

FARMSTEADS AND FUNERARY SITES

**THE M1 JUNCTION 12 IMPROVEMENTS
AND THE A5–M1 LINK ROAD
CENTRAL BEDFORDSHIRE**

**ARCHAEOLOGICAL INVESTIGATIONS
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of all the research notes and data sets are contained within the archive held by Luton Culture.

This publication is dedicated to Anne Foard, who passed away in November 2017 after many years with Northamptonshire Archaeology, and later MOLA Northampton. Her hard-work and dedication during several stages of this project helped this publication come to completion.

Chapter 1

INTRODUCTION

This publication presents the results of archaeological fieldwork conducted on two separate highway schemes in close geographical proximity and with strong archaeological relevance to each other. Both projects were conducted in advance of construction, commissioned by Costain-Carillion Joint Venture (CCJV) for Highways England, monitored and managed by the designer's archaeologists, AECOM (formerly URS, formerly Scott Wilson), in consultation with Central Bedfordshire Council (CBC).

LOCATION AND CIRCUMSTANCES OF THE FIELDWORK

The M1 Junction 12 improvements and the A5–M1 link road both lie in south Central Bedfordshire, immediately to the north of Luton and Dunstable (Fig 1.1). The two schemes are 4.5km apart. The M1 Junction 12 lies on a spur along the north side of the Flit Valley near Toddington and was improved in 2011. The next valley to the south of this belongs to the Ouzel Brook, a tributary of the River Ouzel. The A5–M1 link road,

