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The Royal Clarence Hotel, 16–17 Cathedral Yard, 41–42 High Street, 43–45 High Street, and 47 High Street Exeter, Devon

Tree-ring Analysis of Oak and Conifer Timbers

Alison Arnold, Robert Howard, and Cathy Tyers

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Front Cover: The Royal Clarence Hotel and neighbouring buildings, Exeter. Photograph by Robert Howard

Research Report Series 227-2020

THE ROYAL CLARENCE HOTEL,
16–17 CATHEDRAL YARD, 41–42 HIGH STREET,
43–45 HIGH STREET, AND 47 HIGH STREET
EXETER
DEVON

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SUMMARY

Tree-ring analysis of samples from 100 oak and conifer timbers from different buildings fronting onto Cathedral Yard and the High Street, in Exeter, resulted in the production of one oak site chronology and one conifer site chronology. The oak chronology comprises 42 samples and is 300 rings long. It is dated as spanning the years AD 1337–1636. The conifer chronology comprises three samples and is 154 rings long, but is undated. Two further oak samples were dated individually.

This analysis indicates that the earliest group of timbers are to be found in the rear building of 47 High Street (the possible former kitchen block); a number of timbers here, are likely to have been felled in AD 1479–1504. One, clearly broadly coeval, timber has been dated in the cellar of 47 High Street, which may survive from the original construction of the pair of buildings at 46/47 High Street (previously dated by dendrochronology in 46 High Street to AD 1492–1515). There are, in addition, a few other potentially late fifteenth- or early sixteenth-century timbers plus one mid seventeenth-century timber in the back of this property (in the southern part of a previously independent building in Lamb Alley). The next phase of felling is represented by the roof timbers of 41/42 High Street, these likely to have been felled in the early/mid AD 1560s. The timbers to the rear roof of number 45 High Street are all likely to have been cut in the AD 1630s, with two timbers certainly being felled in AD 1636. The Royal Clarence Hotel contains two timbers that are unlikely to have been felled before the later fifteenth century, as well as one timber that is unlikely to have been felled before the later seventeenth century. 16–17 Cathedral Yard (the Well House Tavern) contains one timber likely to have been felled in the later seventeenth century.

CONTRIBUTORS

Alison Arnold, Robert Howard, and Cathy Tyers

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ARCHIVE LOCATION
Historic England Archive
The Engine House
Firefly Avenue
Swindon SN2 2EH

HISTORIC ENVIRONMENT RECORD OFFICE
Devon Historic Environment Record
Lucombe House
County Hall
Exeter
Devon EX2 4QD

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CONTACT DETAILS
Alison Arnold and Robert Howard
Nottingham Tree-Ring Dating Laboratory
20 Hillcrest Grove
Sherwood
Nottingham NG5 1FT
roberthoward@tree-ringdating.co.uk
alisonarnold@tree-ringdating.co.uk

Cathy Tyers
Historic England
Cannon Bridge House
25 Dowgate Hill
London EC4R 2YA
cathy.tyers@historicengland.org.uk

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INTRODUCTION

The Royal Clarence Hotel and the immediately adjoining Well House Tavern (16–17 Cathedral Yard), along with a group of nine timber-framed, or partially timber-framed, properties running from 39 to 47 High Street along the back of the Hotel, and timber-framed buildings at 11–13 St Martin's Lane, form the largest block of historic houses in central Exeter. This close-set and inter-related complex of buildings stand together in a central insula of the City, bounded on the north-west by the High Street; the north-east by St Martin's Lane; the south-east by Cathedral Yard; and to the south-west by the former Lamb Alley (Fig 1). At intervals starting in the 1970s, varying levels of survey and recording have been undertaken on seven of the High Street buildings (all but numbers 39 and 40), mostly during episodes of repair or alteration. This has resulted in a somewhat piece-meal approach to investigation of this historically important part of the urban area (Thorp 2015; Parker and Allan 2015), which revealed that there was far more extant historic fabric than previously understood.

On 29th October 2016, a fire began in a nearby property and, given the intimate nature of this group of buildings and their intertwined layouts, quickly spread to completely engulf the Royal Clarence Hotel and the Well House Tavern (Fig 2), and damage to varying degrees the nearby buildings on the High Street. The near total loss of the Royal Clarence Hotel, and the potential loss of other historic fabric in this part of the town, led to a concerted programme of archaeological survey and recording of these buildings as an adjunct to their proposed conservation, restoration, and repair.

THE BUILDINGS

The brief descriptions of the buildings in this section are largely based on the list entries referenced.

The Royal Clarence Hotel (SX 92071 92649)

An Exeter landmark, the Royal Clarence Hotel, facing mainly onto Cathedral Yard, is believed to have been built to provide Assembly Rooms for the City of Exeter by William Mackworth Praed, *c* AD 1768 (Figs 3 and 4a). Originally of four storeys with a six-window stucco front, it was considerably altered in AD 1827, with bays being added, glazing bars removed, and windows changed. A large porte-cochere partly hides a Tuscan porch. The building has a dentil cornice. The remains of a central porch are still visible, but the front has been altered with the addition of late nineteenth-century iron balconies. The whole is covered by slate roofs. Part of the Hotel faces onto Martin's Lane. In the past there has been little timberwork immediately visible in the Hotel, but occasional works, such as the lifting of floorboards, have revealed some of the main beams. The hotel is listed at Grade II (LEN 1104027).

16–17 Cathedral Yard (The Well House Tavern - SX 92063 92636/SX 92059 92634)

Adjoining the hotel to the south, and now part of it, are two sixteenth- or seventeenth-century timber-framed tenements with five-story gabled plaster fronts, now forming the Well House Tavern (Fig 3). Sash windows were inserted into number 16 in the nineteenth century, and number 17 has a Georgian bow window with glazing bars on the first floor, and splayed oriels with leaded lattice windows above. Subsequent to the fire, the demolition and stabilisation works in this part of the hotel complex in particular, revealed elements of hitherto unknown, or only suspected, timber framing within the ruins (Fig 4b). The two buildings that make up the Well House Tavern are listed separately at Grade II as 16 Cathedral Yard (LEN 116 9713) and 17 Cathedral Yard (LEN 1104028). In 1933 a Roman well was discovered in the basement of number 16.

The High Street buildings

The group of nine properties running from 39 to 47 High Street form the largest block of historic houses now standing on one of Exeter's main streets (Figs 3 and 5). Over the past half century, investigation and recording has been undertaken to seven of these buildings (all but numbers 39 and 40) to varying degrees during episodes of repair or alteration.

41–42 High Street (SX 92047 92667)

The two houses forming numbers 41 and 42 High Street are listed together at Grade II* (LEN1170491). Dendrochronology undertaken in the 1980s (Mills 1988), demonstrated that these were built as a pair, one the mirror-image of the other, each occupying the full width of the narrow burgage plot, with the main block gable-end facing on to the street (Figs 1, 5 and 6). In both houses this main block is two rooms deep and three storeys high, with attics in the roof space and a cellar below. The front rooms are lit from the street, the rear rooms from the narrow courtyard behind. Originally, a two-storey kitchen/service block ran across the back of the properties, joined to the main block by a gallery.

The roofs of both 41 and 42 High Street comprise five bays formed by six principal-rafter with tiebeam and collar trusses. The trusses support double purlins to each pitch of the roof, these in turn supporting five to seven common rafters per bay. The gable-end trusses contain close-set studs with rails. There is further timbering to the lower floors comprising partition walls of studs and cross-rails. While the roof spaces are largely empty, the lower floors are used as retail, storage, and staff premises.

In addition to the main building fronting onto the High Street there is a lower range to the rear of number 42, this running at a right angle to the main building. The roof of this portion comprises three principal-rafter with collar trusses, these carrying double purlins. The principal rafters all appear to be of one phase, but some of the collars, and all of the purlins, appear to be later insertions. All the apparently primary timbers appear to be of oak, while some of the later timbers are of conifer or some other softwood. This area is also in retail use.

The Exeter City Historic Environment Record describes these properties as a pair of later sixteenth-century houses built with stone outer walls, timber-framed front wall, and interior partitions, with a central stone chimney stack common to both buildings. The two houses are mirror images of each other on either side of a central dividing wall, with front and rear rooms on each floor of the main blocks. They present gable ends to the street, and each is of four storeys plus cellars. The front and rear walls are jettied out at each floor level, and the side wall contains moulded corbelling reflecting this jettying. Originally, each house had a small courtyard to the rear with detached rear blocks (containing kitchens, inter alia) at the back. Taking the two houses as a pair, some trace of the original late sixteenth-century decorative scheme was recovered from most rooms, and this provides an important and unique aspect of the recording of this house: the rear parlour of number 41 contained a mural of St George and the Dragon, whilst the front chamber of number 42 was painted with a bold design of alternating broad orange and blue stripes, with a frieze containing strapwork cartouches with short Latin homilies or inscriptions. The rear chamber of number 41 also retained an original garderobe niche.

A limited episode of tree-ring dating was undertaken on nine samples obtained from this building when it underwent major structural alterations in the 1970s, although, unfortunately, the original location of the sampled timbers is unknown. The results of this analysis would support the date of 'AD 1564' carved on a wooden doorhead formerly in the building (now in Exeter Museum) and believed to commemorate its construction.

43–45 High Street (SX 92041 92662, SX 92038 92658, SX 92036 92657)
The archaeological survey and recording of this insula suggests that 43–44 High Street may be the earliest of the group (Fig 7), dating from the sixteenth century, with both these properties again being built as a single paired structure. They are listed at Grade II separately as 43 High Street (LEN 1103898) and 44 High Street (LEN 1333407), and 45 High Street (LEN 1170494).

The two houses offer a good example of the manner in which the progressive partitioning and flooring of the interior of a medieval town-house provided more space. In the sixteenth century the hall was subdivided into ground- and first-floor rooms (the latter with painted decoration on the roof timbers), and the roof space itself was later pressed into use as a separate room lit by dormers.

In the late-seventeenth or possibly early eighteenth century, number 43 was raised by a full storey and given a new roof. Now underboarded, all that is visible are three principal-rafter trusses with collars, these possibly supporting double purlins. All these timbers are of softwood and may be nineteenth- or even twentieth-century replacements. Although the original roof to number 43 has been lost, number 44 High Street has not been so modified and it retains the arch-braced and smoke-blackened roof of a medieval open hall set behind a former chamber on the street front.

There are no other timbers visible in the lower floors of either number 43 or 44, although there are a few timbers set into the walls of the cellar of number 44, particularly in the partition wall between the two properties (although these are not timbers visible in the cellar of number 43).

On the next plot to the south, number 45 High Street has been built co-joined to number 44, and extends over the site of the former northern end of Lamb Alley (Fig 7). This lane had run to the north side of number 46, right through from Cathedral Yard to the High Street. The north wall of number 46, which was originally exposed to the lane, is decorated with shields, quatrefoils, and other carved decoration, stylistically dated to the early sixteenth century, although this is now only partially visible behind walls to the upstairs rooms of number 45 (Fig 8). Only a short section of Lamb Alley, off Cathedral Yard, now remains.

The roof to the front part of number 45 is totally enclosed by modern softwood boarding to form a useable attic storeroom, and there is no access to any of the timbers which are, in any case, believed to be modern. A rearward section, however, retains a roof comprising several oak common-rafter frames with collars.

To the rear of number 45 (but separated from it by modern in-fill) is a further house, which was originally an independent building in Lamb Alley. At the present time, this Lamb Alley building is divided between numbers 45 and 47 High Street, there being no direct access from one part to the other. The present roof to this part of the building (believed to be a replacement of the original) comprises a single principal-rafter with collar truss with purlins and common rafters.

The present building at 45 High Street, including the medieval tenement fronting on to the High Street and the northern part of the originally independent building in Lamb Alley that now forms part of this property, is listed at Grade II (LEN 1170494).

47 High Street (SX 92030 92651)

As was the case of 41/42 and 43/44 High Street, 46/47 High Street were also built as a single structure constituting a pair of identical houses (Fig 9), both entirely timber-framed in large, close-set, studs tenoned into horizontal rails supported on a low stone wall. While number 46 remained largely unaltered, and was the subject of an earlier programme of dendrochronology (Arnold and Howard 2009a), number 47 has undergone a number of changes and additions, particularly in respect of its current use as a retail outlet. Any timbering it retains is hidden behind later additions and decorative finishes. There are, however, a few timbers to the cellar beneath the forward part of this property.

Both numbers 46 and 47 originally consisted of a block containing a shop on the street frontage, with domestic accommodation of three storeys behind each. Both houses had a small rear courtyard within which stood a subsidiary building probably containing kitchens. These kitchen blocks and the rear courtyards were probably once accessible via Lamb Alley. The rear building of number 46 has been demolished but that to number 47 still survives.

In the late-seventeenth century this rear kitchen block was radically altered with the insertion of two new floors and a new elevation to the courtyard. At this time this block was also linked to number 47 by a gallery at first- and second-floor level (the first-floor gallery now being enclosed). This block retains the remains of a lower roof truss comprising parts of two principal rafters and a collar (possibly with other timbers), above which is a higher truss with at least one principal rafter, a collar, and possibly a tiebeam. All of these timbers are of oak. The other principal rafter to the upper truss is conifer. In addition, there is a shallow cellar giving limited access to the timbers of the ground-floor frame of this part of the building.

Further to the rear, beyond the kitchen block of number 47, is the southern part of the once independent house in Lamb Alley now shared with number 45 High Street. In the eighteenth century this part of the Lamb Alley house was fully incorporated into the forward parts of number 47 to make a virtually continuous front-to-rear range. The present roof to this part of the building (again believed to be a replacement of the original) comprises three principal-rafter with collar trusses, with purlins, and several common rafters, there being clear evidence, by way of redundant peg holes, mortices, and tennons etc, for the reuse here of timber, possibly from the original roof, but possibly also from other structures.

The present building at 47 High Street, including the medieval tenement fronting on to the High Street with its rear building, and the southern part of the originally independent building in Lamb Alley that now forms part of this property, is listed at Grade II (LEN 1170497). The adjacent 46 High Street is listed at Grade II* (LEN 1103899), but no further dendrochronological investigation was deemed necessary as part of this study.

SAMPLING

As part of the proposed conservation, restoration, and repair work following the devastating fire, dendrochronological analysis of salvaged *ex situ* structural timbers and framing elements from the Royal Clarence Hotel and the Well House Tavern was requested by Rhiannon Rhys, Inspector of Historic Buildings and Areas, Historic England). This was subsequently extended to encompass *in situ* timbers in several of the other buildings within this close-set and inter-related complex that suffered lesser damage. This work was undertaken in order to attempt to provide independent dating evidence for previously identified historic timber-framing, as well as timber-framing newly revealed following the fire, thus enhancing understanding and helping to inform the programme of repair and conservation.

With these objectives in mind, as many timbers as possible were retrieved from the charred remains of the Royal Clarence Hotel, labelled with a timber (tag) number, and set aside (Fig 10a). Even though the exact original location of individual timbers could be slightly uncertain because of the severity of the fire and the conditions of the demolition process, it was generally possible to identify their likely positions. This assemblage is believed to represent main beams, common joists, and possibly roof timbers throughout the building.

Those timbers which were beyond conservation were then cut, by the on-site contractors, into smaller more manageable sections, each retaining the timber number. These smaller sections were then collected and taken to the Nottingham Tree-Ring Dating Laboratory. These included samples from 17 *ex situ* conifer timbers and six *ex situ* oak (*Quercus* sp) timbers (Fig 10b). A further four oak samples were taken in the form of cores from *in situ* oak timbers in the framing of the Well House Tavern (16–17 Cathedral Yard). In total, therefore, 27 samples were obtained from the Royal Clarence Hotel/Well House Tavern complex. Each of these samples was given the code EXT-L (for Exeter, site 'L'), and numbered 01–27.

In respect of the High Street buildings, investigative opening-up and preparatory repair works provided greater access to the timber-framing of these properties, these between them providing a total of 73 oak core samples. Each of these samples was given the code EXT-M (for Exeter, site 'M'), and numbered 01–73.

Where possible, the location of the samples was recorded at the time of coring either by location on plans provided, or on sketch plans, or as photographs. These location drawings and photographs are shown here as Figures 11, 12a–c, 13, 14a–i, and 15a–m. The exception to this recording appertains to the salvaged timbers from the Royal Clarence Hotel. While the general location of some of these timbers might be known (see Fig 3 and Table 1), the exact locations may be uncertain. For the purposes of this report all location plans, drawings, and photographs, and any descriptions have been given a 'site north', this being to Martin's Lane. Cathedral Yard lies to 'site east' and the High Street to 'site west'.

ANALYSIS AND RESULTS

Each of the 100 samples obtained from the timbers within the various buildings was prepared by sanding and polishing. It was seen at this time that two of the 17 conifer samples from the Royal Clarence Hotel had fewer than the minimum of 60 rings here deemed necessary for the reliable dating of conifer, while three of the 10 oak samples from the Royal Clarence Hotel and Wellhouse Tavern had fewer than the 40 rings here deemed necessary for the reliable dating of oak. These samples were thus not subject to further analysis. In addition, 13 of the 73 oak samples from the High Street buildings also had too few rings for the reliable dating of oak, and they were similarly excluded from analysis. The annual growth ring widths of the remaining 15 conifer samples and the 67 oak samples were, however, measured, these data being given at the end of this report.

The 67 measured oak ring-width series were then compared with each other by the Litton/Zainodin grouping procedure (see Appendix), as were the 15 measured conifer ring-width series. This comparative process resulted in the production of a single oak site chronology and a single conifer site chronology.

Oak site chronology

The cross-matching oak group comprises 42 samples, two of them from the Royal Clarence Hotel/Well House Tavern complex, the remainder from the buildings of the High Street, these samples grouping at a minimum value of t=3.6. These 42 cross-matching samples were combined at their indicated offset positions to form EXTMSQ01, a site chronology with an overall length of 300 rings. Site chronology EXTMSQ01 was then compared to an extensive corpus of reference chronologies for oak, this indicating a consistent and repeated high level of cross-matching with a whole series of these when the date of its first measured ring is AD 1337 and the date of its last measured ring is AD 1636 (Table 2).

Site chronology EXTMSQ01 was then compared with the 23 remaining measured but ungrouped oak samples, but there was no further satisfactory cross-matching. Each of the 23 remaining ungrouped oak samples was, therefore, compared individually to the full corpus of reference chronologies. This indicated a consistent and repeated cross-match for two further individual samples, EXT-L18 (from the Royal Clarence Hotel/Well House Tavern complex), its 51 rings dated as spanning the years AD 1398 to AD 1448 (Table 3), and sample EXT-L22 (also from the Royal Clarence Hotel/Well House Tavern complex), its 90 rings dated as spanning the years AD 1367 to AD 1456 (Table 4).

The relative positions of all 44 dated oak samples are shown in simple last measured ring date order in the bar diagram, Figure 16.

Conifer site chronology

The conifer site chronology comprises three samples, these grouping at a minimum value of t=6.2. These three cross-matching conifer ring-width series were combined at their indicated offset positions to form EXTPSQ01, a site chronology with an overall length of 154 rings (Fig 17). Site chronology EXTPSQ01 was then compared to the full corpus of reference chronologies for conifers, but there was no satisfactory cross-matching, and the sequence must, therefore, remain undated.

Site chronology EXTPSQ01 was then compared with the 12 remaining measured but ungrouped conifer samples, but there was no further satisfactory cross-matching. Each of the 12 remaining ungrouped conifer samples were, therefore, compared individually to the full corpus of reference chronologies for conifers, but there was no satisfactory cross-matching and all these individual samples must, therefore, remain undated.

INTERPRETATION

Of the 67 oak samples which were measured, 42 have been dated as components of site chronology EXTMSQ01, with two further single samples being dated individually. However, none of the 15 measured conifer samples has dated. Figure 18 shows all dated samples, sorted by individual buildings/areas in last measured ring date order, showing felling dates, estimated felling date ranges, or *terminus post quem* dates for felling. For the sake of completeness, Figure 18 includes the dated samples from 41 High Street and 46 High Street obtained in the earlier programmes of tree-ring analysis in the 1980s (Bridge 1983; Mills 1988; Arnold and Howard 2009a), having been reanalysed.

Where a sample retains complete sapwood out to the bark surface, that is, it has the last ring produced by the tree before it was cut down, the last measured ring date on the sample is the felling date of the tree (this being denoted by upper case 'C' in Table 1 and the bar diagrams). In some cases, due to its soft and fragile nature, while the timber does have complete sapwood on it, all or part of this sapwood can be lost from the sample during coring (this being denoted by lower case 'c'). In such instances, taking into account the date of the last extant sapwood ring on the sample, and the length of the lost sapwood section, and the number of sapwood rings this might have contained, the approximate felling date of the timber can be estimated with reasonable certainty.

Where sapwood is not complete (either on the core or on the sampled timber), but where the sample retains some sapwood or at least the heartwood/sapwood boundary (the latter denoted by 'h/s' in Table 1 and the bar diagrams), a 95% confidence interval of 15–40 sapwood rings is employed to calculate the likely felling date range of the timber, taking into account, of course, the date of the last extant sapwood ring on the sample. It is of course possible that a few timbers could have fewer than the usual minimum of 15 and more than the usual maximum of 40 sapwood rings.

Where a sample retains neither sapwood nor the heartwood/sapwood boundary, a number of 15 (the likely lower limit of the possible sapwood range) is added to the last extant heartwood ring date to indicate a *terminus post quem* date for felling (ie a date after which the timber was felled).

The Royal Clarence Hotel

The earliest timbers from the Royal Clarence Hotel are represented by samples EXT-L18 and EXT-L22, these having last ring dates of AD 1448 and AD 1456 respectively. Neither sample, however, retains the heartwood/sapwood boundary and, given that the timbers could have gone on growing for many years after their last extant heartwood rings dates, it is not possible to suggest when the source trees might have been felled. However, allowing for a minimum of 15 sapwood rings, this would suggest that the respective timbers were felled after AD 1463 and AD 1471.

A later Royal Clarence Hotel timber is represented by EXT-L21. This sample has a last ring date of AD 1632, but is again without the heartwood/sapwood boundary. Using the same minimum sapwood estimate as above indicates that this timber was felled after AD 1647.

16–17 Cathedral Yard (The Well House Tavern)

One timber, EXT-L23, from the Well House Tavern has dated, this having a last ring date of AD 1636. With three sapwood rings, the heartwood/sapwood boundary is dated to AD 1633. Using the usual 95% confidence interval of 15–40 for the number of sapwood rings expected, produces an estimated felling date in the range of AD 1648–73 for this timber.

The High Street Buildings

Interpretation of the results of this study includes consideration of the results of previous programmes of dendrochronology in 41 High Street (Bridge 1983; Mills 1988) and 46 High Street (Arnold and Howard 2009a).

41–42 High Street

The roof timbers of the main roofs of 41–42 High Street, thought to be built as a pair, have produced 17 dated samples. At least one sample, EXT-M60, retains near-complete sapwood with a last extant ring date of AD 1561. Another sample, EXT-M61, has a last measured ring date of 1554, but has probably no more than 10 unmeasured sapwood rings, the sapwood possibly being complete to the bark surface. Taking into account the dates of the last measured rings, and the lost or unmeasured sapwood rings, would suggest that these two timbers were felled in the early/mid AD 1560s. Such a date accords well with the results obtained during the earlier, but limited, episode of tree-ring dating undertaken on samples from timbers of unknown location within this building (Bridge 1983; Mills 1988), although this would suggest that sample HS04 has fewer than the usual 95% confidence interval minimum of 15 sapwood rings.

The average date of the surviving heartwood/sapwood boundary rings on the other eight samples from this pair of roofs is AD 1538; the overall variation being from AD 1529 (EXT-M58 and EXT-M59) to AD 1547 (EXT-M70). Using the same sapwood estimates as above 15–40 rings, would give these timbers an estimated felling date in the range AD 1553–78. It will be seen that this date range includes the early/mid AD 1560s felling date identified for the two timbers discussed above.

Although there are a few timbers that are without the heartwood/sapwood boundary, and which in theory could have gone on growing for many years after their last extant heartwood ring dates, this appears unlikely based on the overall levels of cross-matching obtained between this group timbers. In addition all of the timbers sampled here are integral to each other and could not have been inserted later unless a major programme of reconstruction and resetting of the roofs occurred. As such, it is highly likely that these timbers were also felled in the early/mid AD 1560s as well.

The three timbers sampled from the roof of the rear range of 42 High Street could not be dated.

43–45 High Street

None of the 14 samples from the roof of 44 High Street and the cellar partition wall between 43 and 44 have dated, only four of these samples actually having sufficient numbers of rings to merit measurement.

The rear roof to number 45 High Street has, however, provided 11 dated samples. Two of these samples, EXT-M16 and EXT-M25, retain complete sapwood. In both cases this last complete sapwood ring, and thus the felling of the trees, is AD 1636. Two other samples, EXT-M22 and EXT-M23, retain near-complete sapwood. Taking their last extant sapwood ring dates into account, and allowing for the number of rings the lost sapwood is likely to have contained, it is very likely that the trees these two samples represent were felled in, or about, AD 1636 as well.

The date of the heartwood/sapwood boundary on the other five samples of this group on which it survives is somewhat varied, ranging from as early as AD 1566 on sample EXT-M20 to as late as AD 1597 on sample EXT-M24. This could suggest that some timbers have been felled at different times (though there is no evidence in this roof for the reuse of older timbers or the insertion of later ones). For example, in the two cases highlighted here (and using the standard sapwood estimate), EXT-M20 would normally have a felling date range of AD 1581 to AD 1606, and EXT-M24 a felling date range of AD 1612 to AD 1637; it will thus be seen that the expected felling date ranges of these two timbers do not even overlap with each other.

However, as may be seen from Table 1, at least three samples in this roof have more sapwood rings than to usual 95% confidence interval maximum (40); sample EXT-M16 has 66 sapwood rings, EXT-M19 has at least 52 (allowing for both the measured and unmeasured surviving sapwood rings), EXT-M20 has at least 42 sapwood rings, and EXT-M25 has 42 sapwood rings. Thus, while one or two timbers might have been felled slightly earlier than AD 1636 (though still in the early seventeenth century), it would appear that this group of timbers is relatively unusual in having more sapwood rings than generally found, and thus it is likely that most dated timbers from this roof were felled in the AD 1630s.

47 High Street

Of the 25 samples from the various parts of 47 High Street which were measured, 12 have successfully dated.

