Historic England

Scientific Dating

Church of St Mary and St Edward, Church Road, West Hanningfield, Essex

Tree-ring Analysis of Oak Timbers from the Tower and Bellframe

Martin Bridge

Discovery, Innovation and Science in the Historic Environment

Research Report Series no. 24-2016

Research Report Series 24-2016

CHURCH OF ST MARY AND ST EDWARD, CHURCH ROAD, WEST HANNINGFIELD, ESSEX

TREE-RING ANALYSIS OF OAK TIMBERS FROM THE TOWER AND BELLFRAME

Martin Bridge

NGR: TQ 73508 99825

ISSN 2049-4453 (Online)

The Research Report Series incorporates reports by the expert teams within the Investigation & Analysis Division of the Heritage Protection Department of Historic England, alongside contributions from other parts of the organisation. It replaces the former Centre for Archaeology Reports Series, the Archaeological Investigation Report Series, the Architectural Investigation Report Series, and the Research Department Report Series.

Many of the Research Reports are of an interim nature and serve to make available the results of specialist investigations in advance of full publication. They are not usually subject to external refereeing, and their conclusions may sometimes have to be modified in the light of information not available at the time of the investigation. Where no final project report is available, readers must consult the author before citing these reports in any publication. Opinions expressed in Research Reports are those of the author(s) and are not necessarily those of Historic England.

Requests for further hard copies, after the initial print run, can be made by emailing:
Res.reports@historicengland.org.uk
or by writing to:
Historic England, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth PO4 9LD
Please note that a charge will be made to cover printing and postage.

SUMMARY
Eight timbers were sampled within the tower and five timbers were sampled in the bellframe. The timbers used in both structures were derived from relatively fast-grown oak trees. None of the bellframe timbers could be dated, but two of the large corner posts of the tower were successfully dated and were probably felled at the same time. The mean heartwood-sapwood boundary date of AD 1373 gives a likely empirically-derived felling date range of AD 1382–1414 for these two timbers, whilst their *combined felling date range* derived through OxCal is *AD 1383–99 (95% probability)*.

CONTRIBUTORS
Martin Bridge

ACKNOWLEDGEMENTS
This study was requested by David Eve, Historic England Inspector of Historic Buildings and Areas, and commissioned by Shahina Farid of the Historic England Scientific Dating Team. I am grateful to Mary Armson for arranging access and providing copious drinks and cake. Elphin Watkin assisted with the fieldwork, provided the plans and sections used in this report, and aided understanding of the structures investigated. Kim Wallis assessed the activity of the resident bats on behalf of Natural England, and advised on the timing of sampling. I am grateful to Cathy Tyers, Historic England Scientific Dating Team, for her input throughout the analysis and production of this report.

ARCHIVE LOCATION
Essex Historic Environment Record
Historic Environment Specialist Team
Place Services
County Hall
Chelmsford
Essex
CM1 1QH

DATE OF INVESTIGATION
2015–16

CONTACT DETAILS
Dr M C Bridge
UCL Institute of Archaeology
31–34 Gordon Square
London WC1H 0PY
E-mail: martin.bridge@ucl.ac.uk

CONTENTS

INTRODUCTION

This Grade II* listed church lies towards the east end of the village of West Hanningfield, which is about 8km south of the city of Chelmsford (Figs 1 and 2). It is believed to be of twelfth-century origin but with much alteration taking place in the eighteenth and nineteenth centuries. Perhaps its most interesting feature is the timber-framed tower, dated on construction and stylistic evidence to the early thirteenth century (Hewett 1962). The frame is cruciform in plan and weather boarded. The arms of the cross are of two stages, with low pitched gabled roofs. The bells are presently not operable and have been this way for a considerable period of time. The bells were cast in 1676, and are a rare example of a complete seventeenth-century ring and listed as of historic importance by the Church Buildings Council. An unpublished report on the condition of the bell installation in 2015 by Whitechapel Bell Foundry Ltd. notes that the bellframe was cut to install the 1676 bells, so it is reasonable to assume it predates this, although they also note that some timbers have been replaced since that time.

Dating was requested by David Eve in order to provide independent dating evidence for the primary construction of the tower and bellframe, and any later modifications, to inform advice relating to the impact that the proposed scheme to return the bells to full circle ringing would have on the significance of the timber-framing of the tower and the bellframe.

METHODOLOGY

Fieldwork for the present study was carried out in June 2015, following an initial assessment of the potential for dating a few weeks earlier and consultation with a local bat specialist on the most appropriate timing for sampling to be undertaken. In the initial assessment accessible oak timbers with more than 50 rings and where possible, traces of sapwood, were sought, although slightly shorter sequences are sometimes sampled if little other material is available. Those timbers judged to be potentially useful were cored using a 15mm auger attached to an electric drill. The cores were glued to wooden laths, labelled, and stored for subsequent analysis.

The cores were polished on a belt sander using 80 to 400 grit abrasive paper to allow the ring boundaries to be clearly distinguished. The samples had their tree-ring sequences measured to an accuracy of 0.01mm, using a specially constructed system utilising a binocular microscope with the sample mounted on a travelling stage with a linear transducer linked to a PC, which recorded the ring widths into a dataset. The software used in measuring and subsequent analysis was written by Ian Tyers (2004). Cross-matching was attempted by a combination of visual matching and a process of qualified statistical comparison by computer. The ring-width series were compared for statistical cross-

matching, using a variant of the Belfast CROS program (Baillie and Pilcher 1973). Ring sequences were plotted on the computer monitor to allow visual comparisons to be made between sequences. This method provides a measure of quality control in identifying any potential errors in the measurements when the samples cross-match.

In comparing one sample or site master against other samples or chronologies, *t*-values over 3.5 are considered significant, although in reality it is common to find demonstrably spurious *t*-values of 4 and 5 because more than one matching position is indicated. For this reason, dendrochronologists prefer to see some *t*-value ranges of 5, 6, and higher, and for these to be well replicated from different, independent chronologies with both local and regional chronologies well represented, except where imported timbers are identified. Where two individual samples match together with a *t*-value of 10 or above, and visually exhibit exceptionally similar ring patterns, they may have originated from the same parent tree. Same-tree matches can also be identified through the external characteristics of the timber itself, such as knots and shake patterns. Lower *t*-values however do not preclude same-tree derivation.

