were used to provide domestic water and irrigate terrace systems.

Research conducted by Ann Kendall has shown that these terrace systems had evolved over thousands of years from the pre-Inca period to mitigate against the risk of variable precipitation, frosts and hailstorms that damaged agricultural production and food security. Archaeological excavation and environmental analysis show that by the Inca period, terrace systems were often sophisticated, with double-faced stone walls and stone fill for drainage. Furthermore, their engineering paid particular attention to the need to retain water to encourage microbiological activity that in turn increased the nutrients in the soil, enabling continuous cultivation. Terrace systems also controlled or at least slowed the movement of water, which raised the temperature of the terrace soils, and thus reduced climatic risk.

The success of these systems enabled a healthy agricultural surplus. Estimates of the likely Inca population in the Cusichaca valley compared with the area of cultivated land suggest that about 95 per cent of agricultural production could have been exported, compared to next-to-no surplus produced in the 1970s.

Over the last three decades, our understanding of ancient agricultural technology has been complemented by intensive studies of the Andean historic environment led by the researcher Dr Alex Chepstow-Lusty of the French Institute of Andean Studies in Lima, Peru. Chepstow-Lusty's work began in collaboration with the Cusichaca Trust, when a dried lake was identified at Marcacocha in the Patacancha valley. A pollen core through the lake sediment provided well-dated and continuous vegetation records of Inca and pre-Inca remains over the last 4,000 years. Records suggest a major climate transition around AD 1070, with a marked shift towards higher temperatures. It is now thought that climatic change provided the impetus for the Inca to build terraces for growing crops at altitudes previously too cold to support agriculture. Meltwater was also available for irrigation at these altitudes. Chepstow-Lusty has suggested that the Inca focused their economy around food production, and that this may have been necessary in a region where droughts had destroyed the earlier Wari civilization. Greater long-term food security and an agricultural surplus provided the ability to support an ever-growing population.

BRINGING THE PAST INTO THE PRESENT

The Cusichaca Trust's rural development programmes have combined archaeological and environmental

research with ethnographic, anthropological and historical evidence to understand the different past and current occupation practices of farmers within their study areas. The restoration programmes have resulted in a significant increase in the percentage of production of, for example, maize, potatoes, quinoa and broad beans, all of which can be sold at local markets. In addition, commercialisation projects have helped make products cost effective.

Adopting methodologies from the past can only be useful if they are relevant to current social, economic and environmental conditions and contribute to the sustainability of future populations. It was perhaps easier working with poverty-stricken communities in the 1970s and 1980s than today's Peru, an emerging South American economy, where rural communities have rising aspirations and a desire for modernity. The Trust has worked closely with local partners, devising appropriate projects that reduce poverty and increase self-sufficiency amongst rural communities that are often isolated. Capacity-building workshops undertaken by an independent Peruvian NGO (Asociación Andina Cusichaca) set up by the Cusichaca Trust enable local

Terraces under cultivation © Cusichaca Trust

communities to share the knowledge of their ancestors, and when relevant, reuse it alongside modern practices to improve local agricultural production.

ACTION AGAINST WATER STRESS

Peru is anticipated to become the only South American nation to experience permanent water stress by 2025. The ongoing shrinkage of Andean glaciers has acted as an impetus for a national goal to design rural policies that can benefit thousands of disadvantaged rural residents, while at the same time safeguarding one of the nation's most valuable resources: water. The Peruvian government recently announced a US$35 million project to rehabilitate 300,000 ha of pre-Hispanic terracing with the support of the Inter-American Bank. To ensure the success of such an ambitious scheme, there is a need to draw on the good practice guidelines set out by the Cusichaca Trust and similarly focused NGOs. Chepstow-Lusty's research suggests the benefit of a massive reforestation project, that should run in tandem, to reintroduce native trees, such as alders, to trap moisture blowing over from the Peruvian Amazon and to slow runoff from the highland slopes.

These innovative solutions that reference the Peruvian past will need to be developed alongside modern scientific initiatives to combat the very real threat of climate change and water shortages. In most of the world, from China to North Africa, ancient agricultural terraces and irrigation systems have been abandoned. There is therefore a real potential to share applied archaeological techniques across borders and to offer creative and sustainable models for rural development in other parts of the world. **ES**

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(www.cusichaca.org)

The second World Conference on Nature and Cultures of Terraced Landscapes will be held between 19th and 22nd May 2014 in Cusco.