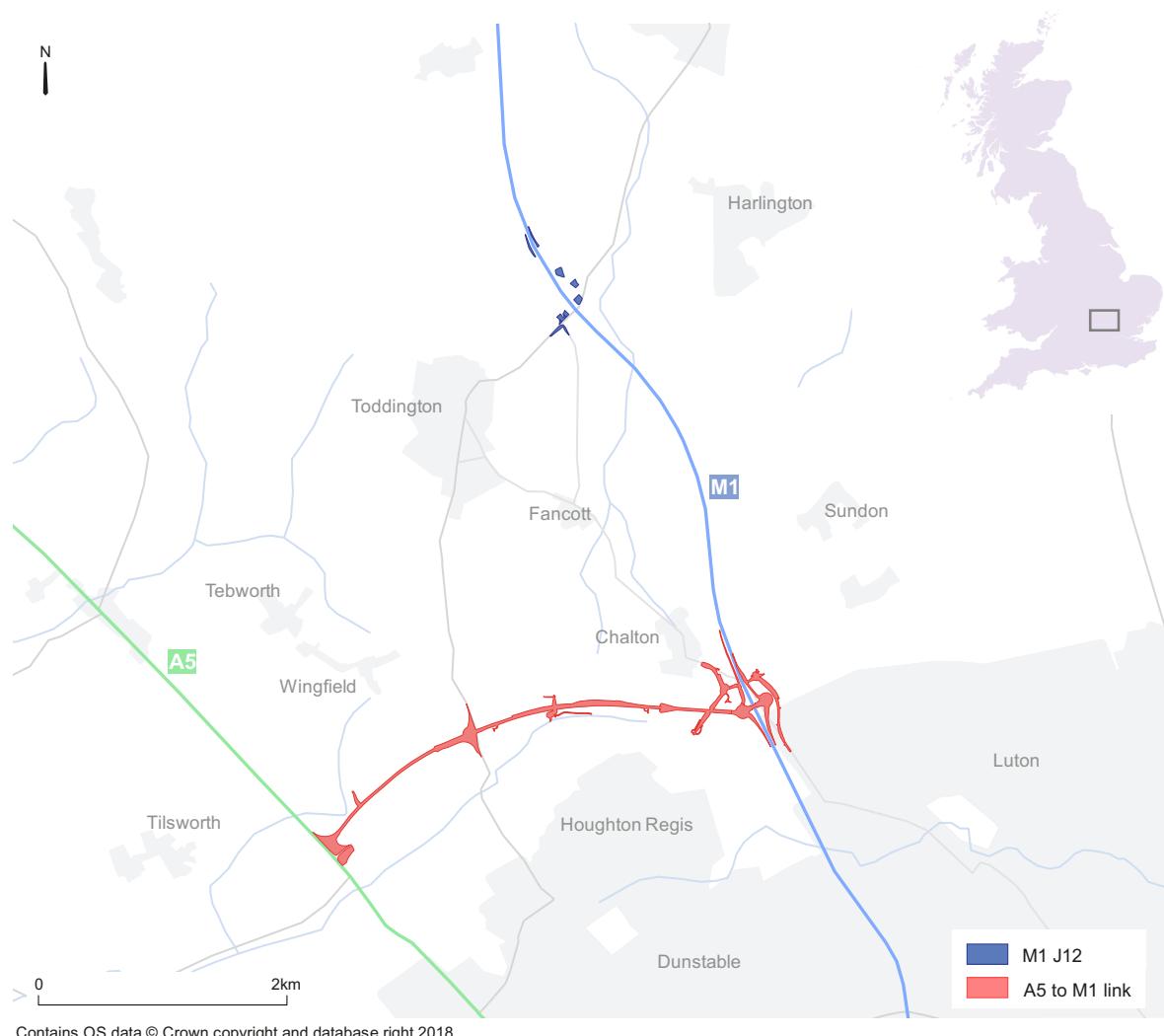


Fig 1.1 Location of the M1 Junction 12 improvements and the A5–M1 link road

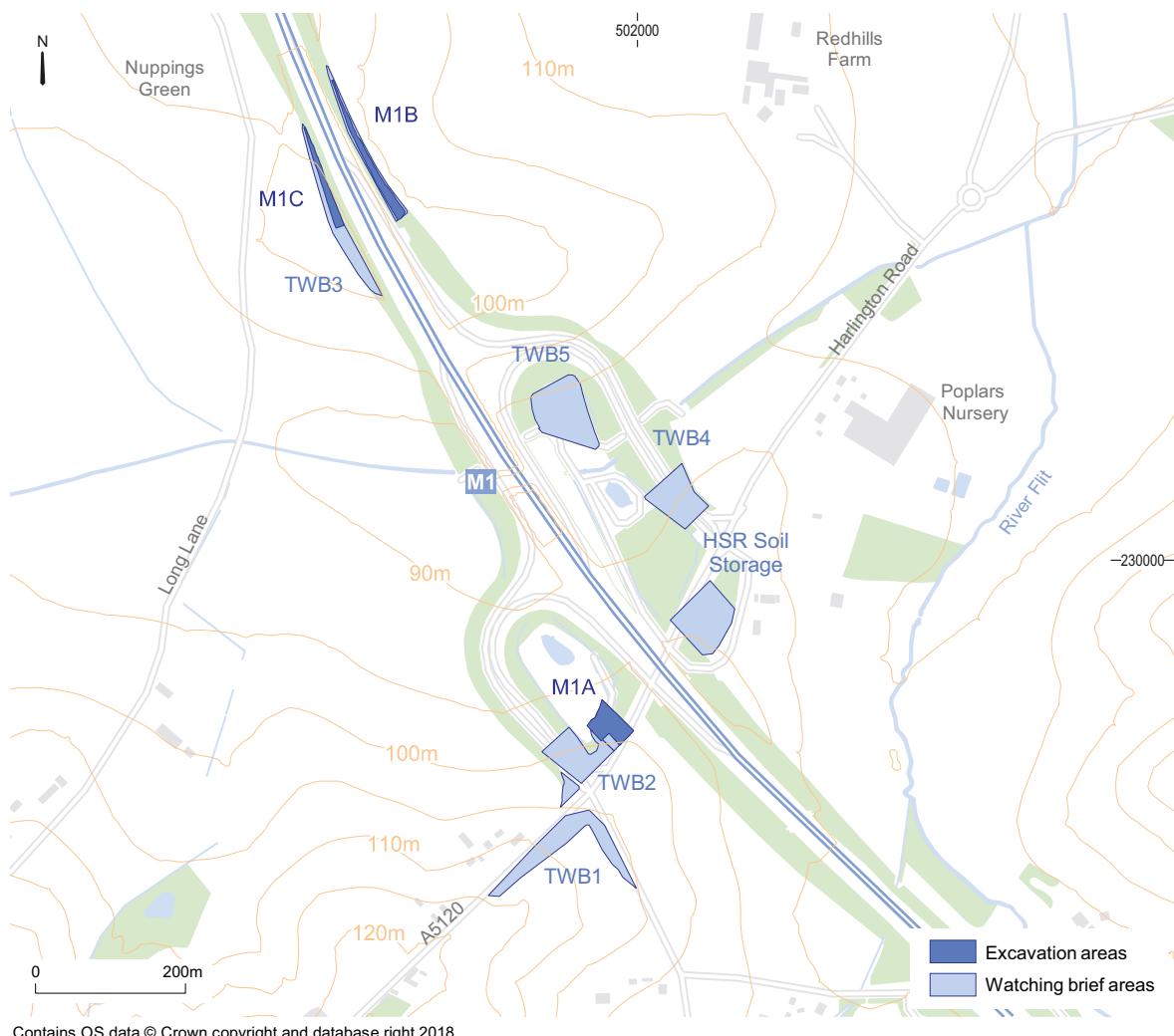


Fig 1.2 Fieldwork locations, M1 Junction 12

which was built in 2015–16, follows a route along this tributary valley and its junction with the M1 (Junction 11a) lies at the crest of the watershed with the Flit Valley at its east end. Both schemes are geographically interrelated and produced evidence that comes from parts of the same archaeological landscape.

M1 JUNCTION 12 IMPROVEMENTS

Between February and April 2011, Northamptonshire Archaeology (NA), now Museum of London Archaeology (MOLA), carried out a series of archaeological excavations in the vicinity of M1 Junction 12, near Toddington, Central Bedfordshire (Fig 1.2; NGR TL 01947 29821 and TL 01699 30297).

A series of works, including an Environmental Impact Assessment, has been undertaken since 1992. Initially, fieldwalking was undertaken in advance of the Environmental Statement for the preferred route of the M1 widening, Junctions 10–15 (Acer 1994; BCAS 1992; 1993; 1995). This was followed by a desk-based study and detailed walkover in support of Stage 2 Assessment for

a modified preferred route. NA conducted fieldwalking and geophysical surveys in 2006 for the Stage 3 Detailed Assessment (Mudd 2006a–b; HA 2007b). Stage 3 reviewed all documentary and desk-based study evidence and the archaeological analysis of LiDAR data (HA 2007d). The work was subsequently updated with the results of additional fieldwalking and geophysical surveys by NA (Burrow 2008a; Butler 2008).

Following these preliminary investigations URS determined that a further programme of archaeological evaluation would be undertaken prior to development to comply with the *Design Manual for Roads and Bridges* (HA 2001). A Written Scheme of Investigation (WSI) outlined the requirements of the programme (HA 2010), and trial trench evaluation was then undertaken by NA (Walker 2010), according to industry guidance and standards and the Northampton Archaeology fieldwork manual (NA 2006).

The evaluation confirmed the presence of important archaeological remains and it became apparent that further investigations would be required. An updated

WSI outlined an archaeological mitigation design (HA 2011), with specific provision for detailed archaeological excavation of significant archaeological sites, targeted watching briefs (TWB), historic hedgerow recording and building recording of the 1960s motorway overbridge. Method statements were prepared by NA in advance of the fieldwork (Brown 2011; Walsh 2011). The Accession code, LUTNM:2010.67, was assigned by Luton Culture in agreement for the receipt of the archive in accordance with their deposition requirements (BM 2010).

Detailed archaeological excavation was required for a late Iron Age/Roman cremation cemetery and adjacent ditches at Site M1A, a pyre site and nearby ditches at Site M1B, and medieval to post-medieval occupation at Site M1C, the latter including a pot bank of pottery wasters (Fig 1.2, 1.20). Five targeted controlled archaeological watching brief areas (TWBs) were defined and monitored for indications of further significant archaeology where sparse or dispersed archaeological remains had been identified (Fig 1.2). Following the discovery of the medieval potters' waste and associated post-medieval building deposits at Site M1C, an updated site-specific excavation strategy was implemented (URS 2011; Figs 1.19 and 1.20).

In addition, a section of historic hedgerow, identified in the Cultural Heritage chapter of the Environmental Statement, was recorded before its removal (HA 2009a), and building recording was conducted to English Heritage Level 2 standard on the M1 motorway overbridge prior to dismantling (EH 2006b; Upson-Smith 2012). A small-scale general watching brief with negative results was conducted at TL 05196 23488, near Leagrave, Luton (Brown 2012a).

After completion of the fieldwork, a Stage 1 assessment report and updated project design was compiled to address key themes for local and regional research and to outline further work (Clarke 2012). This work led on to a Stage 2 analysis report that formed a synthesis of the further work (Brown 2015c), and is the basis for Chapters 4 and 8 within this volume.

A5-M1 LINK ROAD

This scheme comprised a 4.5km long dual carriageway link from the A5, on the north side of Dunstable, to the M1 motorway on the south-west side of Chalton where Junction 11a was built (Fig 1.1; between NGR SP 99602 24460 and TL 0383 2587; Figs 1.5 and 1.6).

Initial archaeological surveys were undertaken in 2006–7 to assess the cultural heritage impact of the scheme and to inform an Environmental Statement (HA 2009b). Desk-based assessment of a Baptist burial ground at Thorn was undertaken by Scott Wilson (HA 2006c). The

report concluded that the extent of the burial ground would not be affected by a proposed overbridge that would be constructed nearby.

Selected geotechnical trial pits were monitored during excavation (HA 2007c) and geophysical survey was conducted along available sections of the route (Burrow 2008a). An archaeological trial trench evaluation was undertaken to assess the results of the geophysical survey, where accessible, and to investigate the archaeological potential near Thorn Farm (Simmonds and Fisher 2008, NA 2006). A total of 29 trenches of various sizes were excavated, which produced evidence of archaeological activity dating from the Bronze Age to the post-medieval period, complementing the geophysical surveys.

Further work commenced in May 2014 to expand the evaluation into areas that were previously inaccessible; the scheme of work was outlined in a WSI prepared by AECOM (HA 2014a-b). A further 43 trial trenches and 27 hand excavated test pits were investigated as part of this phase (Brown 2014a; 2015a-b). These later stages of work were undertaken according to the MOLA fieldwork manual (MOLA 2014b). The product of these evaluations, both in 2007–8 and 2014–15, was a broader overall understanding of the distribution, date and extent of archaeology across the whole scheme, allowing a mitigation strategy to be formulated.