Ascribing felling dates and date ranges

Once a tree-ring sequence has been firmly dated in time, a felling date, or felling date range, is ascribed where possible. With samples which have sapwood complete to the underside of, or including bark, this process is relatively straightforward. Depending on the completeness of the final ring (ie if it has only the spring vessels or early-wood formed, or the late-wood or summer growth) a precise felling date and season can be given. If the sapwood is partially missing, or if only a heartwood/sapwood transition boundary survives, then an estimated felling date range can be given for each sample. The number of sapwood rings can be estimated by using an empirically derived sapwood estimate with a given confidence limit. If no sapwood or heartwood/sapwood boundary survives then the minimum number of sapwood rings from the appropriate sapwood estimate is added to the last measured ring to give a *terminus post quem* or felled-after date.

A review of the geographical distribution of dated sapwood data from historic timbers has shown that a sapwood estimate relevant to the region of origin should be used in interpretation, the empirically derived estimate for this area being 9–41 rings (Miles 1997).

However, an alternative method of estimating felling date ranges has been developed (Miles 2005) which runs as a function implemented in OxCal (Bronk Ramsey 2009; Miles 2006). Following the methodology set out by Millard (2002), Bayesian statistical models are used to produce individual sapwood

estimates for samples using the variables of number of heartwood rings present, the mean ring width of those heartwood rings, the heartwood/sapwood boundary date, and the number of any surviving sapwood rings or a count of those lost in sampling. These individual probability distributions for the felling dates (expressed at the 95% probability level) may then be combined to produce a highest probability density estimate for the *combined felling date range*. When carried out within OxCal, this uses a sapwood model that has to be defined. Miles (2005) suggested several such models, of which the one that has been deemed appropriate to apply to the timbers in this case is that for 'England and Wales AD'. This model is based on timbers from throughout England and Wales, with a bias to those in the most densely-dated counties of Shropshire, Somerset, Hampshire, Oxfordshire, and Kent.

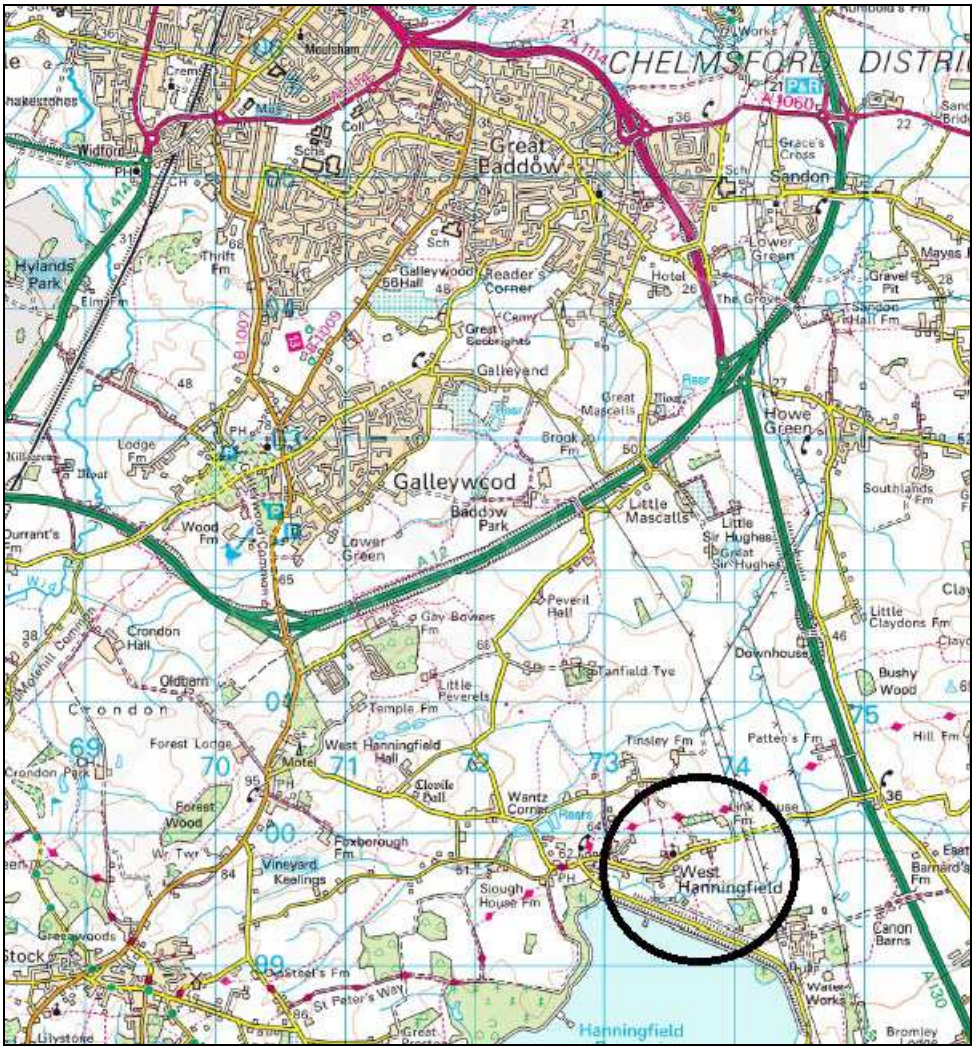

Figure 1: Map showing the location of the village (circled) in relation to the District of Chelmsford. © Crown Copyright and database right 2016. All rights reserved. Ordnance Survey Licence number 100024900