Air pollution and cultural heritage

Jimi Irwin assesses progress on combating the invisible attacks on our buildings and monuments.

To a medieval mason carving statues for one of our great cathedrals, it must have seemed that his work would last forever. He could not have envisaged the iconoclasm of the Reformation and even less that one day the very air itself might destroy his creations. Throughout the world we have a wonderful heritage of buildings and monuments reflecting our diversity of cultures and the skills of craftworkers over the ages. This cultural heritage incorporates many different materials including stone, metals, timber, glass, paint, bricks and mortar. Some monuments may consist essentially of one material, for example the Pentelic marble of the Parthenon while others, such as the facades of the *palazzi* along the Grand Canal in Venice, another world heritage site, use a range of materials – stone, rendering and mortar, and glass mosaics.

Not all of this heritage is vulnerable to air pollution, and often air pollution may not be the most pressing problem, but it does cause significant damage. The impacts on our cultural heritage have been well studied in a series of projects, many funded by the United Nations Economic Commission for Europe (UNECE) and the European Commission. These have examined not only the relationships between pollutant concentrations and rates of damage but also attempted to estimate the amount of material at risk and the value we place on it. This short article draws heavily on the findings[1].

MEASURING CORROSION

From initial studies of the relationship between sulphur dioxide (SO_2) concentration and the corrosion of zinc[2], the effects of a range of pollutants on building materials have been investigated. In 1985 UNECE initiated an International Cooperative Programme on Effects of Air Pollution on Materials, including Historic and Cultural Monuments (ICP on Materials). This was one of a number of effects-oriented research programmes to support the development of the Convention on Long-range Transboundary Air Pollution[3].

BOX 1: PORTLAND LIMESTONE

$$R = 4.0 + 0.0059[SO_2]Rh_{60} + 0.054\ rain\ [H^+] + 0.078\ [HNO_3]\ Rh_{60} + 0.0258PM_{10}$$

where Rh_{60} = Rh – 60 when Rh >60, otherwise 0;

rain = annual average in m;

$[H^+]$ = annual average concentration in mg l^{-1};

all other concentrations are annual averages in µg m^{-3}.

Within the programme the rates of corrosion of a range of stone and metal samples and paint coatings were investigated under a wide range of environmental conditions, climate and topography. These included both samples sheltered from, and exposed to, precipitation.

Samples were exposed for one-, two- and eight-year periods, during which pollutant concentrations were measured. Over time the programme was modified to reflect the fact that in much of Europe SO_2 was no longer the dominant pollutant, so measurements of nitric acid (HNO_3) and particulate matter (PM) were added[4]. Results from this programme have allowed derivation of equations linking rates of surface recession (R) to pollutant concentrations (see **Box 1**).

Similar studies have been carried out in Asia and Africa. These show higher corrosion rates for metals and limestone, due both to higher pollutant concentrations and climatic effects[5].

FORMULATING POLICY

Given an understanding of the relationship between pollutant concentrations and material damage, the issue then arises of how this can be used in policy formulation. But this is only one part of determining policy and, before considering how it has been addressed, it is appropriate to note two other key elements.

The first is to know what is at risk, and the second to establish the value we place on it. Ideally, given the long-range transport of pollutants, the first should be on a continental scale. But in practice, due to the difficulties and high cost of compiling detailed inventories, usually only local studies have been attempted, often on individual buildings or groups of buildings.

Unsurprisingly, many of these have been in Italy, which has the highest number of UNESCO-classified heritage sites[6]. **Table 1** summarises results from three detailed studies of facades near the Ile de la Cité in Paris, the area of Dorsoduro in Venice and the Via del Babuino in Rome. In contrast to the varied surfaces identified in these studies, many individual monuments essentially consist of only one material, for example the limestone carvings of Lincoln Cathedral or the bronze of the horses on St Mark's Basilica in Venice.

Having assessed the stock at risk, we then face the more difficult task of assessing the value we attach to it, and hence what we might be willing to pay to protect it. While the costs of maintenance, repair or replacement and related costs such as losses of revenue due to reduced visitor numbers are comparatively easy to estimate, fully valuing what our cultural heritage means to us is a difficult task. How it can be approached lies outside the scope of this paper but possible methods are well documented[1,7].