As described above, 46/47 High Street, like 41/42 and 43/44, was originally built as a single structure constituting a pair of houses. Thus, although no timbers of the original roof or floor frames in 47 High Street could be sampled, the original construction probably occurred using timbers felled in AD 1492–1516, as suggested by previous a previous dendrochronological study of 46 High Street (Arnold and Howard 2009a). This study dated 25 contemporaneous timbers from the roof, first-floor frame, and second-floor frame of this building.

One of the two samples taken from the main floor-frame beams in the cellar of 47 High Street, EXT-M47, has also dated. With nine sapwood rings and a heartwood/sapwood boundary date of AD 1472, this timber has an estimated felling date in the range AD 1487–1512 and so is probably a survival of the primary construction.

A group of eight dated samples from the roof of the rear building appear to form a coherent group. None of these eight samples retains complete sapwood so a precise felling date cannot be provided. Six of them, however, retain some sapwood or at least the heartwood/sapwood boundary, the average date of this being AD 1464. Using the same sapwood estimates as above would give these timbers an estimated felling date in the range AD 1479 to AD 1504. The two remaining samples of this group, EXT-M27 and EXT-M33 have no heartwood/sapwood boundary. Taking their last extant heartwood rings dates, and allowing for a minimum of 15 sapwood rings in each case, EXT-M33 was felled after AD 1450, whilst EXT-M27 was felled after AD 1451. This, combined with the overall level of cross-matching within the group of timbers suggests that they are likely to be coeval with the AD 1479–1504 felling date range identified. It is possible, therefore, that the roof of the rear building at 47 High Street is also a survival from the primary construction of the pair of houses at 46/47 High Street.

Three samples have been dated from the roof over what was originally the southern part of a separate building in Lamb Alley, but which is now part of 47 High Street. Two of these samples, EXT-M43 and EXT-MM44, are without the heartwood/sapwood boundary, and it is not possible to provide a precise felling date. However, with respectively last heartwood ring dates of AD 1408 and AD 1444, and allowing for a minimum of 15 sapwood rings in each case, EXT-M43 was felled after AD 1423, and EXT-M44 after AD 1459. A further sample from this roof, EXT-M41, is much later, having a heartwood/sapwood boundary, ring date of AD 1624. Using the usual sapwood estimate an estimated felling date in the range AD 1639–64 is obtained for this timber.

Three timbers sampled from the cellar beneath the Lamb Alley building (south) could not be dated.

CONCLUSIONS AND DISCUSSION

Ring-width dendrochronology has resulted in the production of a single dated oak site chronology, accounting for a total of 42 samples, and dated a further two single oak samples individually.

Interpretation of the sapwood and the heartwood/sapwood boundaries on the dated samples indicates that the earliest timbers are to be found in the rear building of 47 High Street (the possible former kitchen block). A number of timbers here are likely to have been felled in the late-fifteenth century, or possibly in the very early sixteenth century. The structural relationship of the timbers to the present building, and the relationship of this rear building to the forward parts of 47 High Street may need further investigation, but the dating obtained here could possibly suggest that this rear building was constructed just prior to the house fronting onto the High Street.

Such an interpretation is based on survey evidence which shows that number 47 High Street was built as one of a pair with number 46, the timbers for which, following an extensive programmed of dendrochronology, were shown to have been felled in the period 1492–1515 (Arnold and Howard 2009a). Timberwork from this period also appears to survive in the cellar of number 47. The tree-ring analysis for such a date is supported by the early sixteenth-century stylistic evidence of the moulding and carving to the side of number 46, obscured when number 45 was built.

There are, in addition, two other potentially late fifteenth- or early sixteenth-century timbers, these being in the roof of the Lamb Alley building; although this does also contain one mid seventeenth-century timber, which possibly reflects the disparate nature of this roof with clear signs of reuse of timber.

The next phase of felling is represented by the roof timbers of 41/42 High Street, these likely to have been felled in the early/mid AD 1560s. The tree-ring dating obtained in this programme of analysis is in keeping with that obtained by Mills (1988), and with the carved date 'AD 1564' on the commemorative doorhead from this building, which is now in Exeter Museum. As such, this date is very much in line with the belief that merchants' houses of this type in Exeter were built from about the middle of the sixteenth century to the later seventeenth century; 41/42 High Street being a particularly good example of the type.

A still later phase of felling is represented by the timbers to the rear roof of number 45 High Street. Although there might be a little variation in the felling date of these timbers, they are all likely to have been cut in the AD 1630s, two timbers certainly being felled in AD 1636. The dating obtained here might indicate a general date when the rear, and perhaps older, parts of the High Street buildings began to be updated or repaired.

Although their exact original locations are uncertain, the Royal Clarence Hotel would appear to contain at least two timbers that were felled no earlier than the later fifteenth century, as well as one timber that was felled no earlier than the latter half of the seventeenth century. The two earlier timbers clearly have *terminus post quem* dates for felling that are broadly coeval with timbers from 46 and 47 High Street, whilst the later timber appears broadly coeval with a single timber from the Lamb Alley roof and a single timber from the Well House Tavern. Although based on only three timbers from the Royal Clarence Hotel, this could be taken as evidence that there might have been an earlier building on this site, from which timbers were reused during construction of the hotel in *c* AD 1768.

Similarly, the presence of the mid/late seventeenth century stud in the Well House Tavern (16–17 Cathedral Yard), may again provide some indication of the presence of early fabric in the building, although this is with the proviso of only one timber having been dated.

Woodland sources

Although site chronology EXTMSQ01 has been compared with reference material from all over Britain, there is a strong tendency for it to show the highest levels of similarity with reference chronologies comprising of data from timbers in other buildings in Devon and its surrounding counties and, as is commonly seen for buildings in Devon, up into the West Midlands region (Table 2). Although the exact woodland sources of the timbers used at these reference sites are themselves unknown, the trend of this cross-matching suggests that the dated timbers used in this complex of buildings in Exeter were obtained from relatively local woodland sources.

The location of the woodland sources for the timbers represented by samples EXT-L18 and EXT-L22 is less clear but is likely hampered by the fact that they are individual series' carrying less climatic information than a well-replicated master chronology such as EXTMSQ01. There is, however, a tendency for the highest levels of similarity to be found with reference chronologies from the south-west and midlands regions.

Wherever the sources, it would appear that some of the dated timbers in these buildings have been derived from the same tree, or possibly from trees growing close to each other in the same woodland. The former is particularly well represented by samples EXT-M17, EXT-M19, EXT-M20, and EXT-M21, all from the rear roof of 45 High Street, which cross-match with each other with *t*-values ranging from 7.7 and 8.8, to as high as 10.6 and 11.4. Possible same-tree matches are also found between sample EXT-M55, from the roof of 41 High Street, and EXT-M66, from the roof of 42 High Street. These samples cross-match with a value of *t*=10.0. These roofs also provide examples of possible same-stand trees (neighbouring tree) matches, with samples EXT-M58 and EXT-M60 (both to the roof of number 41), matching with a value of *t*= 8.0, and samples EXT-M62 and EXT-M70 (both to the roof to number 42), matching with a value of *t*=8.4. A similar match is found between samples EXT-M26 and EXT-M34, both from the rear building to 47 High Street, which match with a value of *t*=8.2.

Ungrouped/undated timbers

Of the 15 conifer samples which were measured, 12 remain both ungrouped and undated, this despite most of them having quite sufficient number of rings for reliable dating, with one sample, EXT-L12, having 234 rings. Conifers, however, are a much more difficult timber to date than oak, usually requiring more extensive sampling to overcome potential issues with multiple sources of imported timber. It appears likely that the timbers represented by the samples obtained here are of different phases, and hence may well be from different sources. However, this data will be reviewed periodically, and it is possible that as the overall corpus of conifer data increases, that these samples will be cross-matched and dated either through standard ring-width data or, as the technique is developed, through blue intensity dendrochronology.

Similarly, a total of 23 measured oak samples also remain both ungrouped and undated. Again, it will be seen from Table 1 that while some of these samples have slightly lower numbers of rings, most, in theory, have sufficient numbers for satisfactory dating, the longest undated oak sample, EXT-M45, having 114 rings. Few of these sample, furthermore, show any problems such as compression or distortion of rings which might make cross-matching difficult. It is possible that some of these timbers are from sources, or grew during periods, for which there is currently insufficient reference data available to provide adequate cross-matching as, although Devon is now well represented with respect to reference chronologies for the last millennium, it is known that some discrete areas within the county remain problematic. It is perhaps also possible that some of the sampled areas contain timbers of different dates, some perhaps being older timbers reused, or later timbers inserted; for example the timbers to the roof of the Lamb Alley building show evidence of reuse. If this were so, it would make such samples 'singletons', and while single samples can sometimes be dated (as with samples EXT-M18 and EXT-M22), it is often more difficult than with groups of samples which supply well replicated site chronologies. The lack of dating does not, however, prove that a timber is of a different date. It is, however, a common, if inexplicable, feature of tree-ring analysis to find that some samples will not date. This undated material will be reviewed periodically as further reference chronologies become available and these timbers may, in due course, also be dated.

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TABLES

Table 1: Details of the tree-ring samples from the Royal Clarence Hotel and 16–17 Cathedral Yard (the Well House Tavern), 41–42 High Street, 43–45 High Street, and 47 High Street, Exeter, Devon (all samples are oak unless otherwise specified)

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date AD	Last heartwood ring date AD	Last measured ring date AD
*Royal Clarence Hotel/Well House Tavern (*ex situ *conifer slices)*						
EXT-L01	Timber 18a/b, bridging beam 2 from third floor, Zone 5	185+20nm	73+20nm	------	------	------
EXT-L02	Timber 23, bridging beam from second floor, Zone 5	104	44	------	------	------
EXT-L03	Timber 24, bridging beam from second floor, Zone 5	94	68	------	------	------
EXT-L04	Timber 28 (conifer), tie beam from roof, Zone 1	nm	---	------	------	------
EXT-L05	Zone 6, St Martin's Lane	123	h/s	------	------	------
EXT-L06	Timber 40, bridging beam, zone 5	69	20	------	------	------
EXT-L07	Timber 47, bridging beam, zone 5 (first floor?)	73	43	------	------	------
EXT-L08	Timber 58, wall plate, Zone 1, second floor north gable	104	40	------	------	------
EXT-L09	Timber 62, post, zone 1, third floor	nm	---	------	------	------
EXT-L10	Timber 66, timber frame, zone 1	107	no h/s	------	------	------
EXT-L11	Timber 69, bridging beam, zone 1	154	no h/s	------	------	------
EXT-L12	Timber 70, bridging beam, zone 1, second floor	234	94	------	------	------
EXT-L13	Timber 73, bridging beam, zone 2	151	no h/s	------	------	------
EXT-L14	Timber 75, bridging beam, zone 3	154	64	------	------	------
EXT-L15	Timber 81, bridging beam, zone 4, ground floor	97	no h/s	------	------	------
EXT-L16	Timber 79, floor joist, zone 2	82	no h/s	------	------	------
EXT-L17	Zone 6, St Martin's Lane, roof truss	57	27	------	------	------
*Royal Clarence Hotel/Well House Tavern (*ex situ *oak slices)*						
EXT-L18	Zone 3, Clarence Hotel, second floor NE room, joist	51	no h/s	1398	------	1448

EXT-L19	Zone 3, Clarence Hotel second floor NW room, joist	75	h/s	------	------	------
EXT-L20	Zone 1, second floor, timber 74, bridging beam	91	20C	------	------	------
EXT-L21	Zone 1, second floor, timber 85, stud	116	no h/s	1517	------	1632
EXT-L22	Zone 3, timber 39, bridging beam	90	no h/s	1367	------	1456
EXT-L23	Zone 1, second floor, Well House, un-numbered frame, top rail	94	3	1543	1633	1636
Well House Tavern (in situ *oak cores)*						
EXT-L24	Zone 1, Well House, tiebeam to south truss	64	h/s	------	------	------
EXT-L25	Zone 1, Well House, north principal rafter to south truss	nm	---	------	------	------
EXT-L26	Zone 1, Well House, collar to south truss	nm	---	------	------	------
EXT-L27	Zone 1, Well House, stud post to south truss	nm	---	------	------	------
41 High Street (roof)						
EXT-M51	South lower purlin, truss 1–2	75	4	1468	1538	1542
EXT-M52	South principal rafter, truss 2	57	h/s	1482	1538	1538
EXT-M53	North principal rafter, truss 3	nm	---	------	------	------
EXT-M54	South principal rafter, truss 3	65	h/s	1479	1543	1543
EXT-M55	South pad block, truss 3	92	no h/s	1378	------	1469
EXT-M56	South principal rafter, truss 4	104	no h/s	1397	------	1500
EXT-M57	South upper purlin, truss 4–5	100	no h/s	1416	------	1515
EXT-M58	South principal rafter, truss 5	113	9	1426	1529	1538
EXT-M59	North lower purlin, truss 5–6	55	10	1485	1529	1539
EXT-M60	North principal rafter, truss 6	87	20c	1475	1541	1561
42 High Street (roof)						
EXT-M61	North upper purlin, truss 2–3	132+10nm	24+10nmc	1423	1530	1554
EXT-M62	North wall plate, truss 2–3	89	9	1464	1543	1552
EXT-M63	South principal rafter, truss 2	115	no h/s	1414	------	1528
EXT-M64	North principal rafter, truss 3	108	21	1450	1536	1557
EXT-M65	South principal rafter, truss 3	94	no h/s	1411	------	1504
EXT-M66	North pad block, truss 3	116	no h/s	1378	------	1493
EXT-M67	North principal rafter, truss 4	48	no h/s	------	------	------

EXT-M68	South principal rafter, truss 4	65	no h/s	------	------	------
EXT-M69	North upper purlin, truss 4–5	107	no h/s	1413	------	1519
EXT-M70	North upper purlin, truss 5–6	104	h/s	1444	1547	1547
42 High Street (rear range)						
EXT-M71	West principal rafter, truss 1	42	no/hs	------	------	------
EXT-M72	West principal rafter, truss 2	46	h/s	------	------	------
EXT-M73	West principal rafter, truss 3	63	h/s	------	------	------
43/44 High Street (cellar walls)						
EXT-M09	Horizontal wall beam	83	h/s	------	------	------
EXT-M10	Main vertical post 1	74	no h/s	------	------	------
EXT-M11	Pad beam	nm	---	------	------	------
EXT-M12	Stud post 1 (east)	nm	---	------	------	------
EXT-M13	Stud post 4 (west)	nm	---	------	------	------
EXT-M14	Main vertical post 2 (to south wall)	nm	---	------	------	------
44 High Street (roof)						
EXT-M01	North principal rafter, truss 1 (from east)	nm	---	------	------	------
EXT-M02	South principal rafter, truss 2	89	8	------	------	------
EXT-M03	North principal rafter, truss 3	nm	---	------	------	------
EXT-M04	South principal rafter, truss 3	46	no h/s	------	------	------
EXT-M05	Collar, truss 3	nm	---	------	------	------
EXT-M06	North principal rafter, truss 4	nm	---	------	------	------
EXT-M07	South principal rafter, truss 4	41	no h/s	------	------	------
EXT-M08	Collar, truss 4	nm	---	------	------	------
45 High Street (rear roof)						
EXT-M15	North rafter, frame 3 (from east)	59	h/s	1538	1596	1596
EXT-M16	North rafter, frame 4	171	66C	1466	1570	1636
EXT-M17	South rafter, frame 5	108	no h/s	1456	------	1563
EXT-M18	South rafter, frame 6	91	no h/s	1467	------	1557
EXT-M19	North rafter, frame 8	120+15nm	37+15nm	1492	1574	1611
EXT-M20	South rafter, frame 8	149	42	1460	1566	1608
EXT-M21	South rafter, frame 9	146	31	1459	1573	1604
EXT-M22	North rafter, frame 11	70	25c	1565	1609	1634

EXT-M23	North rafter, frame 12	118	31c	1505	1591	1622
EXT-M24	South rafter, frame 16	130	3	1471	1597	1600
EXT-M25	North rafter, frame 17	94	42C	1543	1594	1636
47 High Street (cellar)						
EXT-M46	Main east floor-frame beam (below no 47)	58	13C	------	------	------
EXT-M47	Main west floor-frame beam (below no 47)	140	9	1342	1472	1481
47 High Street (rear building)						
EXT-M26	West principal rafter, upper truss 1 (to north wall)	114	13	1357	1457	1470
EXT-M27	Collar, upper truss 1	81	no h/s	1356	------	1436
EXT-M28	West principal rafter, upper truss 2 (to south wall)	73	h/s	1386	1458	1458
EXT-M29	East principal rafter, upper truss 2	92	h/s	1379	1470	1470
EXT-M30	West post, upper truss 2	90	h/s	1377	1466	1466
EXT-M31	East post, upper truss 2	nm	---	------	------	------
EXT-M32	West principal rafter, lower truss (to north wall)	53	no h/s	------	------	------
EXT-M33	East principal rafter, lower truss	63	no h/s	1373	------	1435
EXT-M34	Collar, lower truss	81	h/s	1383	1463	1463
EXT-M35	Tiebeam, lower truss	54	h/s	------	------	------
EXT-M36	West lower purlin	70	h/s	1402	1471	1471
47 High Street (Lamb Alley building (south), roof)						
EXT-M37	South principal rafter, truss 1	nm	---	------	------	------
EXT-M38	South principal rafter, truss 2	58	26C	------	------	------
EXT-M39	Collar, truss 1	61	18	------	------	------
EXT-M40	Collar, truss 2	60	18	------	------	------
EXT-M41	South upper purlin, truss 1–2	56	h/s	1569	1624	1624
EXT-M42	South lower purlin, truss 2 – west wall	91	12	------	------	------
EXT-M43	North lower purlin, truss 1 – 2	72	no h/s	1337	------	1408
EXT-M44	North upper purlin, truss 1 – 2	87	no h/s	1358	------	1444
EXT-M45	North principal rafter, truss 1	114	38C	------	------	------
47 High Street (Lamb Alley building (south), cellar)						
EXT-M48	Main floor-frame beam below Lamb Alley	43	no h/s	------	------	------

	building					
EXT-M49	West floor joist 3 below Lamb Alley building	40	7	------	------	------
EXT-M50	West floor joist 7 below Lamb Alley building	nm	---	------	------	------

h/s = the heartwood/sapwood boundary is the last ring on the sample; C = complete sapwood is retained on the sample, the last measured ring date is the felling date of the tree represented; c = complete sapwood exists on the sampled timber, but all or part of it has been lost from the sample in coring; the likely felling date may be estimated; nm = not measured

Table 2: Results of the cross-matching of site chronology EXTMSQ01 and relevant reference chronologies when the first ring date is AD 1337 and the last ring is dated AD 1636

Reference chronology	Span of chronology	*t*-value	Reference
Holcombe Court, Holcombe Rogus, Devon	AD 1349 – 1536	11.1	Miles and Bridge 2012
Pendennis Castle, nr Falmouth, Cornwall	AD 1358 – 1541	10.4	Tyers 2004
Warleigh House, Tamerton Foliot, Devon	AD 1367 – 1539	10.0	Howard *et al* 2006
Yarde Farm, Malborough, South Hams, Devon	AD 1432 – 1603	9.8	Arnold and Howard 2009b
Sydenham House, Marystow, Devon	AD 1266 – 1629	9.7	Arnold *et al* 2015
St John's Walk, Hereford Cathedral, Herefordshire	AD 1356 – 1504	9.3	Arnold and Howard 2015 unpubl
Muchelney Abbey, Somerset	AD 1148 – 1498	9.2	Bridge 2002
White House, Vowchurch, Herefordshire	AD 1364 – 1602	9.1	Nayling 1999
Poltimore House, Poltimore, Devon	AD 1380 – 1559	9.0	Arnold *et al* 2005
St Andrew's Church, Alwington, Devon	AD 1342 – 1490	8.8	Arnold and Howard 2009c

Table 3: Results of the cross-matching of sample EXT-L18 and relevant reference chronologies when the first ring date is AD 1398 and the last ring is dated AD 1448

Reference chronology	Span of chronology	*t*-value	Reference
1–3 North Gate, Newark, Nottinghamshire	AD 1339 – 1523	6.6	Arnold and Howard 2009 unpubl
Lower Brockhampton Manor, Bromyard, Herefordshire	AD 1304 – 1543	6.5	Arnold and Howard 2014 unpubl
Headstone Manor barn, Harrow, Middlesex	AD 1374 – 1505	6.2	Howard *et al* 2000
Barn, Kings Pyon, Herefordshire	AD 1346 – 1480	6.0	Groves and Hillam 1993
Village Hall, Cradley, Herefordshire	AD 1347 – 1530	5.9	Worthington and Miles 2004
3 Vicars Close, Lichfield, Staffordshire	AD 1350 – 1438	5.9	Arnold *et al* 2002
New House Farm, Moccas, Herefordshire	AD 1350 – 1584	5.4	Arnold and Howard 2013 unpubl
St Bartholowmew's Church, Lower Sapey, Worcestershire	AD 1370 – 1507	5.4	Tyers 1995
Warsop Old Hall, Church Warsop, Nottinghamshire	AD 1382 – 1643	5.4	Arnold and Howard 2018 unpubl
Lower Brockhampton gatehouse, Bromyard, Herefordshre	AD 1368 – 1543	5.2	Nayling 2001

Table 4: Results of the cross-matching of sample EXT-L22 and relevant reference chronologies when the first ring date is AD 1367 and the last ring is dated AD 1456

Reference chronology	Span of chronology	*t*-value	Reference
Leicester Free Grammar School, High Cross Street, Leicester	AD 1337 – 1446	7.2	Arnold and Howard 2005 unpubl
46 High Street, Exeter, Devon	AD 1309 – 1491	6.8	Arnold and Howard 2009a
Keynedon Barton, Devon	AD 1405 – 1478	6.6	Tyers and Groves 2000
20 High Street, Bruton, Somerset	AD 1318 – 1461	6.6	Miles *et al* 1997
Church of St Nectan, Hartland, Devon	AD 1339 – 1473	6.4	Arnold and Howard 2013
Guildhall, High Street, Exeter, Devon	AD 1314 – 1456	6.3	Howard *et al* 1999
Tudor House, Vicarage Street and 1A Chinn's Court, Warminster, Wiltshire	AD 1409 – 1652	6.1	Arnold and Howard 2019 unpubl
Sherborne Abbey Church, Dorset	AD 1339 – 1474	6.0	Bridge 1993
Headstone Manor barn, Harrow, Middlesex	AD 1374 – 1505	6.0	Howard *et al* 2000
Church House, Alcester, Warwickshire	AD 1366 – 1451	6.0	Arnold and Howard 2012 unpubl

FIGURES

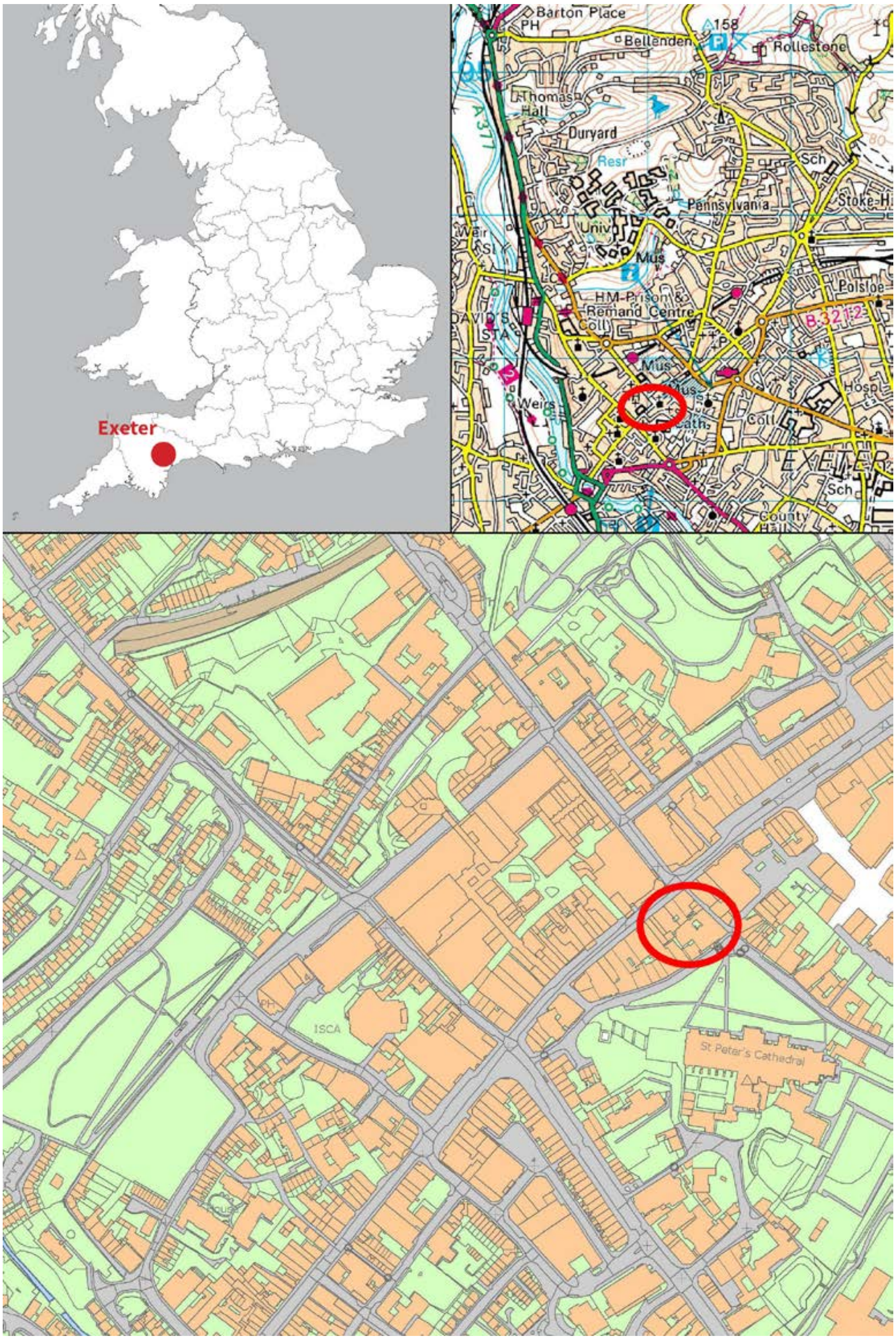


Figure 1: Maps to show the location of The Royal Clarence Hotel and neighbouring buildings in Exeter, marked in red. Scale: top right 1:35000; bottom 1:4000; PTO 1:750. © Crown Copyright and database right 2021. All rights reserved. Ordnance Survey Licence number 100024900. © British Crown and SeaZone Solutions Limited 2021. All rights reserved. Licence number 102006.006

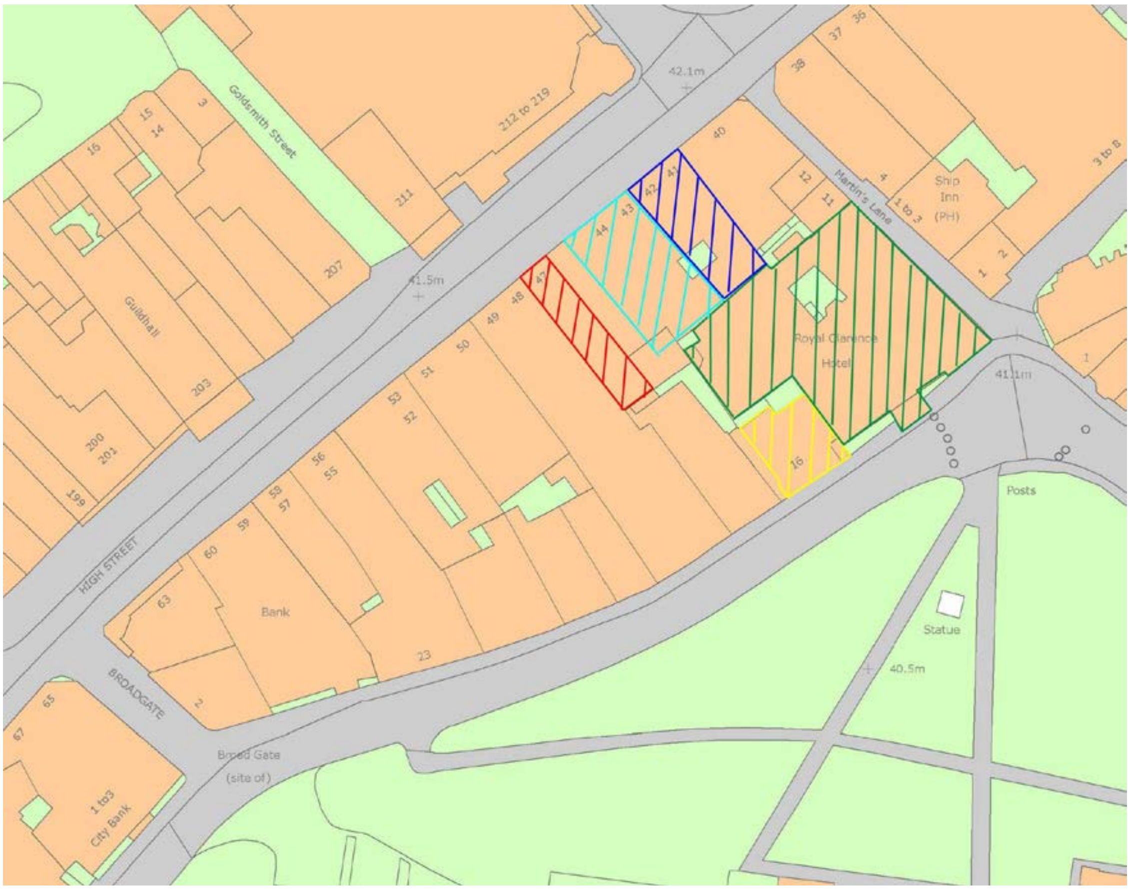


Figure 1 (cont): Map locating properties related to this report, scale 1:750. Royal Clarence Hotel marked in green; 16–17 Cathedral Yard marked in yellow; 41–42 High Street marked in dark blue; 43–45 High Street marked in turquoise, and 47 High Street marked in red.