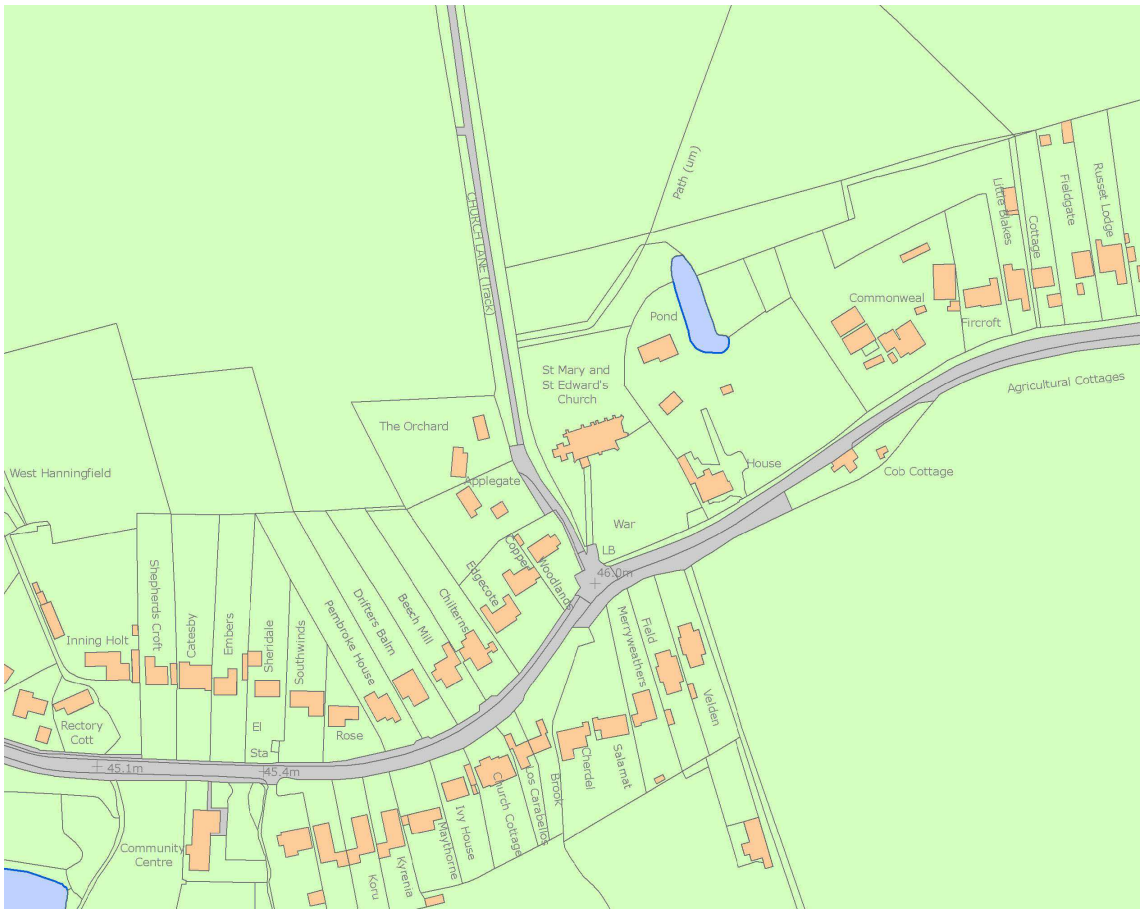

Figure 2: Map of the village, showing the position of the church within the village. © Crown Copyright and database right 2016. All rights reserved. Ordnance Survey Licence number 100024900

It has, however, been found that some samples do not fit the available models well (Tyers 2008). These include samples which have exceptional or sudden variation in mean ring width, such as might be found in pollarded or managed timber. Sometimes a tree will exhibit a sudden drop in mean ring width toward the end of its life, resulting in more sapwood rings being present then might be suggested in the faster-grown heartwood. Additionally, samples which have come from small timbers converted from larger, slow-grown trees would have a much larger number of heartwood rings than were actually present in the sample. Some examples of heartwood ring counts of 25 years or less with a narrow mean ring width are good indicators of this situation, as are observations made during sampling. Thus, it is necessary to very carefully consider whether or not samples are potentially suitable for such analysis.

It must be emphasised that dendrochronology can only date when a tree has been felled, not when the timber was used to construct the structure or object under study. Thus, the dates derived for the felling of the trees used in

construction do not necessarily relate directly to the date of construction of the building. However, evidence suggests that, except in the reuse of timbers, construction in most historical periods took place within a very few years after felling (Salzman 1952; Hollstein 1965; Miles 2005).

RESULTS

The Bellframe

Five samples were taken from the bellframe, two from each of the two southernmost frames, and one from a beam in the south-east corner supporting the raised bellframe (Fig 3; Table 1). They were all of relatively fast-grown oak resulting in the samples having relatively short ring series, and only two of the samples had enough rings to make measuring them viable, the remaining samples having too few rings for further analysis. Neither of the two measured sequences could be cross-matched and when compared with the available dated reference material they could not be successfully dated either.

The Tower

Samples were taken from eight timbers within the tower, including three of the large corner posts, three braces, a sill and a rail (Figs 3–5; Table 1). Duplicate samples (whan01a and whan01b) were taken from the south-east corner post as the first sample (whan01a) had broken, with a loss of rings between the two sections. Although the two sections of this fragmented core, whan01ai and whan01aii, had less than the usual minimum number of rings required for viable analysis they were measured in this instance to enhance the data from whan01b and all three series were combined to form whan01m. The trees used were again all relatively fast-grown oaks and one series (whan06) had abrupt growth changes, possibly due to woodland management, which would adversely affect its dating potential.

Two series whan01 and whan02 cross-matched each other (t = 5.1 with 65 years overlap) and were combined into a single series, WHANFLD1, for subsequent analysis (Fig 6). Series whan04 and whan05 also cross-matched each other (t = 4.5 with 50 years overlap) and were combined into a single series, WHANFLD2, for subsequent analysis (Fig 7). The two combined series and the four unmatched individual series were compared with the available dated reference material. Series WHANFLD1 was successfully dated, some of the strongest matches being listed in Table 2, but none of the other series could be conclusively dated.

INTERPRETATION AND DISCUSSION

Samples whan01 and whan02, both corner posts from the tower, are clearly coeval (Fig 6). They have a mean heartwood-sapwood boundary date of AD 1373, resulting in a likely empirically derived felling date range of AD 1382–1414. This indicates a construction date, shortly after felling, in the latter decades of the fourteenth century or the early-fifteenth century for the tower.

In addition to the conventional empirically derived felling date range it was considered that these two dated timbers were suitable for the application of the Bayesian modelling technique. OxCal v4.2.4 (Bronk Ramsey 2014) was used to produce sapwood estimates for each of the two dated samples (Table 1; Fig 8). The two samples produced identical individual sapwood ranges and thus, a Bayesian approach to combining the individual sapwood estimates following the methodology of Millard (2002), was used to derive the likely *combined felling date range* (Fig 8). The combined index agreement (A_{comb}125.2%, A_n=50%, n=2) shows this to be a coherent pair. This methodology derives a *posterior density estimate* for the *combined felling date range* of *AD 1383–99 (95% probability)*, and construction is assumed to have taken place within months of the trees being felled. This, therefore, refines the result obtained from the conventional empirically derived felling date range and suggests that construction of the tower occurred in the latter part of the fourteenth century.