TYPES OF PROTECTION

At this point it is worth noting that protection can take many forms. One approach is moving an object into a protected environment and replacing it with a copy, as has been done with the bronze horses on St Mark's Basilica in Venice. Another is to protect the object from the atmosphere; for example recent research has suggested a breathable, water-repellent coating based on oleic acid could be used to protect York Minster from pollutants such as SO_2[8].

While European SO_2 concentrations have decreased in recent years, their legacy remains as sulphates in the stonework. As a result current air concentrations do not provide an adequate picture of cumulative exposure. This legacy effect is exemplified by trends at Lincoln Cathedral. Data for Lincoln show that, of the cumulative exposure over the last 60 years, half occurred in the first 15 years and current exposure is less than one-seventh of the maximum in the early 1960s[9].

WHAT IS TOLERABLE DAMAGE?

But in many cases the only practicable policy option is to reduce pollutant concentrations to a level where the damage is tolerable.

Dose–response functions differ for individual systems; in many natural systems there is a critical level below which effects are not observed. For effects on cultural heritage, however, this is not the case and it is necessary to define a tolerable level (K_{tol}) to assist policy formulation. Adopting such an approach acknowledges that there will be residual effects that could be reduced further, but the cost of doing so can not be justified on socioeconomic grounds.

▼ **Table 1. Areas and approximate percentages of different materials in the facades of buildings and monuments[1]**

	m^2	Limestone	Render/mortar	Paint	Brick
Paris	200,305	76	7	15	1
Venice	48,361	10	76		14
Rome	16,913	20	6	68	5

$$K_{tol} = n \times K_b$$

where K_{tol} is the tolerable corrosion rate
K_b is the 'background' corrosion rate
n is a factor based on technical and economic factors

A key challenge, therefore, in studying the impacts of air pollution on cultural heritage is determining what this tolerable level should be[10]. The current approach is to define it as a multiple of a background level.

Within the UNECE ICP on Materials it was decided to recommend the background corrosion or deterioration rate (K_b) as the lowest 10th percentile of the corrosion rates measured in the materials exposure programme[11].

Although defining a background rate as a percentile of measured rates may be regarded as simply convenient, it can be justified on the grounds that there is no implication of a safe level and that such a definition of K_b implies a continuing commitment to pollution reduction – the target acceptable value falls as pollution levels decrease. The challenge now becomes to determine a value for n.

Doing so has drawn on experience in restoration and conservation, in particular to address the questions: what is the tolerable corrosion depth before action? And what is the tolerable time between maintenance events? Even if budgets permitted, it would not be desirable to undertake work too frequently as there are other risks associated with repair and maintenance.

In this way average tolerable corrosion rates for cultural heritage materials have been determined for policy purposes[12]. These data can then be combined with the appropriate background corrosion rates to calculate a tolerable factor, n, as shown in **Table 2**. The table is illustrative and should not be interpreted as a definitive statement of policy; but, based on these calculations, overall a value of 2.5 seems appropriate. That is, a corrosion rate of 2.5 times that in a pristine location would be acceptable.

Based on the dose–response function and tolerable corrosion rate for the material of interest, it is then possible to calculate a tolerable pollutant situation. This is relatively straightforward for a single pollutant but more complex for multiple pollutants.

LIMESTONE AND SO_2

Inevitably in a short overview it is impossible to consider the full range of pollutants or materials. As a large percentage of our cultural heritage in Europe is of limestone and SO_2 has been a major pollutant, they are a reasonable choice to illustrate the issue. Using background corrosion rates and typical average and urban pollution scenarios, SO_2 concentrations for the protection of cultural heritage have been calculated[1].

This work suggests that an SO_2 concentration of 10 μgm^{-3} would protect a range of heritage materials over 80 per cent of European territory at current HNO_3 levels. This concentration is significantly lower than the annual mean of 20μgm^{-3} proposed for the protection of forests and natural vegetation but is the same as the value to protect certain lichen species[13].