The requirements of the mitigation strategy are described in the *Archaeological Strategy Report* (HA 2014a). A WSI was prepared by AECOM that established a detailed design for the archaeological mitigation (HA 2015a). Further *Archaeological Design Documents* (FADDs) were issued to provide greater technical clarification on the scope and extent of mitigation for specific areas, using the initial WSI as the baseline for the project aims, objectives and methodology (Table 1.1; HA 2015b-h). Areas of archaeological mitigation were spread throughout the catchment of the scheme (Figs 1.3–1.4). These works commenced in February 2015 and the majority of fieldwork was completed by the end of June, with final monitoring of general watching briefs in minor areas extending until July 2016.

A single combined archive of records and artefacts was compiled for the evaluation and mitigation work as a whole. The paper archive comprises the initial *Strategy Report* (HA 2014a), *Detailed Design* (HA 2015a), each subsequent FADD (Table 1.1), all pertinent background information, method statements (MOLA 2014a; 2015), permatrace site plans, section drawings, field record sheets, registers, photographs (both digital images and 35mm monochrome contact prints), previous archaeological reports (Simmonds and Fisher 2008; Burrow 2008b; Brown 2014a-b; 2015a-b, d), the Stage 1 *Assessment and Updated Project Design* (Brown 2016), a

FARMSTEADS AND FUNERARY SITES

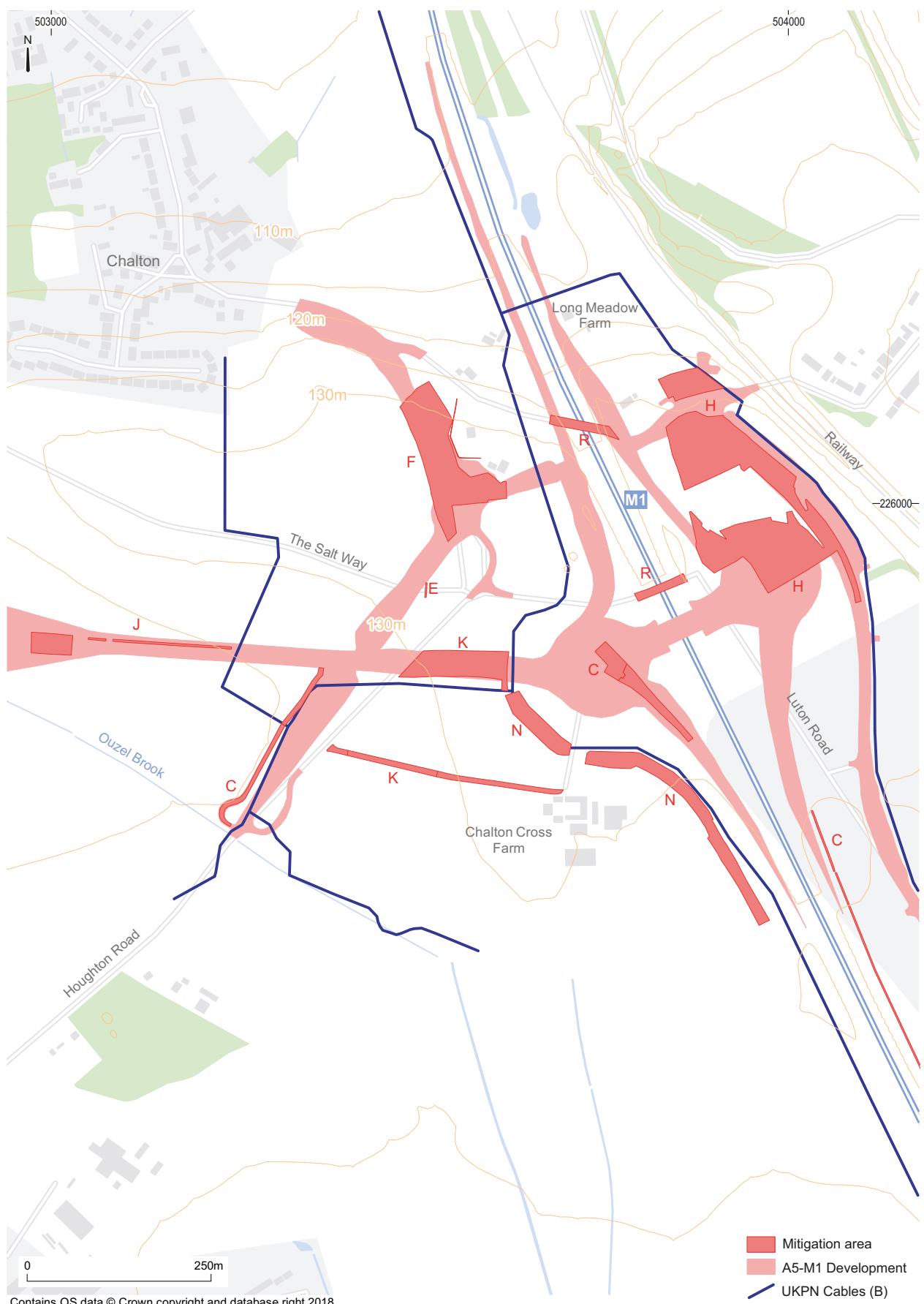


Fig 1.3 Fieldwork locations, M1 Junction 11a for the A5-M1 link road

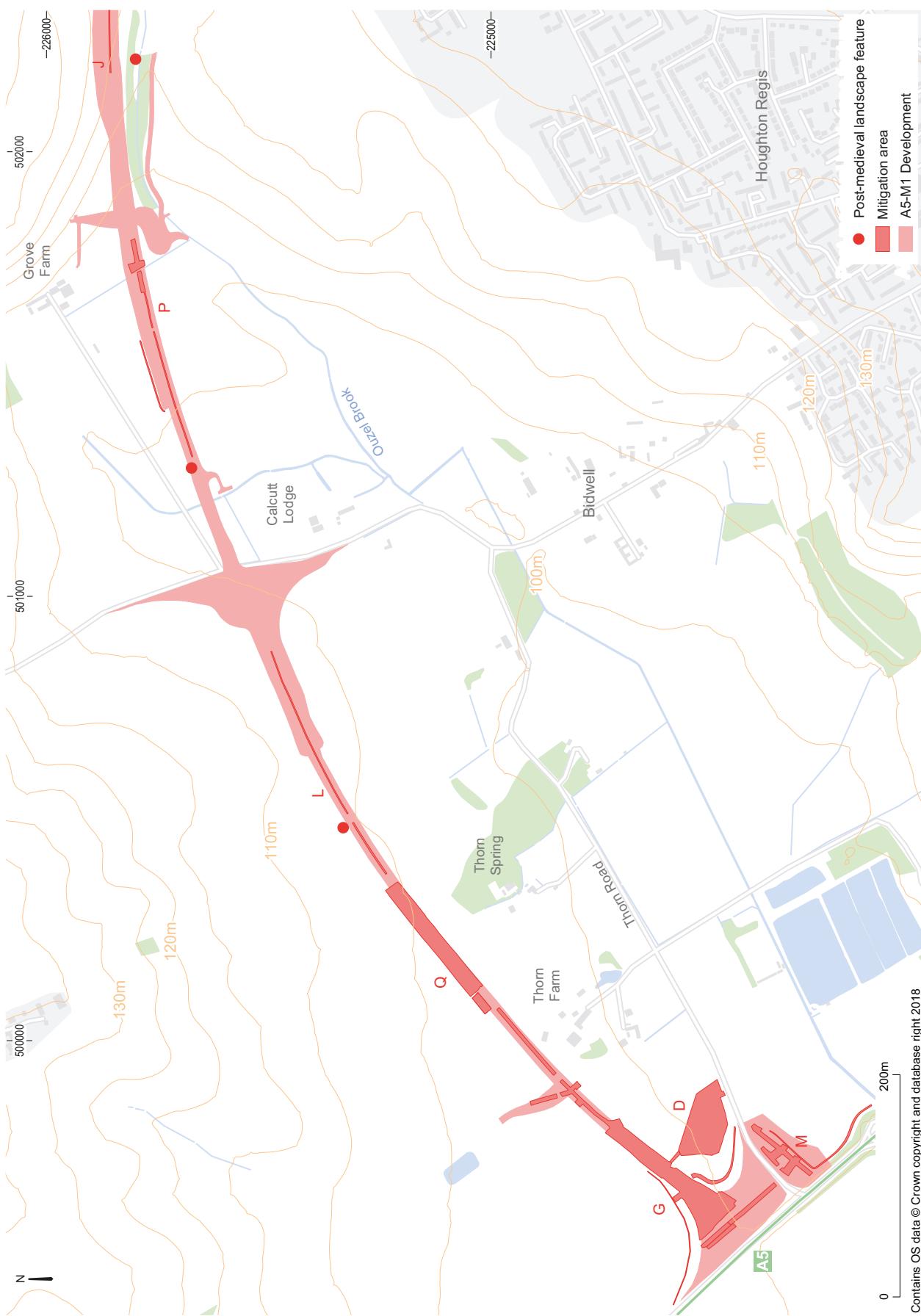


Fig 1.4 Fieldwork locations along the western extent of the A5-M1 link road

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Table 1.1: Site codes and common names used for post-excavation, reporting, publication and accession of the archive

Archive code	Environmental Statement	Specification for work carried out	Location	Description of archaeology found
A	Sites 5-9	Archaeological trial trench and hand-dug test pit excavations (HA 2014b), following on from earlier evaluation surveys (Simmonds and Fisher 2008; Burrow 2008b)	Scheme-wide	various suspected features confirmed and an absence of features demonstrated in other locations
B	Sites 8-9	General watching brief for UKPN on cable trenches (HA 2014c)	Long Meadow Farm NGR TL 04077 25957	undated, probably prehistoric, pit
C	Site 8	General watching brief for CCJV at M1 Junction 11a (HA 2015d)	Chalton Cross Farm NGR TL 03786 25714	late Bronze Age/early Iron Age pits undated, probably middle Iron Age boundaries
D	Site 1	Detailed archaeological excavations of the Thorn Road site compound (HA 2015b)	Thorn Road NGR SP 99743 24516	early Iron Age pit clusters and middle Iron Age field systems
E	Sites 10	Topographic survey and hand excavated mitigation trenches (HA 2014d)	Salt Way (<i>Thiodweg</i>) NGR TL 03482 25886	no evidence of ancient trackway undated spread overlain by post-medieval bank
F	not identified	Detailed archaeological excavations and targeted watching brief at Luton Road, Chalton (HA 2015c)	Luton Road NGR TL 03553 26042	late Iron Age/Roman cremation cemetery and charnel pit early/middle Saxon pottery and loomweights medieval settlement; buildings, enclosures and pits
G	Site 1, Area 2	Detailed archaeological excavations and targeted watching brief between Thorn Farm and A5 Watling Street (HA 2015d-e)	Thorn Road NGR SP 99590 24540	early-middle to late Iron Age settlement widely distributed field boundaries isolated roundhouse, north-east of main settlement