Figure 2: General view of the Royal Clarence Hotel and 16–17 Cathedral Yard (The Well House Tavern) looking west from Cathedral Yard. Only the ground- and first-floor frontage of the Royal Clarence Hotel remain in place, with the five-storey, double bay-fronted Well House Tavern to its left (photograph Robert Howard)

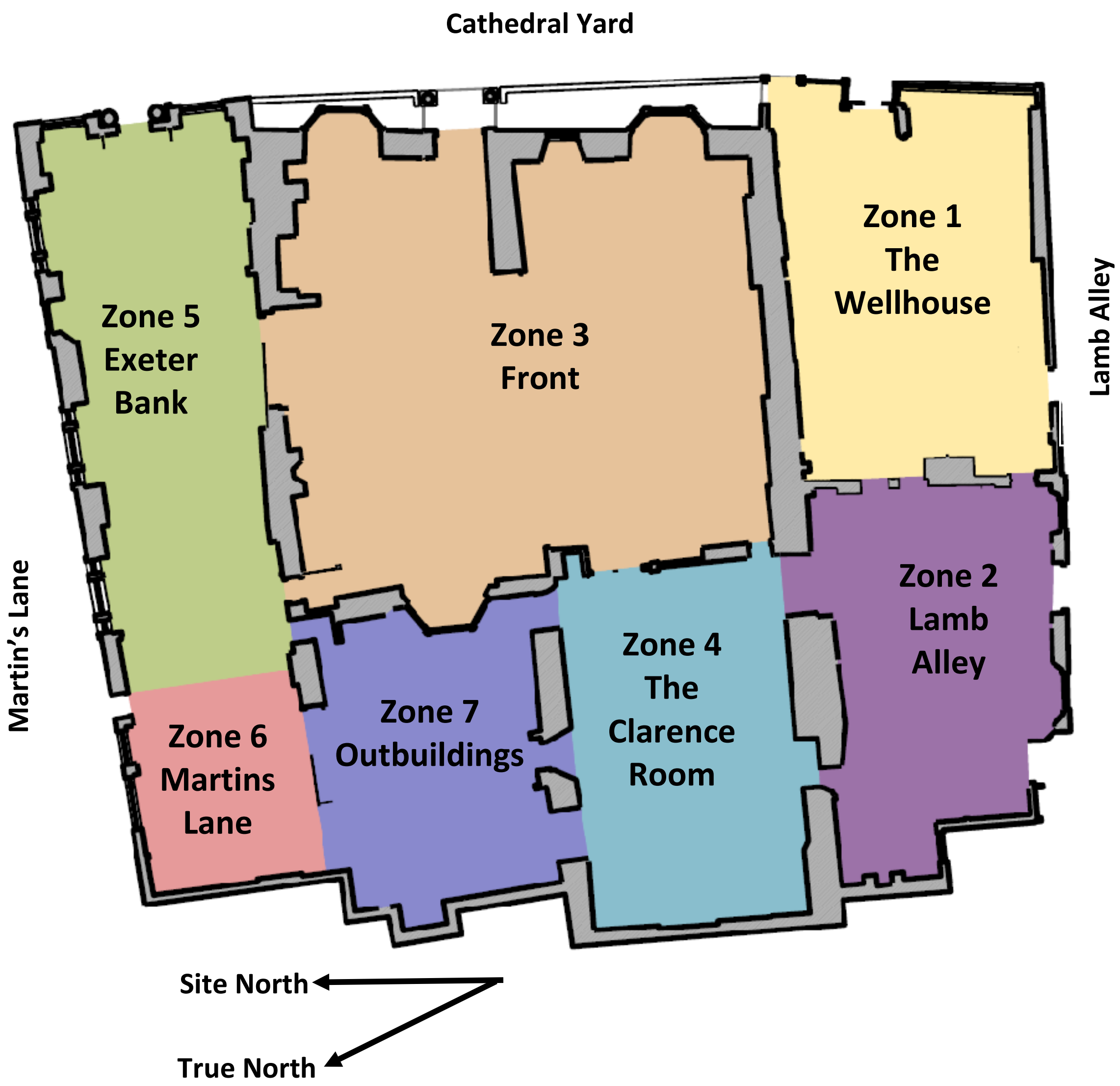


Figure 3: Outline plan of the Royal Clarence Hotel and the Well House Tavern (16–17 Cathedral Yard, after Buttress, Architects)

Figure 4a/b: General view of the timber remains to a rear wall of zone 3 (fig. 3) of the Royal Clarence Hotel (top), and the newly revealed truss in zone 1(fig. 3), the Well House Tavern (16–17 Cathedral Yard, bottom), looking south to north (photographs Robert Howard)

Figure 5: General view looking along the High Street from 41/42 (Laura Ashley), past 43–45 (Costa) towards the still-jettied 47 (L'Occitane, photograph Robert Howard)

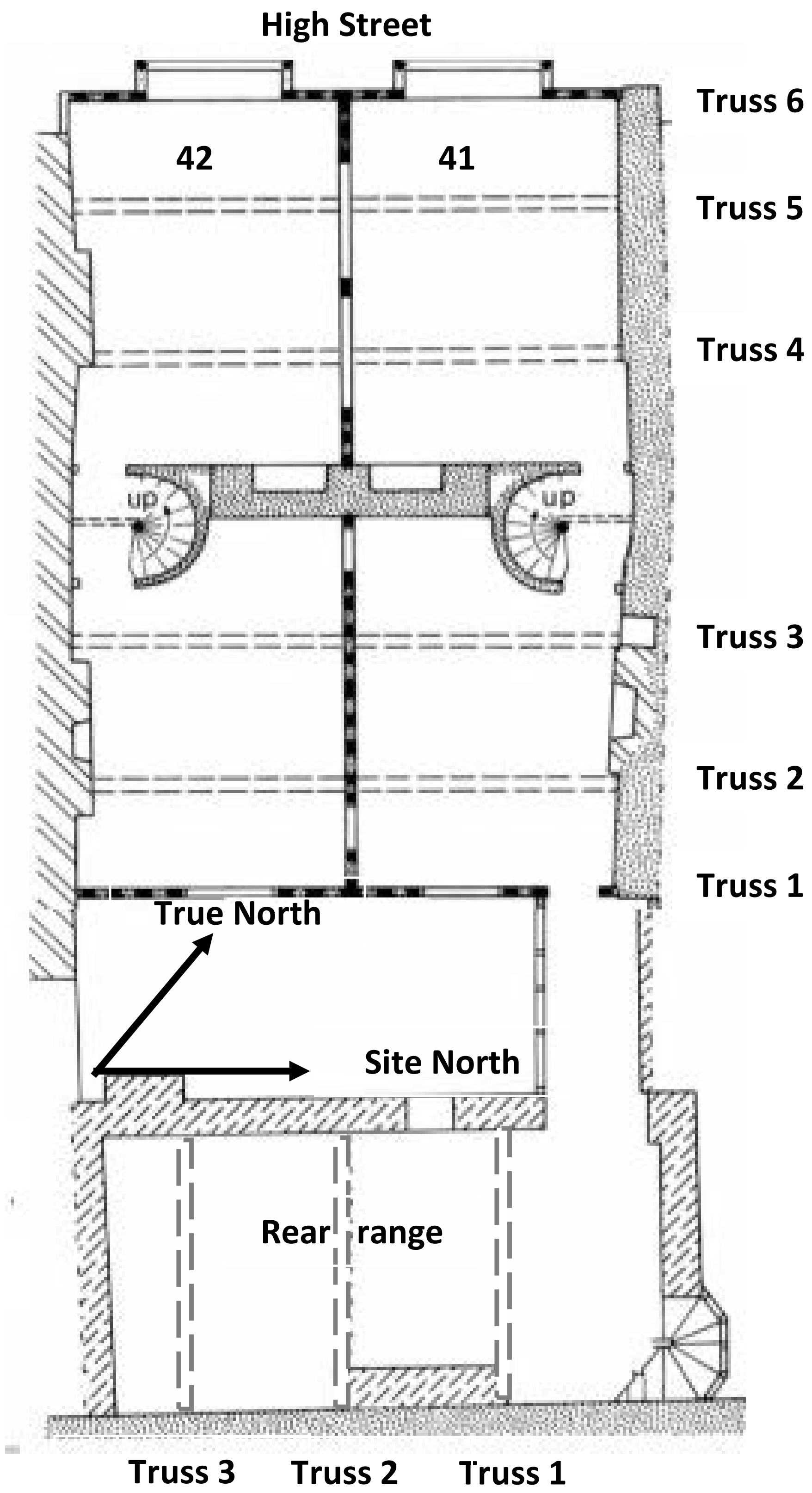


Figure 6: Outline plan of 41/42 High Street to show position of the roof trusses (after John Thorp)

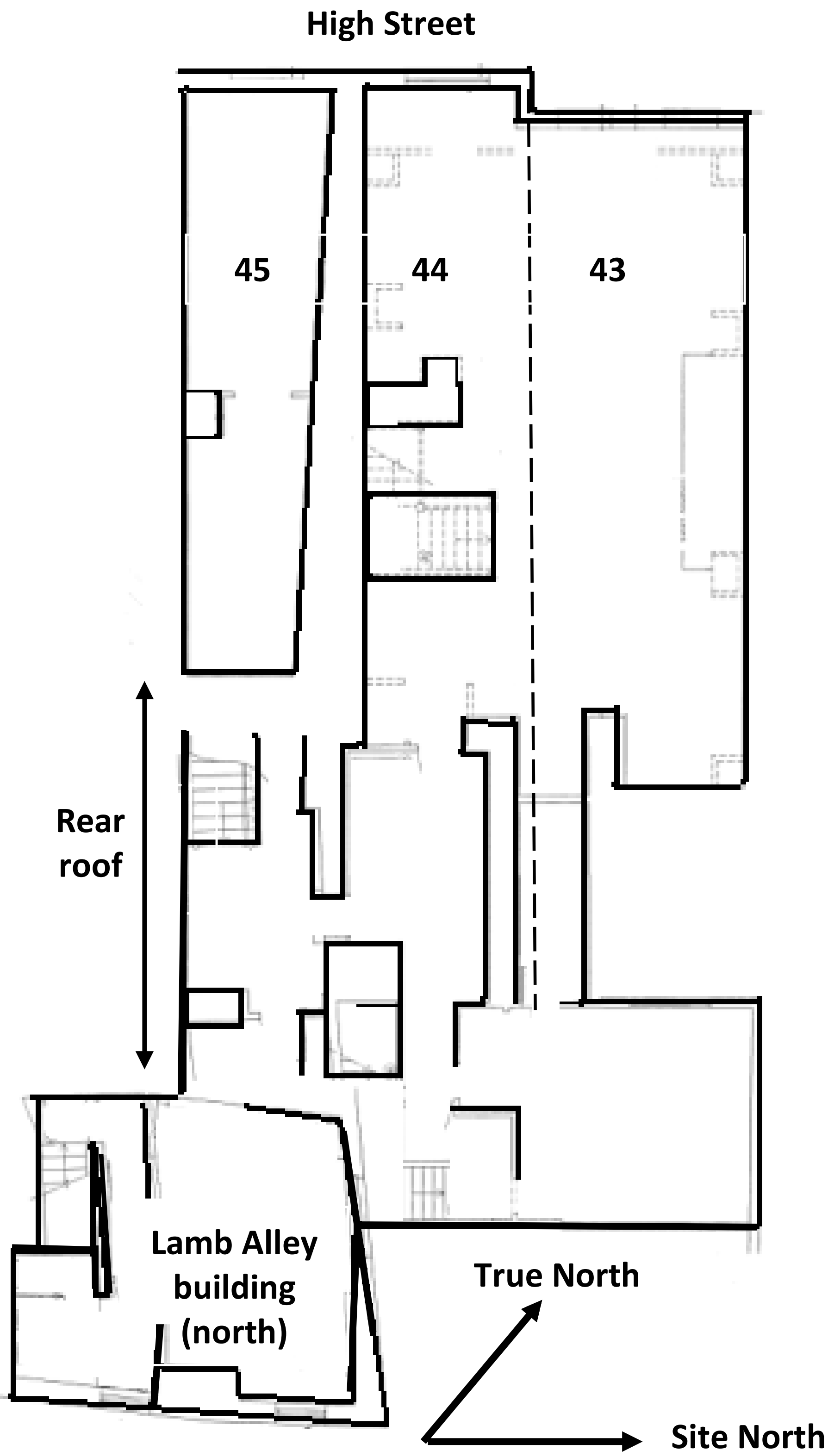


Figure 7: Outline plan of 43–45 High Street (after Ellis Belk Associates Ltd)

Figure 8: View of a section of the east wall of number 46 which was originally exposed to Lamb Alley. This wall was hidden when 45 High Street was built, and sections of it are now only partially visible behind wall panels in the upstairs rooms of number 45 (photograph Robert Howard).

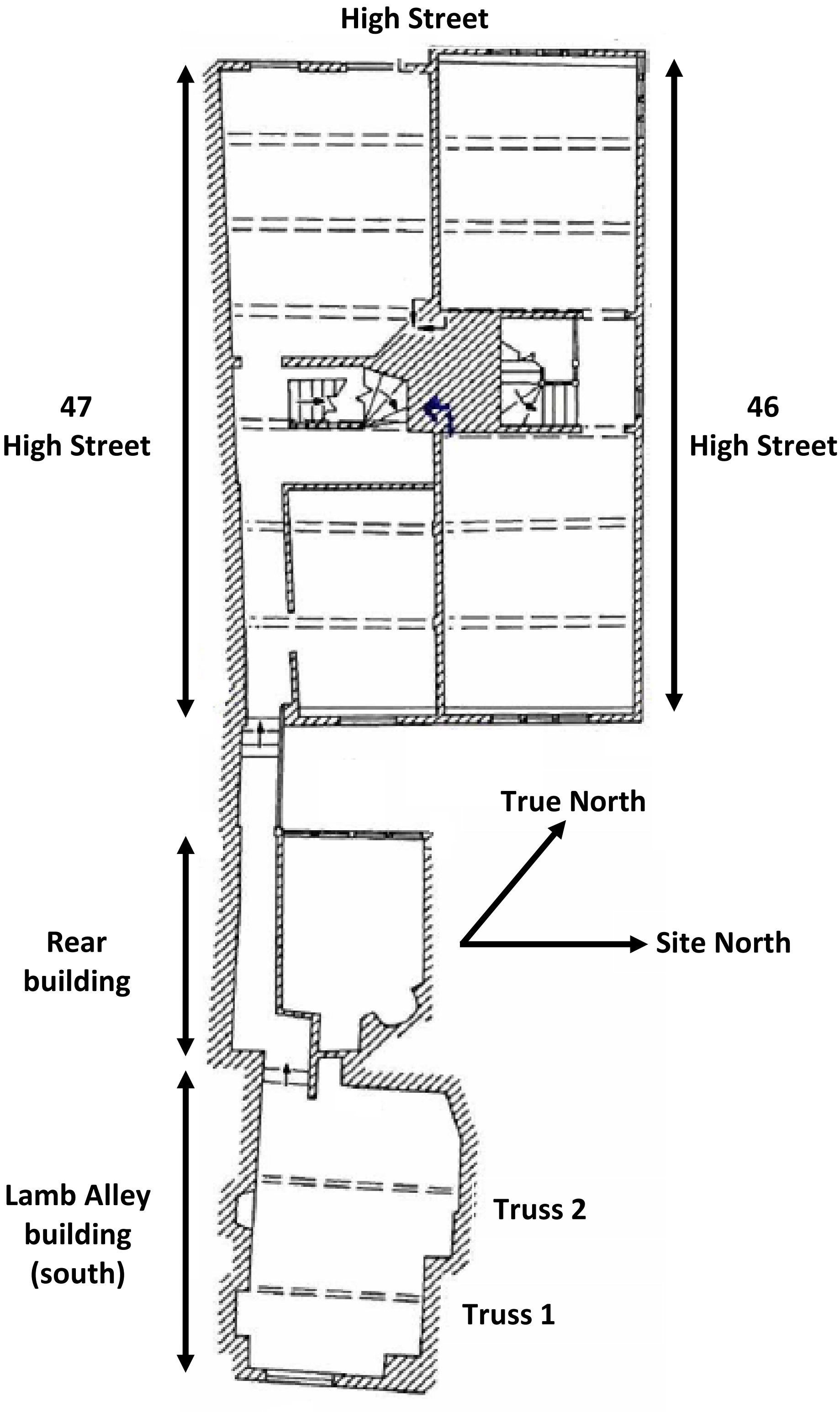


Figure 9: Outline plan of 46/47 High Street and the buildings to the rear (after Richard Parker)

Figure 10a/b: Views of ex situ *timbers salvaged from the Royal Clarence Hotel (top), and the pieces cut from them with a chainsaw and labelled (bottom, photographs Robert Howard)*

Figure 11: Section through the Well House looking north–south to help locate sampled timbers EXT-L23–EXT-L27 (after Buttress, Architects)

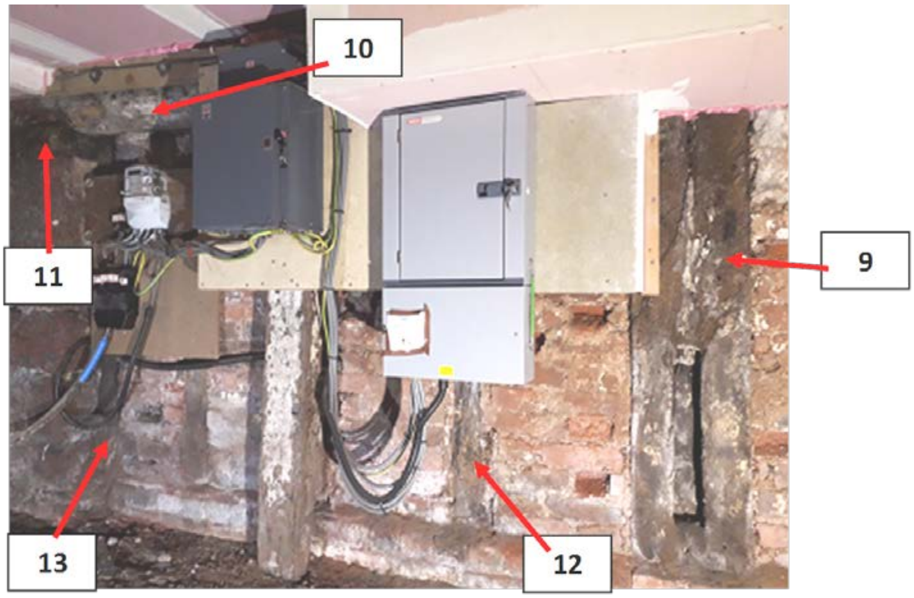
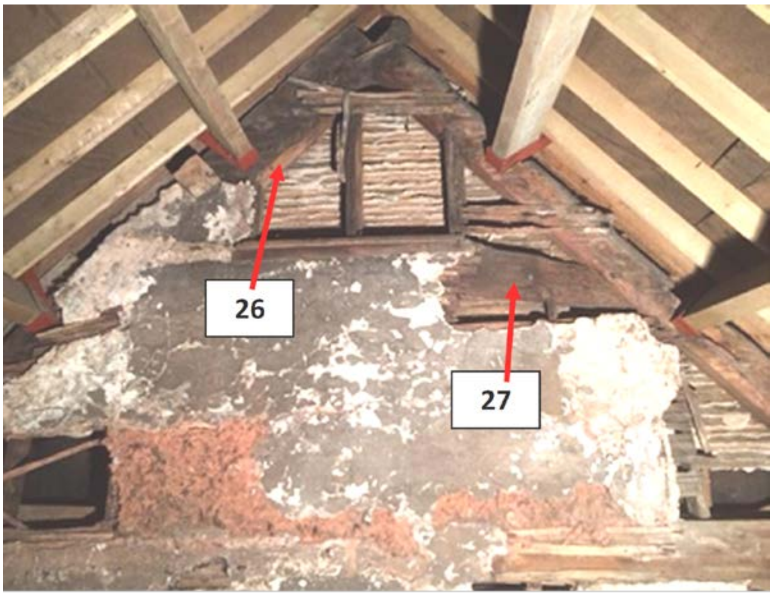


Figure 12a/b: Annotated photographs to help identify sampled timbers from the roof of 44 High Street (EXT-M01–EXT-M08; top) and from the partition wall in the cellar between 43 and 44 (EXT-M09–EXT-M13; bottom, photographs Robert Howard)

Figure 12c: Annotated photograph to help identify sampled timbers from the south cellar wall of 44 High Street (EXT-M14, photograph Robert Howard)

Figure 13: Annotated photograph to help locate sampled timbers from the rear roof of number 45 High Street (viewed looking west to east) (EXT-M15–EXT-M25, photograph Robert Howard)



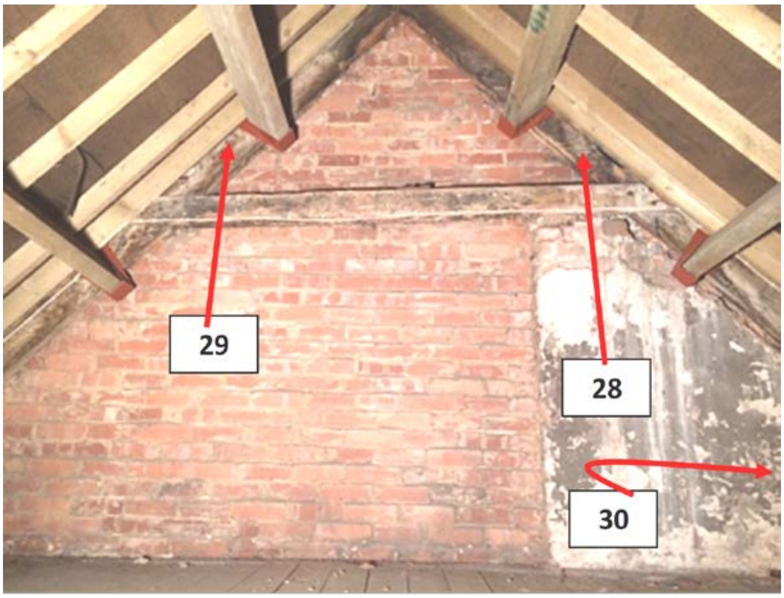


Figure 14a/b: Annotated photographs to help identify sampled timbers from the upper part of the building to the rear of 47 High Street looking south to north (EXT-M26 and EXT-M27; top) and north to south (EXT-M28–EXT-M30; bottom, photographs Robert Howard)

