Historic England

Historic Watermill Landscapes: A national overview

Magnus Alexander with Matthew Edgeworth

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HISTORIC WATERMILL LANDSCAPES: A NATIONAL OVERVIEW

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SUMMARY

Note that this report summarises the position at the end of 2017 and makes no attempt to anticipate changes in legislation or guidance.

Rather than watermill buildings themselves being the focus, this study concentrates on the water management systems that deliver water to the mill, and take it away again, in such a fashion as to allow useful work to be done, and to manage the water when it is not required. It describes the key elements of watermill landscapes, their associations and connections, and examines the factors affecting their significance. These assets include weirs, dams, sluice-gates, leats, and ponds, not to mention a broad range of secondary associations such as granaries, breweries, and bridges, and more remote interconnections defined, for example, by regional industries.

The review emphasises the importance of the interrelationships between these assets, connected as they are by the flow of water. Watermill landscapes are perhaps the embodiment of the phrase 'the whole is greater than the sum of its parts'.

The resource has been assessed by examining a range of Historic England datasets but this primarily highlighted complexities within the data making it difficult to obtain a comprehensive overview of these assets and their landscapes. As things stand, such an overview would require a fundamental reassessment of the underlying Historic England data and a comparison made with information held in local Historic Environment Records (HERs), a task beyond this project. Such a review would, however, be beneficial in understanding what might be most significant and underpin decisions relating to designation and/or management. At present such decisions are largely based upon local knowledge.

The threats and opportunities facing watermill landscapes are then discussed. These range from the global (climate change) to the local (development) to the mill building itself (reuse for micro-hydroelectricity generation). Once again this underlines their complexity and interconnectivity, but an attempt is been made to highlight areas where opportunities lie.

Options for protecting and managing these landscapes are then set out. The first step is the recognition of the landscape as an integrated system. As such HERs have a key role as they underpin both the planning system and agri-environment schemes. There are a wide range of possible approaches, but the key is sustainable management, particularly if a system is active, or if parts of a relict system could be returned to use. Potentially this would have benefits for catchment management and biodiversity. Multiple watermill landscapes have the potential to be managed together rather than as discrete entities.

Key recommendations of the project are to:

- Raise the profile of watermill landscapes
- Produce guidance underpinned by research
- Take opportunities as they arise to reconsider designations and enhance descriptions
- Enhance HERs and feed data into agri-environment schemes
- Work closely with other government agencies to ensure 'joined up thinking'
- Consider an assessment and management toolkit to enable individuals and groups to protect locally significant watermill landscapes

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ARCHIVE LOCATION

This report is based entirely upon secondary sources, there is no archive.

DATE OF RESEARCH

This project was initated in 2012 and completed in 2017.

ABBREVIATIONS

CIRIA – Construction Industry Research and Information Association

COSMIC – Conservation of Scheduled Monuments in Cultivation

DCLG – Department for Communities and Local Government

DCMS – Department of Culture Media and Sport (to June 2017)

DDCMS – Department of Digital, Culture Media and Sport (from June2017)

DECC – Department of Energy and Climate Change (closed July 2016)

DEFRA – Department of the Environment, Food and Rural Affairs

EA – Environment Agency

EH – English Heritage

ERR – Enterprise and Regulatory Reform (Act 2013)

EU – European Union

FRMP – Flood Relief Management Plan

GPA - Good Practice Advice (in Planning)

HAR – Heritage at Risk

HE – Historic England

HER – Historic Environment Record

HLF – Heritage Lottery Fund

LSG – Listing Selection Guide

MPP – Monuments Protection Programme

NE – Natural England

NHLE - National Heritage List for England

NHPP – National Heritage Protection Plan

NPPF – National Planning Policy Framework

NRHE – National Record for the Historic Environment

PPS5 – Planning Policy Statement 5 (DCMS 2010a)

PPG – PPS5 Planning for the Historic Environment: Historic Environment Planning Practice Guide (DCMS 2010b)

RBMP – River Basin Management Plan

RCHME - Royal Commission on the Historical Monuments of England

SHINE – Selected Heritage Index for Natural England

SMC – Scheduled Monument Consent

SPAB – Society for the Protection of Ancient Buildings

SSG – Scheduling Selection Guide

SuDS – Sustainable Drainage Systems

WFD – (EU) Water Framework Directive

FRONT COVER

Venn Mill, Garford, Oxfordshire from the south, 4/3/1979: a deceptively simple watermill landscape with the mill on a watercourse and a bypass channel taking the overflow (© Alan Stoyel, with permission).

The mill can be seen to the left of the road (which is reputed to be of Roman origin), with the waterwheel in the wheel-house at this end, and the mill-house to the right. The former is of about 1800 and the latter early 17th-century (both Listed Grade II) though the site is thought to be mentioned in Domesday Book. The Childrey Brook, runs from left to right and the turbulence of the outfall can just be made out in the river to the right of the bridge. A little upstream from the mill the start of the bypass channel can be seen, the water being directed into it by a weir though this is not visible. The bypass then runs under the road, around the far side of the mill-house, to re-join the brook below the mill. A typical layout for a mill in a mature river course, using a relatively low head of water.

All is not as it seems however. Sinuous dark/light lines in the field in the left foreground that align with a tree-lined ditch to the right of the road probably represent the original course of the brook, a suggestion confirmed by their coincidence with the parish boundary. Rather than a mill on a natural waterway with a bypass channel, the earlier arrangement was the opposite; the mill was on a mill race. Both the present waterways are man-made and the current bypass channel must be relatively late.

Another interesting aspect of the site's history is that a further channel once led off the main brook, between the weir and the mill, ran around the far end of the mill, passed under the road in a stone culvert, and crossed over the bypass stream by a small aqueduct. This was to supply a water meadow, and the pattern of parallel distribution channels can still be seen in the ploughed field on the right-hand side (all information above pers comm Alan Stoyel).

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1. INTRODUCTION

Before steam, the primary source of power (other than the effort of animals or people) in pre-industrial England was the waterwheel, apparently used wherever there was the knowhow and a need for more than muscle-power. Although many studies have examined the standing buildings and internal machinery of watermills, most have paid little, if any, attention to the water supply systems. In their 274 page volume on Yorkshire textile mills Giles and Goodall (1992) devote fewer than nine pages to water power and only four of these to the water supply system, and this is more than most.

In contrast this study concentrates on the wider context of watermills and the former sites of watermill, which are directly connected to the landscape through related features, such as weirs and leats, and indirectly connected to a host of other features, any of which may survive long after the mill buildings have been converted, fallen out of use, or disappeared completely. It provides an overview of these landscapes and forms an initial basis for assessing the significance of their many constituent elements and the landscape as a whole. It also provides an appraisal of the threats these assets face, and considers how they might be managed.

The context in which this work was conceived, and the period in which much of the research was undertaken, pre-date the result of the June 2016 referendum on whether to leave or remain in the European Union (EU). The government intend that the current *European Union (Withdrawal) Bill 2017-2019* will ensure that the whole body of existing EU environmental law continues to have effect. Although it is likely that changes in mechanisms for environmental management will take place, at this time the details of these in a post-Brexit landscape are not clearly defined. Therefore, this report lays out the situation at the end of 2017 and does not discuss any potential changes in policy, practice or legislation.

1.1. Background

'Historic water management assets' was a National Heritage Protection Plan (NHPP) Activity within Measure 4, 'Understanding: Assessment of Character and Significance', this category of assets having been identified as a research need during preparation of the English Heritage Strategy for Water and Wetland Heritage (Heathcote 2012). It was therefore identified as 'Being insufficiently understood, significantly threatened by change, and of potentially high significance in terms of ... heritage values' (EH 2013a, 47). The Activity was summarised thus:

> EU Directives, domestic legislation and policy (e.g. Water Framework Directive and Flood & Water Management Act 2010) as well as demand to develop micro-renewable energy sites will place increasing pressure on a range of historic water management assets (mills, pumping stations, dams, weirs, flood meadows etc). Action will focus on completion of coverage for those categories most at risk of major change and on ensuring minimal loss of significance (EH 2013a, 58).

The overall Aims for the area of research were therefore to develop:

- Detailed understanding of site characteristics and distributions
- Measures for assigning significance
- Tangible protection outcomes

1.2. Aims and Objectives

In the NHPP Activity Programme this project was outlined as a 'national contextual overview of watermills and their water supply systems: resource assessment, research and contextual overview' (EH 2013a, 58).

The Aims and Objectives of this project were therefore set out as:

Aim 1: To determine the key elements contributing to the significance of watermill landscapes.

Objective 1.1: Outline the key elements of watermill landscapes

Objective 1.2: Describe their significant characteristics

Objective 1.3: Assess their relative contributions to the significance of watermill landscapes

Aim 2: To provide an informed basis for managing change in the future.

Objective 2.1: Identify threats

Objective 2.2: Assess their potential impacts

Objective 2.3: Suggest approaches to future management

1.3. Methods

The project comprised two execution stages. As far as possible existing material, such as current databases and published sources, has been used for each of these stages.

Stage 1 was the production of an assessment of the key elements contributing to the significance of watermill landscapes (Aim 1). It consisted of the production of a definition and description of watermill landscapes, which outlined the key elements of these landscapes (Objective 1.1). For each of these key elements their significant characteristics were described (Objective 1.2) and their contribution to the significance of each asset assessed, both for the individual asset type (Objective 1.2) and watermill landscapes as a whole (Objective 1.3).

Stage 2 was a threat assessment that provided an informed basis for managing change in the future. It began with the identification threats to the assets and landscapes assessed in Stage 1 (Objective 2.2). The potential impacts of these threats were then assessed both in relation to individual asset classes and to watermill landscapes (Objective 2.2). This assessment was then used to make suggestions for future management (Objective 2.3).

The project did not attempt to compile a comprehensive listing or detailed catalogue of watermill sites. Any appraisal of the total size of the resource and the different site types represented, as well as their representation in appropriate records and databases would be a significant undertaking. It did not examine tide mills either. These are located within tidal reaches of rivers and estuaries and as such have different (or at least differently organised) associated features and face different challenges.

2. KEY ELEMENTS OF WATERMILL LANDSCAPES

Although watermills are not the focus of this report they are examined here as various factors such as their size, technology and function will impact on the surrounding landscape, determining aspects such as the amount and flow rate of water required and hence the size and length of channels required, as well as other less direct influences. In addition, although most of the examples give are associated with standing mill buildings this is simply because these examples are easier to identify in the literature and appropriate databases. Watermill landscapes are likely to survive long after the watermill itself has gone and the identification of such landscapes can serve to explain otherwise isolated features.

2.1. Watermills

A definition of a watermill might be: 'a building housing machinery powered by a wheel turned by water'. Although this includes tide mills this report will focus on watermills on inland watercourses which utilise unidirectional flows (as noted above). Watermills themselves are not the primary focus of this project, although they occupy a central place within watermill landscapes, which are defined in relation to each watermill. They housed the waterwheel, which was used to power the mill machinery, and the management of the supply of water to this wheel, particularly the creation of a working head of water, was the primary focus of the surrounding 'watermill landscape' (see 2.2 below).

Watermills may be classified on the basis of the type of waterwheel used. Horizontal wheels are the simplest and least efficient. They were also small, typically less than a metre in diameter with minimal landscape impact (Figure 1 and Figure 2), and will not be discussed in any detail. They are only known in England from excavated examples, such as at Tamworth, Staffordshire (Rahtz and Meeson 1992).

Vertical wheels sit on a horizontal shaft supported at both ends and can therefore be considerably heavier and larger than horizontal wheels; a small vertical waterwheel might measure 2.5m in diameter, 4-6m was probably typical and many larger examples are known; the famous Lady Isabella Wheel, Laxey, Isle of Man, has a diameter of over 22m. They are generally sub-divided into undershot (Figure 3), overshot (Figure 6) or breast-shot, where the water ran beneath the wheel, over it, or was delivered somewhere in between respectively. Some overshot wheels turn backwards relative to the direction of flow and are referred to as pitchback wheels.

In vertical corn mills the rotation was transferred though 90 degrees to the horizontal grindstone above by gears (Figure 3). Some industrial processes, such as fulling and forging, required vertical forces so cams projecting from the shaft of the waterwheel raised and released drop or tilt-hammers, though sometimes a secondary shaft was geared from the waterwheel (Figure 4). In some large industrial complexes the power generated by the wheel(s) was transferred by belts and shafts to drive a range of machines (Figure 5). During the 19th and 20th centuries, some wheels were replaced by turbines and used for generating electricity and a few purpose built 19th-century electricity generating mills are known.

Figure 1 – A reconstruction drawing of a horizontal mill based on an example from the Shetlands, Scotland (from John Storck and Walter Dorwin Teague, Flour for Man's Bread: A History of Milling, *illustrated by Harold Rydell (University of Minnesota Press, 1952). Copyright 1952 by the University of Minnesota, renewed 1980)*

Figure 2 – A typical horizontal mill building in the landscape, the small stream that would have driven the mill can just be made out in the shadows to the right, Shetlands, Scotland (Wayne Cocroft, with permission)

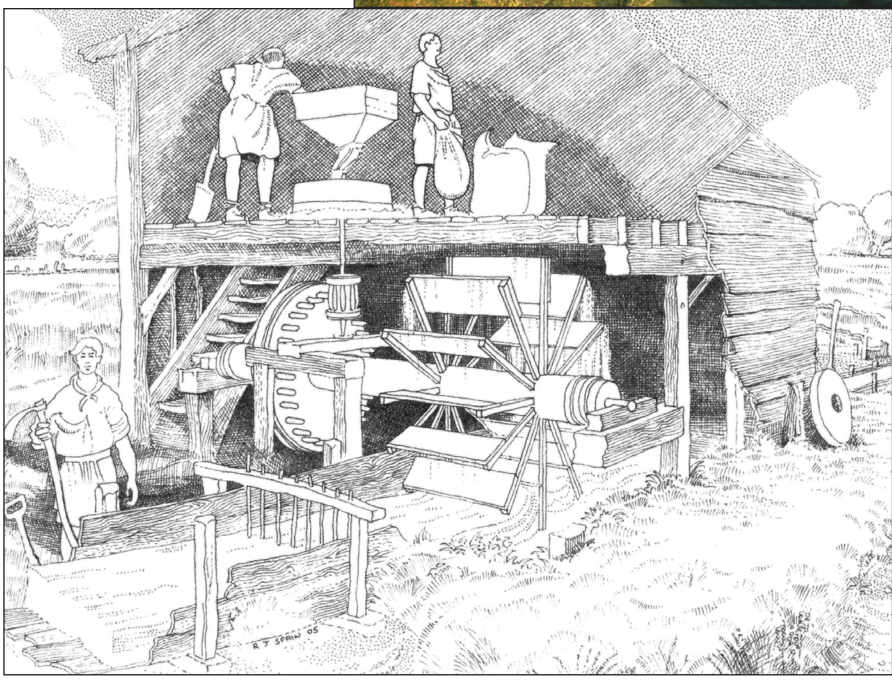

Figure 3 – A reconstruction of one of the Romano-British watermills excavated at Ickham, Kent, a small undershot waterwheel (Bennet et al 2010, 51, Fig 23 by Robert Spain © Canterbury Archaeological Trust Ltd, with permission)

Figure 4 – The stamps and waterwheel at Tolgus tin streaming works, near Redruth, Cornwall (Peter Williams © Crown Copyright. Historic England bb98_13519)

Watermills can also be categorised by the uses to which they were put, demonstrating the range of operations that water-power supported (including boring, grinding, sharpening, sawing, pounding, rolling, planning, and threshing) and the range of materials and products worked upon (such as bone, stone, ochre, grain, wood, starch, and textiles), as well as the range of end products (from pencils to dye, animal feed to mortar). Mills could also have more than one use simultaneously; in the 18th-century a mill at Wadesley Bridge, Yorkshire, was in use as a paper mill and forge and a mill at Dursley, Gloucestershire was both a corn and fulling mill (Crossley 1990, 139). The vast majority of early watermills were used to grind corn using millstones. From the 12th-century mills began to be used for industrial purposes, mainly fulling cloth, iron-working and bark-crushing. The range of industrial activities greatly expanded in the post-medieval and industrial periods. Such considerations are relevant because different types of mills utilised and impacted on the landscape in different ways, often giving rise to distinct kinds of archaeological evidence.

One point worth making here is that there is sometimes an artificial distinction drawn between agricultural and industrial processes, corn mills for example being classed as agricultural and fulling mills as industrial. Yet in the medieval period the corn mill represented the centralisation and mechanisation of what was formerly a domestic hand powered process, using querns and grindstones; they were industrial

Figure 5 – The interior of Helsington snuff mill, Cumbria; note the horizontal shaft running below the ceiling and the belts transferring power to the various machines below (Tony Perry © Crown Copyright. Historic England bb93_13871)

in all but name. For this reason, discussions of significance (see 4 below) draw on both agricultural and industrial guidelines.

The earliest watermills known in England date to the Romano-British period; though rare, examples are known from Hampshire (Cunliffe and Poole 2008) to Hadrian's Wall (Reid 1959, 5). There then appears to be a hiatus; the earliest known Anglo-Saxon mills have been dated to about AD 700. The known Romano-British wheels were all vertical, and although most early Anglo-Saxon examples were horizontal, both mills at Tamworth for example (Rahtz and Meeson 1992), one of the earliest known, at Old Windsor, Berkshire, was vertical (Wilson 1958). These very early watermills are unlikely to be revealed by anything other than excavation and are unlikely to contribute to existing landscapes, though buried deposits and features will survive and their potential presence should be borne in mind. This is though an assumption that perhaps needs to be demonstrated - the Romano-British mill at Fullerton, Hampshire may have been associated with an extant race (pers comm Hannah Fluck, HE).