The two other cross-matched but undated series, whan04 and whan05 were from the south-west corner post and a brace in the north-west corner of the tower respectively. Their relative positions of overlap are shown in Figure 7 and it seems likely that these two timbers are coeval and hence felled at the same, or similar, time as each other.

The lack of dating evidence obtained for the bellframe is disappointing but the dating of the tower, although based on only two timbers, is important not only with respect to enhancing the understanding of this particular church, but also in the wider context of the development of carpentry in the region, as discussed by Hewett (1962). Hewett (ibid) derived a sequence for the likely building of a series of timber towers in churches in Essex, based on the evidence available at that time, and assigned likely construction dates. He postulated a sequence of construction dates for these timber towers from *c* AD 1220 for the Church of All Saints, Doddinghurst, to *c* AD 1480 for the Priory Church of St Lawrence, Blackmore (Table 3; Hewett ibid, pp236–7 and 242–3), later amended (Hewett 1969) to *c* AD1485. This analysis, along with previous dendrochronological studies, has demonstrated that these towers are in fact much closer in date to each other than Hewett proposed (Table 3) and hence allows a greater understanding of the development of such timber towers, at least in Essex.

BIBLIOGRAPHY

Arnold, A J, Howard, R, and Litton, C, 2006 Tree-ring analysis of timbers from the Guildhall Complex and Pedagogue's House, Stratford-upon-Avon, Warwickshire, *English Heritage Res Dept Rep Ser*, **68/2006**

Arnold, A, and Howard, R, 2008 Tree-ring analysis of timbers from St Leonard's Church, Main Street, Apethorpe, Northamptonshire, *English Heritage Res Dept Rep Ser*, **85/2008**

Baillie, M G L, and Pilcher, J R, 1973 A simple cross-dating program for tree-ring research, *Tree Ring Bulletin*, **33**, 7–14

Bridge, M C, 2003 Compilation of master chronologies from East Anglia, unpubl computer file *ANGLIA03*, University College London Dendrochronology Laboratory

Bridge, M C, 2005 Tree-ring analysis of timbers from the Church of St John the Baptist, Thaxted, Essex, *Centre for Archaeol Rep*, **35/2005**

Bronk Ramsey, C, 2009 Bayesian analysis of radiocarbon dates, *Radiocarbon*, **51**, 337–60

Bronk Ramsey, C, 2014 OxCal version 4.2.4, interface build 86, c14.arch.ox.ac/oxcal.html

Hewett, C A, 1962 The timber belfries of Essex, their significance in the development of English carpentry, *Arch J,* **119**, 225–44

Hewett, C A, 1969 *The development of carpentry 1200–1700: An Essex Study*, Newton Abbot.

Hollstein, E, 1965 Jahrringchronologische von Eichenholzern ohne Walkande, Bonner *Jahrbuecher*, **165**, 12–27

Howard, R, Laxton, R R, Litton, C D, 1999 Tree-ring analysis of timbers from St Mary Magdalene Church, Cowden, Kent, *Anc Mon Lab Rep*, **44/1999**

Howard, R E, Laxton, R R, and Litton, C D, 2001 Tree-ring analysis of timbers from the Presbytery Roof, Abbey Church of St Alban's, St Albans, Hertfordshire, *Centre for Archaeol Rep*, **32/2001**

Miles, D H, 1994 The tree-ring dating of the Priest's House Museum, 23-27 High Street, Wimborne Minster, Dorset, *Anc Mon Lab Rep*, **39/94**

Miles, D, 1997 The interpretation, presentation, and use of tree-ring dates, *Vernacular Architect*, **28**, 40–56

Miles, D W H, 2005 *New Developments in the Interpretation of Dendrochronology as Applied to Oak Building Timbers*, unpubl DPhil thesis, Hertford College, Oxford University

Miles, D, 2006 Refinements in the interpretation of tree-ring dates for oak building timbers in England and Wales, *Vernacular Architect*, **37**, 84–96

Miles, D, 2007 The Tree-Ring dating of the White Tower, HM Tower of London (TOL99 and TOL100), London Borough of Tower Hamlets, *English Heritage Res Dept Rep Ser*, **35/2007**

Miles, D H, and Haddon-Reece, D, 1993 List 54 - Tree-ring dates, *Vernacular Architect*, **24**, 54–60

Miles, D H, and Worthington, M J, 2000 Tree-ring dates, *Vernacular Architect*, **31**, 90–113

Miles, D H, Worthington, M J, and Bridge, M C, 2005 Tree-ring dates, *Vernacular Architect*, **36**, 87–101

Millard, A, 2002 A Bayesian approach to sapwood estimates and felling dates in dendrochronology, *Archaeometry*, **44** (1), 137–43

Salzman, L F, 1952 *Building in England down to 1540*, Oxford

Tyers, C, 2008 Bayesian interpretation of tree-ring dates in practice, *Vernacular Architect*, **39**, 91–106

Tyers, I, 1996a *Draft Dendrochronology Assessment: Fastolfs sites*, ARCUS Report, **255**

Tyers, I, 1996b *Draft Dendrochronology Assessment: Rosary sites*, ARCUS Report, **256**

Tyers, I, 1996c Appendix 1 Dendrochronology of shipping from London, twelfth to seventeenth centuries, in *Shipping and the Port of London; twelfth to seventeenth centuries* (P Marsden), English Heritage Archaeological Rep, **5**, 193–7

Tyers, I, 1996d *The tree-ring analysis of five bellframes from the County of Essex*, Anc Mon Lab Rep, **12/96**

Tyers, I, 2002 *Tree-Ring Analysis of Further Oak Timber from the Belfry of All Saints Church, Doddinghurst, Essex*, Centre for Archaeol Report, **116/2002**

Tyers, I, 2004 *Dendro for Windows Program Guide 3rd edn*, ARCUS Report, **500b**

Tyers, I, and Groves, C, 1999 Tree-ring dates, *Vernacular Architect*, **30**, 113–27

Wilson, R, Miles, D, Loader, N J, Melvin, T, Cunningham, L, Cooper, R, and Briffa, K, 2012 A millennial long March-July precipitation reconstruction for southern-central England, *Climate Dynamics*, **40**, 997–1017