H	Site 9	Detailed archaeological excavations and targeted watching brief at Long Meadow Farm, east of the M1 Junction 11a (HA 2015f)	Long Meadow Farm NGR TL 03904 26071	late Bronze Age/early Iron Age pits late Iron Age/Roman trackways and enclosures late Iron Age/Roman pyres and cremation cemetery late-middle Saxon inhumation burials
I	archive code not used		-	-
J	Site 7	General and targeted watching brief for Ch3100-4150 (HA 2015d)	Land north of the Ouzel Brook NGR TL 02999 25815	late Iron Age ditches and pits late Iron Age marsh
K	east of Site 8	Detailed archaeological excavations and targeted watching brief at Chalton Cross Farm (HA 2015g)	Chalton Cross Farm NGR TL 03566 25767	undated, probably middle Iron Age, boundary ditches early-middle Iron Age storage pits and pit cluster
L	Site 11	Topographic survey and hand excavated mitigation trenches (HA 2014d)	Historic hedgerow NGR TL 00500 25320	no evidence of historic boundary modern drainage ditch
L	not identified	General watching brief for Ch1180-1750 (HA 2015d)	Fields west of the A5120 NGR TL 00558 25329	undated palaeochannel Iron Age colluvial/alluvial layers
M	Site 1, Area 1	Detailed archaeological excavation of the Thorn Road balancing pond and general watching brief on the nearby drainage ditch (HA 2015e)	Thorn Road balancing pond NGR SP 99732 24320	largely undated pit alignment, possibly Bronze Age later undated boundary ditches, probably Iron Age
N	east of Site 8	General watching brief for the National Grid gas pipeline (HA 2015d)	Chalton Cross Farm NGR TL 03790 25651	undated, probably middle Iron Age, boundary ditches
O	archive code not used		-	-
P	Site 12	Topographic survey and hand excavated mitigation trenches (HA 2014d)	Historic hedgerow NGR TL 01300 25660	undated, probably post-medieval, bank and ditch
P	Site 6	General and targeted watching brief at Grove Farm (HA 2015d)	Grove Farm NGR TL 01724 25815	undated, probably Iron Age, pit alignments undated, probably Iron Age, boundary ditches

Archive code	Environmental Statement	Specification for work carried out	Location	Description of archaeology found
Q	Site 3	Detailed archaeological excavations at Thorn Farm, north of Thorn Spring (HA 2015h)	Thorn Farm NGR TL 00241 25125	middle Bronze Age enclosure late Iron Age boundary ditches and enclosures late Iron Age/Roman enclosure ditches late Iron Age/Roman burials medieval timber building and boundary ditches post-medieval boundary ditches
R	2017 & 2018	Houghton Regis Overbridge, 2017, and Chalton Overbridge, 2018, Bridge recording at M1 Junction 11a (HA 2014e)	M1 motorway NGR TL 03721 26108 NGR TL 03822 25892	1958-9 motorway overbridges
S	not identified	Archaeological topographic recording and trench mitigation at Ouzel Brook (HE 2015)	Ouzel Brook crossing NGR TL 02212 25788	post-medieval embankment for stream crossing
T	not identified	General watching brief at M1 motorway, Pond 6 (HA 2015d)	M1 balancing pond 6 NGR TL 04420 24530	undated gullies

copy of this Stage 2 analysis report, and supplementary material used during the post-excavation process. The paper archive is accompanied by the material archive, prepared for Luton Culture under LTNMG:1093 (BM 2010).

For the purpose of keeping an orderly archive, a letter was appended to the entry code as a suffix (Table 1.1). These site codes were used to identify archaeological

sites and to separate archival stages of work; they do not relate to area codes in the *Detailed Design* (HA 2015a), many of which became redundant following the evaluation surveys.

The Stage 1 Assessment and UPD, produced after the fieldwork (Brown 2016), laid out the research principles for post-excavation analysis and informed this Stage 2 analysis report.