Domesday Book (AD 1086) documents over 5,600 watermills, some known to have had their origins in the centuries before the Norman Conquest, some already derelict. It is uncertain if any of these mills used horizontal wheels; all known mills in medieval England were apparently powered by vertical wheels. These Domesday entries would all have been corn mills, as they were manorial assets yielding an income to the lord so economically important. Milling soke forced manorial tenants to use the lord's mill and it has been suggested that without this compulsion tenants would have continued to use hand mills and we would not have seen the development of watermills on anything like the scale recorded during the medieval period (Reid 1959, 11). Around the major conurbations corn mills developed to an industrial scale in the 18th-century, fed by corn arriving on the developing canal network (Reid 1959, 14) and later by the railways. Despite their quantity, corn mills have received relatively little archaeological attention, though there has been no shortage of studies of standing mill buildings (Crossley 1990, 139).

After corn mills, fulling mills were probably the most widespread, appearing in England in the later 12th-century (Pelham 1958, 2). There was a rapid increase in numbers during the 13th-century, some being converted from corn mills, though others were new built. It may be that the horizontally rotating shafts required to trip fulling machinery was one factor encouraging the adoption of the vertical wheel in medieval England. By 1331 numerous fulling mills were to be found in the west, along the Thames and Kennet valleys and the chalk streams of south Wiltshire and Hampshire, on the boulder clays in Essex and Sussex, and in West Yorkshire, the heart of the later industrial textile industry (Pelham 1958, 3). Worsted, Norfolk and Kersey, Suffolk both gave their names to types of cloth but the latter needed milling the former only scouring (Pelham 1958, 3); the availability of mill sites determined the type of cloth produced. The number of fulling mills grew slowly through the later 14th and 15th centuries, but in the mid-16th-century numbers began to rise rapidly once more and Tudor fulling mills formed the nuclei of many small manufacturing communities (Pelham 1958, 5). In the post-medieval period further processes became mechanised and from the late 18th-century the fulling mill began be superseded by the integrated textile mill particularly after 1833 when the invention of the rotary fulling machine effectively brought an end to traditional methods (Pelham 1958, 8, 12). Helmshore Mills' Higher Mill, Lancashire, is an exceptionally well preserved and rare late 18th-century example (pers comm John Cattell, HE). As fulling mills dropped out of use many reverted (or converted) to grinding corn (Pelham 1958, 10).

Different regional industries have used watermills as a power source over the years. The iron industry of the Weald in Sussex created a notable concentration of early industrial watermills, described by Camden in 1620:

> Full of iron mines in sundry places, where for the making and fining thereof there been furnaces in every side … To which purpose divers brookes in many places are brought to runne in one channel and sundry meadowes turned into pools and waters, that they might bee of power sufficient to drive hammer milles (quoted in Reid 1959, 5)

In addition, iron in the Forest of Dean, tin in Devon and Cornwall, lead smelting in Derbyshire (Crossley and Kiernan 1992), needle manufacturing in Warwickshire

(Rollins 1970), the Sheffield blade mills (Crossley et al 1989), and the textile mills of the Pennines (for example Giles and Goodall 1992) amongst many others all used watermills, at least in their early stages. Other industries such as paper were also significant users of watermills but were more ubiquitous. Over-generalisation is a temptation that should be resisted though; the textile industry of south-west England comprised wool, serge, flax, hemp, silk, lace, hosiery, and cotton all with distinctive distributions and histories (Williams 2013). In many areas it is hard to comprehend the intensity of early water-powered industrial activity that later moved to other areas, in part freed by the development of steam power, leaving few obvious traces behind.

The landscapes of gunpowder production have probably been examined in more depth than any other watermill based industry. Gunpowder works comprising large complexes including numerous watermills have been identified from the late 17th-century onwards (Figure 18). Those in the south-east, such as Chilworth, Surrey (Cocroft 2003) and Waltham Abbey, Essex (Cocroft 1994) principally supplied the Board of Ordnance. Elsewhere, such as the south-west and the Lake District, the gunpowder was used in the mining industry. Much of the earlier work is summarised in Cocroft 2000, but further work has taken place since this, in particular on the Lake District industry (Jecock and Dunn 2002, Hunt and Goodall 2002, Jecock et al 2003, Dunn et al 2004, Jecock et al 2004, Jecock et al 2009).

Watermills continued to be used throughout the post-medieval period probably peaking in the early 19th-century at about 60,000 occupied sites (Palmer *et al* 2012). Some continued well into the 20th-century, but all currently active watermills are thought to have been brought back into use following a period of neglect (pers comm Mildred Cookson, Mills Archive). In the early industrial period waterwheels remained an important source of power, but in many areas were rapidly superseded by steam-engines, though their boiler water may have been supplied by the original leats. Such replacement was not universal; in some places with limited access to rail and hence cheap coal, such as Wharfedale and Nidderdale, Yorkshire, waterpower remained important throughout the 19th-century (Giles and Goodall 1992, 125). Later, internal-combustion engines and electric motors were used, again often in the same buildings but again the original water supply system could supply cooling water and even generate the electricity used elsewhere on the site. Today, some are being revived as demonstration sites and/or for small scale flour production. The National Mills Weekend website contains a list of over 150 watermills open to the public (http://www.nationalmillsweekend.co.uk/watermills.htm accessed 2/11/2017). The vast majority focus the visitor experience on the mill building itself. Today some former watermills are being used for micro hydro electricity generation with a variety of turbine types replacing waterwheels or using their sites.

2.1.1. Factors relating to the watermill landscape

For the purposes of this study the watermill building can be considered a 'black box'; what it looks like and what happens within it is of little concern. Standing buildings are beyond the scope of this report, but since such buildings are likely to be suitable for listing curtilage will sometimes be an important consideration and may lend protection to associated features (see 6.1.1 Listing below).

What is of interest is how the flow of water to that ‘black box’ has been managed, both to do work when that work is required and to carry it away when it is not, and in extreme situations preventing damage during floods. There are some aspects of watermills that affect the flow of water required to do useful work and these in turn affect the nature of the features required to manage that flow. Conversely, the nature of the surrounding landscape may allow information about a lost mill to be inferred.

Type of wheel

Undershot wheels could do useful work with a minimal fall of water, but would have required higher flow rates than an equivalent overshot wheel since they relied on the kinetic energy of the flowing water to turn them. Overshot and pitchback wheels could work effectively with much less water since it was the fall of the water that turned the wheel. Given the same topography, however, achieving this greater fall required significantly more landscape modification. Breast-shot wheels would fall somewhere between the two depending on form. For these reasons the natural topography and river regime would play a role in determining the type of millwheel employed. Overshot/pitchback wheels tend to be located upstream where the flow is lower, but it is easier to achieve a higher head (Figure 6), undershot wheels downstream where the flows are higher, but the head lower.

Size

The nature, size and number of waterwheels in use will affect the force required from the flowing water to turn them. In physics, f=ma; force equals mass multiplied by acceleration. In this context this equates to the volume of water passing over the waterwheel (mass), calculated from the cross sectional area of the channel multiplied by the rate of flow, and the height through which it falls as it does so (acceleration), though clearly the flow rate will be a factor here as well, through the kinetic energy of the flowing water. The power output from a given waterwheel or set of wheels will therefore be dependent upon channel cross section, flow rate, and fall, all of which will be interdependent variables.

Technology

Initially, most waterwheels were constructed almost entirely of wood and generally turned slowly, but with relatively high torque, as did the associated machinery. Such a mill would have required a relatively slow flow, but high volume of water, a larger channel cross section relative to flow rate or fall, and only have been capable of a maximum of perhaps 10 horsepower. During the 18th and 19th centuries technological improvements increased the efficiency of water-power technology. The use of metal, better bearings and more sophisticated gearing (Figure 7) meant that it became possible for wheels to turn faster and with less torque to create the desired energy, by the mid-19th-century achieving as much as 120 horsepower, more than contemporary steam engines (Giles and Goodall 1992, 125). Such mills could also operate with lower volumes of faster flowing water if necessary. The ultimate

Figure 6 – Levisham Mill, Ryedale, North Yorkshire in the 1950s: a mill with a large overshot wheel; note the pentrough supplying the water to the top of the wheel and the steep local topography which favours this type of mill (John Gay © Historic England aa083599)

Figure 7 – In 1936, the demolition of No. 3 mill on Millhead Stream at the Royal Gunpowder Factory, Waltham Abbey, Essex, exposed the internal gearing and massive stones of this incorporating mill (BB94/8010 © WASC 139)

examples of this technological progression are probably the turbines introduced in the later 19th-century, modern versions of which are now being used in the latest micro-hydro generation schemes (Figure 24).

Function

Function has two relevant effects on watermill landscapes, location and associated features. The role of corn mills in the medieval economy meant they were virtually ubiquitous where there was both arable agriculture and a suitable watercourse. The increasing industrial use of watermills led to their construction in new locations further from arable areas and closer to the raw materials to be processed or the markets for their products. Other factors might also be relevant, for example dye mills were polluting so were generally located downstream from settlements gunpowder mills dangerous so situated in remote areas.

Each watermill also formed part of a process and the watermill would therefore have associations with the other elements of that process, including inputs and outputs (see 2.3 below). For example fulling mills (and later dyeworks and bleachworks) were often associated with closes known as tenter-fields, containing frames for stretching and drying cloth (see Giles and Goodall 1992, Fig 187, 115).

The function of a mill is not always a significant factor affecting the associated water supply system. Since the power supplied by the waterwheel could be put to a wide variety of uses a change of use often only required an internal refit rather than significant modification to the associated landscape. Key considerations may be the original use and changes of use that also saw changes in the overall scale of the enterprise, thus necessitating enlargements of leats, ponds and so on.

2.2. Watermill landscapes

For the purposes of this study, watermill landscapes have been defined as:

> Those landscapes, rural and urban, that have been utilised by people for the purpose of powering, or otherwise relating to the functioning of, a watermill, or group of watermills.

They include both natural features such as the topography, and hydrology in the immediate vicinity of the watermill and artificial features concerned with the manipulation of these natural features to enable the waterwheel to function as and when required; weirs, leats, and so on. These features may be directly associated with the watermill in question, such as those mentioned above, or indirectly, such as the climate, the shape and size of the larger catchment, or the number and size of other mills on the river, each which will affect the flow regime that has to be managed at the mill site itself.

2.2.1. The river and catchment

A major component of watermill landscapes is the watercourse that supplies the water to power the watermill, the nature of which is crucial to its operation. Key to this is the river's overall flow regime which will reflect the climate, changing over the year, as well as specific weather events such as droughts or storms. The overall flow regime will be affected by factors like the extent of winter precipitation as well as any freeze and associated spring thaw which can lead to a peak in flow rates, as well as the level of decrease in precipitation and increase in temperatures and evaporation over the summer which create low-flow conditions. This pattern is largely predictable, though timings will vary year to year, and there will be extremes that are atypical. Any watermill landscape will have been set out to accommodate the expected peaks and troughs by, for example, ensuring the overflow channels are sufficient to cope with the expected maximum flow and the mill pond large enough to store sufficient water to allow useful work during low-flow periods. Although it is not possible to predict individual weather events far enough ahead to be able to influence the watermill landscape, the likely scale of such events, such as the typical degree of storminess or the frequency and scale of flooding, should allow for some level of planning. Under normal circumstances the impact of this on the watermill landscape is likely to be much as for the more predictable river regime.

The river regime is related to the location and form of the catchment. The location will determine the climate, including rainfall and temperature, seasonality, and so on, and will affect the probability of particular weather events. For example, the west of England is generally warmer, wetter, and windier than the east, but less prone to thunderstorms (Met Office 2016). The form of the catchment will affect the way the watercourse responds to these, depending upon their size, shape, topography, and ground cover, including degree of urbanisation. A broad, level and well wooded catchment will see a moderate and extended rise in river levels following rainfall, and any flooding will only follow extended periods of rain, and be predictable. In contrast, a narrow, steep-sided catchment with little vegetation will see a very sharp and rapid rise in river levels following rain and so be prone to unpredictable flash floods.

Although the location and area of each river catchment is fixed, most of the other variables above can change and thus affect the river flow, which will have an effect on the watermill landscape. It is well known that the climate has changed in the past and is likely to change in the future. The picture is complicated though and predictions uncertain. Land use is also changing, generally intensifying both agriculturally and in terms of development which usually increases run off and the potential for flooding. These large-scale changes are beyond the scope of this report and many are covered by other Historic England (HE) work and commissioned work (for example climate change - Howard and Knight 2015, agriculture - Oxford Archaeology South 2015, housing development - Haynes 2014). However, each watermill, as a point in a river valley through which water flows, has an associated sub-catchment within the larger river catchment that more directly affects that mill. Changes within this more immediate catchment will also impact upon the mill landscape, but being more local might be more easily managed.

2.2.2. Water supply system

The terminology applied to many of the elements of watermill landscapes can be confusing; for example, channel, leat, and race are frequently used interchangeably and there are numerous regional variations such as goit. The terminology used here will follow that of the HE Monument Type Thesaurus (3.1.1).

Some watermills stand on the natural watercourse itself with little modification to the landscape other than a weir to create the working head (Figure 8). This is typically low so small undershot wheels tend to be preferred in these situations. The mill building was generally located at one end of the weir or dam with the waterwheel/wheel race part of the same structure. Some examples are known where there were mills at both ends of the weir/dam, such as the monastic mills at Durham (Luckhurst 1964 14, Fig 1). In the narrow valleys flanking the Pennines it was sometimes possible to obtain a significant head with relatively short weirs/dams and this arrangement became more common in the industrial period. These simple systems were however vulnerable to variations in the river flow at times of drought or flood, so more complex water management systems are more common.

In some cases the mill stands on the natural watercourse with an artificial channel bypassing the whole system (Figure 9). In these situations the watercourse acts as a

Figure 8 – Looking downstream along the River Windrush below Bourton on the Water, Gloucestershire, towards a small mill on a weir, one of the simplest possible watermill landscapes (Henry W Taunt 1890 © Historic England cc97_02968)

Figure 9 – Two sketches showing the changes on a length of river resulting from the building of a watermill, in this case a mill on the natural channel with a bypass leat. Before (above); a = river, b = ford with footbridge, c = lanes: and after (below); a = river, b = overflow leat, c = dam, d-e = spillway with sluice, f = road bridge, g = old ford, h = mill farm, j = cottages, k = watermill, l = leat taking water from the river to supply a mill further downstream (Reid 1959, Plate 2; Plate 3, © SPAB Mills Section, with permission)

mill race (below) and the channel takes most of the flow of the river. It seems likely that many of these layouts developed from the simple examples of a mill on a weir described above, but in others it may just have been the most expedient approach.

Perhaps the most developed are what are sometimes referred to as ‘bypass systems’ (though this can create confusion with bypass channels), where the watermill was situated on a mill race, an artificial channel that allowed the flow of water that drove the mill to be managed more efficiently reducing the risk of flood and drought (Figure 10). The mill race has two main parts: the head race above the mill and the tail race below. Some also use the term wheel race for the part flowing past/through the mill, but this is not a Thesaurus term. In some cases the distinction between the ‘natural’ watercourse and artificial channel becomes somewhat blurred. For example, at Rievaulx, the monks cut a canal to supply the mill and straightened the River Rye and it is possible that some sections of the canal utilised sections of the former river course (Luckhurst 1964, 11, fig 5).