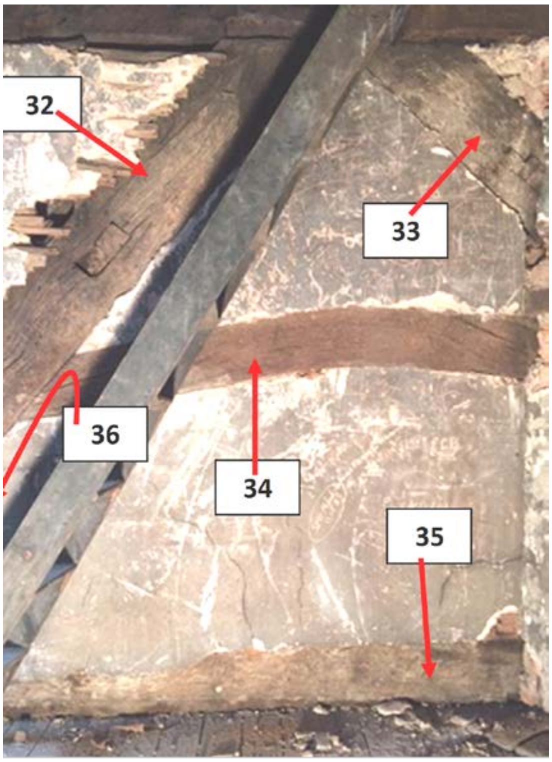
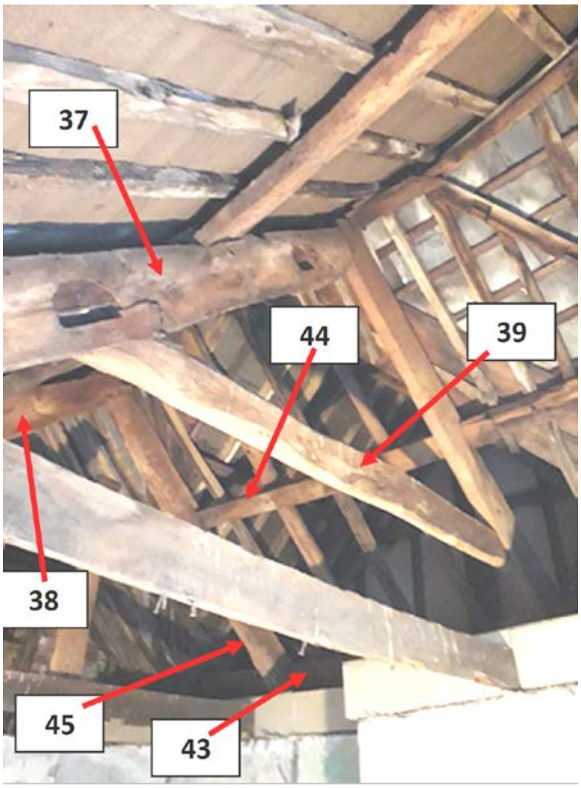


Figure 14c/d: Annotated photographs to help identify sampled timbers from the upper level of the rear building to 47 High Street looking north to south (EXT-M31; top), and of the lower level (EXT-M32–EXT-M36; bottom) looking south to north (photographs Robert Howard)



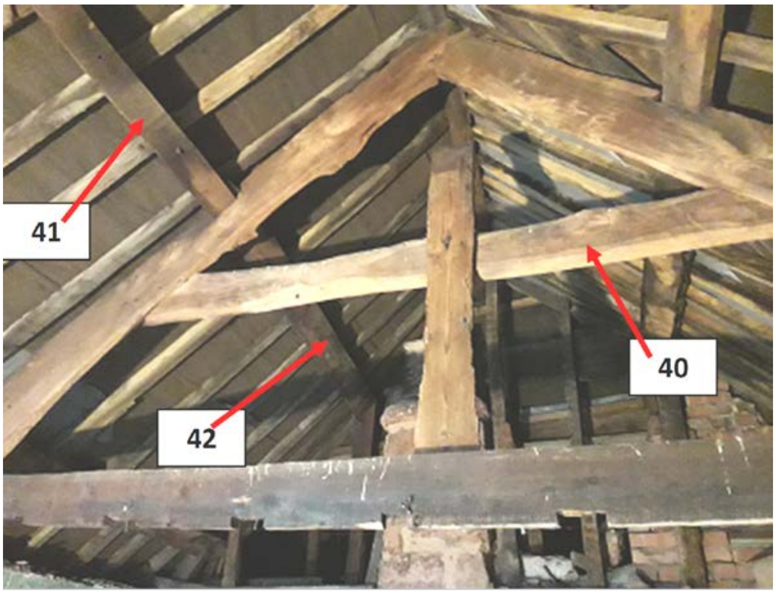


Figure 14e/f: Annotated photographs to help identify sampled timbers from the roof to the Lamb Alley building looking east to west (EXT-M37–EXT-M45, photographs Robert Howard)

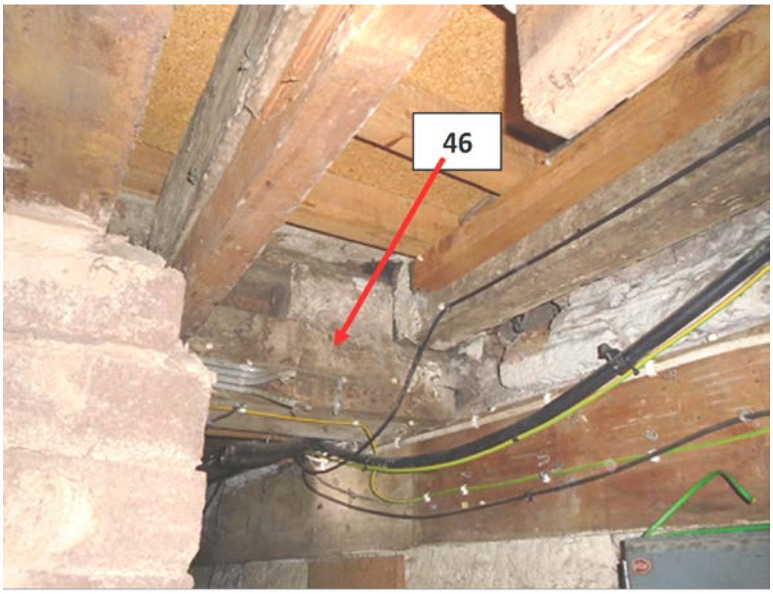


Figure 14g/h: Annotated photographs of the cellar of 47 High Street looking east to west to help identify sampled timbers (EXT-M46 and EXT-M47, photographs Robert Howard)

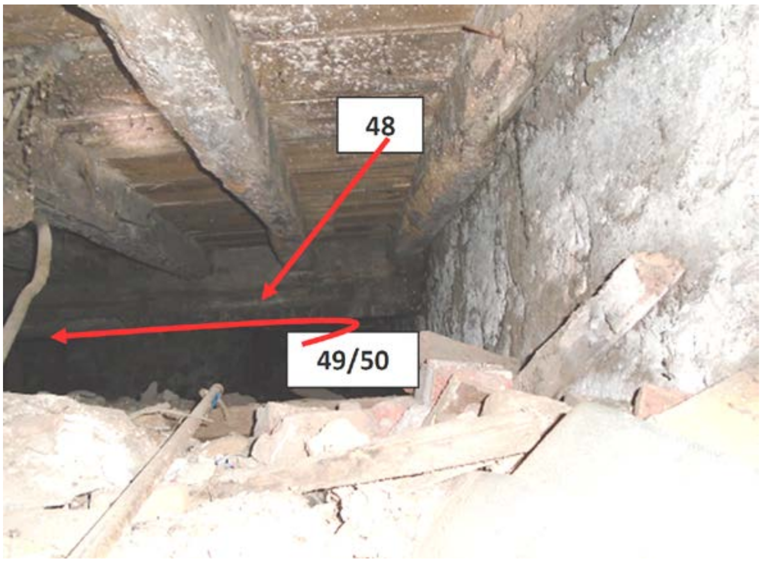


Figure 14i: Annotated photograph of the cellar of the rear building of 47 High Street looking south to north to help identify sampled timbers (EXT-M48–EXT-M50, photograph Robert Howard)

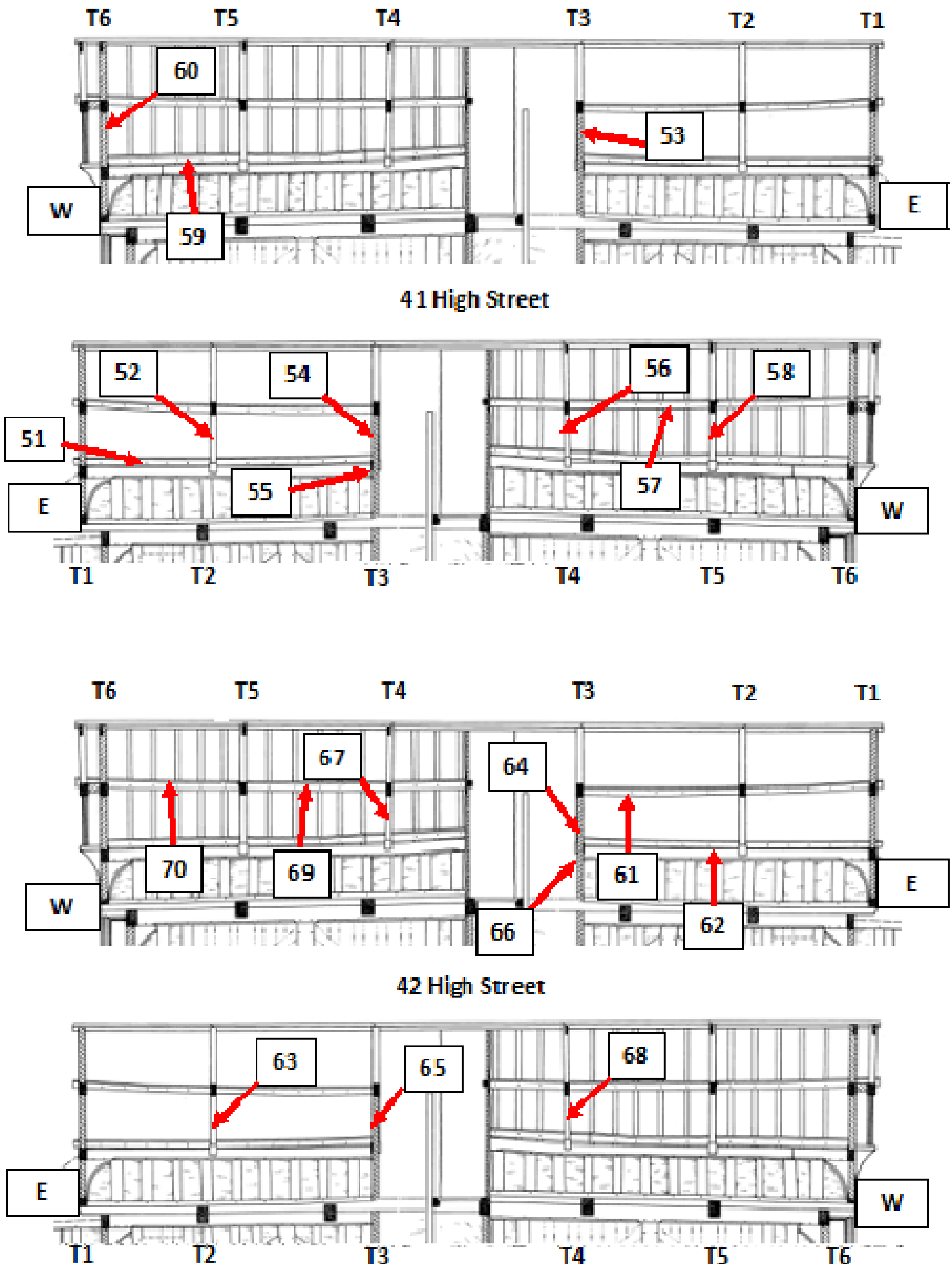


Figure 15a/b: Sections through 41 High Street (top) and 42 High Street (below) looking south to north and north to south, to help locate sampled timbers (after John Thorpe)

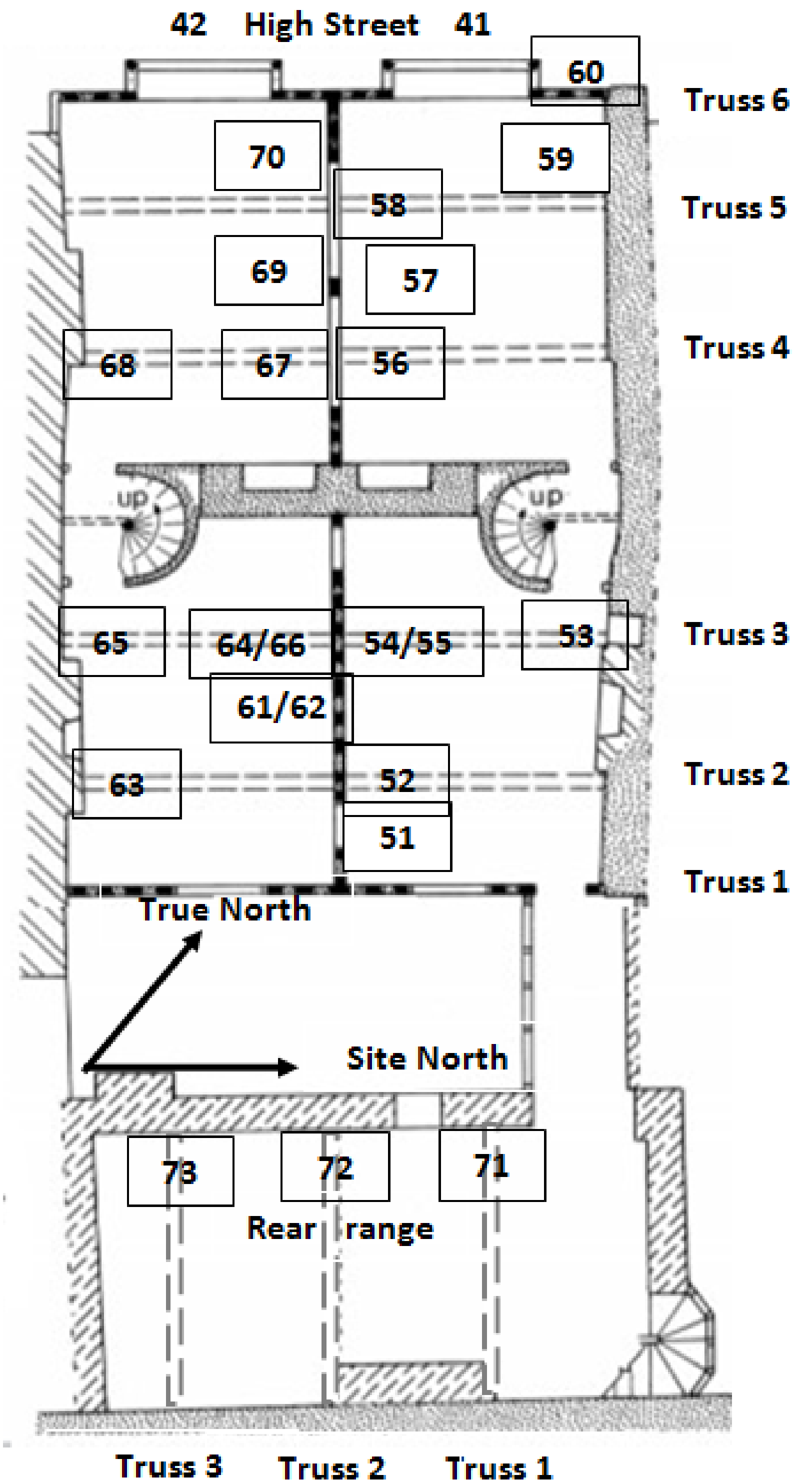


Figure 15c: Plan of 41–42 High Street to help locate sampled timbers (after John Thorpe)

Figure 15d/e: Annotated photographs of the roof space of 41 High Street looking west to east (EXT-M51, EXT-M52, EXT-M54, and EXT-M55; top) and east to west (EXT-M53; bottom) to help identify sampled timbers (photographs Robert Howard)

Figure 15f/g: Annotated photographs of the roof space of 41 High Street looking east to west (EXT-M56–EXT-M58; top) and west to east (EXT-M59 and EXT-M60; bottom) to help identify sampled timbers (photographs Robert Howard)

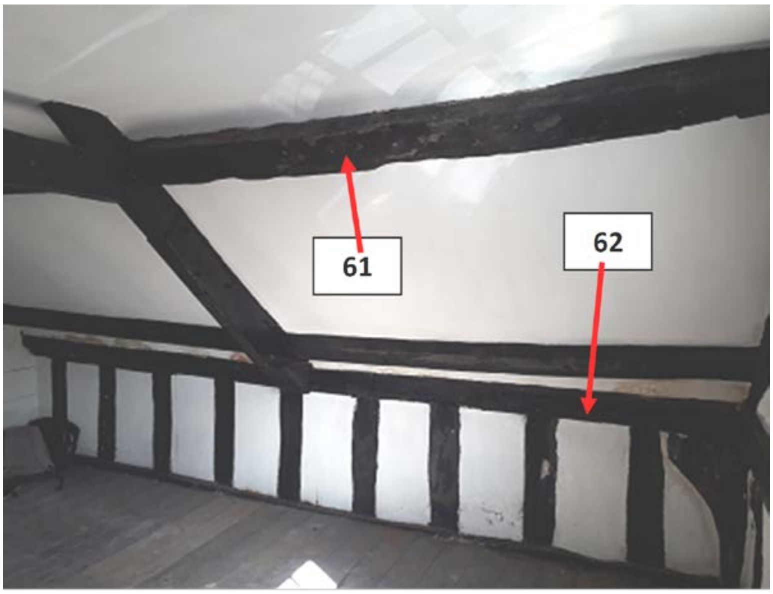


Figure 15h/i: Annotated photographs of the roof space of 42 High Street looking west to east (EXT-M61 and EXT-M62; top) and east to west (EXT-M63; bottom) to help identify sampled timbers (photographs Robert Howard)

Figure 15j/k: Annotated photographs of the roof space of 42 High Street looking west to east (EXT-M64 and EXT-M66; top) and north to south (EXT-M65; bottom) to help identify sampled timbers (photographs Robert Howard)

Figure 15l: Annotated photograph of the roof space of 42 High Street looking west to east to help identify sampled timbers (EXT-M67–EXT-M70)(photograph Robert Howard)

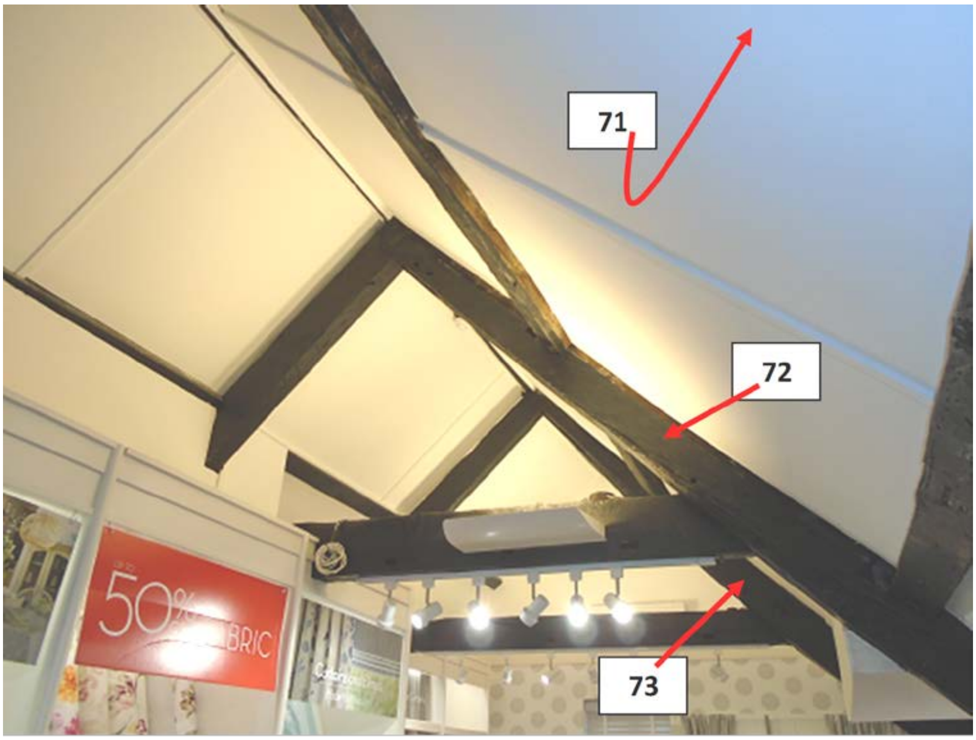


Figure 15m: Annotated photograph of the rear range of 41/42 High Street, looking south to north, to help identify sampled timbers (EXT-M71–EXT-M73) (photograph Robert Howard)

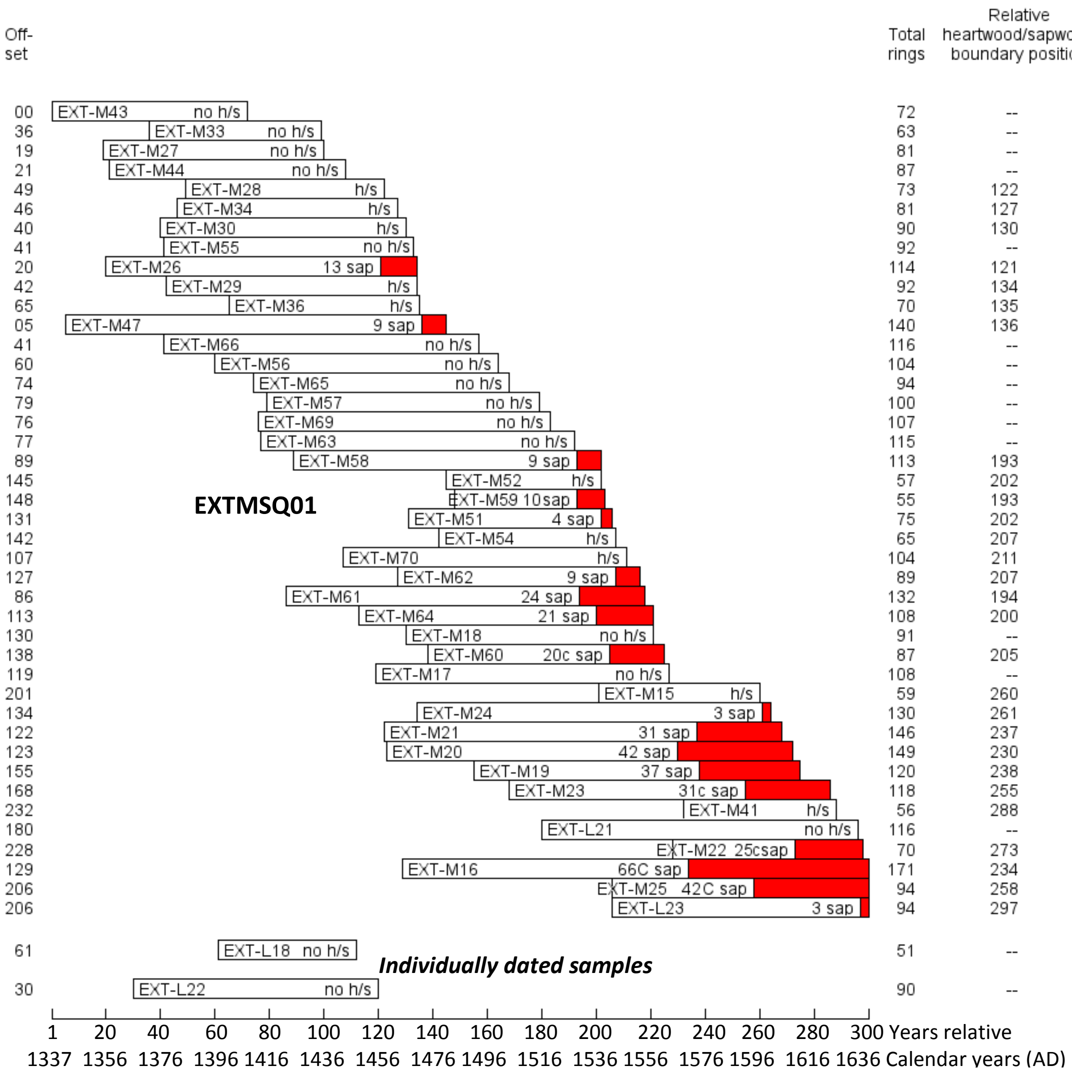


Figure 16: Bar diagram of all dated samples in last measured ring date order

White bars = measured heartwood rings
Solid red bars = measured sapwood rings (unmeasured sapwood rings not shown)

h/s = the heartwood/sapwood boundary is the last ring on the sample
C = complete sapwood is retained on the sample, the last measured ring date is the felling date of the timber represented
c = complete sapwood exists on the sampled timber, but all or part of it has been lost from the sample in coring; the likely felling date may be estimated

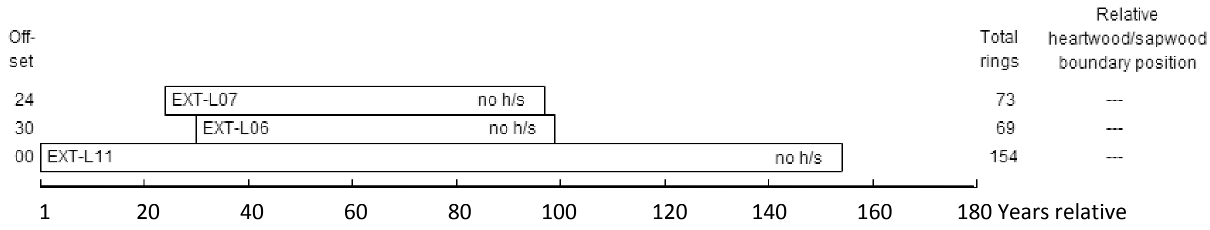


Figure 17: Bar diagram of the three cross-matching conifer samples from the Royal Clarence Hotel in site chronology EXTPSQ01