Fig 1.5 Aerial view taken from above M1 Junction 11a, looking west along the road corridor



Fig 1.6 Aerial view taken from above A5 Watling Street, looking east along the road corridor

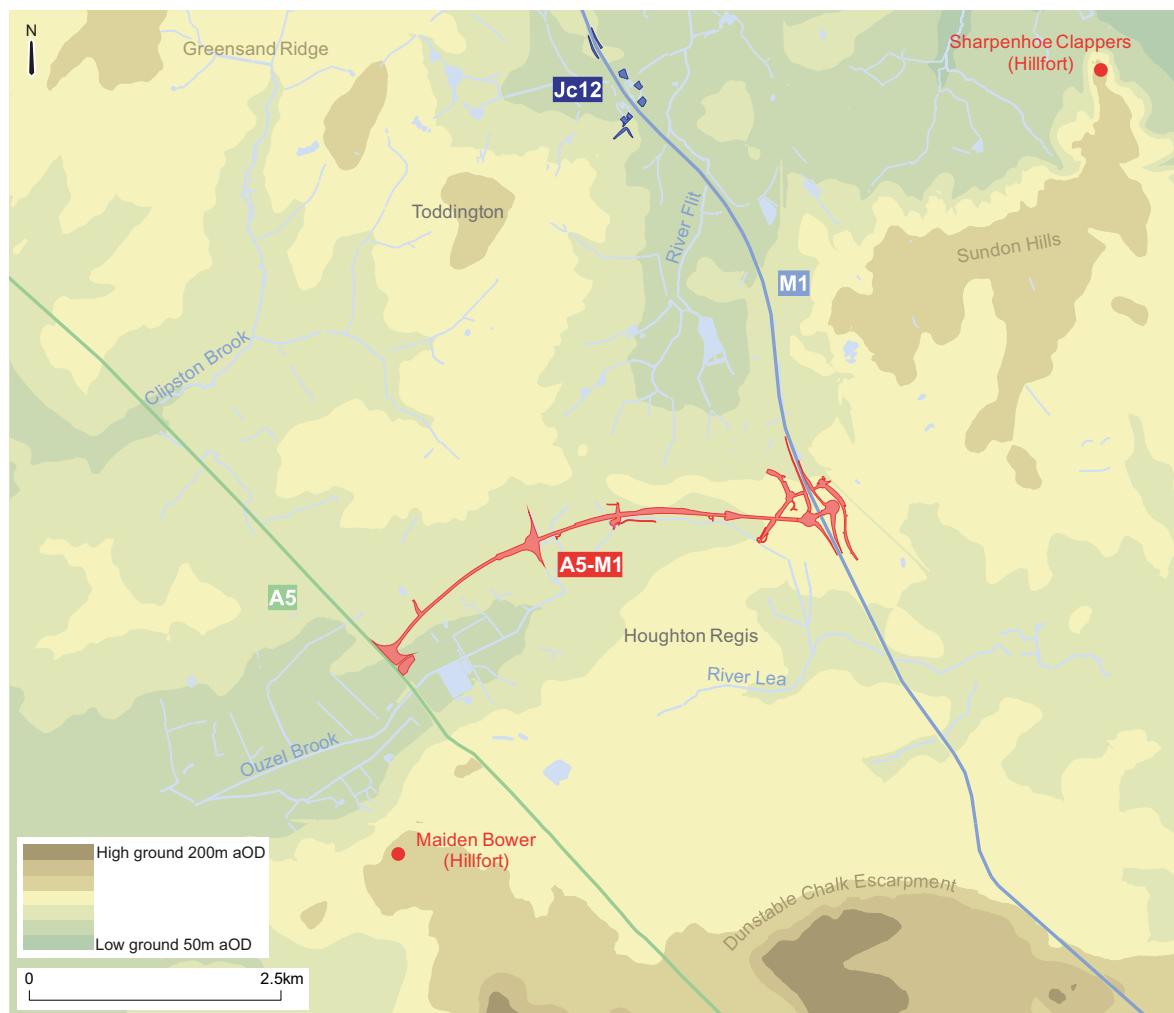
LANDSCAPE CHARACTER, TOPOGRAPHY AND GEOLOGY

The two schemes lay in close proximity in an area of landscape that changes subtly in character between Toddington and Houghton Regis (Fig 1.7). The *Central Bedfordshire Landscape Character Assessment* (CBC 2016) describes the relationship between these areas, both of which have been severely impacted by the intensification of transport and communication routes since the 19th century, further compounded by urban growth. Generally, the landscape changes from clay hills to rolling chalk farmland (*ibid*, types 8 and 10).

Toddington is situated within undulating clay hills that fall away from the Greensand Ridge to the north. Nearby settlements tend to lie upon elevated ground with views across the adjacent vales, similar to the known distribution of Iron Age and later settlements. There is little modern woodland and the countryside is characterised by a patchwork of fields bordered by hedgerows (Fig 1.8). Farmsteads, similarly, are scattered across the clay hills, acting as landmarks. Distant views occur from most major hilltops, giving a sense of landscape and place. Small areas of post-medieval parkland bring together modern arable and older pastoral land introducing livestock to the scene.

South-west of Toddington there survives a medieval pattern of nucleated settlements immediately surrounded by irregular older enclosures, within which earthworks representing shrunken settlement can often be found. Moated sites with fishponds are common to many of these historic sites. Tebworth and Wingfield each have a planned layout based around greens and instances of multiple townships within each parish are not uncommon to the region. To the east of Toddington the historic parish boundaries of Tingrith, Harlington and Westoning had a complicated arrangement, perhaps because a large woodland once lay beyond the open fields of Toddington, and was later cleared for agriculture (CBC 2016). Ridge and furrow, which is otherwise infrequent across the county, is found in many of the pasture fields. The open fields were largely enclosed by Act of Parliament in the late 18th century.

Further south, towards Houghton Regis, the prominent clay hills give way to gently rolling chalkland dominated by arable fields (Fig 1.9). Most derive from parliamentary enclosure with some smaller, perhaps older, enclosures around the edges of villages often associated with earthworks. Hedgerows, wooded coppices and dispersed farmsteads break up the open countryside and sometimes inhibit views. Medium to



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Fig 1.7 Topography of the landscape between Toddington and Houghton Regis



Fig 1.8 View looking north-west from Leighton Road, Toddington, towards Milton Bryan

long range views extend across the flatter land within the valley of the Ouzel Brook. These views are impinged upon by Houghton Regis to the south, creating an invasive urban character that permeates the otherwise rural surroundings. There are distant views towards the South Dunstable Chalk Escarpment that give an

impression of how the terrain appeared before the urban growth, and which provide a distant natural landmark (Fig 1.10). Landmarks, natural or otherwise, are largely absent. Few of the churches, for instance, stand prominently in the landscape, and their bell towers rarely rise above the surrounding settlements.



Fig 1.9 View looking south-east from Chalgrave All Saints Church towards Chalton and Houghton Regis



Fig 1.10 View looking south from Lord's Hill, Wingfield, towards Dunstable

TOPOGRAPHY AND GEOLOGY AT M1 JUNCTION 12

The sites lay between Toddington and Harlington, mainly on the west side of the M1 Junction 12. Prior to construction the site comprised arable fields on either side of the motorway. The ground level rose gently to the north and south of a small tributary valley, c.90–100m above Ordnance Datum (aOD). The various archaeological sites and targeted watching brief areas were located on the slopes, ridges and in the base of this valley (Fig 1.2). The late Iron Age/Roman cemetery site at Site M1A was located on the lower spur of the valley ridge with a tributary confluence to the north-east. Remnants of a pyre site and ploughed-out stone cairn at Site M1B, and the medieval potters' waste at Site M1C, were located on the upper slope and ridge on the opposite side of the valley to the north-west. The whole area is now an active and busy motorway junction compared to its former rural character (Figs 1.11–1.13).