In a bypass system, water is taken off the natural watercourse some distance upstream. This is the first step in creating a working head of water at the waterwheel. Usually, a weir raises the level of the watercourse and directs part of the flow into the

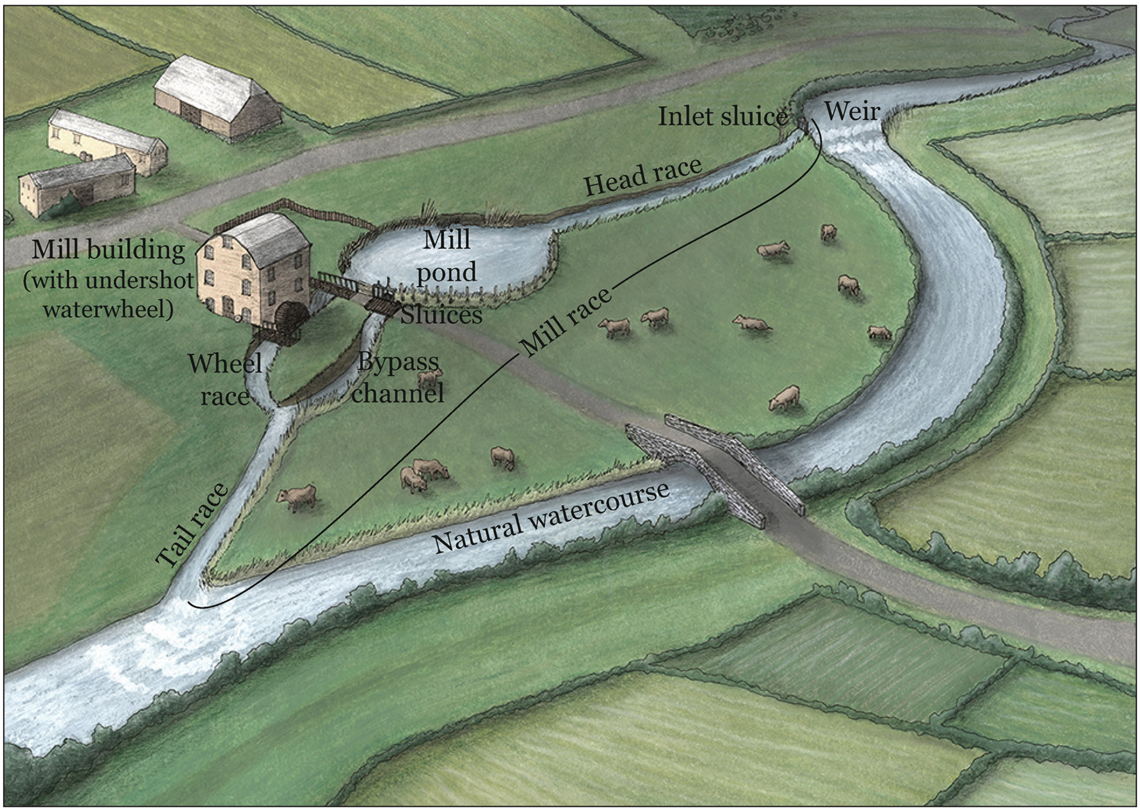

Figure 10 – A sketch of a simplified bypass system (Eleanor Winter © Historic England)

head race further raising the level and allow better control of the flow of water into the race. In some cases a dam is used instead of a weir though this is less common as managing high flows is more complex requiring additional works and more active management. Weirs and dams are typically constructed of timber or stone, or both, with the most durable forms being of pitched stone set between curbs (see Figure 11), later examples were often further strengthened with iron staples. The weir/dam was often angled across the river or placed on a bend in order to reduce the impact of floating debris and assist the flow of water into the leat (Figure 12). The greater length of crest on angled weirs also allowed more water to discharge over the weir during times of flood (pers comm Alan Stoyel)

The balance between the flow of water into the head race and that which continued along the river was typically controlled by a sluice gate at the inlet to the head race, though most dams and some weirs had spillways and sluice gates as part of their structure (Figure 13), either in addition to, or instead of a sluice gate on the head race and some had more complex systems of 'washboards' set along the top allowing their whole height to be adjusted (Figure 11).

The head race then carried water to the mill. Usually it followed the contours of the local topography falling at a much shallower gradient than the natural watercourse, increasing the level of water relative to the river. Head races vary from little larger than a field ditch and a few dozen metres long to substantial canals and lengths of several kilometres (compare Figure 14 and Figure 15). The mill at Reading Abbey was fed by a leat know as Holy Brook that ran from the Kennet at Theale (Luckhurst

Figure 11 – A pitched stone weir on Hebden Brook, Yorkshire with a surviving section of 'washboard' visible in the foreground (Matt Edgeworth © Historic England)

Figure 12 – Two angled weirs on the River Arrow, upstream from Penbridge, Herefordshire; the upper feeds a leat running off left to the Court of Noke water gardens and mill and the lower a leat to the right supplying a waterwheel at Leen Farm (© Alan Stoyel, with permission)

Figure 13 – A sluice gate and spillway at Little Barford Mill, Oxfordshire (Peter Williams © Historic England)

1964, 12), over 6.5km away. Size and length would be determined by the nature of the watermill, as discussed above, and the topography, though other factors such as available resources and likely return on the investment would also play a part. Large leats could carry boats and be used to move materials around extensive sites.

Leats can be constructed by cutting down into the land surface, building up embankments (Figure 14), or most commonly a combination of both approaches with material cut from the upslope side used to build up the downslope bank. Vulnerable areas might be lined or otherwise reinforced. Sometimes all or part of the mill race and/or any bypass channels ran in a culvert or tunnel, particularly in

Figure 14 – View of the small, embanked leat running to the lower corning house on the Lowwood Gunpowder Works site, Haverthwaite, Cumbria (Bob Skingle © Historic England DP003477)

Figure 15 – The leat at Lode Mill, Cambridgeshire (Matthew Edgeworth © Historic England)

built up areas or perhaps to carry water through rather than around a spur. Due to the cramped site, at Easby Abbey, Yorkshire, the tailrace ran in a tunnel beneath the *reredorter* and other parts of the *curia* (Luckhurst 1964, 17). Leats could also be carried across other features via aqueducts (Figure 16).

The head race often fed a mill pond that stored water to act as a buffer in variable conditions, supply the mill during the working day (filling at night), or allowing meaningful, though intermittent, work in low-flow conditions. The size of the pond

Figure 16 – A metal aqueduct across the River Lugg at Day House, Kingsland, Herefordshire, with the farm mill and waterwheel visible in the background (© Alan Stoyel, with permission)

(and dam) varies with the topography and the mill's size, form and function, from little more than a widening and deepening of the leat to very large ponds spanning whole valleys, effectively forming large reservoirs. The term 'mill dam' is often also used for the mill dam and its pond, particularly in the industrial north.

The water is then directed onto the waterwheel(s), sometimes, particularly in overshot or pitchback wheels, via a pentrough (not a Thesaurus term and treated as part of the head race); an open trough carrying the water to the wheel usually with a sluice gate to control the flow (see Figure 6). The waterwheel is generally placed within a wheel pit lined with timber, stone, or brick, sometimes curved to follow the wheel retaining water within the wheel and maximising the thrust applied to it (pers comm Alan Stoyel). This is the part of the system sometimes called the wheel race (again not a Thesaurus term, also treated as part of the head race).

By the 19th-century mills began to be constructed with piped water systems replacing the head race. These were far less dependent on topography and had a less obvious connection with their surrounding landscape as the supply reservoir could be at some distance and the pipes could be buried or more easily removed, particularly as they would have had a reuse or scrap value. The Lady Isabella Wheel at Laxey Mine, Isle of Man, was based on an inverted syphon system and was supplied from water collected in a reservoir in an adjacent valley (Crossley 1990, 141)

The wheel and its race could be located in a wide range of positions relative to the mill building. Where the topography allowed the mill building would often be located away from the floodplain allowing it to be higher and therefore better protected. Vertical waterwheels could be external or internal but there is uncertainty as to the date internal wheels came into use (Reid 1959, 8). By their very nature horizontal wheels are internal and excavated vertical Romano-British watermills are also thought to have been internal (see Figure 1 and Figure 3) so perhaps some were always so. It is also common for formerly external wheels to be enclosed in a secondary extension of the mill building. Commonly the race ran past one end of the building with the wheel mounted on the gable wall, numerous other arrangements are known though. Multiple wheels are also common with pairs of wheels operating at either end of the building, side by side, or sometimes in line in the same race such as at Bourne Mill, Farnham, Surrey (Reid 1959, 8). Occasionally the wheel was located in a wheelhouse separate to the building where the power was required. Possibly the most unusual of these was the 30m high wheelhouse at Lumbutts Mill, Langfield, Yorkshire, which was built in about 1830 and contained three wheels 9.1m in diameter and 1.5m across set vertically one above the other; the details of the water supply system are uncertain, but was probably piped (Giles and Goodall 1992, 129, Fig 211). Usually this was adjacent to the associated workshops and power could be transferred directly by a rotating shaft, but sometimes the building was further away and reciprocating rods might be used.

Once the water passes the wheel it is directed back to the watercourse via the tailrace. The tailrace has to carry water away from the wheel fast enough so that it

Figure 17 – A man fishing in the large outfall pond at Horstead Mill, Norfolk, a late 18th-century watermill which was gutted by fire in 1963 (John Gay 1956 © Historic England aa081027)

doesn't back up and impede its operation so is often relatively short and steep. Very occasionally a waterwheel was located lower than the adjacent river and here the tail race could be hundreds of metres long. In an extreme case a snuff mill on the Porter, South Yorkshire, was so low relative to the river that the tail race was culverted beneath the river joining it further downstream (Crossley 1990, 144). Sometimes there is a mill pond below the mill that would retain water and so even out the flow downstream when the mill was operating (Figure 17). There is often a bypass channel to carry water around the mill when it is not in use, though the river could also act as the bypass.

The extent of the works required to carry water to the mill means that mill sites would have had a tenacity in the landscape not applicable to most other buildings. Many sites were in use for centuries and underwent several phases of reconstruction though others had shorter lives. They frequently changed function and many had several distinct roles; different machinery could be attached to the same power source. While each of these changes required an internal refit, the water management features probably needed little if any modification in many cases.

Survival varies from fully working systems with standing buildings, working machinery and functioning channels, to completely lost landscapes that survive only as earthworks or buried archaeological features, or even just as a place- or field-names or documentary references. Most watermill landscapes will contain a mixture of functional and derelict elements. Of the tens of thousands of former mill sites, only a few hundred are now in use.

Interrelationships

The component features of these landscapes, including weirs, dams, sluice gates, mill races, bypass leats, mill ponds, and so on, should not to be seen as separate, but as interconnected elements of a single system linked or once linked by the flow of water through and between them. This is what connects the various artificial and natural features in a watermill landscape; the main axis to consider is upstream-downstream. The key to interpreting any watermill landscape is the direction of flow, dictated by gradient.

Under all normal circumstances flow on rivers is unidirectional, running along broadly linear, though often sinuous, corridors. Connections between component features of watermill landscapes can work both with and against the current. Each changes the hydrology of the river, which can impact on features both up- and downstream, sometimes over some distance. A weir, for example, slows the current and increases depth upstream, and, increases current and decreases depth downstream, which changes erosion and deposition patterns both within the channel and on the surrounding floodplain. Fluvial interconnections such as these require that the landscape to be seen holistically as the legacy of numerous human

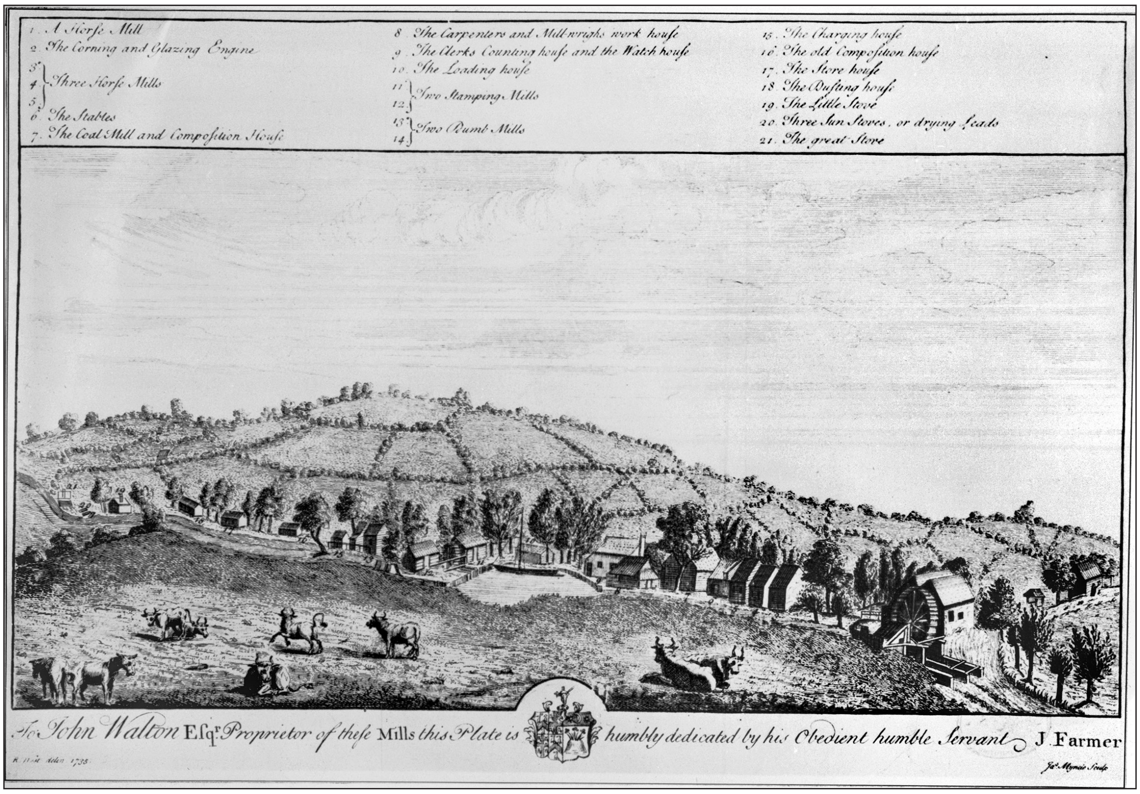

Figure 18 – Engraving of John Walton's mill at the Royal Gunpowder Works, Waltham Abbey, Essex by John Farmer 1735 (© Historic England BB94/08020)
The buildings are described from right to left as: a horse mill, the corning and glazing engine [with the visible wheel], three horse mills, the stables, the coal mill and composition house, the carpenters' and mill-wrights' work house, the clerks' counting house and the watch house, the loading house, two stamping mills [again with a visible wheel], three dumb mills, the charging house, the old composition house, the store house, the dusting house, the little store, three tun stores or drying sheds, the great store

interventions and engagements with flow, rather than a random assemblage of unconnected sites and features.

It is rare for a watermill to exist in isolation on a particular watercourse. Suitable streams and rivers were important resources and would often have had many watermills along their lengths, each with its own water management system, creating the all-important working head at the waterwheel. Sometimes these systems overlap, with water being taken out of the river by one mill before the water from a mill upstream has been returned to the river. On occasions a mill may be fed by the leat from a mill above without being returned to the river at all, though as one became dependent upon the other this was rare unless the mills were jointly owned (Figure 18). Where they were not held together disputes inevitably arose where one mill interfered with the working of another, both where water above the mill was held up or where water held below the mill backed up into its tail race, or impeded other river uses such as navigations. Such disputes were common from the medieval period onwards, and as these disputes were often resolved in the courts it seems likely that mills on densely occupied watercourses might be better documented than isolated examples, which could affect assessments of their significance (below).

These large landscapes of 'stepped' rivers, in effect comprise a series of nested watermill landscapes, interconnected to form a greater whole. It may therefore be necessary to consider aspects of the landscape well beyond that of the mill in question. Where multiple mills form the focus of study or where they have the potential to be managed together, it would make sense to treat them as a whole, rather than discrete landscapes.

2.3. Other associations

Watermills are associated with a wide range of sites and features in addition to those of the water supply system. These also form a part of the watermill landscape.

Most medieval watermills were corn mills and they continued to be the most common for many centuries. Many manors had one, or access to one, and they were key assets under the control of the lord who received an income from their use. They also required considerable investment to establish which could only come from the upper levels of society or large establishments like monasteries. There is therefore a tenurial association with high status sites such as manors and monasteries which can be significant for an understanding of their location, in addition to the topographic factors outlined above.

As a class, monastic watermills deserve some special attention since they form a distinct type of landscape in their own right and monasteries may have had a significant role as innovators. The Rule of St Benedict stated that all necessary requirements, including mills, should be located within the monastery and they were constructed within the precinct if at all possible (Luckhurst 1964, 4-5). Since it is known that water management was a key aspect of monastic layouts and the mill race was often connected to the main drain, which serviced many key buildings, on many monastic sites the watermill landscape is an integral part of the site as a whole

(Luckhurst 1964, 6). Furthermore, monasteries had the resources and ability to plan for the long term, to an extent not available to most other landholders. At Rievaulx, North Yorkshire, the mill was on a race over 2 km long, known as the Monk's Canal, but the monks also straightened the river (Luckhurst 1964, 11) indicating the extent of resource they were able to command. The Knights Templars may have been responsible for introducing the fulling mill to England from the Continent (Pelham 1958, 2) and the monks of Bordesley Abbey, Worcestershire, owned many watermills used for fulling and driving furnaces and forges across a wide area (Rollins 1970, 3).

The watermill might stand alone, but often formed part of a complex with a separate mill house, where the miller lived, and various barns and granaries. Such complexes were probably rare in the medieval period though, as the miller was not typically a free tenant before the 15th-century when the first mill houses are known, and functions such as storing of grain and cleaning flour did not fall to the miller until the 16th-century (Reid 1959, 6-7, 13). Monastic sites may have been an exception; at Abingdon Abbey the mill formed part of a complex with the malthouse, brewhouse, bakehouse, granary, almonry, stables and business premises (Luckhurst 1964, 15).

Some millers built windmills near their watermills, presumably to maximise the potential milling opportunities, although high ground was probably preferred to river valleys. Many millers developed related side-lines leading to an association with bake-houses and brew-houses amongst others. Many elements of the water supply system had secondary uses; mill ponds could be used as fishponds and leats supply other features such as water meadows (see the front cover) or moats. Note that Historic England has produced a guide on conserving water meadows (Historic England 2017), much of which will be relevant to watermill landscapes.

Although they could be relatively isolated as they had to be sited on a suitable watercourse, in many cases the establishment of a watermill led to the development of an associated settlement, initially perhaps a single farm developing into a hamlet, but on occasion developing into a village or even town. This is particularly clear during the 18th and 19th centuries in the newly industrialising areas such as the Pennines - the new mill towns - but appears to have been common throughout the medieval and post-medieval periods. Watermills also had an impact on the form of many existing towns and settlements with leats and crossings affecting their layout. For example much of Winchester's street plan was determined by the various divisions of the Itchen created to serve a variety of mills (Reid 1959, 3) though many of these patterns are being lost as cities are remodelled to suit the motor car.