White bars = measured heartwood rings

no h/s = the sample does not retain the heartwood/sapwood boundary

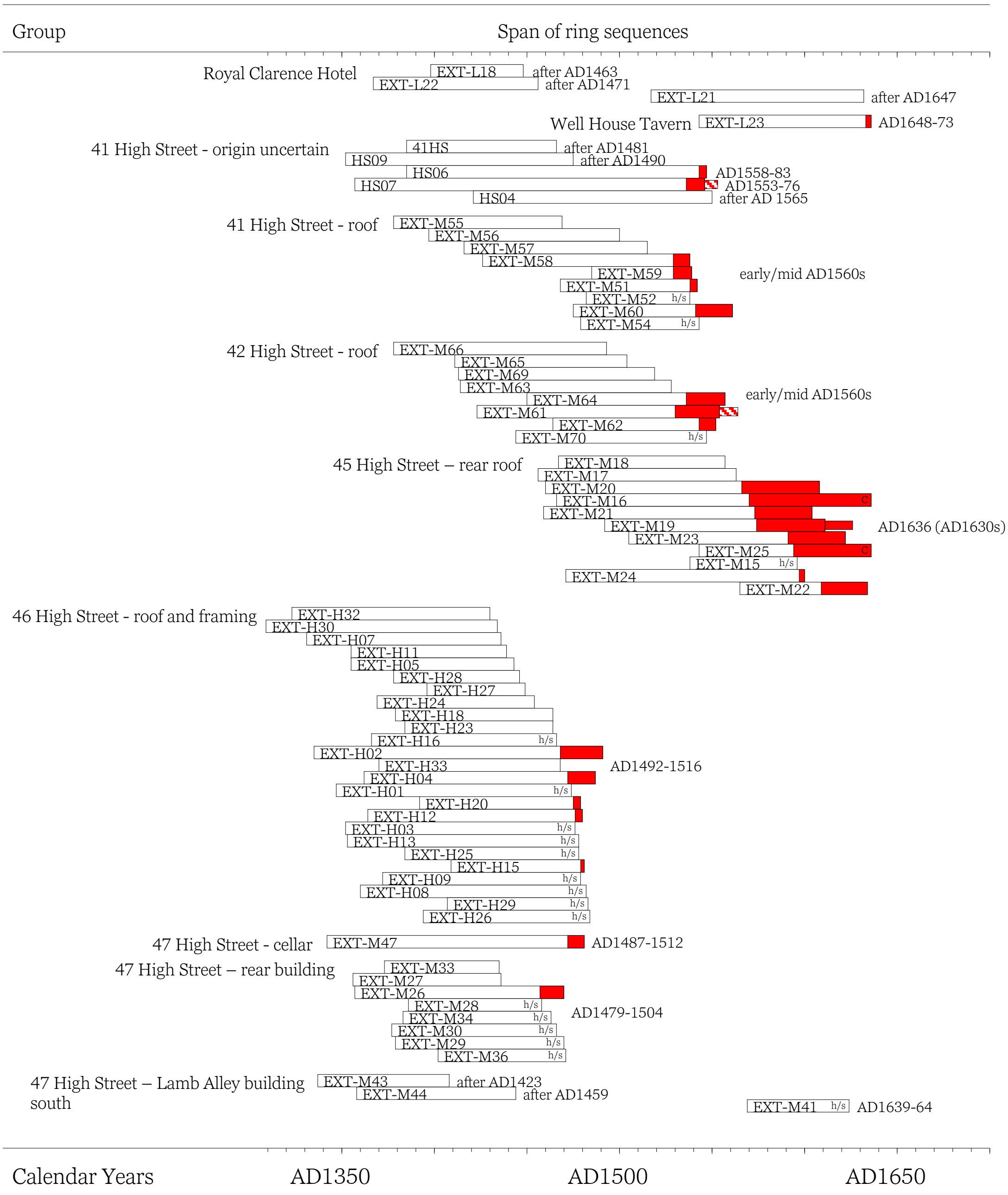


Figure 18: Bar diagram of all dated samples sorted by individual buildings in outermost heartwood ring measured date order, showing felling dates, estimated felling date ranges, or terminus post quem *dates for felling*

White bars = measured heartwood rings
Solid red bars = measured sapwood rings
Narrow red hatched bars = unmeasured (nm) sapwood rings

h/s = the heartwood/sapwood boundary is the last ring on the sample
C = complete sapwood is retained on the sample, the last measured ring date is the felling date of the timber represented

DATA OF MEASURED SAMPLES

Measurements in 0.01mm units

Oak Samples

EXT-L18A 51
372 291 358 319 354 343 362 292 307 330 370 468 317 332 299 392 368 348 285 313
279 195 308 251 226 289 276 300 194 221 278 323 248 263 250 189 189 279 243 231
207 180 245 207 253 182 221 185 115 136 137

EXT-L18B 51
368 292 368 309 369 311 373 260 290 299 371 459 318 323 278 431 396 361 270 299
300 189 301 259 250 250 282 320 207 214 289 282 285 249 303 225 195 289 243 245
201 190 243 199 248 179 217 186 109 132 135

EXT-L19A 75
153 132 169 146 296 344 314 357 302 240 206 216 300 319 307 493 598 350 220 194
188 214 175 104 76 73 109 108 121 145 200 173 129 245 248 239 279 284 156 131
112 118 103 86 93 134 118 153 96 157 221 240 200 170 195 151 173 165 129 85
49 92 118 178 162 153 76 76 56 110 56 60 112 106 127

EXT-L19B 75
151 149 162 155 297 285 232 356 300 244 192 224 312 296 296 502 591 353 225 189
192 206 150 101 76 67 98 89 103 129 185 175 131 255 258 225 287 276 121 119
114 144 123 82 87 133 122 143 101 170 220 250 193 167 179 167 184 148 114 78
67 85 100 145 156 137 108 79 68 104 67 69 105 118 131

EXT-L20A 91
454 104 83 199 202 189 127 136 86 89 91 79 82 130 187 142 130 194 378 465
396 382 302 191 229 268 274 264 323 280 237 125 124 126 137 145 160 120 157 119
227 265 331 101 64 81 76 146 121 154 200 217 289 296 380 294 88 81 92 134
128 92 75 104 159 117 187 170 108 175 114 93 66 50 59 71 56 70 90 86
94 130 207 215 146 69 52 55 83 109 152

EXT-L20B 91
465 96 72 205 206 172 138 131 81 83 103 80 73 135 175 133 162 205 430 353
396 396 294 198 224 289 285 268 325 287 217 129 115 123 135 140 176 114 147 132
228 271 325 83 57 72 87 145 123 179 202 222 286 288 382 293 98 74 93 129
133 92 68 106 156 109 192 180 108 166 116 102 69 43 58 73 67 59 87 87
91 134 211 219 156 71 46 56 78 103 151

EXT-L21A 116
246 154 267 142 217 217 127 178 142 246 284 262 186 241 298 285 180 219 321 228
228 278 291 277 258 223 224 210 150 134 178 193 289 214 216 89 75 92 107 65
89 100 57 132 93 78 75 121 125 148 37 43 46 81 75 77 98 101 73 59
66 75 65 87 62 60 34 43 45 50 82 92 93 78 104 72 75 97 65 84
70 53 87 110 119 110 92 101 51 85 120 141 78 75 102 126 206 116 135 141
159 173 129 140 137 151 161 140 113 87 78 90 122 84 108 110

EXT-L21B 116
247 154 242 177 187 215 152 162 187 242 319 264 212 225 295 265 175 265 364 278

271 275 295 225 242 235 226 235 156 112 163 176 234 201 178 95 75 100 110 96
103 115 96 144 99 94 109 159 142 151 39 54 62 76 66 72 72 69 73 64
69 79 76 70 61 79 24 48 41 58 79 102 84 55 107 49 71 130 88 100
89 73 100 142 149 132 138 140 89 135 140 159 64 104 98 105 134 89 128 139
154 165 132 128 121 137 148 146 107 95 76 94 112 98 103 107

EXT-L22A 90
78 170 240 191 160 104 108 193 175 155 165 129 182 121 135 201 192 217 175 266
235 264 209 128 136 207 209 190 223 200 194 223 203 232 244 209 268 287 292 420
240 300 335 205 150 253 220 265 176 154 237 258 120 189 192 140 212 206 188 204
189 228 171 178 184 263 186 234 278 219 226 326 209 158 221 164 224 175 145 177
251 384 367 384 469 255 271 316 292 450

EXT-L22B 90
80 170 245 188 177 95 108 184 176 150 159 130 189 110 137 191 192 216 185 258
227 276 203 135 135 219 201 191 228 185 205 225 211 232 271 198 273 299 266 421
271 285 348 189 177 255 231 268 170 154 242 253 121 184 190 134 204 210 195 196
193 235 176 171 181 263 191 238 268 240 215 322 217 151 231 181 210 195 146 158
265 408 366 366 446 259 241 373 282 440

EXT-L23A 94
319 348 284 237 326 316 351 383 375 223 169 159 146 92 56 46 60 84 87 71
75 88 121 121 33 49 64 102 87 80 94 114 100 78 65 100 135 178 126 150
53 43 37 46 53 86 81 65 74 25 35 43 48 47 51 53 39 89 86 84
81 78 70 89 70 101 25 32 51 59 85 65 93 84 114 114 89 126 107 121
84 57 49 39 37 50 70 49 67 70 68 52 83 94

EXT-L23B 94
320 349 263 242 355 318 360 372 392 229 184 178 164 89 49 51 57 69 67 73
69 89 121 111 37 49 75 116 106 84 104 110 100 96 69 100 122 161 117 150
50 42 40 53 52 85 81 65 70 23 37 40 59 46 47 52 40 88 86 85
80 83 70 85 55 83 32 32 25 62 87 62 99 87 113 129 100 110 112 109
92 55 50 37 41 54 64 45 78 71 77 53 82 93

EXT-L24A 64
168 169 154 96 132 315 594 471 264 227 268 298 259 200 121 149 46 135 171 121
124 119 167 127 139 163 132 128 189 156 154 257 138 103 132 113 181 195 189 240
183 185 323 437 261 264 205 164 160 206 329 334 460 432 339 492 552 322 443 306
116 230 294 518

EXT-L24B 64
178 193 148 87 152 305 594 464 294 200 293 276 266 203 133 130 60 142 155 137
114 130 139 128 135 161 151 120 186 159 154 260 136 110 126 106 182 188 164 250
185 201 339 420 282 250 216 146 160 221 326 331 467 423 328 501 553 321 453 287
121 236 290 518

EXT-M02A 89
84 92 82 83 145 195 154 174 175 180 175 125 118 366 396 378 314 427 261 300
295 303 282 231 221 227 197 325 192 300 267 343 371 414 501 453 331 365 268 270
236 300 343 237 251 195 184 192 234 256 195 184 166 196 213 188 136 237 247 234
191 178 158 127 103 138 231 148 156 131 118 128 159 176 200 196 141 130 125 118
67 97 112 141 121 103 118 85 149

EXT-M02B 89
97 99 81 81 151 181 160 181 168 170 185 145 144 371 399 366 341 445 275 300
284 271 289 235 219 226 197 325 192 290 257 354 362 400 502 442 339 364 271 284
226 277 308 254 242 196 181 190 254 243 203 183 165 190 219 170 148 236 250 240
208 185 167 121 107 124 228 156 153 155 121 128 160 196 181 177 150 128 118 121
75 93 118 150 119 103 109 96 137

EXT-M04A 46
434 400 513 547 544 377 428 503 523 656 224 139 236 360 247 318 317 359 421 265
256 221 167 203 187 378 214 154 196 181 312 215 155 239 296 254 260 360 295 237
207 455 538 487 435 336

EXT-M04B 46
432 384 508 546 536 372 427 502 525 650 231 130 296 338 227 322 309 365 436 265
247 222 162 198 192 393 215 145 203 179 303 216 153 250 268 279 246 359 278 237
196 451 554 482 428 335

EXT-M07A 41
395 376 326 492 323 340 325 226 257 376 307 251 263 350 341 343 275 260 225 239
247 323 276 307 242 242 279 262 278 235 209 287 310 357 379 307 339 206 126 142
234

EXT-M07B 41
409 351 330 484 319 341 307 257 253 381 330 250 263 341 351 346 280 238 221 261
257 318 287 285 276 290 253 270 271 230 217 278 348 334 360 381 315 220 133 149
234

EXT-M09A 83
200 250 217 147 192 153 136 169 207 222 334 289 287 212 187 59 46 38 58 85
71 89 174 147 218 200 170 157 185 239 262 239 389 248 207 160 140 162 170 373
347 348 317 168 142 226 235 250 226 223 234 203 115 121 155 110 192 150 173 256
134 184 182 267 306 272 229 132 78 103 54 116 106 75 53 83 100 89 55 103
65 78 108

EXT-M09B 83
205 247 211 148 209 150 138 166 199 222 336 282 276 203 191 63 46 33 66 89
69 83 203 138 218 226 172 148 184 237 264 246 389 265 200 151 151 154 159 346
336 357 314 153 159 223 242 248 218 220 227 202 120 122 154 114 184 154 173 251
139 171 192 271 304 268 248 133 83 85 61 121 118 67 60 78 97 89 78 80
73 61 104

EXT-M10A 74
111 126 202 246 211 261 126 162 125 76 51 60 115 86 42 92 94 117 173 114
112 97 82 101 103 164 181 208 181 160 154 139 116 107 115 117 101 135 130 129
92 102 125 109 120 152 194 160 213 198 157 172 111 131 128 129 121 100 121 165
135 204 168 173 145 148 157 167 143 139 118 123 106 165

EXT-M10B 74
113 121 214 230 206 256 125 162 134 76 46 60 114 75 44 74 85 123 171 123
116 96 82 102 106 158 179 213 176 155 166 133 111 108 92 125 92 124 135 130
89 106 119 107 122 142 192 159 218 217 159 178 131 126 125 129 106 96 108 172
142 209 167 173 148 145 170 157 146 134 123 137 95 156

EXT-M15A 59
167 238 185 146 89 232 183 84 97 92 121 166 209 214 170 97 203 167 148 331
312 425 364 435 300 236 266 393 249 128 100 200 192 299 179 231 244 212 129 117
69 134 140 114 103 49 117 123 115 204 142 154 118 243 204 165 196 204 132

EXT-M15B 59
176 243 184 159 88 203 192 86 94 105 110 166 191 223 166 103 200 162 148 326
294 441 357 431 315 231 270 371 260 134 95 198 197 303 175 231 254 212 128 129
90 114 145 116 76 71 124 125 118 210 150 148 115 234 215 157 200 218 129

EXT-M16A 171
103 103 98 89 67 62 50 45 54 79 77 64 57 81 67 61 48 64 79 76
73 60 41 48 51 57 49 55 41 41 48 35 32 62 39 31 32 45 57 33
42 32 39 34 20 42 46 41 43 30 23 39 47 41 30 32 50 20 32 39
46 39 27 31 18 35 32 30 40 49 25 46 27 46 28 18 20 26 39 38
35 35 55 62 84 111 60 77 108 98 78 136 100 111 91 72 79 57 62 71
61 51 45 61 58 58 53 54 50 42 48 40 50 59 51 46 53 36 44 41
42 48 41 39 42 45 35 44 51 41 28 28 27 35 38 41 48 37 39 35
45 26 53 37 35 37 42 30 37 28 21 30 22 29 41 38 39 21 32 49
35 23 23 26 25 33 38 20 32 42 50

EXT-M16B 171
96 108 96 85 77 58 53 44 48 82 73 65 58 89 65 62 48 60 84 79
75 60 40 54 43 55 42 58 44 41 48 35 31 59 41 33 27 45 52 38
36 35 39 35 23 41 46 39 46 25 26 41 46 39 33 30 48 25 37 37
42 37 25 38 21 29 25 35 41 46 32 45 26 41 26 33 20 28 37 35
37 43 54 60 84 96 57 67 112 109 61 129 112 111 90 82 68 56 64 75
57 51 46 55 60 58 56 54 55 44 42 39 50 66 57 45 54 32 43 44
41 48 44 32 42 50 34 43 52 40 25 28 28 35 39 45 42 39 42 33
42 30 55 37 36 36 39 30 36 32 23 28 19 32 41 38 39 22 33 42
36 28 23 25 26 32 37 25 29 38 52

EXT-M17A 108
142 118 106 74 103 97 108 117 82 115 169 182 138 137 146 107 87 82 94 107
92 78 58 83 75 132 106 96 85 143 117 77 75 80 89 110 74 93 96 75
142 69 78 89 85 71 90 113 139 122 85 51 53 55 39 85 145 191 157 60
53 105 71 107 72 59 98 78 46 114 187 151 90 64 48 99 75 83 102 114
97 138 130 171 117 112 48 120 78 46 63 71 67 126 106 148 51 54 126 126
77 192 212 292 192 179 202 237

EXT-M17B 108
136 114 105 77 96 100 112 117 85 115 171 177 140 138 135 91 95 83 91 102
98 85 60 94 72 134 112 91 91 141 104 77 75 83 90 103 71 89 101 70
132 67 67 94 81 66 92 115 128 138 96 47 55 59 34 81 136 202 162 63
51 102 76 104 73 66 100 80 50 103 187 148 92 67 39 100 76 85 105 103
104 134 143 162 121 114 45 118 83 50 54 75 74 115 109 135 56 62 126 128
95 168 216 287 207 166 204 234

EXT-M18A 91
198 248 229 188 151 125 127 133 197 173 189 145 204 135 198 144 139 148 203 152
108 99 103 118 124 82 111 79 77 132 87 91 131 160 96 85 117 203 147 135
109 103 117 76 114 135 168 233 99 104 139 150 164 98 109 145 114 82 95 153
126 103 76 48 85 79 112 112 106 120 146 139 183 256 307 110 75 144 175 97

121 157 212 253 293 121 87 159 153 171 234

EXT-M18B 91
205 246 227 200 149 117 128 125 203 169 164 162 210 148 200 147 145 151 206 158
104 107 96 119 126 82 111 81 71 132 85 90 137 168 89 85 118 195 160 111
92 108 111 72 110 140 165 234 104 98 143 139 168 102 103 146 101 92 90 159
129 107 77 51 75 87 101 110 120 126 139 132 221 268 292 100 76 149 172 100
123 165 208 251 287 117 90 158 159 188 242

EXT-M19A 120
102 67 97 58 114 78 82 110 97 94 94 112 145 79 92 63 66 72 37 81
75 87 108 41 65 71 91 87 78 53 91 48 42 63 75 64 50 48 34 45
38 44 57 57 53 67 40 52 53 46 42 56 41 41 42 49 72 97 94 142
69 49 106 95 82 170 118 138 153 150 114 86 100 87 67 42 50 63 72 71
48 85 87 71 41 54 37 62 91 59 34 37 49 40 50 59 64 49 62 85
45 74 96 67 37 31 25 37 42 48 39 45 54 48 54 57 56 62 53 50

EXT-M19B 120
96 55 99 62 117 75 77 121 96 95 87 116 149 75 84 66 58 73 33 82
76 80 117 46 64 71 82 89 76 62 80 55 44 67 77 64 50 50 36 51
35 46 46 64 46 57 46 64 52 54 35 57 46 40 51 58 69 98 94 139
75 39 103 97 83 161 107 155 152 163 114 97 100 88 70 41 46 69 70 62
57 78 75 65 42 53 42 62 90 59 34 38 53 39 43 65 58 58 50 81
57 77 96 67 36 35 29 32 42 43 40 53 56 53 45 50 54 67 49 50

EXT-M20A 149
171 180 156 188 124 167 155 162 120 121 110 88 64 91 88 166 101 87 71 86
91 91 76 76 102 100 99 83 67 78 64 72 63 62 60 57 89 66 65 128
88 71 93 121 125 72 76 58 66 75 46 62 102 86 81 57 58 81 85 111
60 67 114 67 64 60 92 71 56 43 31 51 40 45 57 56 40 66 44 55
54 51 42 71 56 43 34 34 32 47 49 76 40 61 107 93 79 129 76 90
59 68 68 61 90 84 69 46 56 78 66 69 52 47 43 34 46 45 43 51
65 46 55 44 54 56 52 54 53 56 37 53 45 53 64 40 37 34 26 23
30 32 39 42 44 17 46 42 49

EXT-M20B 149
173 181 157 188 126 175 155 150 130 118 108 87 69 85 89 164 108 91 66 82
91 99 77 70 102 103 96 83 67 78 69 72 63 71 64 60 87 63 67 147
96 67 96 115 125 75 78 54 67 75 48 62 103 84 79 57 60 82 86 110
63 63 117 64 66 54 95 69 53 45 33 49 43 43 59 53 42 62 43 54
60 53 35 70 57 43 37 35 35 43 50 75 43 56 108 95 75 135 76 84
71 60 65 62 96 77 65 54 48 85 60 73 48 48 45 40 45 43 45 54
64 46 53 46 48 59 56 56 50 50 42 53 46 49 66 51 39 34 21 28
30 30 38 42 51 26 42 41 53

EXT-M21A 146
56 77 71 54 62 42 55 48 53 75 64 54 59 28 42 42 65 55 37 33
30 53 57 39 42 64 67 54 38 37 35 34 39 46 35 51 35 46 37 40
53 44 39 46 58 76 30 41 28 46 31 22 34 44 51 65 28 28 41 52
49 51 51 71 35 31 26 41 53 52 50 35 57 34 34 37 58 63 79 67
57 53 66 37 73 51 45 46 56 81 105 112 107 59 37 83 76 73 143 109
139 140 121 120 98 103 120 96 56 64 79 101 93 67 106 123 81 60 53 46
92 115 82 62 53 85 70 68 65 73 53 59 63 73 62 44 42 46 39 45

32 48 37 24 36 35

EXT-M21B 146
57 77 67 62 60 39 55 54 49 75 71 50 50 37 48 37 62 56 31 37
36 46 56 41 45 59 69 53 38 34 36 35 35 44 42 44 37 44 33 41
54 47 37 50 55 75 32 44 33 44 39 19 36 48 51 62 28 32 41 48
53 55 49 73 33 35 23 41 50 54 50 37 56 39 28 36 58 64 78 67
54 52 67 39 67 48 57 40 61 67 100 111 109 53 39 89 69 71 143 107
142 129 131 117 96 110 117 103 57 60 86 95 90 79 109 93 79 56 58 46
83 124 76 60 62 90 57 71 59 78 48 57 61 62 73 48 40 39 26 48
29 51 37 29 34 32

EXT-M22A 70
161 166 112 104 138 158 169 146 168 201 145 106 119 148 155 122 75 53 71 60
66 67 74 91 107 75 89 71 65 85 83 96 60 69 55 83 98 89 81 91
56 74 96 78 89 78 104 69 64 56 89 50 46 71 65 71 64 91 70 54
215 278 96 75 200 184 165 154 169 122

EXT-M22B 70
163 159 110 117 140 149 168 155 168 193 147 108 123 148 153 125 73 53 58 73
69 62 73 92 105 69 90 72 63 87 76 98 57 74 50 85 95 92 77 96
57 69 98 82 89 76 105 72 61 71 80 50 49 71 57 65 70 89 75 60
210 272 96 86 193 191 171 150 168 120

EXT-M23A 118
116 89 97 100 97 65 104 128 154 231 125 89 114 158 180 110 200 228 121 128
126 126 128 117 96 73 121 94 121 123 164 112 124 150 135 120 101 64 87 92
66 55 85 99 60 67 82 70 63 93 56 58 91 63 64 51 47 60 57 78
60 53 52 40 70 60 62 53 72 85 54 56 55 56 56 73 39 32 51 59
53 62 59 50 45 28 42 46 43 46 40 48 35 50 36 38 66 43 43 61
46 51 48 71 53 48 57 32 54 50 53 46 70 65 62 95 66 90

EXT-M23B 118
114 87 97 97 98 71 104 124 152 227 117 84 128 160 181 106 200 225 120 125
124 143 122 143 93 66 104 109 119 113 164 117 130 142 161 121 92 72 101 92
67 72 83 100 70 64 78 67 67 99 72 49 92 65 60 51 46 59 58 78
60 58 50 40 67 60 63 54 67 82 50 62 50 50 57 64 51 37 35 51
56 53 70 54 44 38 48 40 49 45 43 40 40 42 37 50 57 46 37 62
40 59 48 67 53 51 53 36 52 47 54 51 71 64 63 88 61 91

EXT-M24A 130
101 85 126 112 148 97 111 94 109 108 99 63 70 65 71 69 61 49 50 71
44 53 48 48 57 96 69 69 80 78 69 73 94 96 58 73 42 64 64 49
50 56 28 55 29 35 31 33 27 25 19 38 31 29 29 36 31 29 25 25
32 31 30 28 39 37 35 38 42 36 35 25 36 28 26 35 33 43 32 51
29 33 30 30 44 25 37 38 61 81 64 100 114 156 150 133 144 98 106 115
128 112 116 143 117 114 129 175 148 98 37 34 29 51 50 43 53 48 50 53
71 51 30 48 39 37 23 29 28 39

EXT-M24B 130
102 87 123 115 147 98 113 89 108 110 96 58 72 68 73 66 61 53 51 73
42 48 49 48 59 94 64 71 80 78 69 78 92 94 50 76 51 60 65 42
50 50 37 50 28 35 32 31 23 27 36 41 23 24 29 40 37 33 26 28

27 32 32 29 42 28 39 39 39 37 35 26 37 25 29 34 39 39 33 49
36 34 35 28 28 29 38 45 54 78 67 104 117 153 151 138 143 100 114 117
131 111 121 140 122 110 124 171 142 100 46 36 27 44 50 52 57 50 53 35
70 53 26 45 34 37 21 34 29 43

EXT-M25A 94
179 136 85 92 118 113 173 100 101 83 96 159 131 81 176 159 102 97 88 91
94 103 120 85 62 75 105 82 91 80 123 109 86 94 97 85 115 113 114 42
42 82 85 92 132 114 114 57 127 126 86 94 86 98 52 46 60 64 71 67
65 73 57 65 102 91 92 56 51 52 51 40 68 54 65 60 42 67 68 51
57 53 107 71 92 79 93 75 57 85 106 78 84 106

EXT-M25B 94
181 141 89 96 118 112 163 100 107 81 92 159 134 80 182 160 103 98 96 112
91 104 113 85 66 71 102 83 86 79 119 114 83 89 101 88 111 122 111 43
45 81 96 100 125 121 110 56 128 110 86 94 87 97 57 51 66 60 64 64
67 64 61 77 82 92 95 62 48 54 56 37 68 53 67 65 42 56 51 64
53 57 110 78 82 80 89 76 62 85 99 82 86 108

EXT-M26A 114
326 338 218 114 221 341 387 362 208 204 175 117 242 243 231 282 242 326 163 181
241 257 263 223 150 96 107 145 129 271 250 248 173 112 92 89 77 136 185 252
140 118 96 74 92 115 182 189 164 114 64 68 62 91 120 175 175 207 167 85
87 131 119 183 118 87 249 184 176 115 95 93 70 98 127 210 106 103 195 84
102 78 62 87 82 79 84 84 68 103 147 175 162 101 103 105 94 132 117 110
100 136 58 56 53 91 106 106 130 100 118 150 138 254