The bedrock geology is mudstone, sandstone and limestone of the Gault and Upper Greensand Formations and the superficial geology is composed of

diamictite (Anglian till) deposits (BGS 1996; 2001; 2018). The soils are mainly of Ashley association, which are characterised by chalky till and comprise fine loamy over clayey soils with slowly permeable subsoil and slight seasonal waterlogging (LAT 1983, 572q).

TOPOGRAPHY AND GEOLOGY ALONG THE VALLEY OF THE OUZEL BROOK

The A5–M1 link road follows the Ouzel Brook Valley from the high ground in the east and descends westwards towards the A5. The M1 Junction 11a lies upon a low natural plateau between the valley of the River Flit to the north, the headwaters for the River Lee to the south-east, and the Ouzel Brook to the south-west (Fig 1.3). The fields around the junction are fairly level and slope very gradually into the valley from c.130m aOD. As the road corridor proceeds west it drops gradually along the north side of the Ouzel Brook onto the upper flood plain at c.105m aOD where it crosses the A5120 (Fig 1.5). The land is then fairly flat with a very gentle downward slope towards the A5 at c.100m aOD (Fig 1.6). The land through which the road passes is mainly arable, with a small amount of pasture in the



Fig 1.11 View looking north-west from Harlington Road, Toddington, before development



Fig 1.12 View looking north-west from Harlington Road, Toddington, during excavation



Fig 1.13 View looking north-west from Harlington Road, Toddington, after completion



Fig 1.14 Aerial view taken from above Wingfield, looking east toward M1 Junction 11a

vicinity of Grove Farm (Fig 1.14). Land boundaries are defined by modern drainage ditches and hedgerows, usually without an apparent bank.

The solid geology comprises units of the Upper Cretaceous (BGS 2001; 2018). The topsoil and subsoil is underlain by both the West Melbury Marly Chalk Formation (Chalk Marl) and Zig Zag Chalk Formation (Grey Chalk), separated with a thin band of Doolittle Limestone. Glacial till was shown to overlie the chalk upon the ridges around M1 Junction 11a.

The soils of the plateau at M1 Junction 11a are of Swaffham Prior association, comprising well drained calcareous coarse and fine loamy soils over chalk (LAT 1983, 511e). The slopes into the valley are covered by soils of Wantage 1 association, which are similar but siltier, and which follow the Ouzel Brook (*ibid*, 342c). The western extent of the route, from the fields west of Grove Farm to the A5, has soils of Block association, which are permeable calcareous loamy soils over chalky gravel (*ibid*, 512e). These soils only form over Cretaceous chalk.

AIMS AND OBJECTIVES OF THE FIELDWORK

The present work is based upon the *Design Manual for Roads and Bridges* and follows the premise that 'remains should be archaeologically recorded in order

to 'preserve [them] by record' (HA 2001, vol 10-6, pt 1, 2/1). This has been undertaken in accordance with an established documented procedure, using approved methods and in consultation with the local authority.

The directive of the archaeological mitigation was to ensure that the resources channelled into the fieldwork targeted tangible research objectives that would produce outcomes capable of making a contribution to archaeological knowledge, proportional to the significance of the remains that were found. Key research themes were drawn from national and regional research frameworks established by Historic England (EH 1997), and archaeologists in the Eastern Counties (Brown and Glazebrook 2000; Medlycott and Brown 2008; Medlycott 2011), and in Bedfordshire (Oake *et al.* 2007).

The archaeological strategy report for the A5–M1 link road (HA 2014a, 2.3) identified overarching themes that were relevant to the region, but which were in themselves too broad for the scope of this project. These topics were translated into site specific objectives following the Stage 1 assessments (Clarke 2012; Brown 2016a).

The approach to both road schemes was essentially the same. The methods of providing mitigation to achieve these objectives were determined by the archaeological

potential as demonstrated by evaluations, targeted stripping and the likely impact of construction. The methods used were detailed archaeological excavation (HA 2015a), targeted watching brief, general watching brief, Level 3 topographic survey (Historic England 2015b) and Level 2 building recording (Historic England 2015a).

M1 JUNCTION 12 IMPROVEMENTS

Detailed archaeological excavation of Site M1A was required to investigate possible industrial/craft waste identified during evaluation and to understand production processes, sources of raw material, products and the economy of the site. Subsequent investigation led to the discovery of the Harlington Road cemetery.

For medieval rural occupation (Site M1B) there was a directive to investigate the type, form and date of surviving structural or building remains associated with cobbled surfaces and burnt timber identified during evaluation. Two medieval ditches were found at the site, but there was no evidence for a medieval building or surfaces, and the remains were instead found to be associated with a late Iron Age *bustum* burial and pyre site (Fig 1.15).

Chance discovery of medieval potters' waste and post-medieval buildings at Site M1C during the targeted watching brief allowed these objectives to be appropriated for a different site. In addition, the work sought to confirm the relationship with the adjacent historic settlement at Nuppings Green, and to seek to understand its economy, agricultural regimes and cereal crop processing. This was possible from the perspective of the potters' economic activities, although bulk soil samples produced insufficient plant macrofossils to inform upon agricultural activities.

Specific aims of the targeted watching briefs were directed toward obtaining dating material in order to place archaeological features of otherwise unknown date within a chronological framework. This was successful where archaeological features were identified (Site M1C) and detailed hand excavation was undertaken to recover artefacts and other datable evidence.

The specific objective of the historic hedgerow recording was to record the presence/absence and date of any surviving buried soil horizons sealed beneath the hedge bank. In actual fact no buried soil horizons were found. Topographic survey and hand excavated mitigation trenches examined some additional earthworks and historic trackways to



Fig 1.15 Cremation burials required detailed excavation, Site M1A



Fig 1.16 Hand-excavated trench providing a cross-section through Site E



Fig 1.17 The Chalton overbridge before demolition, Site R, looking south-east

examine and record a cross-section of such features before removal (Fig 1.16).

The objective of the building recording survey of the overbridge (Fig 1.17) was to provide a permanent record of the structure to Historic England Level 2 standards.

A5-M1 LINK ROAD

The objectives set out in the Written Scheme of Investigation (HA 2015a, 8) remained fairly general because of the rapid onset of construction immediately following on from the final stages of evaluation. The WSI included research themes from the archaeological strategy report (HA 2014a), which are incorporated into the following section. Although reconnaissance surveys and evaluations had been undertaken from 2006–7, the scheme had sat in abeyance until a Principal Contractor was confirmed in 2014. This meant that completion of the evaluation in many areas had awaited full land access. With little time between evaluation and the start of construction, the ability to establish site-specific objectives was limited and so these evolved as a product of ongoing discoveries, which were subsequently outlined by the Stage 1 assessment report (Brown 2016).

RESEARCH THEMES AND THE SIGNIFICANCE OF RESULTS

The archaeological strategy report for the A5–M1 link road identified specific research themes that were in themselves too broad for the scope of the project (HA 2014a, 2.3). The topics were refined and were incorporated into the research themes below, closely identified with individual site specific evidence and in order to support future synthetic studies in the region.

PALAEOLITHIC, MESOLITHIC AND NEOLITHIC

The sole requirement for these periods was to provide a permanent archival record of worked flint artefacts and stone tools. There were no research objectives immediately relevant for any sub-divisions of the Stone Age. An assessment of residual Neolithic worked flint and a polished stone axe is contained upon the accompanying digital content package.