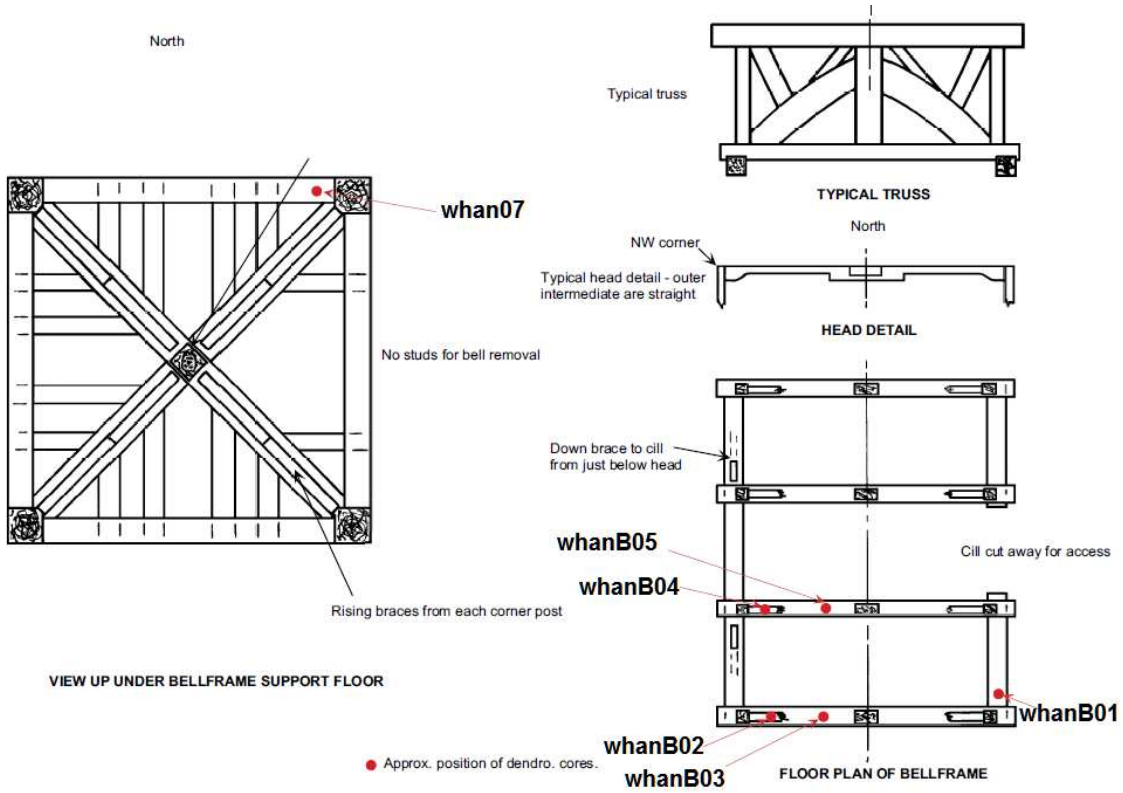

Figure 3: Plan of the tower and the bellframe, showing approximate positions of the samples taken for dendrochronology (Elphin Watkin)

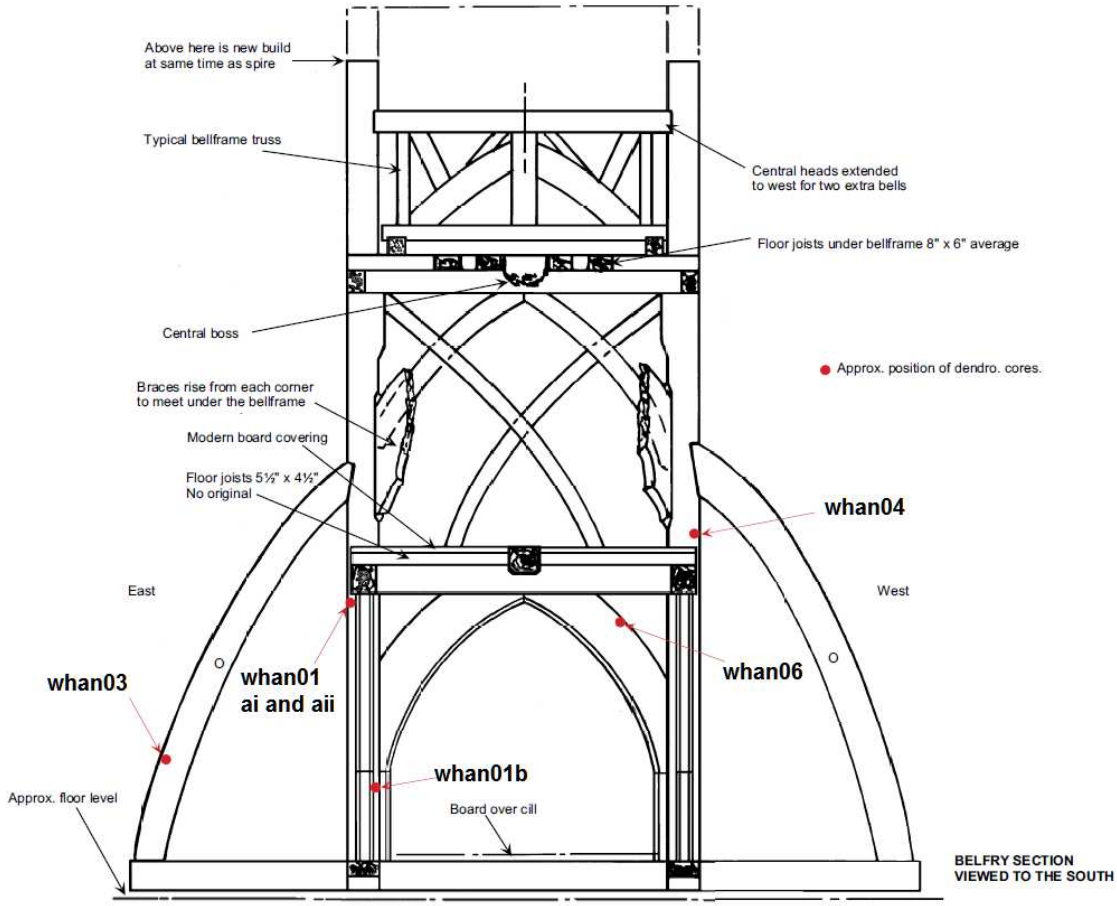

Figure 4: Cross-section of the tower, looking from the north, showing the approximate locations of samples taken for dendrochronology (Elphin Watkin)