Wherever they were located, they needed good communications for the transportation of grain and flour so associations with roads, bridges and fords are common. The weirs and dams associated with watermills not only made river crossings easier, but sometimes carried a road or bridge across the river these, as much as the mill itself, would have attracted settlement. This association could operate in reverse with crossings forming attractive sites for mills; bridging points would also have been suitable for weirs/dams. It has been suggested that the mill dam at St Alban's Abbey, Hertfordshire, made use of the causeway for the Roman road over the River Ver (Luckhurst 1964, 14-15).

Associations related to the role of the mill were common. Fulling mills were often associated with tenter-fields, linear closes with tenter-frames to stretch the cloth and poles and lines where cloth was hung out to dry 'like a laundry' (Reid 1959, 10). Even in the medieval period some watermills were associated with metalworking complexes that included furnaces and forges. Different mills might also perform different tasks within a single complex so an ironworks might have had one mill to crush ore for the furnace and another to power a hammer in the forge. Such interconnected mills often shared elements of the same water supply system and in large complexes a single head race might supply several mills with a single tail race taking the water away (Figure 19).

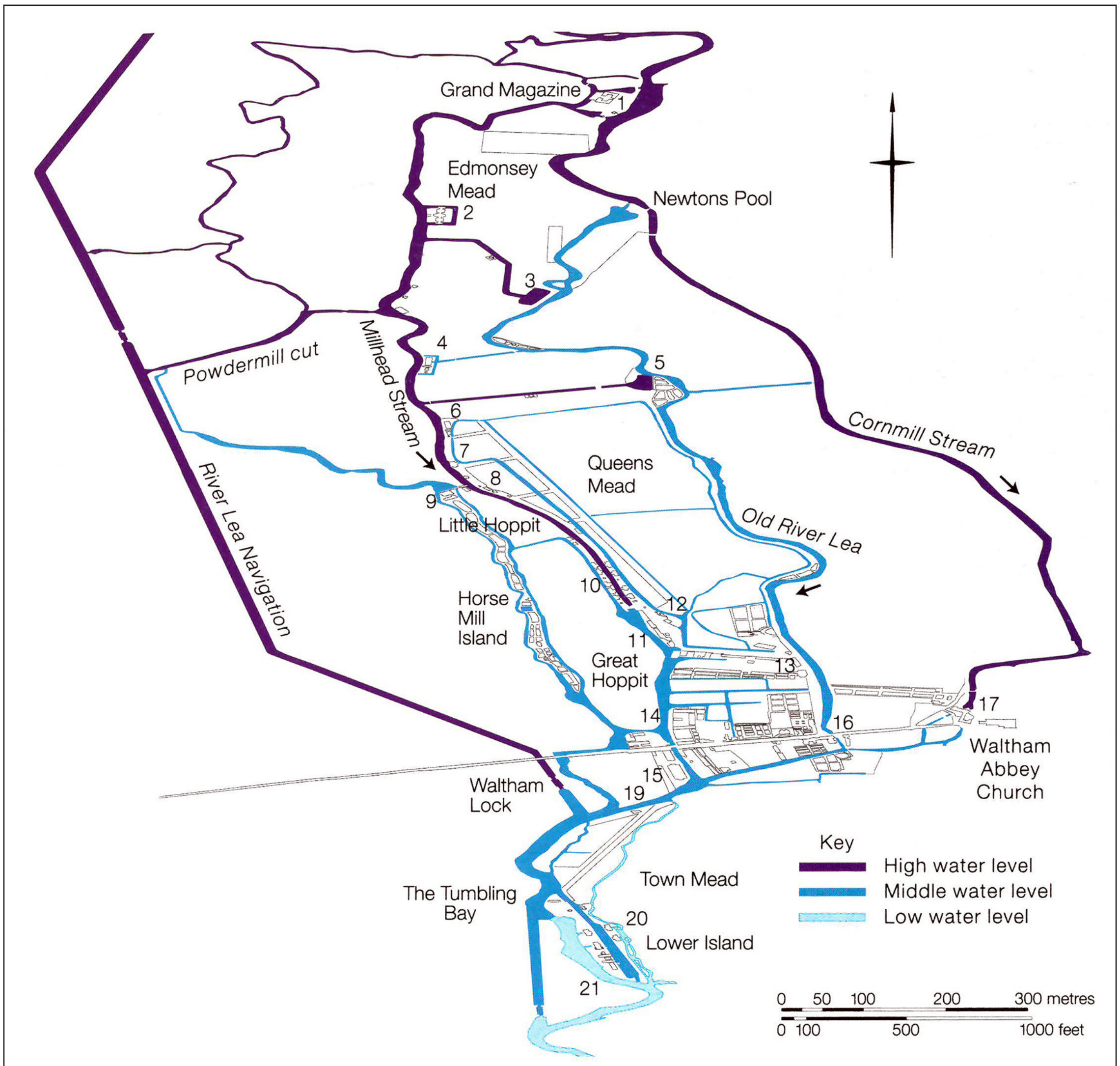

Figure 19 – The Royal Gunpowder Factory, Waltham Abbey in 1827 (Cocroft 2000, 49, fig 2.31 © Historic England). An interesting approach to representing a complex industrial landscape featuring numerous watermills; colour has been used to indicate water levels thereby graphically showing flows. The corn mill at 17 predates the industrial complex, the incorporating mills at 10 and 20 feature single high level head races supplying several mills to either side with paired tail races also serving multiple mills, other mills were located at 4, 6, 7, and 11.

As the range of functions watermills were put to increased, so did the breadth of their associations. Although there are too many potential interconnections to be discussed here, the role of the watermill needs to be borne in mind and the surrounding landscape examined with an eye to that role. It may also be that the changing role of the mill is documented which might allow the dating of related landscape features. The important point is that a true understanding of the significance of each element in a watermill landscape will only emerge from an integrated assessment of a meaningful area, determined by the functioning of the water supply system and/or the associated industrial process. In these contexts the 'process flow' was as important to the understanding of the landscape as the actual flow of water.

2.4. Dating

Dating of watermill landscapes may not be a straightforward process. As noted above the channels and so on will have required on-going maintenance which will remove evidence and it was common for key elements of the supply system to be modified. The mill itself may well be on a site occupied by a mill since the time of Domesday Book or earlier but this will be almost impossible to demonstrate. It is extremely uncommon for any mill building much earlier than the 17th-century to survive, in part due to their vulnerability to flood and degradation. The very ubiquity of mills also means that they may not be well documented, other than on densely occupied watercourses where disputes frequently arose.

Looking at the broader landscape and associations with the various elements of the watermill landscape in question may offer insights. It is a truism but the landscape is a palimpsest and the position of the mill, its works and other associated features within this multi-layered context can often be the most informative guide to its longevity. For this reason, whilst the key associations are set out below, almost any landscape feature can be potentially important to the understanding of a watermill landscape (see the front cover for example).

3. THE RESOURCE

3.1. Asset types

3.1.1. The HE Monument Type Thesaurus

The HE Monument Type Thesaurus (hereafter the Thesaurus, HE 2015d), is a continually updated online resource intended to provide structure and guidelines for the standardisation of heritage data terminology. It contains over 6000 terms and provides the basic framework for the classification of monuments in England. It is widely used by the heritage sector, particularly in databases such as HE's National Record for the Historic Environment (NRHE) and Local Authority Historic Environment Records (HERs). It thereby forms the key to the organisation of data across a wide range of data repositories.

On one hand the Thesaurus is extremely useful in allowing searches for individual features within watermill landscapes across a range of databases. On the other, the same terminology and associated conceptual structure, can make it difficult to identify composite landscapes. Like any set of search terms, they constrain searches, which can be beneficial, allowing standardised searches, but also channelling them along fixed lines. Because there is no category in the Thesaurus for watermill landscapes as such, but only for component parts, a fragmented picture of watermill landscapes inevitably emerges from any interrogation of these databases.

Thesaurus terms

The Thesaurus is hierarchical; it works down from 'class', through 'broad term' to 'narrow term' and also includes 'related terms' (non-hierarchical relationships). For any given term it is possible to follow the Thesaurus hierarchy up (to class or broad term), down (narrow terms) or sideways (related terms). So for example, looking at 'watermill' as a Thesaurus term, its class is 'industrial', its broad term is 'water production site' and the only narrow term is 'horizontal watermill'. Related terms are 'corn mill', 'head race', 'mill dam', 'mill pond', 'mill race', 'tail race', 'tumbling weir', 'turbine mill', 'waterwheel', and 'weir'. The Thesaurus also includes a wide range of non-standard terms for which it gives the 'preferred term' to be used, for example 'head race' being preferred to 'pentrough'.

By following these links, in this order, starting with the term 'watermill' a table of relevant Thesaurus terms was compiled (see 9. Appendix). From this, a reasonably comprehensive list of relevant terms was compiled:

- Water power production site
    - Dam
        - Mill dam
        - Weir
        - Tumbling weir
    - Drainage mill
    - Hammer pond
    - Leat (water channel)

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    - Mill pond
    - Mill race (pentrough)
        - Head race
        - Tail race
    - Pen pond
    - Pump house
    - Pump room
    - Turbine mill
    - Waterwheel (coal mill, millwheel, waterwheel)
        - Breastshot wheel
            - High breastshot wheel
            - Low breastshot wheel
            - Mid breastshot wheel
        - Overshot wheel
        - Pitchback wheel
        - Undershot wheel
    - Watercourse
        - Launder
    - Watermill
    - Water turbine
    - Wheel house
    - Wheel pit
- Mill house
- Corn mill (grist mill)
- Granary
- Transmission rods

Class names are too broad to be useful as search terms, and 'watercourse' includes both natural and artificial channels so is also likely to be too broad. Other terms such as 'corn drying kiln' or 'corn drying oven' are probably too specific. 'Tide mill' has been omitted for the reasons discussed above and 'horizontal watermill' because they are unknown in England apart from by excavation. Other excluded terms are: 'pond bay' which typically relates to metal smelting rather than milling; 'forge', 'helve hammer' and 'purifier' relate to the internal functioning of a mill; and 'sheer hulk' and 'sheer legs' are maritime terms. In addition, the narrow terms related to the broad term 'mill' are all functional, including over 80 terms ranging from 'alpaca mill' to 'yarn mill'. They have been excluded as they are not necessarily indicative of a watermill and are rather too numerous to be dealt with, but need to be kept in mind as they may affect associated features.

3.2. National Record for the Historic Environment

The NRHE is mainly an inventory of sites where recording work or research has been carried out by HE or its predecessor bodies including the former English Heritage (EH) and Royal Commission on the Historical Monuments of England (RCHME), and the Ordnance Survey. As such, the quantity and quality of data is variable, depending on when and where previous work has been undertaken and why. It is principally for internal HE use and as such its role is rather different from that of HERs which have a key role in planning. A version is accessible to the general public through the PastScape web portal (http://www.pastscape.org.uk/). The NRHE is searchable by wide range of methods such as period, location, and monument type however in some ways it is rather limited.

A search for 'watermill' produced 2469 records (all searches conducted 27/10/2017). Each of these is an individual record and it is not possible to readily identify relationships between these and other monuments. For example a search for 'watermill' and 'mill race' produced only 28 records, despite the vast majority of watermills having required a mill race of some type. Clearly, it is only possible to search for 'watermill' and 'mill race' where they occur within a single record, and although it is also possible to perform a geographic search, which will produce all records within a certain area. It is not possible to search for functionally related terms in close proximity within the current database, even if they have been related as parent/child, or other some other association, which is rare.

The inclusion of narrow and related terms (see 9 Thesaurus terms below) increased this to 4059 records, an additional 1639 records. These broke down as:

Related monument type	No. of records
Corn mill	1877
Head race	46
Mill dam	108
Mill pond	454
Mill race	245
Tail race	63
Tumbling weir	1
Turbine mill	5
Waterwheel	263
Weir	186

This amounts to a total of 3248 records, rather than 1639, so there are clearly considerable overlaps, both with the original 2469 watermill records and between the additional records themselves. For example, of the 1877 'corn mill' records, 1069 also included the term 'watermill' and so will have been included within the watermills, and a search for 'mill race' with narrow terms included produced 326 records though the total for the three 'races' listed separately was 354.

Many watermill records include references to other monument types, but a rapid inspection suggests that most of these relate to the mill building rather than the landscape. For example, the description for Jowett Saw Mill in Barnsley (NRHE UID 1269356) reads: 'Early to mid-19th-century water powered corn mill, later a saw mill and now a house. The waterwheel was installed in 1859 and the main part of the building added in 1858.' This record includes the indexed terms 'corn mill', 'watermill', 'waterwheel', 'saw mill' and 'house'. Nowhere is there any reference to the water supply system or the wider landscape and the record has no associated monuments, but a rapid examination of the area in the HE corporate GIS makes it clear that there is a substantial pond with a dam, and several leats, weirs, and sluices associated with the mill, none of which is recorded. In other cases though, the descriptions give holistic accounts of associated landscapes, written with an awareness of how the various component parts are linked to each other. What usually appears to be lacking are the full range of associated monument types within each watermill record, or the creation of separate records for the various associated elements and/or their linkage.

Another issue with recording is that many large, complex sites that contained numerous mills, were entered as a single parent record with several child records and that not every mill was given a separate entry. For example, there were approximately 30-40 watermills of various dates at Waltham Abbey Gunpowder Works, Essex, but few have individual records (pers comm Wayne Cocroft, HE, see Figure 19). A further problem is that the returns above include records that are not related to watermills. For example, of the 808 'corn mill' records not included within 'watermills', about 40 have been classified as 'windmill', and half as 'steam mill'. Although the remaining 750 or so records have not been classified, and the majority will probably be watermills, some will be windmills or steam mills, and a few driven by other means such as animal or electric power.

It is clear that a considerable amount of detailed work needs to be done to assess the resource, not to mention further work to improve it. This work lies beyond the scope of the current project. What is needed is clear guidance on how to record these landscapes.

3.2.1. Other Historic England databases

These include the Listing Department's National Heritage List for England and the Heritage at Risk Register though this only covers listed buildings and scheduled monuments. They are discussed in Section 6 below.

3.3. Local Authority Historic Environment Records

One of the primary functions of HERs is to provide the evidence for planning decisions. As such they have a different role to the NRHE and are often more comprehensive, detailed, and up to date, and are potentially capable of providing a more uniform overview of an asset type or class of assets. Most are located within individual planning authorities so do not form a single national resource however. An assessment of the data they contain lies beyond the scope of this project, but would provide a useful comparison with the NRHE perhaps best undertaken within the context of a regional study.

Many if the issues with the NHRE identified above may also apply to HERs.

3.4. Other sources of information

These are noted here for reference purposes; they were not used in this report.

3.4.1. Society for the Protection of Ancient Buildings Mills Section

The Society for the Protection of Ancient Buildings (SPAB) has a section dedicated specifically to mills. This has a website (http://www.spab.org.uk/spab-mills/) with much useful information including many links to other sites, international, national and regional. The focus is primarily on the mill buildings, but SPAB is the main sponsor of the Mills Archive.

3.4.2. The Mills Archive Trust

The Mills Archive Trust (http://www.millsarchivetrust.org/index.php/) is a charitable educational trust aiming to provide a permanent repository for historical and contemporary material on traditional mills and milling. The Trust's mills index contains entries on over 11,000 mills covering windmills and muscle-powered mills as well as watermills, and is focussed on the United Kingdom, though an increasing number of records relate to other parts of the world. Landscape features and components of water supply systems, apart from the mill buildings themselves, are not indexed as such, though there is a great deal of information about the wider landscape to be found within each record, as well as in the Trust's library and archive.

4. SIGNIFICANCE

4.1. General considerations

Within the context of managing the historic environment, 'significance' is a specific term used to describe the importance/interest/value of a place, as determined by a formal assessment process. Different places will have differing levels of significance depending on a range of factors, from none at all to national or international. The assessed level of significance will affect the level of management and protection that is appropriate for any particular place.

Historic England's approach to significance is set out in Conservation Principles. Principle 3 states that 'Understanding the significance of places is vital' and explains that 'The significance of a place embraces all of the diverse cultural and natural heritage values that people associate with it' (EH 2008a, 21). Heritage values therefore underpin significance and are set out as:

- *Evidential value*, derived from physical remains inherited from the past
- *Historical value*, which tends to be
  - Illustrative, visibly linking past and present people
  - Associative, directly connected with notable persons, events or movements
- *Aesthetic value*, typically
  - Designed, a consciously produced building structure or landscape whether attributable to a known patron or designer, or the product of a vernacular tradition
  - Fortuitous, developing over time as the result of a succession of responses (see fFigure 20)
- *Communal value*, deriving from the meanings of a place to people, may be
  - Commemorative/symbolic
  - Social (see Figure 21)
  - Spiritual

(EH 2008a, 28-32)

Since 2008 there have been several government planning and guidance documents published affecting the historic environment, in particular Planning Policy Statement 5: Planning for the Historic Environment (PPS5) (DCMS 2010a), PPS5 Planning for the Historic Environment: Historic Environment Planning Practice Guide (PPS5 PPG) (DCMS 2010b) and the National Planning Policy Framework (NPPF) (DCLG 2012). The NPPF is the current Government policy for sustainable development and it replaced PPS5 in 2012; PPS5 was mothballed and any definitions regarding heritage contained in it have been superseded by Section 12 of the NPPF and the glossary at the end.