BRONZE AGE

The requirement for this period was to:

- provide a permanent archival record of archaeological features and artefacts where they were encountered; and to,
- include such evidence within the broader scope of understanding the process, development and character of occupation (HA 2014a).

Late Bronze Age/early Iron Age settlement evidence in Bedfordshire was characterised mainly by association with barrows along the river valleys (Dawson 2007, 59). Field systems remain extremely rare. Dispersed small scale activity was noted across the county, mainly as either enclosed or unenclosed groups of structures and pits, but typically lacking firm corroborative evidence

for settlement. Site H presents another example within a small county-wide data set. With little current overall background context, the impetus of work was on data collection and recording.

IRON AGE AND ROMAN

The key research themes for these periods were to:

- Advance the development of a chronologically dated middle Iron Age ceramic type series through the application of radiocarbon analysis;
- Seek to understand the morphological development and change of the middle Iron Age settlement discovered at Sites D and G;
- Securely date the pit alignment at Site M and place it within the context of other Iron Age evidence nearby;
- Characterise the nature of the Roman settlements at Site H and Site Q;
- Examine the evidence for crop processing within the context of features found on each archaeological site;
- Compare the results from faunal assemblages with those from contemporary sites within the region;
- Compare Roman cremation burial, pyre traditions and funerary practices within Bedfordshire;
- Produce a chronological sequence for deposition within the cremation cemeteries;
- Securely date pyre debris using radiocarbon analysis and place this in the context of contemporary funerary practices; and to,
- Compare the Roman evidence with other contemporary sites nearby to address the relevance of historically recorded events in the 1st century AD.

A firm chronological framework was lacking for the 1st millennium BC where ceramics, decorated metalwork and scientific dating can be cross compared (Oake *et al.* 2007, 10–11). Typically spot dates and site phase chronologies were based exclusively on the ceramic work of Slowikowski (2005), and there was significant potential to advance this through the application of radiocarbon analysis against any early ceramic groups where diagnostic sherds could be identified that contributed to a wider typology.

Little previous work has been undertaken to advance the understanding of how settlement nucleation and dispersal occurred over this period (Oake *et al.* 2007, 11). Sites excavated close to Watling Street and on the hilltop between the Ouzel Brook and Flit valleys had the potential to contribute to this work both in Bedfordshire and the wider region (Medlycott 2011). They presented an example of agricultural settlement that helped to elucidate the character of an increasingly organised, farming economy. A

particular opportunity was provided to examine the relationship between settlement enclosure and more widely distributed surrounding field systems (Sites J, K and H; Site D, M and G), and also the relationship with the preceding pit alignments (Sites M and P). Any demonstrable relationships between pit alignments and later boundaries were of significance, as few have been securely dated and investigated in detail (Dawson 2007, 64).

The variety of settlement forms increased in the late Iron Age and it was therefore important to characterise the nature of the Roman occupation settlement at Site H and Site Q (*ibid*, 68). There was a need for greater synthesis of evidence to provide an understanding of how Roman rural communities interacted and functioned (Oake *et al.* 2007, 10–2, 73–4; Medlycott 2011, 31–7).

Plant macrofossil analysis for crop processing and the study of faunal assemblages fed into the study of each settlement site, and there are likely to be specific elements that will provide useful examples for comparison with future work in Bedfordshire (Murphy 2007a, 70–71). Pit clusters, if significant to crop processing, are unrecognised in the county for that purpose (Sites D, G and K). The possibility of a placed horse burial at Longmeadow Farm (Site H) added to a similar example noted at Stagsden (Roberts 2000).

In terms of funerary analysis most of the published work to date has focused upon human bone analysis (Oake *et al.* 2007, 12), providing a good range of comparable data (Murphy 2007b, 80–81). The cremation cemetery from Site F and the burials at Site Q both provided an opportunity to take this further in terms of comparing burial traditions and practices across the region. Examples from the work at M1 Junction 12 (Brown 2015c), Harlington (Dawson 2001), Court Drive, Dunstable (Edwards 2010) and Puddlehill (Matthews 1976) were likely to assist locally in this regard, with others drawn from the wider region (Dawson 2007, 76). Work beyond this project is required to focus on ritual elements such as decapitation, burial position, cremation urn fabrics/forms and grave goods where possible and may feed into the topic of sites intended for ritual functions (Dawson 2007, 69).

The relationship between the unurned cremations and the Iron Age and Roman enclosures and trackways at Site H was confirmed using the process of radiocarbon dating, which also was used to date the associated pyre deposits (Fig 1.18). The results of the analysis enabled incorporation of the funerary site into a broader synthesis and understanding of Roman funerary practices at both Site F and Site H. Differences between the sites posed significant questions for the basis of two contemporary burial traditions, differing in the



Fig 1.18 Cremation urn being wrapped and lifted whole before transport to laboratory for excavation

manner of interment that feeds into topics concerning social identity (Oake *et al.* 2007, 13).

With the Roman road, Watling Street, in such close proximity to the Scheme, it was appropriate to consider comparison of the Roman settlement at Site H, Site F and Site Q with Puddlehill (Matthews and Warren 1992) and other contemporary sites nearby. At Puddlehill it was suggested that the excavated evidence supported clearance either in the aftermath of the Roman conquest, AD43, or around AD61 during the Boudican revolt when Verulamium (St Albans) was sacked (*ibid*, 38–39).

MIDDLE SAXON

The key research themes of this period were to:

- Publish the inhumation cemetery at Site H as a recently excavated example of possible early Christian burial practices; and to,
- Provide comparison with examples excavated previously in support of future research as further middle Saxon funerary sites come to light in the region.

Archaeology of this period is of a character particular to the county, rather than the wider Eastern region, and few recent examples were available (Oake *et al.* 2007, 12). There are few examples of middle Saxon cemeteries in Bedfordshire with which to compare the inhumations from Longmeadow Farm (Site H), with the most recent burials published by Dawson (2004) likely to be pre-Christian. Earlier sites studied in the county include those published by Hagen (1971), Eagles and Evison (1970), Hyslop (1963), Matthews (1962a-b) and Morris (1962a-b). All of these emphasise finds at the expense of contextual detail or spatial recording and rarely provided sufficient information to make detailed



Fig 1.19 Detailed archaeological excavation of the medieval settlement, Site F

observations about the populations or communities they represented (Edgeworth 2007a, 90). Where they were excavated as part of settlements at Harrold (Eagles and Evison 1970) and Puddlehill (Matthews 1962a), they were not published as integrated elements of those sites. The distribution of known cemeteries has been mapped (Wingfield 1995; Bilikowska 1980), but the resultant picture must be a severe underrepresentation of the county's potential for such sites in this important part of south-central Mercia.

LATE SAXON AND MEDIEVAL

The key research themes for the late Saxon and medieval periods were to:

- Publish the non-nucleated settlement found at Site F to redress the balance of studies and corpus of information available on similar type sites (Fig 1.19);
- Publish the timber-framed building and associated medieval features at Site Q as an example of finds in close proximity to a moated site;
- Map the extent and orientation of ridge and furrow cultivation, where found, in support of county-wide and regional research;
- Provide analysis of historic maps and aerial photographs at Nuppings Green (Site M1C) to elucidate the extent and character of the settlement; and to,
- Publish specialist analysis of the pottery wasters recovered from the pot bank at Nuppings Green (Site M1C).