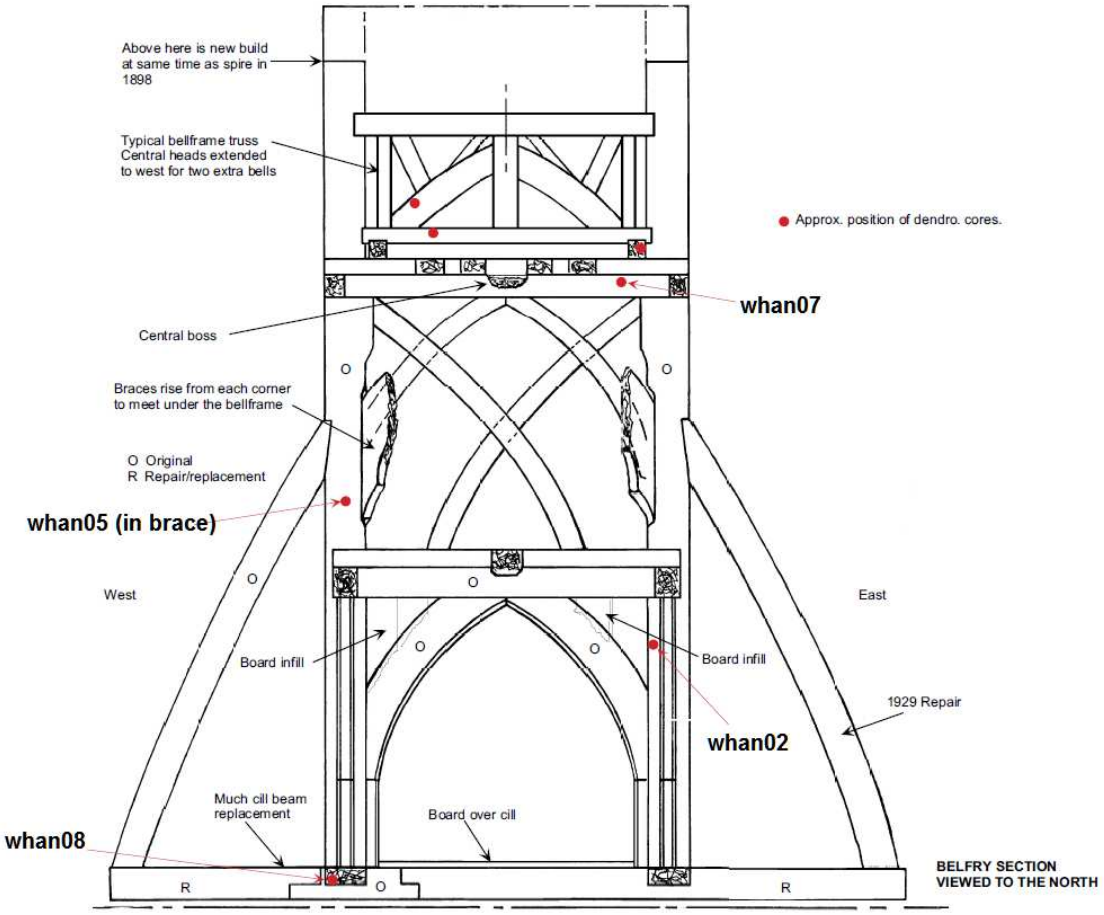

Figure 5: Cross-section of the tower, looking from the south, showing the approximate locations of the samples taken for dendrochronology (Elphin Watkin)

Table 1: Details of samples taken from the Church of St Mary and St Edward, West Hanningfield, Essex

Sample number	Timber and position	No of rings	MRW (mm)	Dates spanning (AD)	h/s boundary (AD)	Sapwood rings	Mean sensitivity	Empirical felling date range (AD)	Oxcal-derived felling date distribution (95% probability)
Tower									
whan01ai	South-east corner post	33	4.15	1308–40	-	-	0.25		
whan01aii	South-east corner post	19	1.99	1353–71	-	-	0.22		
whan01b	South-east corner post	66	2.21	1308–73	1373	h/s	0.28		
whan01m	Mean of 01ai, 01aii, and 01b	66	2.60	1308–73	1373	h/s	0.25	1382–1414	*1381–1405*
whan02	North-east corner post	71	2.48	1302–72	1372	h/s	0.20	1381–1413	*1381–1405*
whan03	East curved brace to south-east post	48	3.53	-	-	h/s	0.26	-	-
whan04	South-west corner post	57	2.20	-	-	-	0.15	-	-
whan05	North brace to the north-west corner post	64	2.42	-	-	16½C	0.27	-	-
whan06	Curved inner brace from south-west corner post to the rail supporting the floor	64	2.32	-	-	h/s	0.25	-	-
whan07	North top rail supporting the floor	58	1.84	-	-	28½C	0.21	-	-
whan08	Sill running west-east near north-west corner post	51	2.09	-	-	h/s	0.27	-	-
Bellframe									
whanB01	Beam in south-east corner, supporting raised frame	<30	NM	-	-	-	-	-	-
whanB02	West long brace to outer southern frame	75	1.64	-	-	24½C	0.17	-	-
whanB03	Sole beam to outer south frame	39	1.95	-	-	-	0.14	-	-
whanB04	West long brace to inner southern frame	<30	NM	-	-	-	-	-	-
whanB05	Sole beam to inner southern frame	<30	NM	-	-	-	-	-	-

Key: MHW= mean ring width; h/s = heartwood-sapwood boundary; NM = not measured; ½C = complete sapwood, felled the following summer

Table 2: Dating evidence for the site sequence WHANFLD1 at AD 1302–73

Source region:	Chronology name:	Publication reference:	Filename:	Span of chronology (AD)	Overlap (years)	*t*-value
Regional chronologies						
London	London Master Chronology	(Tyers pers comm)	LONDON	413–1728	72	5.8
East Anglia	East Anglia Master Chronology	(Bridge 2003)	ANGLIA03	944–1789	72	5.3
S Central England	South Central England	(Wilson *et al* 2012)	SCENG	663–2009	72	5.2
Site chronologies						
Hertfordshire	Presbytery Roof, Abbey Church, St Albans	(Howard *et al* 2001)	STACSQ04	1302–1369	68	6.3
London	Hays Wharf, Southwark	(Tyers 1996a; Tyers 1996b)	HAYS_W85	1248–1647	72	6.1
London	Bankside, Southwark	(Tyers 1996c)	37BSBOAT	1313–1476	72	6.0
Essex	St John the Baptist Church, Thaxted	(Bridge 2005)	THXTDCH	1212–1404	72	5.9
Warwickshire	Guildhall/Pedagogues House, Stratford-on-Avon	(Arnold *et al* 2006)	SUABSQ01	1305–1403	69	5.6
Dorset	Priests House, Wimborne Minster	(Miles 1994)	WIMBORNE	1259–1634	72	5.5
London	White Tower, Tower of London	(Miles 2007)	WHTOWR5	1260–1489	72	5.4
Kent	St Mary Magdalen Church, Cowden	(Howard *et al* 1999)	CWDASQ03	1254–1439	72	5.2
Oxfordshire	Manor Farm, Swinbrook	(Miles and Haddon-Reece 1993)	MANORFM	1296–1401	72	5.2
Northamptonshire	St Leonards' Church, Apethorpe	(Arnold and Howard 2008)	APTCSQ01	1211–1403	72	5.2
Hampshire	North Warnborough	(Miles and Worthington 2000)	OAKHOLME	1300–1401	72	5.2