EXT-M26B 114
321 342 197 125 227 370 384 364 205 210 171 107 160 245 225 275 242 332 154 187
240 255 268 225 145 96 110 139 136 262 275 236 169 114 88 91 85 135 188 248
143 129 101 87 92 128 214 157 171 120 68 51 62 81 107 169 196 195 159 96
71 137 126 174 126 89 245 182 175 101 90 100 73 95 125 215 113 112 207 93
105 80 70 90 74 75 81 84 87 98 159 165 156 100 112 107 93 139 106 131
96 128 53 59 43 85 112 121 131 88 119 155 142 264

EXT-M27A 81
347 207 227 153 134 220 173 244 232 119 97 96 110 117 109 91 103 93 93 122
112 160 179 232 171 189 125 138 113 104 145 151 160 114 98 92 52 97 92 97
111 94 71 63 115 109 156 182 131 121 106 67 68 153 140 114 160 153 190 162
90 93 140 120 226 182 101 215 181 143 135 78 111 126 132 155 245 131 98 116
162

EXT-M27B 81
343 211 224 200 161 245 202 192 186 118 107 96 114 126 110 96 101 87 91 133
131 176 194 228 175 152 115 139 113 103 147 147 187 112 97 93 65 94 86 101
110 97 77 61 101 110 166 184 125 117 99 70 62 153 137 115 173 155 193 150
104 107 134 115 230 157 98 212 173 150 143 81 131 121 110 158 257 135 81 107
156

EXT-M28A 73
372 267 345 336 266 415 197 217 185 210 226 160 240 237 200 292 197 195 200 146
168 171 166 225 198 141 185 203 187 181 165 220 220 126 274 218 150 285 260 314
303 301 376 278 252 288 151 123 134 190 162 192 120 145 148 189 142 225 206 180

190 63 31 29 48 71 37 50 74 69 130 106 170

EXT-M28B 73
378 268 337 348 270 420 198 196 210 243 230 152 242 236 203 291 198 196 200 142
182 157 180 219 202 140 198 210 190 190 167 201 226 132 261 207 160 263 306 343
312 301 371 295 269 264 154 121 137 188 186 168 116 145 153 189 139 240 193 178
184 65 35 28 46 72 54 51 76 69 125 109 171

EXT-M29A 92
384 407 307 326 305 350 296 489 301 360 358 253 407 220 300 203 187 140 138 178
214 196 264 149 132 142 110 71 78 104 106 96 86 129 154 171 132 114 153 134
100 154 152 107 228 159 204 191 282 220 125 178 176 127 104 90 145 165 148 79
82 118 145 143 153 132 175 148 105 71 65 65 106 85 98 134 100 147 121 139
118 170 144 120 146 107 114 184 134 161 188 146

EXT-M29B 92
371 402 318 326 297 359 303 494 291 359 362 258 400 217 290 203 178 171 128 185
215 166 304 143 136 148 104 82 76 98 98 96 84 117 160 176 135 117 143 142
100 167 160 101 225 169 213 184 284 220 129 178 177 137 100 90 139 180 125 88
89 120 147 143 147 134 174 141 108 81 57 68 102 79 95 135 97 146 121 136
125 175 125 122 161 103 115 189 140 159 206 147

EXT-M30A 90
69 74 245 170 72 61 103 79 50 75 104 237 215 218 466 258 471 249 268 241
171 161 234 314 283 269 148 170 203 228 237 257 434 320 280 300 306 326 253 171
210 245 162 193 126 120 198 229 235 237 195 235 289 396 360 348 171 168 214 425
625 467 156 134 114 155 146 143 115 71 167 159 98 53 46 48 51 106 68 198
195 207 193 172 154 112 107 86 91 131

EXT-M30B 90
68 75 247 176 77 58 91 79 42 84 110 223 217 220 477 251 466 246 260 246
187 155 232 326 282 270 148 174 192 230 230 242 443 326 298 309 297 297 251 160
228 245 144 179 114 114 192 208 237 262 170 214 304 402 364 339 165 170 228 433
609 468 157 118 131 150 136 159 115 75 165 157 100 50 52 46 53 104 75 190
202 206 184 178 137 114 103 103 92 128

EXT-M32A 53
407 351 341 383 194 196 225 275 241 260 187 279 303 260 303 250 158 198 160 233
215 248 271 190 169 226 203 139 162 131 123 107 103 100 90 137 175 229 150 128
139 192 176 110 201 145 182 167 114 122 109 128 184

EXT-M32B 53
417 370 334 369 192 189 215 280 229 236 195 309 302 257 285 238 164 164 158 235
227 239 264 205 186 224 202 129 171 142 112 109 110 85 73 120 171 226 159 129
142 188 178 125 198 159 171 178 97 122 112 121 179

EXT-M33A 63
153 240 190 254 328 313 355 337 267 207 300 350 247 425 399 268 349 360 597 512
714 379 467 446 337 489 368 367 518 493 432 287 397 443 280 170 236 276 169 185
178 186 180 115 198 283 159 246 203 131 270 212 215 156 134 128 134 168 153 200
168 117 231

EXT-M33B 63

167 237 188 256 317 309 351 346 251 208 298 319 246 442 401 232 357 372 601 511
717 407 473 459 400 516 379 376 523 467 421 309 382 448 247 167 260 260 165 195
208 215 194 126 225 262 157 238 201 140 262 187 214 159 131 131 138 167 160 239
131 129 234

EXT-M34A 81
317 333 272 518 492 432 364 251 141 104 155 224 512 467 403 361 245 285 319 281
282 284 265 184 107 173 228 261 232 335 278 275 243 128 125 265 176 251 189 150
259 210 201 129 78 131 117 120 106 170 134 93 134 107 108 141 115 115 120 128
134 136 121 156 187 240 206 152 153 218 150 193 155 165 168 163 90 128 130 173
274

EXT-M34B 81
317 336 272 501 462 426 348 253 153 100 165 232 521 517 432 350 254 285 314 274
331 316 267 198 110 156 229 274 215 334 285 276 245 123 132 268 160 270 206 147
255 225 196 118 83 132 128 114 109 170 154 95 145 106 110 134 107 110 113 159
110 131 121 159 181 234 212 140 163 210 145 169 156 178 155 176 85 154 130 173
276

EXT-M35A 54
199 234 151 185 211 301 300 303 410 326 284 145 174 222 314 195 300 286 153 245
308 284 369 284 132 65 62 65 117 243 217 251 227 382 247 264 274 192 244 297
267 218 274 225 209 195 203 185 304 214 248 179 260 254

EXT-M35B 54
210 234 145 180 210 276 309 299 421 323 292 150 176 223 314 194 312 268 158 246
307 280 385 270 147 74 60 61 118 232 232 245 225 379 250 265 289 203 246 295
259 209 291 235 206 189 189 210 307 214 234 192 254 259

EXT-M36A 70
284 192 366 235 281 187 171 164 153 85 44 62 64 57 51 67 74 50 89 71
53 85 76 60 62 57 80 62 92 110 203 83 115 157 92 134 68 67 51 86
86 92 76 73 54 48 72 74 99 132 103 118 231 151 239 164 107 70 103 93
87 101 67 70 90 102 108 110 98 138

EXT-M36B 70
283 187 363 224 293 186 163 166 173 82 55 62 60 62 53 65 92 44 84 72
57 78 76 58 57 58 81 64 82 111 205 88 108 147 100 141 78 60 46 94
91 102 74 70 58 51 69 70 93 132 94 110 236 136 243 157 100 69 135 73
90 110 58 64 95 101 100 116 114 139

EXT-M38A 58
138 157 217 199 169 207 202 176 169 153 135 166 123 159 160 184 137 144 145 142
150 141 157 121 89 161 128 132 117 142 147 134 125 119 134 180 157 144 117 118
96 110 135 122 150 187 131 179 179 141 124 145 153 179 140 162 133 199

EXT-M38B 58
126 143 214 204 177 226 213 173 172 132 142 157 108 155 149 182 128 151 148 141
161 131 156 117 93 153 130 134 120 132 142 135 137 116 136 173 152 142 107 115
110 105 128 108 174 195 117 189 184 145 120 145 146 190 156 160 126 209

EXT-M39A 61
202 215 233 197 225 215 175 183 175 113 136 197 192 198 196 173 215 150 128 125

240 265 118 175 89 143 92 75 86 82 92 110 101 128 144 122 127 108 102 112
97 84 106 118 107 145 148 153 157 112 104 120 104 96 150 134 106 82 89 121
132

EXT-M39B 61
189 218 222 198 231 228 171 186 171 103 126 189 171 217 236 180 210 153 123 122
243 268 121 174 87 142 92 79 88 82 91 108 100 137 136 142 114 125 85 112
92 81 101 125 115 134 153 157 154 104 123 109 128 114 132 120 103 82 92 120
139

EXT-M40A 60
139 204 202 155 141 117 94 72 70 92 104 100 93 90 99 170 110 110 86 125
126 98 178 134 150 114 96 174 136 157 153 139 228 174 126 110 118 135 163 126
84 100 150 125 131 109 169 150 81 141 79 86 73 95 76 70 87 89 106 115

EXT-M40B 60
147 204 153 137 166 130 83 83 66 92 105 95 120 112 112 144 105 103 97 123
125 98 167 137 159 114 97 167 136 160 143 126 227 176 129 96 131 134 153 126
86 102 146 119 128 123 167 157 75 140 96 83 82 84 68 78 92 88 95 115

EXT-M41A 56
404 419 492 417 359 291 236 144 146 154 163 240 184 149 185 184 252 189 210 202
201 142 179 148 151 188 210 190 107 118 101 106 168 138 113 112 85 117 139 176
127 97 118 114 128 118 146 150 159 177 147 194 202 202 165 198

EXT-M41B 56
409 408 510 401 364 294 241 164 151 143 168 239 164 139 182 185 254 179 226 203
199 139 168 174 157 196 175 179 115 97 106 121 146 154 128 106 90 109 139 178
121 104 121 109 130 126 139 147 165 172 152 209 201 199 169 196

EXT-M42A 91
290 399 438 462 326 348 387 318 204 275 255 307 288 243 213 200 150 199 146 135
194 180 166 117 112 128 181 148 125 107 112 84 76 106 114 100 138 184 134 114
87 60 76 90 82 81 71 73 81 145 96 90 69 87 98 68 82 123 89 132
96 112 120 143 140 118 123 118 121 142 153 150 93 115 139 109 139 120 172 263
170 142 144 142 120 93 94 95 106 106 118

EXT-M42B 91
300 402 436 456 321 353 398 304 214 267 253 307 285 240 214 196 157 189 152 131
189 183 164 120 110 132 184 142 139 99 109 87 65 109 112 107 139 168 149 117
78 65 86 98 79 85 67 75 81 109 95 84 65 93 95 68 79 118 96 125
101 103 117 157 143 123 119 128 124 153 142 149 77 108 133 100 125 135 180 264
167 160 140 147 115 95 86 94 102 108 120

EXT-M43A 72
417 451 377 343 244 244 378 276 300 205 253 242 303 202 268 210 285 203 114 182
173 182 137 94 88 72 150 177 129 90 177 197 143 134 110 79 90 87 127 144
118 121 176 164 149 135 157 160 210 307 153 126 140 110 92 61 104 140 137 192
129 75 105 137 239 275 209 192 187 274 306 296

EXT-M43B 72
420 466 369 335 254 246 368 271 286 212 290 217 303 188 265 192 302 203 127 176
182 191 142 91 89 82 172 154 123 104 181 190 135 120 103 74 87 85 139 146

126 121 176 162 150 135 149 175 206 296 146 138 132 112 90 71 95 139 140 177
139 73 100 142 234 290 215 189 198 248 296 305

EXT-M44A 87
105 86 71 59 52 155 175 121 105 128 109 129 117 83 71 85 96 138 134 137
107 162 185 162 137 117 116 117 153 128 132 142 122 108 89 91 108 101 170 113
63 92 134 170 164 233 134 142 156 160 135 133 109 114 104 126 110 100 88 78
65 75 98 83 117 112 168 173 101 78 101 92 104 106 157 82 104 140 114 104
83 85 112 87 106 107 129

EXT-M44B 87
104 82 70 64 46 159 178 121 108 125 106 126 125 83 74 81 91 133 135 139
110 166 173 160 137 118 108 130 155 123 127 146 122 108 84 94 116 113 135 107
69 90 129 174 164 236 122 137 150 146 132 135 113 114 104 129 101 95 82 70
71 75 95 84 93 126 159 165 100 81 103 93 109 98 169 79 109 131 115 92
89 79 131 92 103 104 130

EXT-M45A 114
450 440 283 343 369 282 228 75 150 131 132 174 150 135 143 145 163 186 189 332
221 142 121 129 213 192 215 214 174 143 268 121 232 173 196 257 196 211 200 300
228 137 178 173 148 165 112 145 207 163 146 178 189 125 31 29 26 39 32 28
37 31 31 34 37 37 30 28 53 51 38 54 45 34 20 65 100 62 42 45
39 32 46 69 63 79 65 67 38 33 29 23 24 21 28 31 48 40 10 25
31 28 45 35 29 32 31 24 21 13 18 25 21 28

EXT-M45B 114
458 442 308 368 400 293 235 77 143 124 150 171 144 129 147 148 158 177 195 327
235 139 128 124 221 182 213 222 171 140 281 120 242 164 196 257 196 198 198 306
206 145 174 190 145 195 93 152 202 153 134 187 191 120 35 34 28 39 30 32
29 28 30 34 35 40 23 21 60 48 45 56 42 34 29 64 98 57 37 49
35 39 43 57 70 76 68 68 40 25 28 25 28 24 25 34 45 35 14 29
29 26 45 29 35 32 33 23 21 15 18 27 21 27

EXT-M46A 58
127 96 97 57 88 85 70 44 33 46 80 81 98 114 137 118 112 93 94 92
83 91 86 90 94 108 78 75 76 67 51 61 99 116 98 103 105 103 82 95
97 100 94 96 95 86 101 102 124 85 75 75 99 75 56 85 89 87

EXT-M46B 58
143 93 100 62 85 82 72 41 39 43 80 78 94 110 133 127 113 107 96 93
87 96 83 101 102 108 80 67 80 62 58 57 96 107 102 114 111 113 72 98
89 114 102 98 103 79 90 121 114 94 74 79 90 71 64 94 73 93

EXT-M47A 140
72 92 117 176 97 106 150 122 158 133 198 90 83 62 100 194 197 192 175 210
247 217 238 158 167 149 144 181 175 121 117 126 85 117 128 117 107 135 146 121
127 96 97 78 96 89 85 84 71 54 57 62 53 73 89 67 70 78 93 84
63 70 90 96 99 82 87 78 64 53 62 81 106 76 57 56 73 53 65 92
60 82 93 96 91 100 83 83 80 77 79 81 86 97 95 105 86 67 72 98
75 88 98 72 101 75 89 79 88 89 68 71 78 76 78 67 110 83 78 77
81 90 84 58 57 46 55 53 68 64 57 63 60 60 79 67 43 72 61 111

EXT-M47B 140

90 91 122 176 89 110 140 114 155 135 204 85 88 67 92 176 186 204 171 213
242 228 234 155 151 150 128 198 171 123 114 125 85 110 142 104 108 142 125 125
125 96 102 83 92 85 89 85 71 52 61 59 62 67 76 75 71 71 89 82
71 76 85 96 94 92 75 72 64 46 71 73 102 72 66 56 70 54 59 96
65 87 93 96 93 92 85 82 76 70 89 77 84 96 99 101 84 70 73 98
75 84 95 79 95 81 93 79 85 82 71 70 79 71 82 82 101 79 83 77
79 95 77 58 58 47 46 50 74 69 58 56 59 63 78 70 44 64 57 100

EXT-M48A 43
128 82 106 60 63 276 200 199 225 348 350 306 305 282 401 257 367 296 369 524
325 328 360 355 252 293 407 298 250 265 284 246 309 231 207 227 292 268 272 272
329 432 543

EXT-M48B 43
115 92 100 67 56 279 203 188 239 340 344 300 312 284 401 259 366 325 370 521
325 325 364 350 256 293 431 273 239 260 287 246 301 228 210 224 289 246 270 270
334 439 500

EXT-M49A 40
246 238 297 193 170 201 229 195 167 237 210 196 166 141 228 162 282 140 187 160
146 178 155 133 92 86 96 121 171 416 321 319 346 354 258 311 231 357 137 198

EXT-M49B 40
263 242 292 188 174 202 225 236 171 228 196 204 164 146 215 178 228 130 175 168
150 179 153 142 78 93 100 135 167 405 319 326 342 341 269 300 240 356 149 211

EXT-M51A 75
192 149 209 170 165 182 200 187 264 119 103 141 201 257 301 318 266 231 272 139
125 139 169 157 182 193 176 211 333 185 162 259 146 157 170 220 221 132 120 170
200 135 91 131 183 123 229 148 101 116 126 146 121 175 176 112 126 120 129 103
96 172 244 456 290 344 225 303 271 339 390 309 256 212 125

EXT-M51B 75
172 150 215 175 156 180 203 190 252 116 102 150 199 255 301 321 257 238 282 133
124 124 175 153 175 194 182 202 341 171 182 221 155 155 167 210 218 118 120 161
177 137 85 156 207 131 228 160 100 124 120 134 123 164 190 103 114 122 124 98
100 171 232 467 289 308 218 292 282 359 403 294 273 191 124

EXT-M52A 57
254 217 250 201 279 199 114 150 235 147 138 173 220 163 234 189 171 199 231 147
125 160 212 173 173 204 237 194 132 132 140 168 163 157 142 135 140 171 170 154
223 177 162 145 108 132 189 194 206 193 120 135 151 115 128 217 221

EXT-M52B 57
247 211 259 205 273 192 111 148 230 160 142 166 221 157 234 181 168 203 235 153
135 169 203 157 181 200 223 202 122 128 135 164 145 167 142 138 126 176 167 153
226 172 163 142 102 122 188 200 203 168 123 132 153 112 139 205 227

EXT-M54A 65
166 157 190 213 216 217 145 176 160 171 173 210 130 128 157 194 164 218 153 182
215 185 161 156 183 184 100 154 137 150 143 120 139 146 139 171 120 125 103 161
204 160 126 171 140 135 111 132 151 149 104 93 120 106 115 89 157 148 158 198
198 156 193 150 182

EXT-M54B 65
144 164 196 220 209 219 153 182 157 178 164 217 121 114 159 203 155 207 170 161
227 192 157 157 184 194 116 157 135 155 142 122 148 137 155 158 119 127 112 154
208 166 142 160 140 142 109 126 159 142 98 87 124 108 120 98 148 150 173 178
210 164 189 156 181

EXT-M55A 92
213 418 519 514 287 349 241 205 455 459 384 253 177 158 242 355 198 187 314 175
123 229 367 253 165 264 246 182 217 209 248 276 246 209 220 274 298 235 132 117
170 115 187 159 178 223 220 271 166 101 131 114 131 134 201 155 156 230 150 195
179 165 126 151 107 95 64 78 100 135 84 134 97 101 96 72 87 71 78 81
70 47 46 78 87 70 87 108 119 149 131 116

EXT-M55B 92
233 399 517 497 273 344 255 227 448 475 377 253 178 149 252 350 200 184 307 186
130 221 362 265 170 263 242 178 201 203 264 266 231 217 240 262 295 223 138 112
157 118 189 179 165 240 211 276 168 101 129 114 123 135 206 143 166 237 152 198
181 196 118 162 113 86 69 75 100 131 90 129 106 103 92 65 85 88 80 71
73 53 41 69 84 59 103 109 112 143 112 117

EXT-M56A 104
126 155 177 167 136 132 117 130 80 106 90 99 94 150 169 178 180 216 180 183
182 206 128 161 114 139 196 193 192 121 135 193 161 107 103 187 141 166 215 150
181 111 164 112 167 159 120 162 150 193 210 210 245 220 228 171 145 162 165 170
186 170 126 175 182 168 134 137 137 160 167 156 134 148 155 196 139 140 192 159
134 137 152 153 190 204 217 175 177 176 191 162 195 239 177 168 184 212 210 265
186 159 221 221

EXT-M56B 104
131 152 179 179 150 146 126 119 66 98 97 92 86 156 151 187 184 217 167 192
167 198 121 166 121 121 208 183 197 117 135 193 162 109 101 192 142 152 233 142
182 109 164 108 162 171 110 152 153 206 212 214 243 220 229 176 134 153 175 175
185 170 138 169 175 153 145 139 132 157 182 162 145 157 164 198 126 153 177 158
129 144 150 156 201 198 218 181 168 188 185 158 190 237 181 168 177 215 200 269
196 150 240 218

EXT-M57A 100
172 140 211 134 206 196 114 189 184 212 140 148 219 272 255 194 159 195 198 246
135 114 103 164 164 214 194 168 122 163 178 157 136 173 154 166 145 150 152 145
148 150 183 164 162 181 173 149 129 173 158 196 162 160 167 160 135 135 154 189
174 139 145 126 168 226 184 173 212 185 162 143 125 92 173 117 155 150 213 131
143 160 136 189 187 146 143 159 225 107 187 82 67 95 87 106 88 101 58 114

EXT-M57B 100
168 136 217 124 204 201 105 193 185 216 139 153 210 282 256 198 159 198 193 252
139 117 100 162 163 215 203 156 117 148 189 152 131 172 155 171 153 140 154 155
134 153 196 151 164 173 167 148 132 175 156 182 160 178 176 150 137 129 148 180
179 136 150 134 168 240 178 167 201 184 180 139 109 101 156 134 153 134 205 159
152 158 124 181 191 141 151 153 231 126 188 78 74 87 90 105 94 75 56 72

EXT-M58A 113
132 157 165 130 139 140 159 119 175 211 187 196 160 105 125 198 161 136 138 192

251 202 178 242 201 212 153 139 143 142 162 147 148 127 157 170 176 141 95 139
173 143 98 129 117 90 125 109 175 233 157 131 121 203 239 257 203 188 225 204
175 143 109 127 184 104 160 170 207 178 221 121 139 195 153 131 157 134 137 121
137 144 150 140 100 178 150 171 161 128 100 89 96 149 159 121 165 128 89 72
89 96 86 82 65 84 104 86 109 90 68 87 150

EXT-M58B 113
133 165 165 130 130 147 155 115 178 209 193 191 148 104 123 199 159 138 140 198
239 200 178 239 202 201 152 130 146 135 167 149 154 117 159 157 162 135 96 142
162 148 98 130 125 90 123 117 174 235 166 125 122 201 235 253 206 200 218 198
171 143 106 125 178 93 168 162 218 148 220 132 140 182 174 137 154 129 150 122
125 138 156 142 111 167 140 175 160 125 95 93 88 150 158 122 177 110 78 73
79 91 76 86 65 84 117 83 121 83 75 78 171

EXT-M59A 55
178 272 166 100 96 163 134 136 119 180 114 159 114 101 191 170 159 154 180 147
105 94 125 137 148 98 101 169 130 162 128 128 117 139 163 132 164 158 129 86
87 78 82 96 106 105 102 68 66 65 51 58 96 131 149

EXT-M59B 55
183 276 174 108 90 158 134 128 123 181 121 157 108 105 189 183 134 144 186 151
89 96 124 137 151 86 111 184 94 165 132 115 117 139 161 133 158 145 125 139
75 60 77 109 104 92 92 75 75 59 43 62 95 131 128

EXT-M60A 87
167 186 136 99 209 227 268 185 216 232 198 189 171 142 159 184 108 160 199 250
127 228 139 141 187 175 142 262 146 197 153 109 165 136 106 92 153 138 167 197
137 100 90 104 182 128 140 150 113 87 79 80 97 71 96 73 159 98 103 77
67 82 170 146 167 107 156 87 92 148 162 139 170 142 248 207 234 206 210 301
196 117 279 292 204 201 282

EXT-M60B 87
145 165 144 89 219 218 254 207 220 228 188 190 171 150 160 181 112 162 190 252
153 223 141 138 194 175 134 261 162 205 132 112 160 133 106 103 149 134 168 196
142 95 92 106 185 128 135 148 128 74 70 78 98 77 85 78 171 86 96 85
69 83 154 146 178 114 134 84 92 150 150 153 167 157 235 195 254 192 202 303
179 120 285 278 221 209 272

EXT-M61A 132
154 177 117 110 111 121 162 112 143 136 96 126 166 142 173 137 144 126 96 126
110 98 107 116 119 139 89 87 107 86 98 125 85 85 80 125 94 96 76 114
103 100 132 78 85 82 65 106 96 85 97 112 110 111 114 95 115 118 137 131
120 165 140 165 126 73 62 93 92 82 95 128 86 96 101 85 95 101 89 90
90 87 84 81 103 108 95 79 75 79 81 94 78 68 65 84 89 90 85 157
104 79 85 63 70 79 85 87 85 84 64 67 67 90 137 107 120 170 154 85
111 146 171 135 103 91 78 100 203 158 147 161

EXT-M61B 132
141 185 127 121 108 126 134 145 124 150 93 142 153 145 167 155 128 125 110 128
112 91 100 112 122 139 88 82 103 92 103 132 95 82 73 134 108 87 78 96
95 103 138 76 84 79 67 110 92 96 97 103 110 123 114 96 117 129 135 128
112 175 148 168 112 73 89 95 90 106 85 112 84 98 98 90 96 104 92 76
85 101 92 81 106 104 89 71 79 90 87 97 71 67 73 87 97 82 90 145

104 81 78 64 78 79 80 84 84 85 67 70 68 84 143 125 106 179 153 82
104 138 179 146 96 87 74 101 193 168 131 184

EXT-M62A 89
176 120 146 216 201 124 172 117 144 104 108 137 178 117 139 155 141 232 144 151
159 137 190 136 125 115 210 146 156 160 191 115 243 145 147 173 201 172 114 150
145 96 120 117 154 139 174 190 178 187 229 153 132 167 148 176 123 126 129 153
126 95 78 103 105 165 109 143 89 103 106 93 140 217 196 208 145 164 101 193
137 145 126 87 150 174 156 206 215

EXT-M62B 89
159 111 149 221 201 126 170 119 129 108 100 146 171 119 139 164 132 245 165 144
160 132 200 136 131 114 203 150 165 166 192 112 242 135 160 174 197 171 119 145
165 87 126 118 154 154 176 179 175 195 210 159 135 173 142 184 125 118 143 139
135 93 83 106 104 156 120 135 87 112 101 78 144 221 203 210 128 181 93 178
145 128 114 120 156 187 148 204 227