NPPF defines significance as 'The value of a heritage asset to this and future generations because of its heritage *interest*' (author's emphasis, DCLG 2012, 56) rather than heritage value and goes on to summarise these as 'archaeological,

Figure 20 - Gibson Mill, Hebden Beck, West Yorkshire (Listed Grade II); the view across the mill pond towards the early 19th-century mill buildings was unlikely to have been intended to be as attractive as it is to the modern eye (Matthew Edgeworth © Historic England)

Figure 21 – A view across the River Stour towards Flatford Mill, Babergh, Suffolk, with swimmers enjoying the watermill landscape, future recall of such days will add to the communal value of the place (John Gay © Historic England aa081735)

architectural, artistic or historic' (DCLG 2012, 56). These types of interest can to a very large extent be mapped onto those outlined in Conservation Principles, however, despite mentioning them, most of the forms of significance mentioned above are not detailed in NPPF so we are forced back onto earlier definitions:

- *Archaeological interest = evidential value*: 'Heritage assets with archaeological interest are the primary source of evidence about the substance and evolution of places, and of the people and cultures that made them' (DCLG 2012, 50)
- *Architectural and artistic interest = Aesthetic value*: 'These are interests in the design and general aesthetics of a place. They can arise from conscious design or fortuitously from the way the heritage asset has evolved' (DCMS 2010b)
- *Historic interest = historic value and communal value*: 'An interest in past lives and events (including pre-historic). Heritage assets can illustrate or be associated with them. Heritage assets ... can also provide an emotional meaning for communities derived from their collective experience of a place and can symbolise wider values such as faith and cultural identity' (DCMS 2010b)

It is perhaps better therefore to use the term 'heritage interest' and the key types of interest as set out above, but bearing in mind the additional detail set out in Conservation Principles, all be it in slightly different terms.

The NPPF notes that significance also derives from a place's setting which it defines as the 'surroundings in which a heritage asset is experienced' (DCLG 2012, 56). Once again these largely equate to several of the elements set out in Conservation Principles and are set out in detail in *The Setting of Heritage Assets - Historic Environment Good Practice Advice in Planning Note 3* (GPA 3; HE 2017).

Conservation Principles then goes on to outline an approach to identifying the significance of a place by first understanding its fabric and evolution before considering: who values it and why; how its values relate to the fabric; their relative importance; the contribution of associated objects; the contribution of setting and context; and comparisons with places sharing similar values (EH 2008a, 35-9). The PPS5 PPG also highlights the importance of understanding, in particular: the nature of the significance; the extent of the fabric that holds that interest; and the level of importance of that interest'(DCMS 2010b, 20). The recent *Managing Significance in Decision-Taking in the Historic Environment - Historic Environment Good Practice Advice in Planning: 2* (GPA 2) also assigns the same importance to understanding the nature, extent and level of the significance of heritage assets (HE 2015c, 2).

Also relevant are the principals set out in the policy statement on *Scheduled Monuments* (DCMS 2013, 10-11). These relate to determining the importance of a monument when it is being considered for scheduling, and although only the most significant examples will make the grade, the framework they provide may be used to structure the assessment of any monument, see for example English Heritage's Monuments Protection Programme (MPP) which originated in 1986 (Schofield 2000, 4). They are; period, rarity, documentation/finds, group value, survival/condition, fragility/vulnerability, diversity and potential. The criteria and general principles used in the selection of buildings for Listing are rather different though there is some overlap (see DCMS 2010d, 4-6), however since the primary focus of this report is the landscape they will not be discussed in detail.

For assigning significance to a place it is therefore necessary to:

- Understand its fabric and evolution (see the designation criteria)
- Determine who values it and why (particularly for historic interest/communal value)
- Assess its heritage interests
- Relate the heritage interests to the fabric
- Consider the relative importance of the heritage interests
- [?Assess the contribution of associated objects]
- Assess the contribution of setting and context
- Compare with places sharing similar values

The final step set out in Conservation Principles is to 'articulate the significance of the place' in the form of a 'statement of significance' (EH 2008a, 40). This should summarise a place's current 'cultural and natural heritage values' and distil 'the particular character of the place'. In order to achieve this:

> It should explain the relative importance of the heritage values of the place (where appropriate, by reference to criteria for statutory designation), how they relate to its physical fabric, the extent of any uncertainty about its values (particularly in relation to potential for hidden or buried elements), and identify any tensions between potentially conflicting values. So far as possible, it should be agreed by all who have an interest in the place. (EH 2008a, 40)

Note that both Conservation Principles and NPPF were being revised and out for consultation at the time of writing (March 2018).

4.2. Understanding the nature and level of significance

This is discussed here in terms of the 'non-statutory criteria' outlined above. As noted there, although they are used to determine if heritage assets meet the required significance for designation (typically scheduling in the case of landscape features though structures may be listed), the criteria provide a framework that can be used to assess the significance of any asset whether or not it merits statutory protection.

4.2.1. Period

In general, the older the asset the more significant it is likely to be. For listed buildings this is set out as: pre-1700 with significant surviving historic fabric it will be listed; 1700-1840 most are listed; and post 1840 listing is increasingly selective (DCMS 2010d, para 12). With regards to scheduling, period is less rigidly defined, 'All classes of monuments that characterise a category or period should be considered for preservation' (DCMS 2013, 10)

This is not entirely straightforward to assess however as different classes of watermill have different histories; a late example of one type may pre-date an early example of another. Further, as noted above, many watermill sites and their associated landscapes had long lives, remaining in use for centuries and frequently changing functions, perhaps several times. As such they will represent many periods.

> While this can lead to complexity, and perhaps a lesser immediate legibility, in general such sites may have added interest and potential where evidence of early works still survives; where later works have obliterated the early ones, this will not be the case. (EH 2013b, 14)

Watermill supply systems would have been regularly maintained and the clearing of channels is likely to have removed much early evidence. It may also be possible to demonstrate historically that waterwheels were replaced, and particularly if the size and/or the number of wheels increased, the races may have been remodelled, again removing earlier evidence. Significant evidence may still remain though in the form of mill foundations, piles and so on. On excavation, the earliest in situ walls of 17th-century Garnett's Paper Mill, Otley, West Yorkshire, were found to have been built on foundations of reused timber (Anon 2016) suggesting an earlier building on the site. Without such detailed investigation it will be impossible in many cases to determine the extent of survival of early features so it is probably better to err on the side of caution and apply the truism 'absence of evidence is not evidence of absence'.

4.2.2. Rarity

Again, in general terms, the rarer a given type of heritage asset is, the more important a surviving example is likely to be. This assessment also needs to be made with care. Although watermills were common, or a given type may be rare, there is not necessarily any direct correlation between the rarity or otherwise of the mill type and that of its associated landscape; a common mill type might have unusual aspects to its landscape and vice versa.

Without a broad resource assessment it is difficult to determine what types of watermills, associated assets, and landscapes are particularly significant, or to be sure which factors should be considered when making such judgements. In the absence of such a framework, assessments will have to be based upon professional judgement, supported by evidence from the NRHE, the National Heritage List for England (NHLE) or local HERs, though this is not ideal.

The current Scheduled Monument policy statement states that they should include 'the typical and commonplace as well as the rare' and 'should take account of all aspects of the distribution of a particular class of monument, both in a national and a regional context' (DCMS 2013, 10). Just because something is commonplace does not mean that it is not significant. Again this may be a difficult judgement without a detailed resource assessment, though a smaller study might be sufficient where a national or regional specialism is concerned, such as the needle industry around the River Arrow in Warwickshire (Rollins 1970, Fig 4).

It should be noted however that the principles for listing are rather different and age and rarity treated together (see DCMS 2010d, para 12). This will only be relevant to some individual structures though and the mill buildings themselves are not a consideration here.

4.2.3. Documentation/finds

Good documentation may increase significance, whether historic or modern. This includes the results of recent research, though this may also demonstrate a lack of significance. Archaeologically finds are a form of evidence treated in much the same way as documents by the historian and, where preserved from previous investigations, as significant.

Watermills probably have a longer documentary record than other industrial sites, partly because of their long history, but also because of their importance to the medieval economy. Many may trace their origins back to Domesday Book and some even earlier, though this can be hard to demonstrate;. a watermill identified as a manorial asset in 1086 was not necessarily on the same site as a later mill in the parish of the same name, though many assume this to be the case, perhaps not unreasonably.

Disputes over water rights on densely occupied rivers were common and it is likely that mills in these situations will be better documented than isolated examples. Court records may therefore be an important historical source.

4.2.4. Group value

This aspect of importance is vital to the understanding, assessment and management of any landscape containing a range of integrated assets. It is particularly so in watermill landscapes. A weir may not be particularly noteworthy in itself, but because of its role feeding water into the mill race it is clearly important to the rest of the system.

In addition to the flow of water through the water management system, mills have a place in industrial processes and there is an equivalent ‘process flow’:

> Industrial sites function by taking in raw materials, subjecting them to one or more processes to produce a product (normally along with waste products), with the output then transported off-site to market or to form a raw material for another industry. Sites where this sequence of activities or ‘process flow’ is still recognizable are often of greater importance than sites where only part of the industrial process can be identified. (EH 2013b, 15)

Not only are there on-site processes which will have their own ‘flow’ in which watermills will play a part, but materials are brought to the site and products leave it, and the routes and modes of these are also potentially significant:

> With industrial sites it is important to consider how they functioned in terms of process-flow: from receiving and storing raw materials,

> via the various manufacturing stages, through to warehousing and the selling of the end product. In addition, other structures may be present which served the needs of the workforce or facilitated maintenance. (HE 2017, 10)

Finally, it is worth noting that:

> Another form of group value occurs were there are a number of different industrial concerns clustered together, especially where there were historical linkages. (EH 2013b, 15)

Study of a particular watermill landscape may not reveal such connections, but they should be borne in mind. In many cases they will be obvious though as it is likely that such a cluster might be linked, or created, by the system supplying water to the mills concerned.

4.2.5. Survival/condition

Greater survival and better condition, can indicate an asset with higher significance than a less fully or well preserved example. Any active watermill landscape should be considered potentially significant, but even if not, it might still be so, particularly where legibility remains. Even sites only surviving in a state of decay may retain some significance, particularly perhaps where valued by the local community, for example as a leisure resource (see 4.3.2 below).

There is a distinction to be made between general deterioration, which leads to degradation of the site and therefore reduce its significance, and deliberate historic modification, which might remove earlier features but may in itself be significant, see for example architectural interest.

4.2.6. Fragility/vulnerability

Where a site has survived in good condition, the more fragile or vulnerable it is, the more important it is to protect it. In general, most assets associated with watermills are likely to be fairly substantial, and as such may not be seen as particularly fragile, though as noted elsewhere they usually rely on flowing water and can decline rapidly. Their association with watercourses, able to move large amounts of material over the years and exert significant forces during flood, also makes them more vulnerable than might be immediately apparent, especially in changing hydrological regimes.

4.2.7. Diversity

Some monuments may be selected for designation because they possess a combination of high quality features and others because of a single important attribute. In the case of the landscapes discussed here though, one of the primary arguments is that the whole is likely to be more significant than the sum of its parts so diversity in this sense is proibably not a primary consideration.

4.2.8. Potential

Sometimes, the nature of the evidence cannot be precisely specified, but it may still be possible to document reasons for anticipating its existence and importance and so to demonstrate potential. The greater the likelihood that such evidence will be revealed through investigation, the higher the potential significance of the site.

Reference to known archaeology, map evidence and other documentary sources can serve to demonstrate potential. It is also often possible to demonstrate potential through relatively small scale interventions, such as walk-over survey or coring, which can reveal the presence of leats and so on or deposits suitable for environmental sampling.

4.3. Interest

According to GPA 2:

> Understanding the nature of the significance is important to understanding the need for and best means of conservation. For example, a modern building of high architectural interest will have quite different sensitivities from an archaeological site where the interest arises from the possibility of gaining new understanding of the past. (DCMS 2015b, 2)

4.3.1. Archaeological

To rephrase archaeological interest as a question: does the heritage asset hold, or potentially hold, evidence of past human activity worthy of expert investigation at some point? Both buried features and upstanding remains may contain such evidence, but early standing buildings are less likely to survive than buried features, and features in active watercourses are less likely to survive than those in relict channels. Relict channels are particularly important for their potential to contain waterlogged deposits that preserve organic artefacts and environmental evidence, potentially relating to the area as a whole, not just the watermill landscape itself. A particularly important feature might be the wheel pit as this was typically the deepest part of the water supply system and so the most likely to survive. As noted, archaeological information can also survive in standing structures. Conversion, restoration and reconstruction can provide opportunities to access this information.

> In many industries ... techniques used during the industrial revolution were often closely-guarded secrets that were not documented. Archaeological analysis of deposits can play an important role in understanding these poorly documented processes ... This will seldom be the case when a full documentary record survives (EH 2013b, 15).

4.3.2. Architectural/artistic

The question of architectural and/or artistic interest might be put as: are the design and general aesthetics of the heritage asset of interest (whether arising from conscious design or fortuitously)?

Most assets relating to watermill landscapes were functional and unlikely to have been intended to have any intrinsic architectural or artistic merit. Even by this limited measure though this is not always the case; Howsham Mill, an 18th-century watermill near Malton, North Yorkshire (and nominated for a Heritage Angel Award) was described in 1965 by a RCHME Inspector as 'of great architectural interest as it is a very rare example of the Gothic Revival style as applied to a functional building' (http://howshammill.org.uk/about/history accessed 5/12/17). Such attention was rare though, and the mill building is typically the most visible element of the watermill landscape so similar attention has probably been applied to other elements of the landscape even less often. The 18th-century 'pastoral aesthetic' might be significant though, for example an existing mill pond might be used to mirror a country house by carefully placed approaches and planted blocks of woodland. For example the 17th-century mill adjacent to Dunham Massey Hall, Cheshire is listed Grade II* (NHLE UID 1067903). In contrast, cases based on the 'sublime' are also known. This is the idea that the terrible viewed from a distance becomes delightful, an example being the early 19th-century garden at Basingill, Cumbria, which deliberately incorporated gunpowder mills into its layout (Hunt and Everson 2004).

Architectural interest is not purely aesthetic however, and goes beyond the 'art' of the design. It may lie in the plan form of a building or the layout of an industrial complex; both are consciously designed though without any aesthetic value in themselves. Such designed elements may also inform about technological developments or other innovations. Early mills designed to be steam driven derive interest from the way in which the engines were incorporated into the building, as do mills utilising new materials such as cast iron.

The idea of fortuitous architectural or artistic merit seems more difficult to grasp and depends more on current perceptions rather than past intent. The vernacular has come to be appreciated in ways never intended or expected (Figure 20), and a secluded location, the sight and sound of tumbling water, glimpsed wildlife and so on might all be considered 'aesthetic' today in ways that they were not in the past, or which were not applicable; many industrial complexes that would have been hives of activity are now tranquil places.

4.3.3. Historic

When looking at historic interest the question is: does the heritage asset illustrate, or is it associated with, past lives and events? Almost any site can potentially be illustrative of the past though this quality is likely to be higher where the site is more complete and 'legible'. Functioning water supply systems, particularly associated with working mills, will have a much higher illustrative historic interest than dysfunctional, damaged, incomplete, fragmented or overgrown examples.

Associative historic value will clearly be specific to each site so it is harder to generalise. It is unlikely that many medieval corn mills will have associative historic interest because they were so ubiquitous, but their role in the lordly or monastic economy may be important. Where millers are named however, particularly where some details of their lives can be reconstructed, there may be some local associative interest. Conflicts over water rights may also generate legal documentation of interest. Nationally significant associative historic interest is more likely on later sites; new sites, new uses, industrial innovation and better documentation make this increasingly probable, as with the gunpowder industry for example (Figure 18).

In addition, communal value may also contribute to its historic interest. A watermill landscape might have heritage values arising not only from its history, design, location and so on, but also from its value as a childhood playground or venue for other leisure activities such as fishing (Figure 17) or even swimming (Figure 21). Memory may add to its interest.

4.4. The extent of the fabric that holds interest

GPA 2 states that:

> Understanding the extent of that significance is also important because this can, among other things, lead to a better understanding of how adaptable the asset may be and therefore improve viability and the prospects for long term conservation (DCMS 2015b, 2)

By understanding the key elements of the asset that hold significance and defining their location and extent it will be possible to also determine which areas do not hold, or hold lesser significance. This is vital for determing what should not change, what might be enhanced and what might adapted, modified or removed.

4.5. The level of significance

This refers to the assessment of significance relative to other assets, and set against the benefits of the proposed development. Once the nature of the significance has been determined and set out in detail it should be possible to determine how that asset compares to others. This will provide an indication of suitable approaches to protection and management. If the asset is of national significance then, in most cases, it will be a candidate for either listing or scheduling. In the case of listing a secondary consideration will be the level of that listing which will usually also be determined by a comparison with other similar examples. It is worth restating here that undesignated heritage assets should also be considered in decisions about the management of an area.

The level of importance of an individual asset within a landscape cannot be applied to the landscape as a whole, but if an important element is dependent upon other elements of the landscape then they become more so. As pointed out elsewhere, a nationally important working mill may be dependent upon an unremarkable weir located some distance away. In a sense this is the value of the group, as opposed to 'group value' which usually requires a close geographical association.