Table 3: Comparison of dates for Essex bell towers proposed by Hewett (1962) with dendrochronologically-derived dates

Location	**Date (AD) proposed by Hewett (1962)**	**Dendrochronologically-derived date (AD)**
All Saints' Church, Doddinghurst	*c*1220	undated (Tyers 1996d; Tyers 2002)
Church of St Thomas the Apostle, Navestock	*c*1220–50	1365–91 (Tyers and Groves 1999)
Church of St Mary and St Edward, West Hanningfield	13th century, probably pre-1245	1382–1414 [*1383–99*]
All Saints' Church, Stock Harvard	*c1245*–1315	-
Church of St Margaret, Margeretting	*c*1450	-
Priory Church of St Laurence, Blackmore	*c*1480	1400 (Miles *et al* 2005)

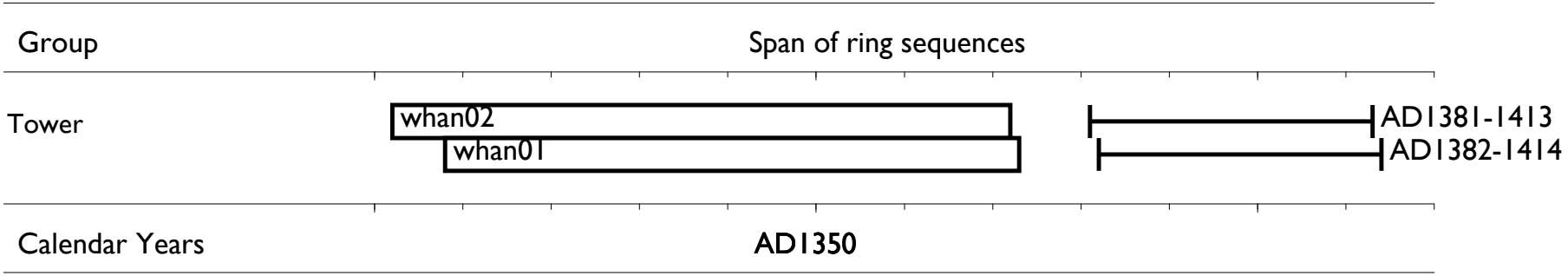

Figure 6: Bar diagram, WHANFLD1, showing the relative positions of overlap and likely empirical felling date ranges for the dated samples from the tower of the Church of St Mary and St Edward, West Hanningfield, Essex. White bar – heartwood

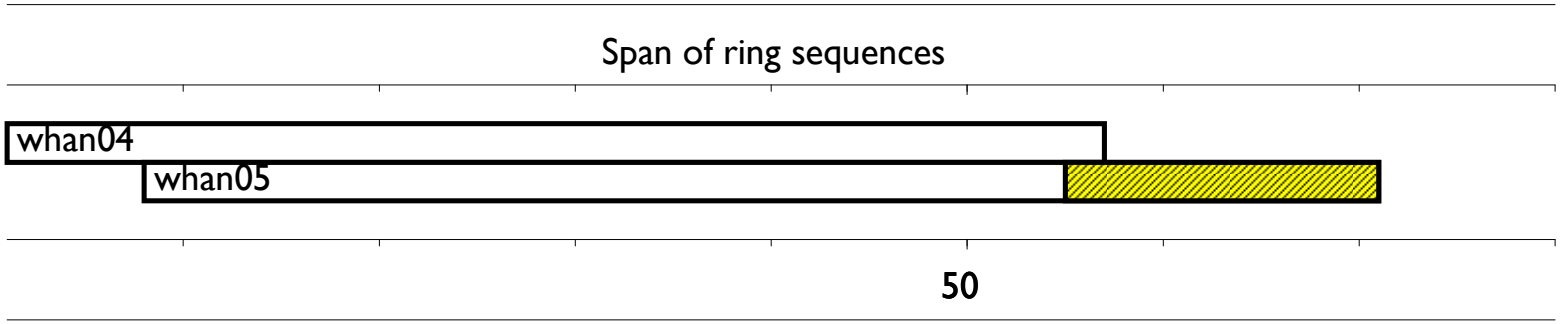

Figure 7: Bar diagram WHANFLD2, showing the relative positions of overlap of two undated samples from the tower of the Church of St Mary and St Edward, West Hanningfield, Essex. White bar – heartwood; yellow hatched bar – sapwood