This approach has been applied in recent detailed studies of the Parthenon in Athens and the facades of buildings in central Paris. Using the dose–response functions described above and pollution data for 2009–2010, recession rates of limestone were calculated for both sites. The results, 5.60 and 5.75 $\mu m\ year^{-1}$ respectively, are lower than the proposed tolerable rate of 8.0 $\mu m\ year^{-1}$ for 2020 (when n = 2.5) and also below the suggested target of 6.5 $\mu m\ year^{-1}$ for 2050 (n = 2.0)[14].

BUT WHAT OF THE FUTURE?

Both materials and pollutants may change. A recent

Table 2. Average tolerable corrosion rates for different cultural heritage materials and how they are calculated

Material	Corrosion depth before action (µm)	Tolerable time between maintenance (years)	Tolerable corrosion rate (µm year^{-1})	Background corrosion rate (µm year^{-1})	Factor, n
Limestone	100	12	8.3	3.2	2.6
Sandstone	100	12	8.3	2.8	3.0
Copper	10	20	0.5	0.25	2.8
Bronze	10	15	0.7	0.3	1.7

study, using idealised air pollution and climate data for London and Prague, has found that the 21st century seems likely to provide a less aggressive environment for stone and metals, with improvements in air quality the main driver. On the other hand, polymeric materials (plastic, paint, and rubber) may show slightly increased rates of degradation, due in part to increased oxidant concentrations but also the possibility of increased solar radiation[15].

So our medieval mason might well be surprised, and disappointed, that his work has not survived as he had hoped. But he would surely be pleased that it still means so much to us and that we continue to make efforts to protect it from the problems that we have created.

Jimi Irwin was formerly Head of Risk and Forecasting for the Environment Agency where his remit covered the application of risk principles across the range of Agency activities. Including flood risk management and environmental protection. He is a visiting professor at the University of the West of England, where his research interests include developing a more risk-based approach to air quality management and investigating social inequality in exposure to pollution. He has been a member of the IES Council since 2007 and is the portfolio lead for the environmental SCIENTIST.

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Old buildings, new energy: the restoration of Howsham Mill

Martin Phillips describes how an 18th-century building is now being used to generate electricity and facilitate environmental education.

For centuries the power of flowing water has been used to turn stones and grind corn into a form that humans and animals can consume. Where there was a significant fall of water, such as over a weir, the gravitational energy of the falling water has been turned into mechanical energy to drive the stones.

One such site is on a small island in the River Derwent in North Yorkshire near the village of Howsham. There has been a mill on this site for nearly 900 years – it is mentioned in the Domesday Book. The last incarnation was built in 1755 by Nathaniel Cholmley, the then new owner of Howsham Hall, a largely late Jacobean house. From the lawn the family could look across to the mill, and this is perhaps why he decided to build it in a grand mock Gothic style as an eye-catcher, a folly to impress their visitors. He commissioned John Carr, then an up-and-coming architect from York, to design it. It has both open and blind windows with Gothic arches; one window is the height of the building with a single mullion and ogee arch, and there are a pair of blind quatrefoil windows on each elevation. Crocketed finials adorn the dormer windows and the corners of the pyramidal slate roof. At the apex of the roof was a lead figure of Diana, the goddess of hunting. However, the granary, not seen from the house, has a purely functional design. Also, the inside of the building is brick lined rather than stone.

The mill was in use for nearly 200 years, grinding animal feed between a pair of grit stones and wheat for flour between finer French burr stones. For its last 50 years, only animal feed was processed as newer mechanical mills were producing much finer flour. Farmers brought down a few sacks of their own corn on a horse-drawn cart that had to cross the swing bridge, built to allow barges to pass down the canal that went around the weir. An Act of Parliament established navigation rights in 1702, and there was a regular trade, mainly of coal, from the West Riding of Yorkshire up to Malton, with wheat and barley on the return trip from the productive soils of the East Riding of Yorkshire.

With the coming of the railway from York to Scarborough in 1845 and a shorter journey time, navigation declined, though it became a popular river for pleasure craft. In 1935 the navigation rights were rescinded by Parliament due to conflicts between maintaining high water levels for navigation and land drainage. There was an attempt to re-open navigation in the 1980s, which lead to a protracted court case between the boating lobby and conservationists. The case went all the way to the House of Lords where the conservationists prevailed. Most of the length of the river was designated a Site of Special Scientific Interest (SSSI) and is considered one of England's best lowland rivers for wildlife.