4.6. Setting

The forms of interest discussed above are expressed not only through the monument itself, but also its setting. This is defined in NPPF as:

> The surroundings in which a heritage asset is experienced. Its extent is not fixed and may change as the asset and its surroundings evolve. Elements of a setting may make a positive or negative contribution to the significance of an asset, may affect the ability to appreciate that significance or may be neutral. (DCLG 2012, 56)

For a full discussion of setting see HE 2017.

In looking at watermill landscapes we are clearly paying attention to the setting of individual assets, particularly the watermill building, but this is typically a functional view with an eye to the ways the assets relate to and interact with one another and therefore to approaches to management. In contrast, setting is broader and if we treat a watermill landscape as a whole setting will refer to changes beyond that landscape (rather than within it) that may negatively affect the experience of it. Development close to a watermill landscape could have a significant impact on its setting without affecting it directly and these impacts may not be immediately obvious. Road noise might intrude into a previously peaceful location for example.

4.7. Summary

4.7.1. Individual assets

Individual assets will have significance in their own right and the issues around such assessments are covered by the various guidance documents such as the SSGs for Industrial Sites and Agriculture (EH 2013b, EH 2012). In summary these come down to the following questions/factors.

What is the:

- Nature of the significance?
  - Archaeological interest?
  - Architectural/artistic interest?
  - Historic Interest?
- Extent of the fabric that holds that interest?
  - Mapped/annotated/described
- Level of importance of that interest? Determined in relation to:
  - Period
  - Rarity, is it:
    - Rare?
    - Part of a national distribution?
    - Part of a regional specialism?
  - Documentation

Group value
Survival/condition
Fragility/vulnerability
Diversity
Potential

4.7.2. Watermill landscapes

Looking at a watermill landscape as a whole will raise rather different issues to looking at each asset in isolation. This will to some extent be covered by the concept of group value, but may go some way beyond this since it will incorporate elements of the natural environment (see 2.2.1) and heritage assets that are clearly of only minor heritage significance but that are necessary to the functioning of whole, such as a length of leat.

It is clear that the significance of all assets concerned is enhanced by the extent to which the landscape of which they form a part remains functional or legible. A broad hierarchy of significance can be perhaps be outlined in these terms:

- Fully functional
- Partially functional
- Not functional, but legible
- Illegible, but substantially intact
- Fragmented, but with some connections remaining
- Isolated elements only

This functionality/legibility will be determined by:

- The extent of survival of the major elements of the system (with suitable allowance made for maintenance and replacement)
- The degree to which the relationship between the artificial and 'natural' elements of the system remain – the relationship to the watercourse
- The extent to which these remain watered
- The survival of minor features that add to the picture
- The extent to which these remain visible

However there is more to it than this. A fully operational mill and its landscape will clearly be highly significant, but an earlier relict landscape where it is possible to make sense of how the constituent elements once contributed to the functioning of the whole may be just as or more significant. We know relatively little about medieval mills and few examples have been excavated making any identified example of great potential interest. Also significant therefore are factors such as:

- The date of the system as a whole (bearing in mind individual elements could be later replacements or heavily modified)
- If the system represents innovation or tackles any unusual technical challenges

The various factors contributing to the interest must however be weighed in balance.

It was noted on several occasions above that it is difficult to make decisions regarding significance in the absence of a detailed resource assessment. However, the problems with the NRHE and the fragmented nature of HERs, discussed in 3 The resource above, mean that any national review would be a significant undertaking for which it is unlikely resources will be available in the foreseeable future. Resources need to be focussed on smaller, better defined areas that have already been identified as significant or where there are particular management issues. It may then be possible to extrapolate key conclusions to other areas. Regional studies such as the textile mills of Yorkshire (Giles and Goodall 1992) or thematic studies such as that examining the explosives industry (Cocroft 2000) would be useful approaches but even these may be beyond current resources. Perhaps the research agenda developed for the Derwent Valley provides a more useful exemplar (Knight 2016).

5. THREATS AND OPPORTUNITIES

The following section discusses the main threats to watermill landscapes. Many of these are linked, and several can combine to compound problems. There is sometimes a tendency to split threats up for analytical purposes but this should perhaps be countered by a recognition of the complex reality of multiple and interconnected threats and of factors representing both threats and opportunities.

5.1. Erosion and deposition

Erosion and deposition are on-going processes in all watercourses whether natural or artificial. Where flow is high material can be picked up and transported by the current to be dropped where the flow slows. The flow rate required for erosion to occur depends upon many factors, but the size and nature of the material to be transported is probably primary; clays require very low flow, boulders very high.

Watercourses are shaped by erosion and deposition (Figure 22), and this is not necessarily undesirable. They are natural processes which have become entangled with human projects, but the effects have been greatly influenced and accentuated by

Figure 22 – Erosion has undermined the bank causing this tree to fall across Hebden Brook, Yorkshire, further damaging the bank. Within the channel meanwhile, debris has started to accumulate against the trunk holding up the flow – in flood conditions this could act as a weir forcing water out of the channel leading to further erosion and deposition altering the form of the channel (Matthew Edgeworth © Historic England)

human factors such as intensified agricultural practices, drainage works, changes in climate, river management schemes, and so on (below).

Watermill landscapes were created to operate within a given river regime and when actively maintained are usually able to cope with typical conditions. In fact flows are used as part of the maintenance cycle allowing the scouring of leats for example. Occasional extreme conditions can also be coped with; there was often the assumption that a mill building might flood occasionally so they were usually designed accordingly. Problems occur when watermill landscapes are neglected and so can no longer cope with the conditions they were intended to deal with or the river regime changes, increasing the frequency of atypical conditions to the point where it becomes unsustainable. Erosion and deposition can also be problematic for relict watermill landscapes; erosion removes evidence and deposition masks it.

5.2. Flooding

Rivers and their valleys are susceptible to flooding, usually as a result of high precipitation causing rivers to rise and burst their banks, though spring melts can add to water levels and coastal flooding from storms and tidal surges can have consequences a long way inland.

As discussed above, catchments vary widely in their behaviour. Some are able to absorb large amounts of precipitation which then feeds into rivers over an extended period of time leading to steady and predictable rises and falls in level. Others are unable to store this water which feeds rapidly into the watercourse leading to flash floods. Both development and the intensification of agriculture (below) can reduce this 'storage capacity' leading to an increased tendency towards flash flooding. This is potentially highly damaging since it has much more force, is more likely to overwhelm any drainage systems or defences and is unpredictable.

Watermills and their wider supply systems have generally been designed and adapted to cope with anticipated rises and falls of water levels. The age of many surviving mill buildings testifies to their durability in the face of a wide range of river conditions. In most cases specific measures such as bypass channels are in place to prevent serious flood damage. However, as noted elsewhere climate change and changes to catchments are changing river basin hydrology which is having an impact on watermill landscapes, and neglect will reduce their capacity to cope with extreme events. Nevertheless the reinstatement of former watermill landscapes can help mitigate the flood threats.

Flood protection works in response to hydrological changes can themselves have unforeseen consequences. Projects to mitigate flooding in some parts of a river catchment may have an impact on the hydrological regime elsewhere. Hard barriers or river straightening in one area, intended to increase through flow and thereby reduce the chance of flooding, may well increase the potential for flooding elsewhere. Management of flooding emphasises the need to view catchments holistically.

5.3. Drought

Drought, leading to low water flows and levels, is also a threat to watermill landscapes. In working systems it can cause the drying out of structures and silting and vegetation growth in channels and ponds; the functionality of weirs and leats is best preserved by keeping them in operation. Relict systems with buried archaeological structures are perhaps better protected from the effects of drought, but a long term reduction in the level of the water table can lead to the rapid decay of waterlogged deposits newly exposed to aerobic conditions, and wetting/drying cycles are just as damaging, if not more so.

5.4. Climate change

There is now a strong scientific consensus on the reality of climate change, with the latest report from the Intergovernmental Panel on Climate Change (IPCC) indicating that the both that it is occurring and is 'extremely likely' (over 95% certain) to be the result of human activity, particularly atmospheric pollution since the industrial revolution (IPCC 2015, 4, 37). There are clear increases in the concentrations of carbon dioxide, methane, and nitrous oxide in the atmosphere which reduce the amount of heat radiating into space (hence the term 'greenhouse gases') which is giving rise to increasing global temperatures – 'global warming'. Many details of the likely effects of this are, however, uncertain. Potential effects and implications of climate change on the historic environment in general are set out in the EH report on climate change (EH 2008b; Cassar 2005).

In general terms a changing climate is likely to change river regimes and this will affect watermill landscapes by increasing the frequency of conditions that they were never intended to cope with. On a global scale, higher temperatures are predicted to lead to increased melting of glaciers and ice-caps, and thermal expansion of oceanic waters, resulting in rising sea-levels. This will have an obvious effect on all heritage assets close to sea level and can have an impact surprisingly far inland particularly for assets within river valleys.

More specifically, the British Isles are predicted to experience changing patterns of precipitationt with an increase in severe weather events such as storms. Flooding seems likely to become a more significant problem, both in terms of higher winter flows (though with spring snow melt being less problematic) and the chances of flash flooding from extreme precipitation all year round. More extended periods of drought in the summer months also seem likely which could damage watermill landscapes that were not previously susceptible. Combined with increased storminess this is also likely to lead to rapid erosion as dry deposits tend to be more unstable. To some extent all of these are existing threats but 'climate change should be seen as a risk multiplier, accelerating changes that are already happening' (Heathcote *et al* 2017, 89-90). Extensive further information on these threats and a range proposed of responses has been set out by Fluck (2016) in a detailed Historic England report.

5.5. River management

Rivers have been managed for centuries. They have been straightened, diverted, widened, narrowed, deepened, filled and modified in countless other ways since the Romano-British period (Blair 2007), with increasing evidence of human intervention in rivers in prehistoric periods too. Two of the main reasons for modifying rivers, certainly by the medieval period, was to supply watermills, and to improve navigation. In the modern period there have been significant changes in the roles of rivers; watermills and water meadows are no longer important and any remaining river navigations are primarily for leisure, but floodplains are becoming increasingly built up. Today the primary roles for river management schemes are flood control and environmental quality. Many stretches of rivers or tributary streams have been embanked, dredged, lined or culverted, in an effort to prevent flooding and erosion of adjacent developed land (above), others are having obstacles such as weirs removed or their banks and channels modified to improve biodiversity. Even where historic features have been retained they can be damaged by insensitive but otherwise well intentioned works. An unsightly concrete fish-pass has been added to the face of the 1820 weir at Meredith's Foundery, Kington, Herefordshire, which has also included a nick in the level of the crest to ensure water flows down the pass but which has left the rest of the face of the weir dry and so vulnerable. A similar example at the nearby Mortimer's Cross watermill suggests that such cases are not uncommon (pers comm Alan Stoyel).

The sheer extent to which English rivers and floodplains have been modified in the past has led to the river restoration movement, which seeks to counter human intervention in river systems by returning them to something like their ‘natural state’ (River Restoration Centre nd). This is usually seen as a gently and steadily falling channel with natural banks meandering through a broad floodplain, as opposed to the straightened, embanked and stepped channel partly divorced from its floodplain characteristic of many English rivers. Some aspects of river heritage are so inextricably entangled with hydrological, biological and geomorphological forces however, that the very idea of ‘natural’ as a category which excludes human involvement is deeply problematic, especially when it leads to the attempt to remove physical traces of that involvement. In the USA, a study of meandering streams that had previously been held up as models of natural watercourses, showed that an extensive series of 17th to 19th-century mill dams had played a major role in the formation of the present river channels and floodplains, yet had somehow passed unnoticed by previous investigators (Walter and Merritts 2008). If this is the case in North America how much more likely is it to be so in England with a much longer tradition of watermill construction and use? The concept of the ‘natural’ river needs to take heritage into account.

Another potential river management problem arises from the EU's 'Water Framework Directive' introduced in 2000. Although not seeking to naturalise rivers in the same ways it can be harmful to heritage assets as they are not always taken into consideration by natural environment professionals when looking at installing fish passes, improving water flows, or removing 'blockages' (such as weirs).

The problem is that historic watermill landscapes consist of precisely those features that some managers seek to remove. The impacts of poorly designed schemes on historic sites and landscapes can be profound, and watermill landscapes in particular are affected in numerous ways. Potential problems that have been identified include:

- Altering the physical characteristics of water bodies by modifying or removing in-channel structures and re-cutting river channels (hydro-morphological adaptation)
- Flood mitigation measures: reducing flood risk, improving resilience and informing responses to flooding events
- Creating infrastructure and changes in land management
- Changing surface hydrology
- Changing groundwater flows and chemistry on buried, waterlogged archaeological and palaeo-environmental remains
(adapted from Heathcote 2014)

5.6. Water abstraction

This is the removal of water from rivers and streams. This might be done for industrial or agricultural purposes (for example cooling industrial processes or irrigation), or for replenishing the public water supply. Water might also be taken out of the river for a wide range of minor uses such as fish farms. It should be borne in mind that there is long tradition of abstraction as part of human involvement with rivers, and watermill landscapes are themselves examples of systems of abstraction, though the abstracted water is (or was) nearly always returned to the watercourse a short distance downstream.

The most serious effects of abstraction occur when water is removed and not returned, lowering water levels, though this may only be a problem during periods of drought when water levels are already low. Lowered water tables can lead to drying out of wetlands and wet deposits within former channels, radically affecting the preservation of organic remains, including timber structures and artefacts (Chapman 2002, 242-244). Periods of low flow can be worsened by high abstraction rates. With regard to functioning structures such as weirs and leats, it has already been noted that these are best preserved through constant use, and quickly fall into disrepair if allowed to dry out.

5.7. Development

The primary form of development is the provision of housing, a pressing and ongoing concern. In the year to June 2017, newly built house completions totalled 153,330 (DCLG 2017), but government has estimated that 'the starting point for local plans across England should be 266,000 homes per year' (DCLG and Javid 2017). It should be noted though that these figures are not universally accepted; the Campaign to Protect Rural England (CPRE), for example, argue that the figure should be considerably lower as the government analysis is based upon demand rather than need (see for example CPRE 2015). Other relevant forms of development include the construction of commercial properties such as warehouses and supermarkets, transport development such as road and rail construction and capacity enhancement, and so on. In terms of areas affected though, these are an order of magnitude smaller, even combined (pers comm David McOmish, HE). Much of this development favours floodplains, attracted by the availability of undeveloped flat land which reduces building costs.

There is clearly the possibility that development will damage or remove elements of watermill landscapes. These direct impacts could affect part of a watermill's landscape and thus degrade the whole, but could potentially obliterate it entirely. It is likely though that the development control process will pick up some of these issues and mitigate them, at least in relation to those assets already identified as significant, though unidentified assets remain highly vulnerable. However, there is a reason why this land has remained undeveloped; floodplains flood. This typically results in works ancillary to the main developments to protect them, such as flood banks or channel dredging that will also have a direct impact, which may also need to be mitigated. The development and the protective ancillary works will also have indirect effects though, principally changed drainage patterns. Precipitation drains into watercourses faster from roads, pavements and gardens and once there everything possible is done to speed its flow away downstream where there will be an increased tendency towards flash flooding, which can be extremely damaging (above). A move towards sustainable drainage systems (known as SsDS) is likely to be beneficial (see 6.5.1 below). Watermill landscapes may be able to contribute to these systems.

It is not only large-scale developments that are an issue. Continuous small-scale or piecemeal development can gradually degrade any landscape to the point at which it loses enough significance to no longer merit protection and/or management. In the context of small scale development the conversion of mill buildings to domestic accommodation is potentially a positive reuse of a redundant building. The construction of outbuildings such as garages and perhaps the 'tidying' of the immediate surroundings to create driveways, gardens and might, however, have a negative impact on the visible connectivity in the surrounding watermill landscape.

Finally off site development can have an impact on the setting of watermill landscapes through visual or auditory intrusion even though there is no direct effect on the landscape itself.

5.8. Agriculture and forestry

Some watermill landscapes are under arable cultivation and ploughing has major direct impacts on some sites as well as indirect impacts caused by increased run off, often carrying increased sediment loads. Run-off can also increase fertiliser levels stimulating aquatic plant growth (eutrophication), which will also increase silting by slowing flow. The flow regime of rivers can also be altered by drainage works such as field drains, or agricultural practices which compress the soil, reducing infiltration. There are, however, a wide range of recommended practices through which farmers and land managers can reduce these risks and care for heritage assets on their land, many of which are also good for soil structure and fertility (Defra and NE 2009 (2017)).

It is worth bearing in mind that many relict watermill landscapes have survived because they have been under pasture, and therefore not available for other types of development which might be more harmful. Their continued use as such may be the optimum management solution; preserving them while at the same time allowing the farmer to make a living off the land.

Current agri-environment schemes aim to provide incentives to farmers to manage their land for the benefit of the environment, including heritage aspects (see 6.4 below). However many of the options currently proposed for capital grants, such as 'Constructed wetlands for the treatment of pollution' are potentially highly damaging to watermill landscapes if undertaken in the wrong place or inappropriately (see NE 2015, 64-6). It is unfortunate that heritage and environment seem to be seen as separate; landscapes such as those discussed here can be managed effectively for the benefit of both.