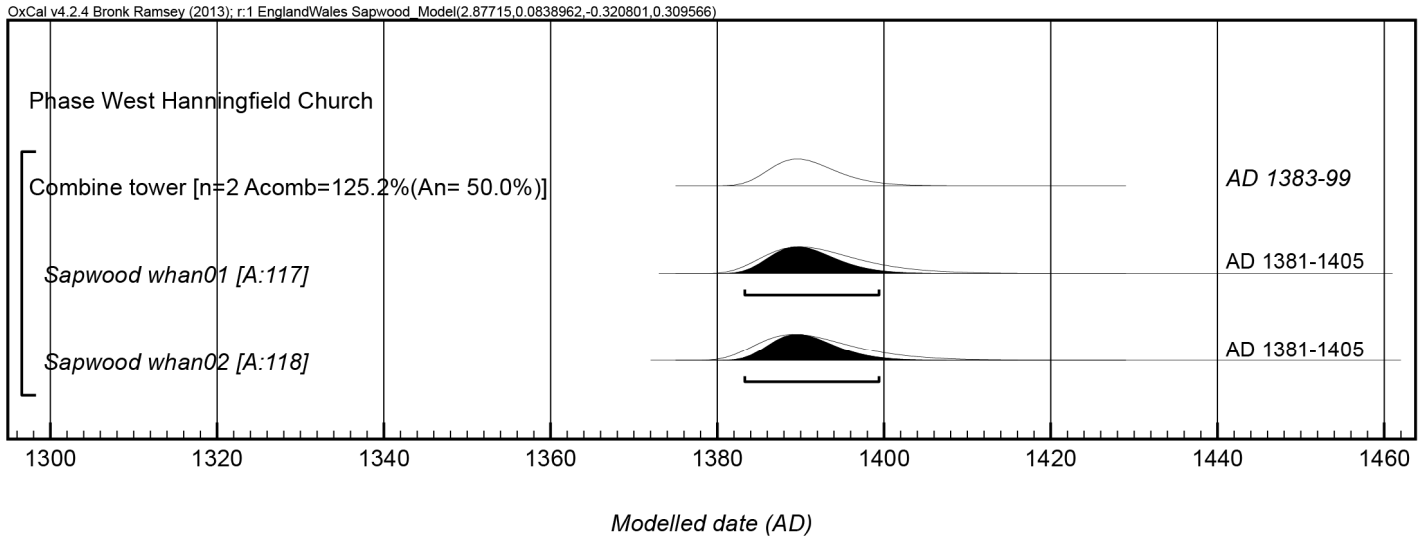

Figure 8: Church of St Mary and St Edward, West Hanningfield: combined felling date range and individual felling date distributions for timbers from the tower included in site chronology WHANFLD1. Individual felling date distributions are shown in outline and the 95% probability individual felling date ranges are listed. The 95% probability combined felling date range is shown in black and italic text

APPENDIX

Ring width values (0.01mm) for the sequences measured

whan01ai

546	512	449	314	404	335	590	780	610	463
319	516	455	444	545	420	518	344	218	421
471	495	568	372	402	419	375	247	166	156
183	340	314							

whan01aii

314	201	275	188	232	227	223	168	145	202
215	283	209	123	118	104	167	183	209	

whan01b

491	403	401	302	436	305	179	266	309	278
191	348	298	327	475	510	587	389	233	460
360	414	456	237	299	387	141	71	52	58
95	113	134	126	122	203	161	255	246	127
140	146	88	125	109	176	148	145	124	150
123	127	66	50	93	144	154	151	115	87
91	124	106	110	224	208				

whan02

420	279	209	401	401	394	463	416	375	320
464	394	525	463	394	364	305	493	313	291
296	245	202	138	136	212	212	154	111	98
121	173	231	145	158	143	157	271	271	229
237	209	242	345	234	210	175	220	158	221
166	275	307	250	213	173	170	180	153	143
252	217	184	233	178	174	158	140	166	140
128									

whan03

410	453	308	211	112	121	354	350	502	251
189	263	243	358	407	275	488	495	477	530
447	636	458	594	364	495	273	473	621	537
336	335	350	251	335	440	388	361	306	296
306	316	261	208	202	173	128	256		

whan04

292	286	270	348	245	307	272	302	234	204
242	190	180	147	207	282	283	285	293	215
237	213	224	257	235	168	204	228	225	160
158	182	240	246	229	259	213	229	165	242
258	194	191	178	150	125	156	179	193	211
187	202	154	169	215	193	175			

whan05

344	537	290	442	289	415	235	183	299	233
344	220	114	168	182	259	364	370	196	278
327	382	264	270	411	337	346	137	99	117
132	161	215	303	213	236	240	122	87	92
129	147	152	186	253	293	283	298	283	260
226	363	327	310	246	329	158	154	138	94
109	144	162	197						

whan06

293	360	404	526	589	486	326	273	284	326
376	307	267	219	172	157	202	210	158	216
159	113	111	190	199	218	147	191	182	125
253	63	66	68	49	53	75	121	111	151
155	332	302	110	87	117	88	137	234	198
210	250	215	441	481	347	244	273	282	287
304	387	319	242						

whan07

253	208	214	320	620	710	986	613	303	188
270	247	189	144	168	220	188	201	193	157
108	115	118	165	99	93	131	138	90	149
121	111	131	101	116	136	166	127	112	120
131	98	93	86	76	86	119	113	110	89
93	88	108	119	90	113	102	103		

whan08

322	524	275	244	193	326	223	259	269	383
337	350	165	190	143	261	158	134	178	280
245	340	231	231	206	312	191	157	152	202
309	196	276	228	256	291	174	152	217	90
63	57	66	64	66	73	71	96	106	153
188									

whanB02

318	252	280	207	283	197	217	219	238	295
258	251	244	252	178	172	231	259	201	165
180	189	198	173	151	179	113	117	164	141
159	206	144	125	168	109	118	102	151	178
178	220	146	120	111	106	149	123	116	150
166	114	111	144	137	122	128	135	168	130
112	113	151	103	134	119	99	116	96	88
111	138	124	122	125					

whanB03

179	166	167	230	198	188	190	176	134	210
198	163	241	229	232	154	193	192	218	210
260	243	240	256	258	250	143	164	182	178
142	168	188	185	187	167	128	201	206	

Historic England Research and the Historic Environment

We are the public body that looks after England's historic environment. We champion historic places, helping people understand, value and care for them.

A good understanding of the historic environment is fundamental to ensuring people appreciate and enjoy their heritage and provides the essential first step towards its effective protection.

Historic England works to improve care, understanding and public enjoyment of the historic environment. We undertake and sponsor authoritative research. We develop new approaches to interpreting and protecting heritage and provide high quality expert advice and training.

We make the results of our work available through the Historic England Research Report Series, and through journal publications and monographs. Our online magazine Historic England Research which appears twice a year, aims to keep our partners within and outside English Heritage up-to-date with our projects and activities.

A full list of Research Reports, with abstracts and information on how to obtain copies, may be found on www.HistoricEngland.org.uk/researchreports

Some of these reports are interim reports, making the results of specialist investigations available in advance of full publication. They are not usually subject to external refereeing, and their conclusions may sometimes have to be modified in the light of information not available at the time of the investigation.

Where no final project report is available, you should consult the author before citing these reports in any publication. Opinions expressed in these reports are those of the author(s) and are not necessarily those of Historic England.

The Research Reports' database replaces the former:

Ancient Monuments Laboratory (AML) Reports Series
The Centre for Archaeology (CfA) Reports Series
The Archaeological Investigation Report Series and
The Architectural Investigation Reports Series.

ISSN 2059-4453 (Online)