A PROJECT IS BORN

When Dave Mann, one of the founders of the Renewable Heritage Trust (RHT), was looking for a place for his family to live, he came across the ruined mill hidden by trees and vegetation. When the mill ceased working in 1947, it quickly fell into disrepair. Today it seems strange that such an unusual, ornate building should be abandoned. A fire in the 1960s had brought down the roof, floods brought in silt and trees soon sprouted up. Dave Mann was interested in small-scale hydroelectricity generation and saw the potential for using the weir. He was told that planning permission to restore the building as a domestic house would not be granted due to flooding, but went ahead and bought the mill and the island on which it is situated anyway. He and Mo MacLeod formed the Renewable Heritage Trust in mid-2004, made over the mill to the Trust and started looking for funding for the project.

The vision was to restore the building for use as an environmental education centre and camping barn, repair the waterwheel and connect it to a generator. The old flash lock or sluice looked ideal for installing an Archimedes screw turbine running a generator. The project had lots of attributes that made it attractive to the public and, crucially, funders. First, planning permission had to be obtained, and this was not automatic as the planning officer recommended rejection, suggesting that RHT would like to keep it as a 'managed ruin'. Fortunately the Local Authority planning committee was more far-sighted and could see the potential for volunteers enjoying working in the countryside, renewable electricity and promoting the environment.

A local architect, Andrew Yeats of Ecoarc, prepared drawings, an ecological survey was done, a woodland management plan prepared, a historical review written and a budget prepared. The roofless building was still structurally sound and restoration possible. The restoration was divided into two phases: first the simpler granary and then the main part of the mill. At the same time, plans were drawn up to repair the waterwheel and its sluice gate and install the Archimedes screw turbine, which would be the first one in the UK. This form of turbine is simply a reversed Archimedes screw, used for over 2000 years to lift water, often for irrigating fields and for land drainage. The idea of using the screw as a turbine by allowing the flow of water to turn it is recent and comes from Germany. They have been shown to be efficient with a fall of 1–10 m, and importantly not to injure fish, as they can pass through.

VOLUNTEERS SWING INTO ACTION

First there was an awful lot of groundwork to be done. Ash and willow trees encroaching on the building were felled, shrubs and other vegetation removed, and lots of silt dug out. The River Derwent floods regularly and leaves behind soil that has washed off farmland. Siltation and elevated phosphate levels are the reason the SSSI is classified as being in unfavourable recovering condition. Much effort, supported by Defra and the Environment Agency, has gone into encouraging farmers in the catchment to adopt measures to reduce soil loss.

Volunteers would give up a Sunday to dig out the mud in front of the wheel, in the wheel pit, and in the mill pond and spread it thinly over parts of the island. Other bits of machinery and stones were removed from the building and the silt dug out to reveal the original flagstone floor. Ivy was removed from the walls and they were stabilised, awaiting the time when enough funds could be raised to re-build them.

The first milestone was reached in May 2006, with the installation of a working waterwheel. The paddles of the old one were twisted and damaged beyond repair, so a company in Whitby was commissioned to make and fit new spokes and paddles to the existing cast-iron shaft and install a new hydraulically operated sluice gate. Later that year the mill featured in the BBC programme *Restoration* Village hosted by Griff Rhys-Jones, and won the northern heat. Later some of the remaining money was granted to RHT. The following year an application to the Rural Enterprise Scheme, an EU-funded scheme administered by Defra, was successful and work on the granary began. That summer there was the first of what were to become regular floods; the winter of 2012–13 was the worst period, with the building flooded four times. The work was completed by the end of 2007 and provided a kitchen, meeting room and secure space to house the electrical control panels required for the turbines.

INSTALLING THE ARCHIMEDES SCREW

Access to the mill is one of the bigger challenges. The only public right of way to the island is a footpath along the river bank from the road bridge over the river, a distance of 300 m. The only other route was up the river. A pontoon was purchased, made of a series of connecting plastic blocks, strong enough to carry about 10 t. The screw arrived from the manufacturer Ritz-Atro, Nürnberg, Germany by truck, was lifted by crane onto the pontoon at the bridge and began its perilous journey upriver guided by a small electric outboard motor. Volunteers standing on the pontoon pulled on a large rope laid along the length of the river to the weir to get the pontoon to the sluice. Here a frame had been constructed with a steel beam the length of the sluice. The pontoon was parked at the end of the frame so that the 9.5 t, 5 m long and 2 m wide screw could be lifted using blocks and chains, pulled along the beam and dropped into position. The installation demonstrated what could be done with pulleys, levers and rollers, though was a complicated, slow, and at times worrying operation.