EXT-M63A 115
142 108 100 120 136 64 92 103 71 96 78 71 57 56 59 55 60 35 46 49
39 57 50 60 50 43 47 54 55 47 53 75 134 125 83 151 94 103 103 102
101 60 67 56 96 82 113 91 113 107 105 113 103 79 50 57 67 48 75 61
46 68 76 41 39 60 53 56 50 79 84 86 74 74 79 96 99 75 85 114
128 94 134 93 117 100 90 92 100 117 134 84 119 122 77 78 85 123 96 129
113 96 91 75 113 198 125 126 156 100 75 71 57 78 94

EXT-M63B 115
147 109 115 110 140 78 108 97 51 98 85 65 58 58 59 56 59 39 47 40
48 50 51 61 48 35 46 47 58 52 41 79 140 116 85 142 92 107 105 105
85 53 58 64 86 71 94 103 116 120 111 109 104 77 53 50 67 50 61 66
47 77 72 50 48 65 43 57 52 82 82 84 78 68 79 95 78 78 86 110
121 89 151 107 103 106 105 91 98 121 118 98 123 114 90 86 93 117 112 121
109 94 97 85 106 193 125 122 154 125 81 64 64 77 101

EXT-M64A 108
135 144 108 118 123 147 112 108 129 123 140 103 113 137 108 91 76 89 83 117
131 143 149 139 155 207 129 84 87 108 132 182 155 173 158 171 167 131 104 85
145 97 172 132 132 140 160 138 128 165 184 179 195 150 206 157 144 167 184 159
107 143 189 173 193 123 146 112 160 206 189 160 157 128 164 127 103 107 185 200
171 275 205 207 156 217 268 297 268 247 257 209 131 159 181 200 194 223 160 178
185 300 198 165 262 229 150 137

EXT-M64B 108
131 137 106 113 135 139 120 102 124 122 135 109 119 125 107 96 78 100 82 121
126 137 150 152 160 205 135 87 94 94 133 175 171 193 142 173 177 132 104 94
123 113 153 148 130 128 150 128 142 151 184 178 196 163 201 148 156 168 178 140
96 157 193 160 186 145 126 117 157 198 206 162 145 139 148 134 96 119 177 192
189 275 179 209 176 210 266 290 275 238 241 222 103 142 184 206 209 241 171 193
174 287 187 172 277 203 167 165

EXT-M65A 94
173 214 242 272 184 176 154 184 144 222 218 146 260 257 348 167 200 214 228 213
210 216 196 224 303 245 223 166 155 140 164 176 146 106 151 178 180 110 162 109
126 82 96 107 106 88 94 120 135 155 134 156 153 112 117 121 140 117 151 192

140 110 138 146 125 143 70 58 93 117 133 161 181 153 137 135 76 54 42 68
60 114 140 162 137 150 125 100 109 137 153 146 189 284

EXT-M65B 94
179 229 238 270 192 175 145 193 149 219 212 148 247 268 353 170 197 209 228 213
207 211 203 227 292 249 212 150 155 141 162 186 126 118 151 176 175 110 154 100
121 88 92 109 103 85 98 120 148 157 142 154 163 114 114 128 136 115 145 165
148 118 131 137 139 126 87 46 89 117 147 157 189 151 151 123 92 51 43 60
64 110 136 161 128 162 106 121 99 134 142 166 167 240

EXT-M66A 116
233 180 149 167 179 275 230 202 314 337 358 217 200 166 229 318 217 128 232 164
103 212 177 163 157 238 207 195 163 167 233 307 198 164 187 197 255 190 164 123
157 226 201 203 146 175 153 189 87 75 89 104 112 128 190 132 114 145 89 109
96 115 118 123 95 76 46 62 112 115 57 106 79 89 70 70 78 76 66 84
84 48 50 91 106 93 82 88 88 115 112 93 53 56 53 70 50 43 51 50
60 48 62 59 64 68 68 59 65 43 39 35 71 57 46 68

EXT-M66B 116
265 167 155 171 178 272 227 204 314 337 351 225 209 164 222 316 217 133 225 153
107 196 207 159 148 257 185 178 159 173 233 312 190 169 178 204 257 186 165 120
176 201 211 175 141 173 173 184 75 85 96 107 114 128 168 132 112 146 96 104
101 125 126 109 93 81 50 62 106 123 59 121 79 88 75 62 81 78 57 81
91 47 56 82 109 90 84 81 87 108 115 90 60 59 46 67 55 38 56 44
64 45 58 63 61 71 63 62 62 46 38 46 65 49 53 60

EXT-M67A 48
135 121 117 72 104 109 105 233 209 154 162 217 226 108 108 139 182 135 115 95
110 108 110 105 101 69 76 99 153 153 153 97 112 110 90 64 106 168 187 216
140 145 155 185 147 179 211 196

EXT-M67B 48
137 123 123 76 106 112 112 217 210 155 172 197 219 93 102 157 189 123 124 98
109 100 108 107 93 64 74 99 149 158 138 94 113 110 97 77 101 167 169 217
147 148 150 173 176 193 207 184

EXT-M68A 65
196 215 151 146 114 184 108 190 209 145 192 228 205 130 180 166 127 164 143 178
142 195 182 118 106 110 74 92 150 158 84 93 103 105 105 128 134 29 40 27
53 50 67 67 70 80 76 89 72 67 64 92 87 79 79 82 101 95 107 93
79 83 99 103 117

EXT-M68B 65
185 219 162 150 109 186 108 178 211 156 212 237 201 144 166 154 132 151 162 160
130 189 183 110 110 110 85 92 165 146 77 96 101 115 126 117 122 30 40 35
50 49 64 67 71 83 73 85 64 73 79 87 90 81 90 76 109 90 114 89
82 68 117 100 140

EXT-M69A 107
139 252 185 179 168 168 89 165 167 105 142 118 129 105 180 152 163 139 157 183
151 190 209 202 171 100 160 155 200 179 146 185 228 234 194 202 221 197 191 145
196 203 162 167 150 193 156 135 137 175 145 68 106 127 146 140 140 164 114 118
126 143 135 151 143 100 170 172 177 144 151 165 164 101 106 71 84 92 75 120

126 145 118 147 97 137 118 100 113 131 106 104 86 99 147 121 116 101 112 113
140 126 64 84 82 83 126

EXT-M69B 107
190 256 187 172 180 167 114 152 149 111 139 116 133 134 187 200 162 151 144 197
169 185 207 217 180 106 143 152 211 180 142 184 217 224 189 217 240 192 179 152
180 176 179 181 176 185 175 127 121 170 145 70 110 123 154 145 167 151 114 121
117 143 142 160 139 112 173 165 165 165 143 145 162 109 103 85 80 90 89 110
125 139 107 154 101 128 117 94 124 125 109 93 102 94 137 117 122 109 108 109
134 131 71 84 74 84 165

EXT-M70A 104
61 76 87 81 58 80 63 69 75 91 89 70 67 78 103 94 59 92 112 90
108 138 139 112 110 89 100 87 82 76 74 86 155 92 103 82 90 137 103 103
112 108 146 97 77 81 125 112 124 138 130 104 145 105 133 151 116 120 97 103
111 70 126 71 151 116 101 116 108 117 162 118 79 71 105 116 107 75 102 100
85 60 61 78 123 153 127 169 97 100 104 101 109 158 139 129 101 148 58 132
138 125 117 145

EXT-M70B 104
64 83 88 85 49 81 65 75 77 92 85 75 72 75 96 87 70 94 105 99
116 153 121 113 116 90 105 83 82 89 69 91 155 96 102 100 97 141 96 110
114 112 137 103 73 89 117 114 127 134 137 102 150 106 131 153 110 118 99 104
110 85 101 75 134 110 94 133 107 114 157 128 75 77 107 117 107 75 100 98
87 64 53 80 128 136 135 169 99 100 107 95 121 146 125 123 107 135 61 138
123 111 98 165

EXT-M71A 42
490 551 527 651 608 393 301 331 414 519 513 446 470 410 397 393 496 498 496 354
389 410 290 464 395 389 329 272 150 282 307 312 259 312 232 473 389 394 184 353
330 329

EXT-M71B 42
497 618 517 628 625 439 304 315 419 517 522 417 468 403 387 392 510 489 487 359
384 407 256 435 370 401 329 270 136 282 301 330 250 288 256 471 434 393 184 312
326 338

EXT-M72A 46
380 430 522 378 327 355 301 228 490 286 545 239 400 207 335 264 235 260 269 277
358 219 500 201 343 204 159 123 171 156 278 155 190 129 213 185 200 157 231 231
223 242 252 155 225 171

EXT-M72B 46
400 449 509 386 324 352 300 245 490 277 532 230 411 215 325 278 237 260 267 259
401 223 492 207 345 206 156 126 168 157 276 157 193 115 200 171 195 154 203 271
217 239 265 142 234 179

EXT-M73A 63
390 453 470 575 299 289 287 323 585 635 704 447 412 457 385 423 506 453 307 204
239 245 134 353 317 392 271 285 139 242 196 243 163 242 208 341 364 426 159 215
227 109 134 196 389 453 271 302 247 231 371 338 370 434 221 262 263 246 200 190
131 149 233

EXT-M73B 63
400 452 473 563 351 305 339 332 566 632 727 383 423 496 419 381 526 435 306 191
246 249 131 336 303 389 232 264 146 231 223 251 170 257 195 343 376 431 153 216
220 112 134 192 388 437 259 289 254 215 398 338 386 412 215 228 256 264 226 168
153 146 240

Conifer Samples

EXT-L01A 185
187 202 237 265 164 211 64 25 57 132 119 142 150 155 148 194 187 255 289 221
196 217 178 225 164 132 189 206 221 302 289 242 186 206 198 160 179 161 235 203
165 101 134 150 68 81 154 154 100 115 104 121 112 146 139 112 92 81 87 114
112 115 142 35 12 17 25 19 29 22 22 35 58 67 57 53 58 52 50 62
56 42 54 34 29 21 48 39 25 29 40 65 52 41 62 60 60 70 54 53
63 57 45 53 39 68 53 38 34 29 26 15 23 26 29 31 26 28 21 27
53 56 56 65 25 31 37 31 37 52 38 28 28 34 46 52 64 58 65 61
50 85 65 71 56 59 62 67 68 50 62 25 33 38 36 43 49 48 39 41
43 39 37 46 45 58 75 50 62 43 43 46 39 42 40 40 33 21 42 41
57 44 35 31 43

EXT-L01B 185
197 189 244 261 161 203 69 33 62 125 107 133 144 134 146 170 203 280 254 233
264 200 213 207 151 126 203 194 202 292 282 238 202 224 193 147 170 148 253 217
179 106 117 142 84 89 135 136 85 115 106 123 114 135 144 119 89 84 87 117
125 115 145 35 14 19 20 21 27 27 22 34 59 71 54 48 55 50 50 65
59 37 57 32 29 23 48 42 26 26 43 73 48 46 62 57 63 70 48 54
51 65 40 51 44 66 60 37 35 28 23 9 26 23 32 35 25 28 21 25
46 57 56 60 30 28 40 31 42 45 27 28 27 33 50 50 63 66 64 61
46 80 69 73 53 59 65 62 72 50 61 25 30 37 38 43 47 46 37 47
40 37 37 50 48 55 77 52 51 48 42 44 36 46 39 38 34 26 35 42
55 45 47 33 40

EXT-L02A 104
221 263 278 297 259 255 223 192 194 164 151 108 141 141 89 103 78 55 81 82
133 85 62 89 160 205 200 217 217 321 339 325 132 95 159 157 258 276 323 339
248 292 212 234 210 40 51 107 82 78 142 146 143 129 117 132 159 129 169 118
95 118 190 137 125 142 133 82 71 60 73 44 46 131 87 101 91 119 145 123
153 131 171 140 131 95 89 168 98 121 181 207 152 132 95 94 125 61 46 46
56 42 67 88

EXT-L02B 104
220 277 268 308 255 260 226 196 185 165 146 125 150 135 98 105 67 63 72 79
135 100 49 82 154 210 203 237 240 302 342 325 125 83 154 172 239 276 301 338
251 290 235 233 212 34 45 93 100 75 142 146 146 129 117 135 167 123 162 123
93 118 189 139 116 143 137 85 71 66 81 60 56 110 96 118 114 160 121 134
137 118 162 131 138 103 110 134 114 100 206 203 159 125 85 73 143 73 56 39
56 46 56 88

EXT-L03A 94
279 353 231 356 243 140 175 232 326 361 211 264 257 221 383 294 278 217 210 143
206 132 273 281 233 264 359 217 243 173 151 117 124 90 153 186 166 205 187 121
148 104 134 225 225 203 200 213 175 143 100 134 160 85 83 145 104 126 156 110

139 103 88 133 112 115 84 42 42 34 50 55 63 53 56 40 43 59 48 13
26 28 36 34 68 82 81 98 119 87 75 70 97 81

EXT-L03B 94
285 348 241 342 250 142 173 228 324 360 225 258 251 225 374 300 278 219 198 149
195 139 271 286 242 256 353 218 250 167 135 132 126 88 140 186 194 183 189 121
146 118 156 223 267 170 189 196 203 146 98 145 148 88 89 113 110 150 150 130
122 115 87 132 117 109 89 42 34 41 41 58 65 57 52 37 41 50 42 19
21 26 32 40 57 94 80 121 100 85 79 70 99 86

EXT-L05A 123
43 57 63 51 94 129 145 133 177 128 147 122 184 134 128 155 164 146 162 139
135 168 116 123 112 141 207 182 209 207 167 146 133 142 128 114 124 95 76 77
82 135 133 135 164 166 175 172 139 145 135 115 120 146 109 134 125 131 103 111
140 159 165 156 129 110 106 84 20 20 57 84 104 120 143 172 142 164 142 129
137 132 149 153 218 142 90 89 113 119 110 84 100 85 104 121 115 126 128 119
176 146 164 146 92 90 86 70 52 86 54 65 61 76 80 50 65 40 23 26
26 25 37

EXT-L05B 123
42 62 58 54 104 129 150 125 176 123 146 122 186 141 126 155 160 148 156 146
157 159 114 130 121 130 202 173 213 228 164 143 125 145 127 117 117 105 71 69
80 132 149 150 175 171 203 152 129 127 122 111 117 151 113 150 125 125 107 110
145 160 169 148 131 106 98 81 17 21 54 84 112 118 140 178 135 163 147 126
140 138 146 153 216 140 93 90 111 122 98 84 103 89 101 120 116 127 128 121
191 151 153 143 93 100 96 65 57 81 73 65 56 69 62 50 54 40 23 25
28 31 39

EXT-L06A 69
366 355 452 505 549 469 527 378 421 375 442 417 392 347 306 295 323 296 285 246
212 328 313 332 309 267 235 268 260 192 271 256 208 196 195 154 184 154 143 167
145 154 149 149 110 169 143 148 170 168 147 121 84 45 69 50 26 38 42 43
44 74 85 137 139 78 154 107 118

EXT-L06B 69
364 348 459 494 552 468 539 406 422 350 444 410 393 353 312 293 341 330 235 248
212 345 312 340 296 264 238 255 282 198 259 276 214 209 189 154 181 154 140 168
154 165 140 159 126 164 143 136 155 163 146 134 79 39 62 59 31 34 40 50
37 56 93 119 153 91 146 104 121

EXT-L07A 73
396 422 374 338 408 310 268 287 339 298 367 330 360 259 332 253 307 343 300 310
298 259 284 284 229 204 233 267 270 273 260 287 195 195 183 160 207 206 176 168
166 140 157 138 131 168 162 141 143 118 110 134 133 140 178 175 173 153 105 63
68 65 34 53 62 65 51 95 82 121 137 90 147

EXT-L07B 73
391 408 386 334 413 318 253 310 346 300 362 345 333 262 327 265 307 346 310 297
296 253 282 279 220 220 232 279 270 260 267 296 193 187 185 163 207 209 167 152
163 138 160 137 135 161 154 131 129 108 112 136 135 139 182 182 167 162 106 54
77 63 37 51 59 65 53 87 84 123 131 100 146

EXT-L08A 104

178 247 166 178 113 124 102 88 50 102 121 100 99 169 153 137 160 156 120 114
100 82 64 60 80 106 188 199 231 218 209 188 164 123 183 184 182 214 182 196
192 292 274 306 193 128 118 109 148 151 135 99 179 228 174 184 186 204 178 128
140 142 93 115 109 81 76 92 78 70 78 62 87 66 54 73 45 46 64 70
59 94 125 114 121 110 170 201 168 137 100 79 92 78 68 144 109 81 59 53
46 75 51 65

EXT-L08B 104
173 246 168 186 119 125 117 90 59 97 123 100 100 163 155 134 146 151 126 117
112 76 58 56 107 107 182 198 233 220 207 182 170 132 180 180 185 210 184 182
185 309 271 300 204 132 137 109 143 160 125 112 178 225 166 180 189 206 167 145
146 153 96 110 109 84 81 76 71 67 73 73 84 67 70 65 50 40 60 73
56 96 134 134 117 133 177 207 121 168 114 55 96 88 100 129 90 78 62 51
46 68 55 66

EXT-L10A 107
177 281 209 268 322 331 256 310 325 269 300 200 287 323 128 107 249 221 232 199
182 127 175 168 132 109 93 104 139 126 100 134 126 84 89 121 147 92 124 112
137 78 45 51 64 60 75 88 71 90 81 107 78 69 66 76 68 70 106 92
99 70 78 71 56 56 63 43 34 36 66 89 119 99 109 85 101 85 70 87
89 95 118 112 96 120 115 93 53 57 59 56 62 50 48 44 49 57 62 44
39 35 39 41 58 50 71

EXT-L10B 107
171 279 201 270 328 260 234 305 360 273 291 185 295 318 135 103 250 216 239 201
178 121 179 165 142 93 108 104 136 117 107 149 129 81 95 115 145 96 127 108
150 75 46 50 53 68 71 87 70 98 79 102 82 73 73 73 71 71 106 99
97 75 81 75 57 57 50 44 31 40 65 92 113 100 110 85 101 85 70 85
90 85 115 126 93 117 108 94 54 53 57 59 53 51 53 48 53 59 63 50
40 37 37 45 51 51 71

EXT-L11A 154
249 202 245 219 159 174 192 170 168 212 203 57 26 23 44 50 64 146 155 216
194 165 129 130 164 160 184 179 139 128 116 169 200 194 179 178 175 178 188 183
139 143 139 112 132 153 178 220 223 169 150 181 165 184 150 115 91 107 95 95
64 73 93 73 115 89 125 125 124 101 121 136 120 98 69 60 55 94 69 89
71 67 43 23 48 67 30 39 68 50 42 57 52 53 45 23 26 20 28 28
31 43 64 98 104 125 107 101 62 62 50 40 60 53 59 50 68 56 82 70
88 71 84 74 43 49 44 43 43 37 34 37 56 84 139 75 66 43 37 29
30 26 25 18 26 42 44 44 44 69 69 137 109 143

EXT-L11B 154
254 208 257 241 145 154 185 161 167 197 188 58 21 16 30 53 56 156 157 215
194 142 136 152 148 175 180 200 130 125 117 168 221 185 177 181 160 181 160 192
146 148 127 121 128 151 179 218 221 162 154 162 190 189 151 98 90 115 98 82
71 79 93 81 107 90 132 118 126 101 120 129 117 98 83 67 53 87 81 90
59 71 39 23 50 70 26 43 63 52 39 60 49 59 41 26 25 21 28 26
24 42 73 95 103 121 107 103 66 61 53 37 59 53 58 50 64 54 81 63
106 78 81 68 50 48 43 44 37 37 40 37 53 83 132 81 64 44 33 28
31 25 21 18 28 45 41 50 40 73 75 122 107 138

EXT-L12A 234
197 335 385 316 272 193 209 268 192 171 201 175 151 151 127 161 156 81 71 74

79 67 92 71 53 53 75 75 103 84 44 58 59 64 73 62 90 105 98 60
42 42 47 44 39 30 28 24 36 38 61 87 53 30 35 35 64 63 131 135
140 104 165 182 118 191 164 254 232 182 127 75 90 82 73 117 48 54 51 106
75 70 82 56 67 76 99 89 87 85 98 100 153 127 180 159 129 120 126 132
104 106 118 93 111 108 106 79 81 98 85 115 139 143 111 97 107 109 109 112
156 136 109 171 121 81 63 51 56 43 46 51 51 47 56 53 63 58 68 59
63 46 40 46 43 52 50 62 53 62 54 34 25 29 31 37 43 37 34 36
39 33 28 31 40 31 37 37 31 27 37 44 37 31 34 18 27 29 33 32
41 33 39 30 30 35 31 34 31 43 47 47 44 51 34 40 43 44 42 38
45 32 31 43 45 46 32 28 31 27 43 59 65 51 64 50 39 40 56 68
63 43 22 22 10 18 18 37 35 31 44 36 46 61

EXT-L12B 234
209 336 376 321 270 197 212 264 176 194 180 189 146 123 141 166 144 84 71 69
88 68 85 71 57 56 71 78 106 82 42 57 53 66 72 61 94 107 96 64
43 45 48 42 42 31 21 29 39 40 62 76 54 26 37 35 68 59 142 127
140 109 160 189 117 191 164 250 259 176 134 78 90 75 74 114 51 45 53 96
90 73 83 57 67 78 95 93 85 85 98 95 159 125 190 154 132 121 129 139
90 103 114 100 115 104 103 87 82 94 85 118 145 132 110 93 105 106 109 105
157 140 112 163 115 93 57 53 48 54 42 50 50 50 59 50 56 62 65 65
53 48 38 43 46 56 50 68 49 64 50 34 24 28 31 40 46 38 31 34
40 37 25 31 42 28 37 36 31 29 39 43 36 30 34 19 27 33 28 37
37 37 37 31 28 36 25 37 30 50 41 46 46 50 38 36 46 44 40 37
43 31 25 43 40 54 28 32 25 28 40 59 67 56 62 50 34 43 55 76
65 35 20 28 9 19 25 34 28 25 43 35 49 55

EXT-L13A 151
260 186 175 149 138 171 222 203 133 142 180 223 187 172 167 173 132 132 151 167
164 164 169 169 149 114 139 115 136 110 78 78 81 89 89 107 92 90 92 114
110 113 115 92 98 88 79 70 102 103 117 79 104 109 137 108 82 92 96 95
131 103 121 131 121 121 93 84 82 76 81 96 81 98 115 132 109 114 110 92
94 100 96 88 56 57 58 66 80 104 118 112 90 90 111 92 115 129 142 103
96 120 125 164 162 135 109 131 148 146 131 106 107 128 126 139 115 107 144 146
113 118 103 149 109 114 163 109 171 151 140 100 130 138 116 98 84 105 89 78
53 52 59 75 84 65 70 119 115 134 118

EXT-L13B 151
273 183 179 146 138 169 220 195 142 142 175 219 195 166 160 177 136 119 146 171
157 164 177 162 146 121 142 123 128 109 81 81 82 92 86 110 92 100 92 104
112 115 110 99 99 87 77 72 93 110 118 78 107 117 131 114 78 87 98 93
138 111 112 134 118 128 95 75 84 79 73 93 82 101 106 122 114 107 121 96
98 107 103 89 61 64 49 75 82 100 121 115 95 92 118 106 121 134 124 111
96 136 116 170 172 143 112 125 136 156 128 117 87 133 135 128 121 127 137 155
99 127 118 161 107 126 145 117 146 150 157 104 126 156 113 93 78 118 83 73
45 49 61 54 64 75 76 110 108 146 111

EXT-L14A 154
139 177 242 163 127 175 134 216 155 157 205 157 139 108 91 107 69 64 164 192
210 174 175 241 189 221 193 201 239 254 231 277 213 153 200 202 231 242 307 210
209 229 167 184 162 194 205 175 172 169 203 135 168 144 129 104 57 85 100 110
93 120 98 109 103 142 130 125 85 121 100 109 89 103 87 73 79 79 114 82
70 85 68 114 150 75 84 136 133 139 168 102 114 97 100 109 93 62 50 59
72 87 78 65 53 80 47 119 94 56 68 75 84 103 90 81 69 51 76 53

62 78 55 52 20 34 48 88 52 59 47 50 60 47 40 30 31 37 39 27
44 26 48 38 37 52 100 79 121 96 50 62 79 115

EXT-L14B 154
136 188 235 166 135 180 133 203 150 172 205 152 138 111 86 112 83 58 164 192
214 175 171 242 183 218 196 196 240 255 233 277 210 161 192 195 239 246 316 222
185 236 168 175 155 200 210 181 175 151 201 143 164 129 134 89 54 84 100 115
95 106 104 109 101 122 121 118 73 120 93 122 87 87 76 73 64 95 114 82
87 87 84 101 148 76 84 126 150 137 174 105 118 93 100 106 91 71 51 79
68 91 90 64 37 70 49 124 98 76 56 69 74 115 85 87 65 64 58 50
62 81 60 57 26 33 49 74 57 54 44 47 48 59 42 43 25 33 34 29
46 33 48 46 46 48 111 78 117 97 57 56 81 115

EXT-L15A 97
297 282 424 451 518 551 478 425 502 404 369 385 315 303 290 285 197 173 257 334
431 179 200 271 362 173 298 360 254 240 231 229 254 235 204 202 264 185 123 190
242 251 251 178 255 237 179 214 235 109 143 157 237 231 162 134 143 122 165 174
165 109 148 172 74 63 61 93 69 96 92 107 128 148 106 84 87 89 122 137
85 112 88 84 72 84 93 93 86 50 68 81 70 62 68 85 92

EXT-L15B 97
300 268 423 458 515 534 466 460 482 410 375 372 321 330 312 301 207 151 251 339
437 180 189 273 370 271 267 279 240 258 207 234 263 268 220 206 270 203 115 170
233 240 219 178 231 199 199 238 222 130 125 168 239 243 184 125 139 145 170 159
175 104 136 176 84 64 75 83 68 92 99 102 121 144 105 84 84 91 121 137
91 104 97 87 62 98 101 74 75 52 62 79 68 96 68 86 98

EXT-L16A 82
282 255 257 223 257 276 256 379 355 378 296 310 378 438 328 409 439 305 377 572
643 612 676 494 544 458 444 325 334 484 381 362 277 346 245 302 263 273 210 250
266 321 347 300 326 368 287 225 231 293 240 215 201 236 185 253 266 281 275 309
313 280 251 135 181 191 206 279 262 216 153 141 180 152 203 273 187 214 243 142
154 149

EXT-L16B 82
278 257 244 225 251 261 286 380 375 364 303 338 368 455 320 385 425 310 391 589
609 673 673 531 550 453 443 332 346 456 382 373 264 334 266 286 262 270 209 249
266 319 354 300 325 367 302 218 217 296 235 204 203 239 203 247 273 271 270 313
317 290 251 137 169 198 210 290 240 231 137 140 183 145 207 272 194 199 241 157
160 150

EXT-L17A 57
118 154 109 272 223 225 293 286 241 261 227 210 309 316 352 300 352 310 308 300
294 289 292 262 314 290 337 218 259 270 361 331 301 245 200 247 211 272 203 221
254 232 273 190 190 167 164 185 142 164 156 171 155 154 173 238 205

EXT-L17B 57
115 169 112 265 229 220 283 281 226 289 221 207 288 305 335 320 364 325 310 300
274 316 302 291 321 289 298 219 238 279 346 354 314 284 221 270 249 248 182 232
250 229 274 188 200 155 159 179 130 162 176 185 150 155 167 224 195

APPENDIX: TREE-RING DATING

The Principles of Tree-Ring Dating

Tree-ring dating, or dendrochronology as it is known, is discussed in some detail in the Nottingham Tree-ring Dating Laboratory's Monograph, *An East Midlands Master Tree-Ring Chronology and its uses for dating Vernacular Buildings* (Laxton and Litton 1988) and *Dendrochronology: Guidelines on Producing and Interpreting Dendrochronological Dates* (English Heritage 1998). Here we will give the bare outlines. Each year an oak tree grows an extra ring on the outside of its trunk and all its branches just inside its bark. The width of this annual ring depends largely on the weather during the growing season, about April to October, and possibly also on the weather during the previous year. Good growing seasons give rise to relatively wide rings, poor ones to very narrow rings and average ones to relatively average ring widths. Since the climate is so variable from year to year, almost random-like, the widths of these rings will also appear random-like in sequence, reflecting the seasons. This is illustrated in Figure A1 where, for example, the widest rings appear at irregular intervals. This is the key to dating by tree rings, or rather, by their widths. Records of the average ring widths for oaks, one for each year for the last 1000 years or more, are available for different areas. These are called master chronologies. Because of the random-like nature of these sequences of widths, there is usually only one position at which a sequence of ring widths from a sample of oak timber with at least 70 rings will match a master. This will date the timber and, in particular, the last ring.