Forestry can also be both a threat and beneficial to watermill landscapes. Tree roots can damage buried archaeological remains, and the processes of felling and logging can be very damaging to surviving earthworks. However, uncontrolled vegetation growth can cause just as much harm (Figure 22) and properly managed woodland on floodplains can form an important part of river management, preventing soil erosion and absorbing water that would otherwise run into the river much more rapidly thereby ameliorating flood risk. Ideally though, plantations need to be planned with due care for both existing flows of water in extant channels and archaeological remains that may be largely hidden in relict watermill landscapes.

As with development both agriculture and forstry can have an impact on the setting of a watermill landscape.

5.9. Mineral extraction

The type of mineral extraction which impacts most on watermill landscapes is quarrying for sand and gravel (Humble 2008). This is because many watermill landscapes are on or adjacent to river terraces consisting of gravel laid down by outwash streams at the end of the last glacial period. Because it is open-cast, gravel quarrying is destructive of earthworks and buried archaeology. An additional impact of mineral extraction on wetland archaeology is change in the water table, affecting watermill landscapes and the preservation of buried deposits as described above. There is also a significant visual change resulting from the creation of lakes at the end of extraction.

Well planned mineral extraction does, however, provide the opportunity for archaeological investigation of riverside landscapes to be undertaken, prior to the quarrying taking place. For example, at Hemington on the Trent traces of at least two Norman mill-dams made of stone rubble, one with an eel-trap installed into its structure, were found alongside the remains of three medieval bridges (Clay and Salisbury 1990; Clay 1992). Because of the dynamic character of the Trent, the relict channels, dams and bridges had been buried beneath quite deep fluvial deposits and it is unlikely that this watermill landscape would have been identified during conventional archaeological evaluation.

5.10. Neglect

In order to function, watermill landscapes require regular maintenance. When this maintenance ceases, and flow is no longer controlled, problems arise. Dereliction of weirs, sluice gates and other structures, overgrowth of vegetation and silting of leats will lead to a watermill landscape rapidly becoming relict.

Leats are generally at least partly self-scouring, though some regular maintenance is required too. The normal flow of water keeps most sediment in suspension and carries away some build-up of material. This is usually supplemented by occasional scouring by increasing the flow and clearing vegetation. Once the flow slows or stops, leats rapidly clog up with silts and vegetation encroaches, making them more difficult to clean out. There is a great difference in character between a leat which is still operational and a leat that has degraded into a stagnant ditch (Figure 23); it is only a matter of time before it becomes completely redundant (Figure 24).

Working watermill landscapes are unusual. Most ceased to function many years ago and rapidly became relict landscapes. In these cases the threat of neglect is perhaps less pressing, but no less important. Scrub growth can obscure the landscape and make it impossible to 'read'. Unmanaged vegetation growth can lead to considerable

Figure 23 – The head race and sluice of a mill, silting up and filling with debris, probably Southover, Frampton, West Dorset but could also be Southover, Tolpuddle, West Dorset (1963 Joseph Addison © Historic England aa043572)

Figure 24 – Lewell Mill Farm, West Knighton, Dorset: the arch of the tailrace can be seen at the base of the wall of the wheelhouse to the right of the farm- (or rather mill-) house with the derelict channel of the former tailrace visible in the foreground; beyond, the embankment for the head race is visible (1960 Joseph Addison © Historic England aa042870)

damage as identified by the Heritage at Risk programme (6.2 below) and livestock can cause poaching leading to serious damage. The most significant areas such as leats containing waterlogged deposits are potentially the most vulnerable.

5.11. Hydroelectric energy generation

In hydroelectric energy generation turbines driven by flowing water rotate at high speed driving a generator which converts this mechanical energy into electrical energy. The amount of energy produced depends upon the speed and force of the water and the type of turbine used. According to the Department of Energy and Climate Change (DECC) the UK typically generates less than 1% of its power from hydroelectricity with most coming from large-scale schemes in the Scottish Highlands (DECC 2015). Although the potential for further large scale schemes may be limited, particularly in England, there may be scope for exploiting small-scale hydro resources. Based upon weirs and other river ‘barriers’ which have a head of at least 1.5m, the Environment Agency (EA) has identified over 21,000 potential sites for small scale hydropower plants in England (EA 2010). Although this may seem high, it is probably an underestimate; micro hydro plants can work with a head of as little as 1m and sites which require restoration have also been excluded.

The parallels with watermills are obvious and there is inevitably considerable overlap between watermill landscapes and sites suitable for small-scale hydroelectric schemes. Most of the 21,000 plus sites identified by the EA are likely to be associated with historic assets which are or were part of watermill landscapes:

> Many old mill sites were built with either a moderate length of intake channel, a tailrace channel, or both … Many of these mill races still exist and provide the majority of current opportunities for low head projects (EA 2009: 7).

Watermills occupy an optimal location, they already have a supply system providing a head of water and some have already been refurbished and used to generate hydroelectric power. Hydropower schemes have also been installed on weirs and leats that were once parts of watermill landscapes (Figure 25). This means that the impact of hydropower schemes on watermill buildings and landscapes needs to be considered and guidance has been produced by EH for development of micro-hydro schemes within traditional watermill buildings (EH 2014). As far as the EA is concerned however, when a hydroelectric scheme is being proposed, the most important permission that needs to be obtained is their abstraction licence, which permits water to be taken from rivers or streams for the purpose of power generation (EA 2009, 2010, EH 2014). The EA makes an assessment of environmental sensitivity based upon: water resources and hydromorphology, conservation, chemical and physio-chemical elements, fisheries and biodiversity, flood risk, and navigation (EA 2009: 5). Of these, only conservation is applicable to the heritage of the site, and archaeological or historic aspects are currently only considered in relation to designated assets. In addition, whilst consultation with Natural England (north-east) was referred to, consultation with EH (now HE) was not (EA 2009:

Figure 25 – A micro-hydro generation installation on a weir at Tor Mills, Derbyshire, with an Archimedes screw turbine within the protective cage behind the railings in the foreground (Matthew Edgeworth © Historic England)

10). There was consequently no explicit framework for including the heritage of the site within the environmental sensitivity audit which is somewhat at odds with the rationale of the drive for more hydro power schemes, which is based on utilisation of a historic resource as the quote above makes clear. Further work by HE and the EA is required to develop a better understanding of the issues and approaches needed to enable development to be undertaken with sensitivity to the historic environment.

Should the extensive development of small-scale hydropower schemes proposed by the EA therefore be regarded as a threat to historic watermill landscapes, or as positive re-use? Almost certainly both, and it will be a case of balancing the two, but these are issues that have rarely been considered before in the context of archaeological characterisation of watermill landscapes. From the point of view of protecting historic assets there are advantages to be gained from re-use, especially in the light of the threats posed by neglect (above). It can be argued that re-using watermill landscapes to supply new hydropower schemes provides motivation and financial support for their maintenance; it can lead to the repair and upkeep of structures which would otherwise fall into disrepair. Note the good condition of the weir and the low visual impact of the hydropower scheme itself shown in Figure 25. Historic England provides guidance on micro-power generation and the historic environment (EH 2014).

5.12. Summary

Many of the threats identified above apply to all or most categories of archaeological evidence, at least when located in river basins, and it is not possible in this report to consider measures for dealing with all of them. The intention here is to highlight the most significant threats, and to discuss their implications.

Flooding is perhaps one of the most serious threats, given the nature of watermill landscapes and their obvious susceptibility, particularly in the face of climate change and other pressures affecting the hydrological regime. However, watermill landscapes are designed to cope with floods. The idea of 'resilience' rather than 'resistance' is particularly appropriate here. Good river management is crucial, both in the catchment as a whole and on the scale of the watermill landscape itself, since it is this that enables the most effective flood management. Another problem identified was low water levels, but the answer to this comes down to the same thing; good management of the river. In this respect weirs and other working elements of watermill landscapes have both functional and heritage values.

Another relevant consideration is perhaps ideological and demonstrates that river management is not always straightforward. River restoration sets out to resolve problems of river ecology through restoring rivers to their 'natural' state, but this is a problematic concept, based on an opposition between nature and culture, which could lead to removal of historic features. What is needed is a critical examination of relationships between concepts of cultural heritage and the natural environment.

Another 'threat' draws attention to the potential of watermill landscapes, that of micro-hydropower. Identification by the EA of over 20,000 suitable sites recognises the value of watermill landscapes, which provide most of the proposed locations. How the potential of these sites for re-use should be balanced against the protection of their heritage value, and whether there is any contradiction in heritage assets having a functional role in the economic activity of power generation is clearly an issue.

Arising from the above discussion a final broader threat can also be identified, that of uncoordinated policy. Responsibilities for managing catchments rest with a number of government departments such as DDCMS (formerly DCMS), DEFRA, agencies like the Environment Agency, and NE, as well as local government, in addition to HE. Policies intended to address one set of issues may have unintended consequences for others. This can be a problem within a single policy document (it has been noted above that Countryside Stewardships grants could be used for work intended to improve water quality, but that could be damaging to the historic environment) and between separate documents or agencies (such as past river management plans intended to address biodiversity leading to the loss of historic weirs) for example. A more joined up approach towards management is called for and better working relationships are being developed between HE and NE.

6. PROTECTION AND MANAGEMENT

From the discussion above it is apparent that many watermill landscapes require management and/or protection. The assessment of significance, and the degree of threat, will be the key factors in determining the best approach to be taken. There are, however, numerous practical considerations to be taken into account, increasing with the extent and complexity of the landscape.

6.1. Designation

6.1.1. Statutory protection

One option is statutory protection by listing and/or scheduling.

Listing is the primary form of protection applied to standing buildings, and is currently administered under the designation regime set out in the Planning (Listed Buildings and Conservation Areas) Act 1990. As of 2016 there were approximately 377,500 listed buildings in England classified into 3 grades: Grade I, buildings 'of exceptional interest' (about 2.5% of listed buildings); Grade II*, 'of more than special interest' (about 6% of listed buildings); and Grade II, 'of special interest' warranting every effort to preserve them (just over 91% of listed buildings). In November 2017 the National Heritage List for England (NHLE) contained 964 Listed Buildings indexed as watermills; five at Grade I (0.5%), 96 at Grade II* (10%) and 863 at Grade II (89.5%). Although the mill building is not the prime consideration in this report the listing might extend, through curtilage, to some associated structures and thereby offer some protection. Curtilage is however complex and administered by local authorities.

Archaeological assets or other heritage assets that are unsuitable for listing, mainly archaeological sites and unused or ruinous buildings, may be suitable for scheduling. Scheduling was the first form of heritage protection, dating from the 1882 Ancient Monuments Act, most recently updated as the 1979 Ancient Monuments and Archaeological Areas Act. Scheduled monuments form a carefully chosen sample and are tightly managed with very high levels of legal protection. The bar for scheduling is 'national importance' rather than 'special interest', the bar for listing at Grade II. Scheduling is discretionary and there are sometimes other management options that may be more sustainable. In November 2017 the NHLE contained 65 Scheduled Monuments with indexed watermills but this may be missing some entries. During the searches it was noted that although one watermill had been added to the list since 2014 the number of results had risen by 36 due no doubt to additional indexing. Further, a comparison with the NRHE, based upon a geographical correlation within the Historic England corporate GIS, showed that 122 watermills coincided spatially with a Scheduled Monument. Some of these additional scheduled sites may incorporate watermills (and elements of their landscapes) but have not been indexed as such. This is most likely to be the case with old entries containing very limited information. The mill and its landscape may be specifically excluded from the scheduling though. It is crucial to both check the List entry and to bear in mind that undesignated assets are still potentially important.

The two approaches are not mutually exclusive. In an industrial complex for example, the standing buildings may be listed but the underlying earthworks and archaeological deposits scheduled. It seems highly likely that were a watermill landscape considered to be of sufficient significance a mix of these designations, dependent upon the nature of the landscape, could be the most beneficial approach.

Historic England has produced a range of selection guides explaining the factors taken into account when considering recommending places for designation (see https://www.historicengland.org.uk/listing/selection-criteria/ which also covers other forms of designation (below) and contains links to underpinning government policy on listing and scheduling).

Once a heritage asset has been designated restrictions are placed upon what owners and managers are entitled to do and explicit permission must be sought for many, if not most works. These are explained in Scheduled Monuments - A Guide for Owners and Occupiers (EH 2013c) and for listed buildings (and conservation areas, below) via the Historic England 'Your Home' portal (https://historicengland.org.uk/advice/your-home/).

6.1.2. Other forms of national designation

The other forms of designation available are registration on the Register of Historic Parks Gardens of Special Historic Interest in England or on the Register of Historic Battlefields, though the latter is unlikely to be directly relevant. Although statutory lists, they bring no additional statutory powers, instead working through the development control system to provide a tool for the protection of the areas defined. The NPPF states (para 132) that great weight must be given to the conservation of sites included on the registers and that substantial harm or loss can only be justified in exceptional cases.

The NHLE included (November 2017) a single Registered Park and Garden and no Registered Battlefield with 'watermill' as an index term. More watermills and elements of their landscapes might be included in these registered landscapes than is immediately apparent though. The comparison with the NRHE showed that 56 watermills coincided spatially with a Registered Park and Garden, and 2 with a Registered Battlefield.

6.1.3. Conservation Areas

Conservation Areas are designated places 'which are especially valued for their historic character and associations... What makes them special is the combination of buildings, streets, spaces and archaeology, which we enjoy, work and live in' (https://www.historicengland.org.uk/advice/heritage-at-risk/conservation-areas-at-risk/). No individual elements of a Conservation Area have statutory protection arising from the Conservation Area itself (though many will contain high numbers of listed buildings and so on), but special considerations apply to planning permission and other development control procedures in them. They are mainly created and administered by Local Planning Authorities, though HE can designate them in

London. They were first created in 1967 and currently operated under the Planning (Listed Buildings & Conservation Areas) Act 1990. There are now over 8000 in England.

They are a potentially useful tool in managing broad areas since Conservation Areas can tie together a range of assets into a meaningful area designation, flag up the importance of the area in a holistic manner, and encourage unified approaches to management. Historic England has published advice on their designation, appraisal and management (https://content.historicengland.org.uk/images-books/publications/conservation-area-designation-appraisal-management-advice-note-1/heag040-conservation-area-designation-appraisal-and-management.pdf/).

Many watermill landscapes are located within, or partially within, Conservation Areas. There are 317 listed buildings indexed as watermills that lie within conservation areas and a total of 649 AMIE records of watermills which are within or partly within a Conservation Area. Although there is considerable overlap between these two sets of figures it is clear that several hundred Conservation Areas include watermills, and no doubt significant elements of the associated landscapes. Others will incorporate relict watermill landscapes and those where the mill itself is long gone.

6.2. Heritage at Risk

The aim of HE's Heritage at Risk (HAR) programme is to protect and manage key designated heritage assets that are 'at risk' or vulnerable of becoming so. It does not cover undesignated assets, nor Grade II listed buildings. HAR has its origins more than two decades ago in the Monument Protection Programme (MPP), although MPP did not look at watermills nor their associated landscapes (pers comm, Wayne Cocroft, Historic England). Local authorities also maintain their own HAR registers.

The HAR programme provides a dynamic picture of the health of England's designated heritage. Through the annual publication of the HAR Register and sharing the results of HE's analysis of trends and data, HAR provides the evidence needed to direct help towards those sites most in need. Local HAR teams work with owners, funders and other stakeholders to find the right solutions for sites on the Register. It has proved to be a very successful way of highlighting historic buildings and sites in need of repair and conservation, and encouraging their re-use as generators of jobs, providers of new homes and focal points for pride in urban, rural and marine heritage.

There are currently (November 2017) 29 entries on the national HAR register categorised as a 'mill' (narrower terms are not available), though it is unlikely that these are all the mills. A search for entries including 'mill' in the name returned 138 though this figure included multiple entries for complex sites (such as five for Ditherington Flax Mill), and entries clearly not mills. It is possible that other entries on the register include watermills or elements of their landscapes, but the register is indexed either by the part of site actually at risk, or 'the monument type thought to best represent the entry as a whole' (pers comm Debra Ward, HE). Of the 29 categorised mill entries a rapid inspection indicates that 13 are watermills two may be and one is an industrial Victorian flax mill adjacent to a river that may have developed on the site of an earlier watermill. The remainder were mainly windmills. Most are listed buildings; 11 at Grade II* and one at Grade II. Four are scheduled monuments. Some examples had multiple designations (only the primary designation is given above), for example the 'at risk' elements of Hibaldstow Mill include a scheduled area and two buildings listed separately at Grade II* and II. This is also the only entry to mention elements of the wider mill landscape; the walls to the mill pond and wheel race, both likely to be close to the mill building itself. Where the reasons for being on the register were given the most common was 'deterioration' (four entries) followed by 'collapse' (two entries), and 'damaging tree growth'/'development requiring planning permission'/'erosion of fabric – other (e.g. renders, timber) – severe'/'forestry'/'natural erosion – moderate'/'rain entry' (one entry each).

6.3. The planning system

The aim of the current planning system is sustainability; meeting the needs of the present without compromising the ability of future generations to meet their own needs. As such it should permit sustainable development, a key aspect of which is environmental; 'protecting and enhancing our natural, built and historic environment' (DCLG 2012, 7). It is clear that watermill landscapes embody all three.