The screw drives a gearbox with belt drive to a generator mounted on it, converting the 30 rpm of the screw into 1000 rpm to generate electricity. The flow of water (up to 2 m^3 per second) through the sluice is controlled by a hydraulically operated gate that can open and close automatically if the generator is disconnected by the grid. Electricity from the screw and waterwheel are carried along a buried armoured cable to a three-phase transformer and thence to a high-voltage cable running along the road. Grid connections can be very expensive and RHT was fortunate in securing a grant to pay for it. However the trench for the high-voltage cable was largely dug by volunteers. It took until February 2010 to get connected to the grid and at last surplus electricity could be sold.

THE WATERWHEEL IS CONNECTED

Due to the problem of flooding, the plan was to run a hydraulic pump through a gearbox from the waterwheel and a hydraulically driven generator located well above flood level. This worked for about a year, but suffered a major pump failure and was unexpectedly noisy, limiting use of the building. Instead a submersible generator was attached to the gearbox. It has proved much quieter, though not entirely waterproof. In 2012, the 150-year-old cast-iron shaft sheared under the torque of the new arrangement. Replacing it was a major undertaking. It weighed over 2 t and had to be extracted horizontally from the wheel pit and then out of the building. Once again, all this was done using hand-operated pulleys and muscle power; but this was how our ancestors had fitted it in the first place. A new mild steel shaft on new bearings has replaced it.

PHASE 2 – THE GOTHIC BUILDING RESTORED

A successful application to the Heritage Lottery Fund and match funding from the Country Houses Foundation and electricity sales meant that the main mill could now be restored. A local contractor, Stephen Pickering Traditional Services Ltd, and several local subcontractors started work in June 2012. New stone to replace all the ornate sections lost from the roof level was cut and carved at a quarry in Sussex, the best match of stone both visually and geologically. As before, materials were brought to the site by traditional means, this time horse and cart and barrows. Roof beams and stone were lifted into position by muscle power and pulleys. Reclaimed bricks, lime mortar and reclaimed slates were used for the roof, and English oak was used for the roof beams, the first floor and staircase. New double-glazed windows and doors were handmade. Insulation was fitted in the roof and of course the building now has electricity. A replacement sculpture of Diana in stainless steel wire mesh was made by Nikki Taylor and placed on the apex of the roof. The mill looks much as it did when abandoned in 1947. The quality of the work is a tribute to all those involved.

ACHIEVEMENTS AND THE FUTURE

This was an ambitious project that succeeded. The building is now used as an environmental education centre promoting the wider heritage of the area. (The camping barn idea has been dropped for now.) It has saved a most unusual example of a Georgian folly for future generations to use and appreciate, without compromising the integrity of the building. It has demonstrated the viability of small-scale hydroelectricity schemes and to date has generated just over 500,000 kWh, saving more than 200 t carbon dioxide. From this first Archimedes screw turbine has emerged a successful small business installing them in the UK (Mann Power Consulting Ltd). Electricity sales will provide enough income to run the project for the foreseeable future.

The mill has a rainwater harvesting system, heats water from solar energy, heats the building through a wet underfloor system run from the hydroelectricity supplemented by a stove fuelled with wood from the island's resources. Simple compost toilets deal with biodegradable waste. The project has not been without problems – too much water, not enough water, access issues, periodic lack of funds and cash-flow problems, mechanical failure, vandalism and theft. But the enthusiasm and support of local people and funders have prevailed and the original vision for Howsham Mill has been realised.

For the future a second slightly larger screw is planned parallel to the first. This would exploit fully the hydroelectricity potential of the weir. Other uses for the building are being considered, such as corporate training, meetings and social events. What is clear is that this is an environmentally and financially sustainable project that can inform and inspire others, as surely there are many such opportunities both within the UK and globally. **ES**

Martin Phillips has been a trustee of the Renewable Heritage Trust since 2004 and has been closely involved in the mill's restoration. He has a professional background in agricultural research and giving agri-environmental advice to farmers.