If the bark is still on the sample, as in Figure A1, then the date of the last ring will be the date of felling of the oak from which it was cut. There is much evidence that in medieval times oaks cut down for building purposes were used almost immediately, usually within the year or so (Rackham 1976). Hence if bark is present on several main timbers in a building, none of which appear reused or are later insertions, and if they all have the same date for their last ring, then we can be quite confident that this is the date of construction or soon after. If there is no bark on the sample, then we have to make an estimate of the felling date; how this is done is explained below.

The Practice of Tree-Ring Dating at the Nottingham Tree-Ring Dating Laboratory

1. Inspecting the Building and Sampling the Timbers.

Together with a building historian the timbers in a building are inspected to try to ensure that those sampled are not reused or later insertions. Sampling is almost always done by coring into the timber, which has the great advantage that we can sample *in situ* timbers and those judged best to give the date of construction, or phase of construction if there is more than one in the building. The timbers to be sampled are also inspected to see how many rings they have. We normally look for timbers with at least 70 rings, and preferably more. With fewer rings than this, 50 for example, sequences of widths become difficult to match to a unique position within a master sequence of ring widths and so are difficult to date (Litton and Zainodin 1991). The cross-section of the rafter shown in Figure A2 has about 120 rings; about 20 of which are sapwood rings – the lighter rings on the outside. Similarly the core has just over 100 rings with a few sapwood rings.

To ensure that we are getting the date of the building as a whole, or the whole of a phase of construction if there is more than one, about 8–10 samples per phase are usually taken. Sometimes we take many more, especially if the construction is complicated. One reason for taking so many samples is that, in general, some will fail to give a date. There may be many reasons why a particular sequence of ring widths from a sample of timber fails to give a date even though others from the same building do. For example, a particular tree may have grown in an odd ecological niche, so odd indeed that the widths of its rings were determined by factors other than the local climate! In such circumstances it will be impossible to date a timber from this tree using the master sequence whose widths, we can assume, were predominantly determined by the local climate at the time.

Sampling is done by coring into the timber with a hollow corer attached to an electric drill and usually from its outer rings inwards towards where the centre of the tree, the pith, is judged to be. An illustration of a core is shown in Figure A2; it is about 150mm long and 10mm diameter. Great care has to be taken to ensure that as few as possible of the outer rings are lost in coring. This can be difficult as these outer rings are often very soft (see below on sapwood). Each sample is given a code which identifies uniquely which timber it comes from, which building it is from and where the building is located. For example, CRO-A06 is the sixth core taken from the first building (A) sampled by the Laboratory in Cropwell Bishop. Where it came from in that building will be shown in the sampling records and drawings. No structural damage is done to any timbers by coring, nor does it weaken them.

During the initial inspection of the building and its timbers the dendrochronologist may come to the conclusion that, as far as can be judged, none of the timbers have sufficient rings in them for dating purposes and may advise against sampling to save further unwarranted expense.

All sampling by the Laboratory is undertaken according to current Health and Safety Standards. The Laboratory's dendrochronologists are insured.

Figure A1: A wedge of oak from a tree felled in 1976. It shows the annual growth rings, one for each year from the innermost ring to the last ring on the outside just inside the bark. The year of each ring can be determined by counting back from the outside ring, which grew in 1976

Figure A2: Cross-section of a rafter, showing sapwood rings in the left-hand corner, the arrow points to the heartwood/sapwood boundary (H/S); and a core with sapwood; again the arrow is pointing to the H/S. The core is about the size of a pencil

Figure A3: Measuring ring widths under a microscope. The microscope is fixed while the sample is on a moving platform. The total sequence of widths is measured twice to ensure that an error has not been made. This type of apparatus is needed to process a large number of samples on a regular basis

Figure A4: Three cores from timbers in a building. They come from trees growing at the same time. Notice that, although the sequences of widths look similar, they are not identical. This is typical

2. Measuring Ring Widths.

Each core is sanded down with a belt sander using medium-grit paper and then finished by hand with flourgrade-grit paper. The rings are then clearly visible and differentiated from each other with a result very much like that shown in Figure A2. The core is then mounted on a movable table below a microscope and the ring-widths measured individually from the innermost ring to the outermost. The widths are automatically recorded in a computer file as they are measured (see Fig A3).

3. Cross-Matching and Dating the Samples.

Because of the factors besides the local climate which may determine the annual widths of a tree's rings, no two sequences of ring widths from different oaks growing at the same time are exactly alike (Fig A4). Indeed, the sequences may not be exactly alike even when the trees are growing near to each other. Consequently, in the Laboratory we do not attempt to match two sequences of ring widths by eye, or graphically, or by any other subjective method. Instead, it is done objectively (ie statistically) on a computer by a process called cross-matching. The output from the computer tells us the extent of correlation between two sample sequences of widths or, if we are dating, between a sample sequence of widths and the master, at each relative position of one to the other (offsets). The extent of the correlation at an offset is determined by the *t*-value (defined in almost any introductory book on statistics). That offset with the maximum *t*-value among the *t*-values at all the offsets will be the best candidate for dating one sequence relative to the other. If one of these is a master chronology, then this will date the other. Experiments carried out in the past with sequences from oaks of known date suggest that a *t*-value of at least 4.5, and preferably at least 5.0, is usually adequate for the dating to be accepted with reasonable confidence (Laxton and Litton 1988; Laxton *et al* 1988; Howard *et al* 1984–1995).

This is illustrated in Figure A5 with timbers from one of the roofs of Lincoln Cathedral. Here four sequences of ring widths, LIN-C04, 05, 08, and 45, have been cross-matched with each other. The ring widths themselves have been omitted in the bar diagram, as is usual, but the offsets at which they best cross-match each other are shown; eg the sequence of ring widths of C08 matches the sequence of ring widths of C45 best when it is at a position starting 20 rings after the first ring of C45, and similarly for the others. The actual *t*-values between the four at these offsets of best correlations are in the matrix. Thus at the offset of +20 rings, the *t*-value between C45 and C08 is 5.6 and is the maximum found between these two among all the positions of one sequence relative to the other.

It is standard practice in our Laboratory first to cross-match as many as possible of the ring-width sequences of the samples in a building and then to form an average from them. This average is called a site sequence of the building being dated and is illustrated in Figure A5. The fifth bar at the bottom is a site sequence for a roof at Lincoln Cathedral and is constructed from the matching sequences of the four timbers. The site sequence width for each year is the average of the widths in each of the sample sequences which has a width for that year. Thus in Fig A5 if the widths shown are 0.8mm for C45, 0.2mm for C08, 0.7mm for C05, and 0.3mm for

C04, then the corresponding width of the site sequence is the average of these, 0.55mm. The actual sequence of widths of this site sequence is stored on the computer. The reason for creating site sequences is that it is usually easier to date an average sequence of ring widths with a master sequence than it is to date the individual component sample sequences separately.

The straightforward method of cross-matching several sample sequences with each other one at a time is called the 'maximal *t*-value' method. The actual method of cross-matching a group of sequences of ring-widths used in the Laboratory involves grouping and averaging the ring-width sequences and is called the 'Litton-Zainodin Grouping Procedure'. It is a modification of the straightforward method and was successfully developed and tested in the Laboratory and has been published (Litton and Zainodin 1991; Laxton *et al* 1988).

4. Estimating the Felling Date.

As mentioned above, if the bark is present on a sample, then the date of its last ring is the date of the felling of its tree (or the last full year before felling, if it was felled in the first three months of the following calendar year, before any new growth had started, but this is not too important a consideration in most cases). The actual bark may not be present on a timber in a building, though the dendrochronologist who is sampling can often see from its surface that only the bark is missing. In these cases the date of the last ring is still the date of felling.

Quite often some, though not all, of the original outer rings are missing on a timber. The outer rings on an oak, called sapwood rings, are usually lighter than the inner rings, the heartwood, and so are relatively easy to identify. For example, sapwood can be seen in the corner of the rafter and at the outer end of the core in Figure A2, both indicated by arrows. More importantly for dendrochronology, the sapwood is relatively soft and so liable to insect attack and wear and tear. The builder, therefore, may remove some of the sapwood for precisely these reasons. Nevertheless, if at least some of the sapwood rings are left on a sample, we will know that not too many rings have been lost since felling so that the date of the last ring on the sample is only a few years before the date of the original last ring on the tree, and so to the date of felling.

Various estimates have been made and used for the average number of sapwood rings in mature oak trees (English Heritage 1998). A fairly conservative range is between 15 and 40 and that this holds for 95% of mature oaks. This means, of course, that in a small number of cases there could be fewer than 15 and more than 40 sapwood rings. For example, the core CRO-A06 has only 9 sapwood rings and some have obviously been lost over time – either they were removed originally by the carpenter and/or they rotted away in the building and/or they were lost in the coring. It is not known exactly how many sapwood rings are missing, but using the above range the Laboratory would estimate between a minimum of 6 (=15-9) and a maximum of 41 (=50-9). If the last ring of CRO-A06 has been dated to 1500, say, then the estimated felling-date range for the tree from which it came originally would be between 1506 and 1541. The Laboratory uses this estimate for sapwood in areas of England where it has no prior information. It also uses it when dealing with samples with very many rings, about 120 to the last heartwood ring. But in other areas of England where the Laboratory has accumulated a number of samples with complete sapwood, that is, no sapwood lost since felling, other estimates in place of the conservative range of 15 to 50 are used. In the East Midlands (Laxton *et al* 2001) and the east to the south down to Kent (Pearson 1995) where it has sampled extensively in the past, the Laboratory uses the shorter estimate of 15 to 35 sapwood rings in 95% of mature oaks growing in these parts. Since the sample CRO-A06 comes from a house in Cropwell Bishop in the East Midlands, a better estimate of sapwood rings lost since felling is between a minimum of 6 (=15-9) and 26 (=35-9) and the felling would be estimated to have taken place between 1506 and 1526, a shorter period than before. Oak boards quite often come from the Baltic region and in these cases the 95% confidence limits for sapwood are 9 to 36 (Howard *et al* 1992, 56).

Even more precise estimates of the felling date and range can often be obtained using knowledge of a particular case and information gathered at the time of sampling. For example, at the time of sampling the dendrochronologist may have noted that the timber from which the core of Figure A2 was taken still had complete sapwood but that some of the soft sapwood rings were lost in coring. By measuring into the timber the depth of sapwood lost, say 20mm, a reasonable estimate can be made of the number of sapwood rings lost, say 12 to 15 rings in this case. By adding on 12 to 15 years to the date of the last ring on the sample a good tight estimate for the range of the felling date can be obtained, which is often better than the 15 to 35 years later we would have estimated without this observation. In the example, the felling is now estimated to have taken place between AD 1512 and 1515, which is much more precise than without this extra information.

Even if all the sapwood rings are missing on a sample, but none of the heartwood rings are, then an estimate of the felling-date range is possible by adding on the full compliment of, say, 15 to 35 years to the date of the last heartwood ring (called the heartwood/ sapwood boundary or transition ring and denoted H/S). Fortunately it is often easy for a trained dendrochronologist to identify this boundary on a timber. If a timber does not have its heartwood/sapwood boundary, then only a *post quem* date for felling is possible.

5. Estimating the Date of Construction.

There is a considerable body of evidence collected by dendrochronologists over the years that oak timbers used in buildings were not seasoned in medieval or early modern times (English Heritage 1998; Miles 1997, 50–5). Hence, provided that all the samples in a building have estimated felling-date ranges broadly in agreement with each other, so that they appear to have been felled as a group, then this should give an accurate estimate of the period when the structure was built, or soon after

(Laxton *et al* 2001, fig 8; 34–5, where 'associated groups of fellings' are discussed in detail). However, if there is any evidence of storage before use, or if there is evidence the oak came from abroad (eg Baltic boards), then some allowance has to be made for this.

6. Master Chronological Sequences.

Ultimately, to date a sequence of ring widths, or a site sequence, we need a master sequence of dated ring widths with which to cross-match it, a Master Chronology. To construct such a sequence we have to start with a sequence of widths whose dates are known and this means beginning with a sequence from an oak tree whose date of felling is known. In Figure A6 such a sequence is SHE-T, which came from a tree in Sherwood Forest which was blown down in a recent gale. After this other sequences which cross-match with it are added and gradually the sequence is 'pushed back in time' as far as the age of samples will allow. This process is illustrated in Figure A6. We have a master chronological sequence of widths for Nottinghamshire and East Midlands oak for each year from AD 882 to 1981. It is described in great detail in Laxton and Litton (1988), but the components it contains are shown here in the form of a bar diagram. As can be seen, it is well replicated in that for each year in this period there are several sample sequences having widths for that year. The master is the average of these. This master can now be used to date oak from this area and from the surrounding areas where the climate is very similar to that in the East Midlands. The Laboratory has also constructed a master for Kent (Laxton and Litton 1989). The method the Laboratory uses to construct a master sequence, such as the East Midlands and Kent, is completely objective and uses the Litton-Zainodin grouping procedure (Laxton *et al* 1988). Other laboratories and individuals have constructed masters for other areas and have made them available. As well as these masters, local (dated) site chronologies can be used to date other buildings from nearby. The Laboratory has hundreds of these site sequences from many parts of England and Wales covering many short periods.

7. Ring-Width Indices.

Tree-ring dating can be done by cross-matching the ring widths themselves, as described above. However, it is advantageous to modify the widths first. Because different trees grow at different rates and because a young oak grows in a different way from an older oak, irrespective of the climate, the widths are first standardized before any matching between them is attempted. These standard widths are known as ring-width indices and were first used in dendrochronology by Baillie and Pilcher (1973). The exact form they take is explained in this paper and in the appendix of Laxton and Litton (1988) and is illustrated in the graphs in Figure A7. Here ring-widths are plotted vertically, one for each year of growth. In the upper sequence of (a), the generally large early growth after 1810 is very apparent as is the smaller later growth from about 1900 onwards when the tree is maturing. A similar phenomenon can be observed in the lower sequence of (a) starting in 1835. In both the widths are also changing rapidly from year to year. The peaks are the wide rings and the troughs are the narrow rings corresponding to good and poor growing seasons, respectively. The two corresponding sequence of Baillie-Pilcher indices are plotted in (b) where the differences in the immature and mature growths have been removed and only the rapidly changing peaks and troughs remain, that are associated with the common climatic signal. This makes cross-matching easier.

t-value/offset Matrix

	C45	C08	C05	C04
C45		+20	+37	+47
C08	5.6		+17	+27
C05	5.2	10.4		+10
C04	5.9	3.7	5.1	

Bar Diagram

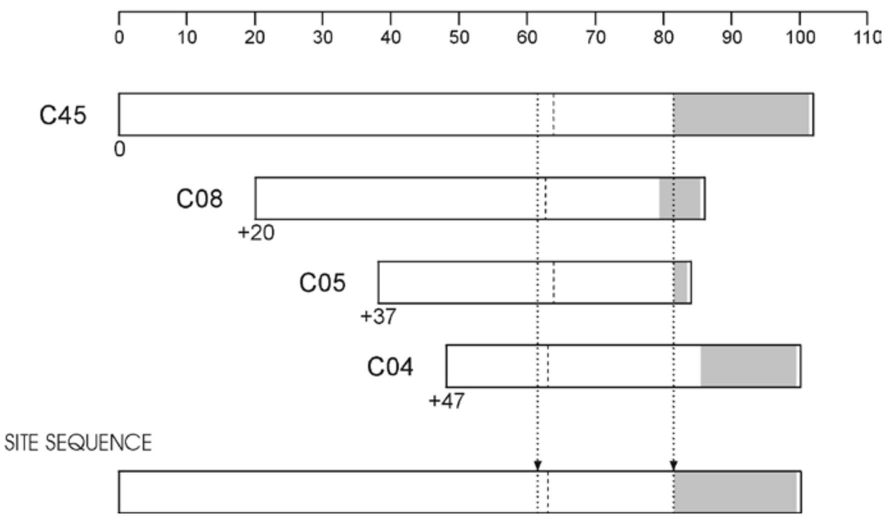


Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them

The bar diagram represents these sequences without the rings themselves. The length of the bar is proportional to the number of rings in the sequence. Here the four sequences are set at relative positions (offsets) to each other at which they have maximum correlation as measured by the *t*-values. The *t*-value/offset matrix contains the maximum *t*-values below the diagonal and the offsets above it. Thus, the maximum *t*-value between C08 and C45 occurs at the offset of +20 rings and the *t*-value is then 5.6. The site sequence is composed of the average of the corresponding widths, as illustrated with one width.

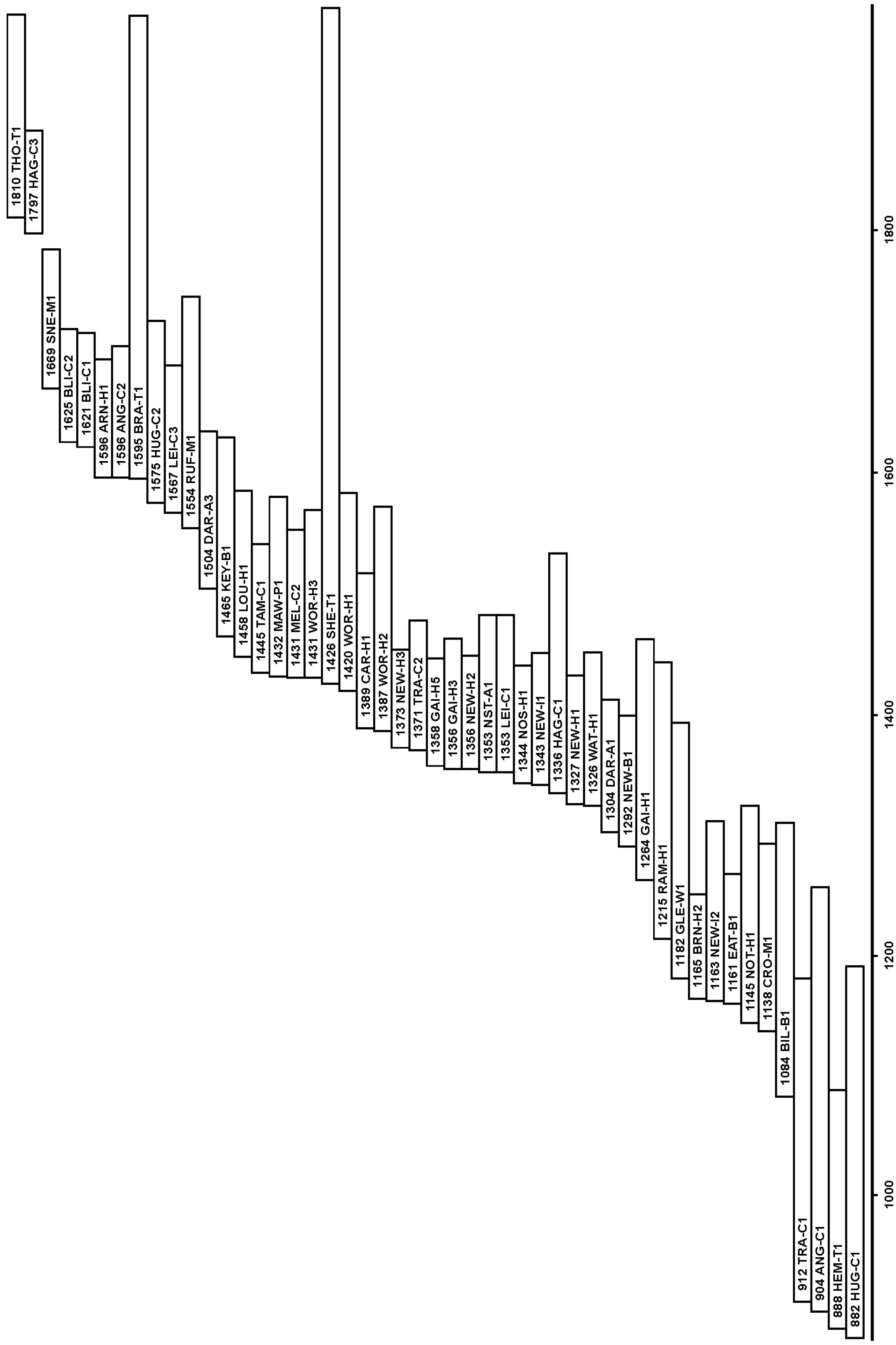
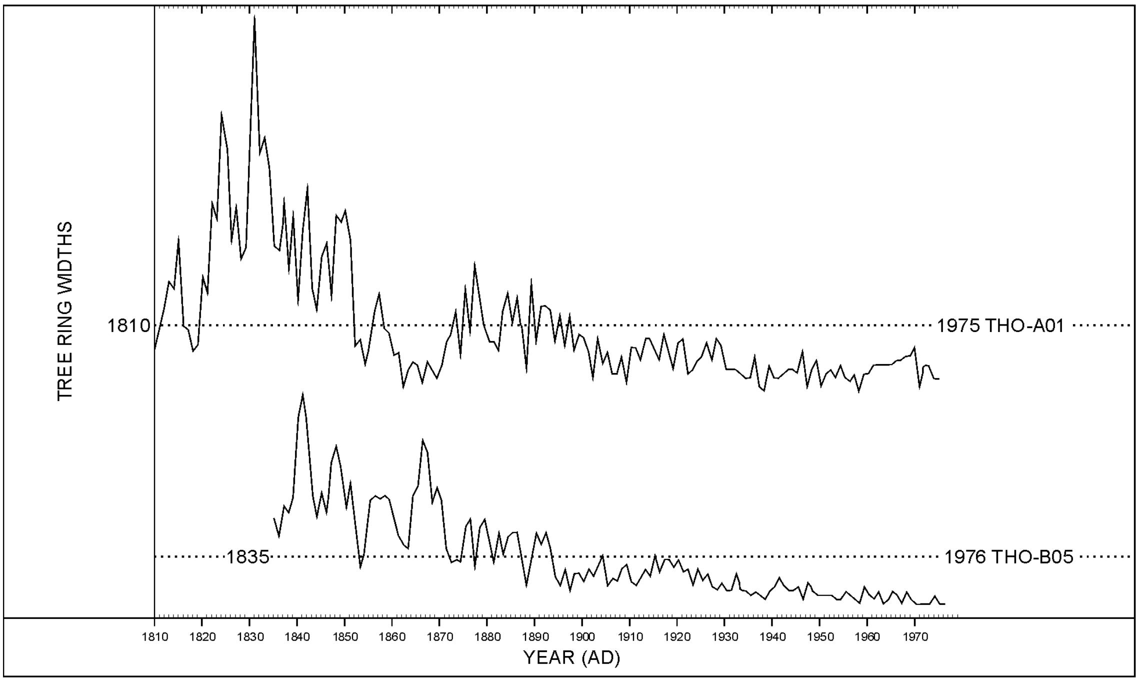


Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

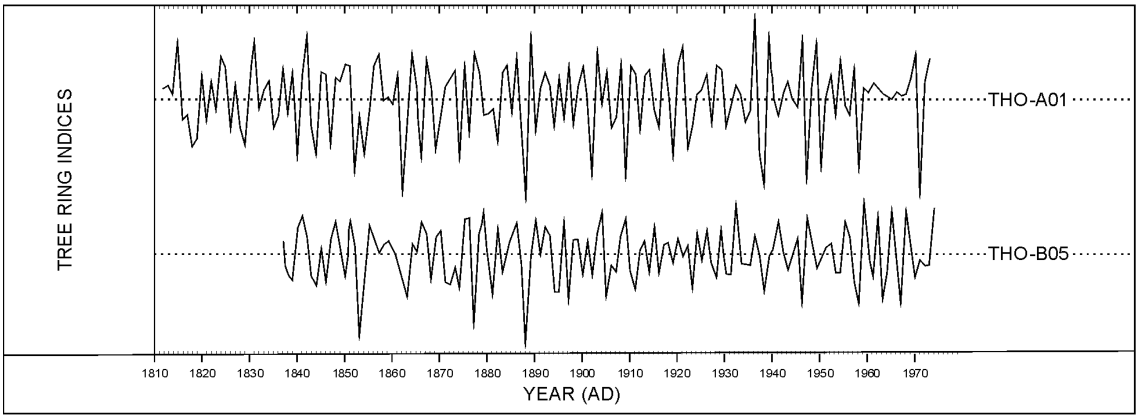


Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known

Here the ring widths are plotted vertically, one for each year, so that peaks represent wide rings and troughs narrow ones. Notice the growth-trends in each; on average the earlier rings of the young tree are wider than the later ones of the older tree in both sequences

Figure A7 (b): The Baillie-Pilcher indices of the above widths

The growth trends have been removed completely

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