The system provides a high level of control over development, but does not cover most agricultural buildings (permitted development) or indeed any agricultural activity (see 6.4 Agri-environment schemes below). Current planning policies are set out in the National Planning Policy Framework (NPPF, DCLG 2012) which includes policies for the historic environment. This replaced Planning Policy Statement 5 (PPS5, DCMS 2010a) which was accompanied by the PPS5 Historic Environment Planning Practice Guide (PPS5 PPG, DCMS 2010b). The latter guidance has also been replaced, by *Conserving and Enhancing the Historic Environment* (CEHE, DCLG 2014). The NPPF and CEHE are material considerations in planning applications, listed building consents and planning permission for relevant demolition in a Conservation Area. They do not apply to scheduled monument consents, but are relevant to other permissions for activities affecting scheduled monuments.

There are two main strands to the planning system. Local plans set out what the needs of the area covered are likely to be over the plan period (informed by national policies in some instances) and where development to meet these should take place (HE 2015a), and the development control process manages the consents and permissions for developments themselves (HE 2015b). The latter include planning permission, and listed building consent, but not scheduled monument consent. The NPPF also makes it clear that undesignated assets may be significant which gives them weight in planning decision making. Local lists are a key element in flagging these assets (see Historic England's advice https://content.historicengland.org.uk/images-books/publications/local-heritage-listing-advice-note-7/heag018-local-heritage-listing.pdf/).

It would be beneficial for the management of watermill landscapes if they could be taken into account in both local plans and development control. To do this planners and curators need to be aware of watermill landscapes and their significance; both Historic Environment Records and Conservation Areas are vital tools in this.

6.3.1. HERs

Historic Environment Records (HERs) are repositories of information on local historic assets that underpin the work of local authority historic environment services and are usually maintained by local planning authorities. They can help improve the protection, conservation and management of heritage assets by informing the planning process of significant heritage assets in their area (see http://www.heritagegateway.org.uk/gateway/). As such the quality of the information they contain is crucial but maintaining standards in the face of pressure on services is problematic and backlogs are increasing.

In an ideal world it would be beneficial if high-level records and GIS polygons could be created for watermill landscapes that pulled together all the relevant subsidiary entries. This would highlight their significance as holistic landscapes and go a long way to helping protect them, particularly from piecemeal development that gradually degrades them. This would have significant resource implications and is unlikely to be feasible in current circumstances, but a review of the various thesauri and an addition to recording guidelines may gradually improve the situation in the future allowing particular cases to be addressed as they arise.

6.4. Agri-environment schemes

Agri-environment schemes provide a mechanism whereby farmers can be rewarded for managing their land in ways that benefit the environment, including its heritage. As such they can be seen as complementary to the planning system. The current scheme, known as Countryside Stewardship, began in April 2015 and replaced the previous Environmental Stewardship scheme. In summary: 'The main priority for Countryside Stewardship is to protect and enhance the natural environment, in particular the diversity of wildlife (biodiversity) and water quality. Other outcomes include: flood management; the historic environment; landscape character; genetic conservation; and educational access' (NE 2015, 3). Further information is available from https://www.gov.uk/government/collections/countryside-stewardship-get-paid-for-environmental-land-management.

Although several of the scheme priorities are relevant to watermill landscapes they are of secondary importance. For example schemes suitable for capital grants omit any heritage benefits and some are potentially harmful. Perhaps it should be emphasised that many historic landscapes provide numerous habitats and that management to protect their heritage significance can support other aims. It does not need to be an either/or situation.

Countryside Stewardship is dependent upon the quality of data contained in HERs in the same way as the planning system (above). HER data feeds into the database, known as SHINE (the Selected Heritage Index for Natural England), used by NE to identify which land parcels are eligible for inclusion in the scheme based upon their heritage value (see http://www.myshinedata.org.uk/home). The issues identified in relation to HER data therefore also apply to SHINE data.

6.5. River management

Responsibility for river management lies primarily with the EA, the government body with responsibility for managing and improving the environment. This is primarily articulated through River Basin Management Plans (RBMPs), focussed on environmental quality, and Flood Risk Management Plans (FRMPs) intended to reduce the hazards of flooding. The EA have adopted a catchment-based approach for both based upon 10 large, geographically-determined River Basin Districts covering England that are subdivided into more than 90 Water Management Catchments each of which is based upon a major river, or part of a larger river system.

To some extent both can be seen as threats to watermill landscapes and in the past they have not always considered heritage adequately, but heritage issues are being flagged up in current consultations and this seems likely to improve considerably in plans currently being prepared. Sensitively handled RBMPs and FRMPs present opportunities for environmental improvements and the promotion of river catchment management in ways that can also sustain and enhance local heritage character and distinctiveness.

6.5.1. Sustainable drainage schemes (SuDS)

As noted above (5.7), most development typically features hard surfaces, landscaping and drainage which tends to increase the probability of flooding within a catchment. The intention of sustainable drainage schemes (SuDS) is the opposite; to slow down water and thereby maintain a more 'natural' hydrological response. SuDS use a suite of methodologies including: green roofs and green walls; water butts and rainwater harvesting systems; rain gardens and bio-retention systems; permeable paving; surface rills and channels; water bodies and features; and rainwater recharge of groundwater. These can generally be applied most easily to new builds, but can also be retrofitted. Some are clearly suited to watermill landscapes and this approach highlights the ways in which the restoration of a watermill landscape can enhance water management within a catchment. Use of this approach also has substantial benefits for biodiversity. HE guidance on Sustainable Drainage Systems (SuDS) and the Historic Environment is currently in preparation. The Construction Industry Research and Information Association (CIRIA) also provides guidance on SuDS, though with a focus on design and construction, this is currently only available to members.

6.6. Management agreements

Management agreements are one way of facilitating close partnerships between owners, local planning authorities and a potentially wide variety of other relevant organisations and are also promoted by HAR (above). They can be informal, but can also be powerful legal tools, particularly in relation to designated assets. Such agreements for listed buildings are enabled by The Enterprise and Regulatory Reform (ERR) Act 2013. Amongst other measures this allows heritage partnership agreements to be entered into between local authorities and owners setting out works for which Listed Building Consent is granted. With regard to scheduled monuments, Section 17 of the 1979 Ancient Monuments and Archaeological Areas Act (as amended) allows for the creation of agreements between the Secretary of State, HE, or a local authority and 'the occupier of an ancient monument'. These can include arrangements relating to 'maintenance and preservation', 'carrying out of … work', 'public access', 'restricting … use', and prohibition of specified activities. Section 17 can clearly be a powerful tool allowing management agreements to be drawn up that both protect scheduled monuments and enable their maintenance and development.

6.7. Summary

A range of options are available to protect and manage watermill landscapes judged to be significant enough.

Statutory protection is an option for many elements of watermill landscapes of the required level of significance. Listing can be applied to standing buildings and other structures, whereas scheduling may be more appropriate to derelict structures, and as area designations for buried archaeological remains. The register of historic parks and gardens contains landscapes protected because of their design and offers an element of protection through the planning process. Mills may be an element of parkland design and add to its interest. Where mills are located within Conservation Areas it is likely that they and their landscapes will contribute to their character. The best approach might be a combination; listing and scheduling could target the most significant assets with registration and/or Conservation Areas providing coverage of the wider area including less significant assets. The HAR programme has developed a range of approaches to identifying designated assets 'at risk' and then reducing that risk, all of which would be useful approaches to managing watermill landscapes, including:

Nevertheless, the majority of individual assets will not be of sufficient importance to merit designation, but taken as a whole a watermill landscape may be more significant than the component assets suggest. In these cases statutory protection may not be suitable and they will have to be managed in some other way, perhaps through the planning system, as set out in the National Planning Policy Framework (NPPF). This relies on good quality HER data feeding into local plans and the development control process.

Countryside Stewardship provides incentives to farmers to manage their land for the benefit of the environment including heritage, but is optional and competitive, and again relies on good quality data feeding into SHINE. With heritage apparently being seen in this context as a lower priority than biodiversity, water quality and flood management it is both less likely to receive funding and more likely to suffer if there are opposing aims. There are likely to be similar issues with river management plans. In all these cases it should be possible to find solutions if heritage is taken into consideration at an early stage and ideally there needs to be a mechanism to ensure this takes place.

7. CONCLUSIONS AND RECOMMENDATIONS

Watermill landscapes are complexes of interrelated historic assets linking natural and artificial watercourses and a wide range of structures into a whole constituting far more than the sum of its parts. Individual assets may have limited significance yet be crucial to the operation or understanding of the whole and as such might deserve protection and management beyond that likely to be recommended if viewed in isolation. In addition to this, each asset may well support several others in better condition than they would be were they to become isolated. The HAR programme makes the point that regular maintenance is cheaper and better in the long run than costly repairs and in watermill landscapes flowing water is a maintenance tool.

Assessing the significance of watermill landscapes is not straightforward. Guidance has been published that can be used to make assessments of individual elements, such as the SSGs for Agriculture and Industrial Sites and the LSG for Industrial Buildings, which discuss aspects of group value that can be applied to watermill landscapes. Some studies of water management assets in particular areas such as on the Kennet/Avon catchments (Firth 2014) and in South Yorkshire (ECUS 2015) have been undertaken as have surveys of particular assets types, such as weirs on the Lugg (Stoyel 2014); all identify criteria for assigning significance. Whilst these are valuable they tend to treat assets in isolation rather than look holistically at the landscapes of which they form a part. The lack of a broad resource assessment of water management assets makes it difficult to identify which particular classes or types of asset are rare, what might constitute a particularly early or innovative example, which local or national distributions are significant, what particular features should be looked out for when assessing significance, or which assets might be particularly under threat and from what source. This is much more the case when watermill landscapes are looked at; they have rarely been studied holistically and it is difficult to say what might be special or what commonplace.

Watermill landscapes are vulnerable to a wide range of often interrelated threats. River basins are geomorphologically dynamic with constant erosion and deposition removing and masking features. The direct relationships between watermill landscapes and watercourses also make them vulnerable to flooding and drought which will probably be exacerbated by climate change. Extraction of groundwater may compound problems by lowering the water table. These landscapes can be resilient and have developed to cope with flood and low flow, but this relies on continuous maintenance and neglect can be a serious problem, and become so quite rapidly. Much development is now favouring floodplains which has a direct impact on heritage assets, changes the hydrological regime and increases pressure for flood management schemes which have their own impacts. Mineral extraction, particularly of river terrace gravels, has similar direct and indirect effects. Agriculture can also be a problem; ploughing can be directly damaging and have indirect effects with increasing run off leading to increased silting and raised fertiliser levels leading to eutrophication and land drainage lowering infiltration and water tables. There is consequently pressure to manage rivers more holistically with the aim of improving water quality, biodiversity and the natural environment as a whole, a laudable aim, but often without proper consideration of the historic environment.

The HAR programme has highlighted a range of approaches to management, many of which are particularly relevant when working with dispersed, but interrelated assets. These include; partnership working, the provision of evidence based advice and guidance, and to a limited extent targeted funding. To make best use of limited resources the use of management plans and agreements enables works to be prioritised and facilitated.

It is emphasised above that watermill landscapes represent a clear case where group value must be a primary consideration when assessing significance. It would therefore be valuable to draw the boundaries of any designated areas to include all the elements of the system if at all possible. Similarly it would be beneficial were HERs to create high level records for whole watermill landscapes, which would also help to protect significant examples not felt to meet the level of importance required for designation. These should also be fed through to SHINE and incorporated into agri-environment schemes where possible. Where a watermill landscape clearly adds to the character of an area more generally it may well be worth creating, or incorporating it into, a Conservation Area, redrawing boundaries if necessary. It might also be beneficial to add the watermill landscape to the description of a Registered Park and Garden (or even a Registered Battlefield), where it is a significant element of that landscape, to ensure it is considered when planning management options.

To summarise, the key recommendations of this project are:

- Raise the profile of watermill landscapes (perhaps through a new Introductions to Heritage Assets publication) with:
  - Landowners and farmers
  - The full range of government agencies involved with environmental management
  - Local authorities, including planners and curatorial staff
  - Community and amenity groups
- Produce guidance supported by underpinning research (in decreasing order of required resource):
  - Full resource assessment
  - Holistic study of a range of watermill landscapes
  - Management case studies
- Take opportunities as they arise to reconsider designations and enhance descriptions
- Make better use of Registration and Conservation Areas to tie together Individual Listed Buildings and Scheduled monuments into holistic areas
- Enhance HERs and feed data into agri-environment schemes
  - This may require the re-evaluation of current Thesaurus terms and HER recording guidelines
- Work closely with other government agencies to ensure ‘joined up thinking’
- An assessment and management toolkit might enable individuals and small groups to protect locally significant watermill landscapes

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9. APPENDIX: THESAURUS TERMS

The following table identifies key Thesaurus terms (see 3.1.1 The HE Monument Type Thesaurus) by following links embodied in the Thesaurus, an online resource, from 'WATERMILL' down through narrow terms (NT), horizontally to related terms (RT) and back up to broad terms (BT). Over 80 narrow terms for 'MILL' have been omitted as they are functional; fulling mill, gunpowder mill and so on.

Table 1 A summary of Thesaurus terms related to 'WATERMILL'

Term	Scope note	Class	Broad term	Narrow term	Related terms
WATERMILL	A mill whose machinery is driven by water.	INDUSTRIAL	WATER POWER PRODUCTION SITE	HORIZONTAL WATERMILL	CORN MILL HEAD RACE MILL DAM MILL POND MILL RACE TAIL RACE TUMBLING WEIR TURBINE MILL WATERWHEEL WEIR
BT= WATER POWER PRODUCTION SITE	Buildings, sites and structures associated with the production and use of water power.	INDUSTRIAL	POWER GENERATION SITE	DAM DRAINAGE MILL HAMMER POND LEAT MILL POND MILL RACE PEN POND PUMP HOUSE TIDE MILL TURBINE MILL WATER TURBINE WATERWHEEL WATERCOURSE WATERMILL WHEEL HOUSE WHEEL PIT	
NT= HORIZONTAL WATERMILL (use for Greek Mill)	A water mill where the waterwheel directly drives a vertical shaft with grindstones on.	INDUSTRIAL	WATERMILL		

Term	Scope note	Class	Broad term	Narrow term	Related terms
RT= CORN MILL (use for Grist Mill)	A mill for grinding corn. Use with power type where known.	INDUSTRIAL	FOOD PROCESSING SITE		CORN DRYING KILN CORN DRYING OVEN GRANARY MILL HOUSE PURIFIER TIDE MILL
		INDUSTRIAL	MILL		MILL POND TUMBLING WEIR WATERMILL
RT= HEAD RACE	Water channel leading to waterwheel.	WATER SUPPLY AND DRAINAGE	MILL RACE		MILL POND TUMBLING WEIR WATERMILL
		INDUSTRIAL	MILL RACE		WATERWHEEL
RT= MILL DAM	A dam constructed across a stream to raise its water-level and make it available to power a mill wheel.	INDUSTRIAL	DAM		MILL POND WATERWHEEL WATERMILL
		WATER SUPPLY AND DRAINAGE	DAM		POND BAY
RT= MILL POND	The area of water retained above a mill dam for driving a mill.	WATER SUPPLY AND DRAINAGE	POND		FURNACE POND HAMMER POND HEAD RACE LEAT MILL DAM MILL RACE SHEER HULK SHEER LEGS TAIL RACE WEIR
		INDUSTRIAL	WATER POWER PRODUCTION SITE		MILL DAM MILL RACE PEN POND WATERMILL
RT= MILL RACE (use for Pentrough)	The channel of water that provides a current of water to drive a millwheel.	INDUSTRIAL	WATER POWER PRODUCTION SITE	HEAD RACE TAIL RACE	LEAT MILL POND WATERMILL WEIR
		WATER SUPPLY AND DRAINAGE	WATERCOURSE	HEAD RACE TAIL RACE	LEAT MILL POND TUMBLING WEIR WATER CHANNEL WEIR

Term	Scope note	Class	Broad term	Narrow term	Related terms
RT= TAIL RACE	A water channel leading from a waterwheel.	INDUSTRIAL	MILL RACE		
		WATER SUPPLY AND DRAINAGE	MILL RACE		MILL POND TUMBLING WEIR WATERMILL
RT= TUMBLING WEIR	An outfall from a canal, river or reservoir.	INDUSTRIAL	WEIR		FORGE HEAD RACE MILL RACE TAIL RACE TIDE MILL WATERMILL
		WATER SUPPLY AND DRAINAGE	WEIR		
RT= TURBINE MILL	A mill which is powered by a turbine.	INDUSTRIAL	WATER POWER PRODUCTION SITE		PUMP HOUSE WATER TURBINE WATERMILL
RT= WATER-WHEEL	A structure associated with forges, watermills, water-powered factories, etc.	INDUSTRIAL	WATER POWER PRODUCTION SITE	BREASTSHOT WHEEL OVERSHOT WHEEL PITCHBACK WHEEL SCOOP WHEEL UNDERSHOT WHEEL	HEAD RACE HELVE HAMMER MILL DAM POND BAY TIDE MILL TRANSMISSION RODS WATERMILL WHEEL HOUSE WHEEL PIT
RT= WEIR	A dam constructed on the reaches of a canal or river designed to retain the water and to regulate its flow.	INDUSTRIAL	DAM	TUMBLING WEIR	CANAL MILL RACE WATERMILL
		WATER SUPPLY AND DRAINAGE	DAM	TUMBLING WEIR	CANAL EEL TRAP FISH LADDER FLASH LOCK FORD FORGE MILL POND MILL RACE RIVER NAVIGATION SLUICE WATER CHANNEL WATERMILL

     

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