Settlement studies in Bedfordshire remain limited in number, but recent years have seen an increase in the quantity of those conducted around the historic core of rural villages and on the edges of existing historic settlements (Oake *et al.* 2007, 14). Most of these studies



Fig 1.20 Archaeologists excavating medieval pot bank deposits with the M1 behind, Site M1C

follow nucleated settlement patterns, although there is a diverse variety of settlement morphology in the county. Isolated village ends, smallholdings and other non-nucleated settlement, such as the occupation at Site F, and moated settlements or sites close to them (i.e. Site Q) were underrepresented and therefore a priority for study. Smaller dispersed settlements, such as the occupation at Nuppings Green (Site M1C; Fig 1:20), were also rarely examined in detail, especially any with an associated craft activity (*ibid*, 106-7; Medlycott 2011, 67-8).

The transition between late Saxon to Norman England is generally accepted to be one of continuity; however, at site level, it is often hard to date closely. St. Neots ware pottery production took place over a long period between 10th-13th centuries and so any work that assists in refining site dating in the county is beneficial (Edgeworth 2007a, 98). Dating in the post-Conquest period is greatly aided by the diversity of local pottery manufactories in the surrounding counties.

Human remains are generally few and rural burials of medieval date, if corroborated by scientific dating techniques, would be a valuable addition to the dearth of information (Murphy 2007c, 112).

The open fields around the medieval villages, comprising ridge and furrow cultivation, survive poorly across the county but at one time characterised the nature of local farming practices in keeping with Northamptonshire and Buckinghamshire. Their origins and development are poorly understood and so mapping the locations and orientation of cultivation evidence is of value at a county-wide and regional scale (Oake *et al.* 2007, 14).

POST-MEDIEVAL AND MODERN

The sole requirement for this period was to:

- Provide a permanent archival record of post-medieval and modern landscape features, contained within the accompanying digital content package.

Topics of research for both Bedfordshire and the East of England focus on fortifications, parks and gardens, and industrialisation (Oake *et al.* 2007; Medlycott 2011). The rural landscape receives little priority where it is not associated with one of these key themes, or where it is not part of a continuity of landscape from the medieval period (Edgeworth 2007b, 119). In this vein there were no priorities for historic hedgerows, field systems created through Parliamentary Acts of Enclosure, post-medieval trackways, agricultural landscape features (Sites E and S), or for modern architectural structures such as motorway bridges, beyond their recognition and permanent archival record.

ORGANISATION OF THIS REPORT

Chapters 2 to 8 of this report present the excavated evidence for sites both on the M1 Junction 12 Improvement Scheme and the A5-M1 link road. Each chapter is ordered chronologically, so that contemporary evidence is presented together by site. The chronology loosely follows conventionally recognised eras within British archaeology. The phasing of these is based on a combination of spot dates from artefact assessment using pottery and registered finds, radiocarbon determinations and stratigraphic relationships where they were relevant.

Each individual chapter contains a narrative of the excavated evidence, specialist studies on finds and environmental material and an end of chapter discussion that includes a summary of the relevant background historical data. General site interpretations are presented in the discussion and contain the observations of site archaeologists and

specialists, distilled separately from the narrative of archaeological features and finds reports. Each chapter ends with a concluding statement addressing the contribution towards published research themes with recommendations for the future. It was the intention to present a collection of short essays, wherein more thematic discussions could draw in a wider synthesis of regional evidence, but this lies beyond the scope and time constraints of this report.

Evidence collected from M1 Junction 12 and from the A5-M1 link road is presented within individual chapters within the broader chronology. For the A5-M1 sites certain work areas with different site codes are amalgamated where they are deemed to be part of the same archaeological site (i.e. Sites D and G). Sites of contemporary or topical relevance are presented independently, but within the same chapter, such as the funerary evidence and sites within the valley of the Ouzel Brook that are relevant to middle Iron Age farming practices. Medieval sites at Chalton and Thorn are presented together based on their broadly contemporary occupation, but evidence at Nuppings Green is kept separate in order to maintain the distinction between projects.

The letter codes attached to the archive are retained for reference purposes; the use of common place names has been avoided where possible to prevent confusion. All previous site reference names and numbers have been dropped to maintain consistency. In the case of the M1 Junction 12, the sites which were formerly referred to as Sites A-C are prefixed with M1. This is so that Site M1A will not be confused with the trial trench evaluation stage of the A5-M1 link road, Site M1B will not be confused with the general watching brief on the UKPN cable replacement, and Site M1C will not be confused with the A5-M1 link road general watching brief on drainage ditches and slip roads. The common name of Nuppings Green is only used in a medieval or post-medieval context.

Following on from the present introductory chapter there are a further seven chapters that describe the archaeological evidence. Chapter 2 presents evidence from the middle-late Bronze Age. This same chapter also addresses the largely undated pit alignments on the flood plain.

Chapter 3 presents the study of the landscape and looks at the evidence for the emergence of farming within the valley of the Ouzel Brook, covering a broad period between the 5th-2nd centuries BC. The chapter begins with early Iron Age pit clusters before advancing to the middle Iron Age settlement up until its abandonment in the late Iron Age. The chapter also incorporates the earlier-middle Iron Age pit cluster and storage pits at Site K.

The cremation cemetery and boundary ditches that began in the late Iron Age from M1 Junction 12 are presented in chapter 4. The larger portion of this chapter focuses upon the Roman cemetery evidence from Site M1A. A smaller section within the chapter includes a brief presentation of the non-funerary evidence, restricted mainly to the changing boundaries over the period of cemetery use. The theme of cremation burial then leads towards chapter 5, wherein the funerary evidence is presented from the A5-M1 link road in its detail.

After the detailed burial information is provided the dialogue of chapter 6 returns to the study of the contemporary landscape in the late Iron Age/Roman transitional period, which looks at trackways and enclosures nearby. The crossover enables the sites where there is a distinct continuity in occupation from the late Iron Age into the early Roman period to be separated from those sites that are exclusively pre-Roman.

Chapter 7 advances the chronological framework with an initial presentation of Saxon inhumations and then pursues the origins of settlement at Site F, starting with the scattered evidence for early/middle Saxon activity and leading into the medieval settlement evidence. Contemporary with 12th-century occupation at Site F, but geographically removed, was the medieval occupation at Site Q, which is presented in the same chapter. The last of the medieval site narratives is from the M1 Junction 12 improvements, in chapter 8, and presents the late medieval potter's waste dump at Nuppings Green and the subsequent post-medieval occupation of the site.

Since each individual chapter contains within it the specialist studies associated with the archaeology of specific sites, some of the detail has been distilled into the accompanying digital content, such as methodologies. All specialist datasets from both the Stage 1 assessment and Stage 2 analysis are also held upon the accompanying digital content package, together with smaller reports that found no home within the main narrative of archaeological sites. This is particularly the case for Neolithic flints, a polished stone axe, the topographic surveys of post-medieval features such as hedgerows and bridle paths, and the building recording of the 1959 motorway overbridges. Copies of all relevant reports are included, together with the background documentation supporting the project. An inventory of the data sets and reports held upon the accompanying digital content package is contained within this volume.

SUMMARY OF CHRONOLOGY WITHIN THIS REPORT

Table 1.2 summarises the evidence by grouping the sites into a chronology. The periods represented are commonly accepted eras known within British archaeology. The positioning of date ranges is accorded by the specialist contributions through spot dating pottery and other finds from these sites, fitted into broadly published conventions. The main significant archaeological features and sites are presented within the relevant chapters, whilst minor sites and finds of low significance are not included, but their assessment is held upon the accompanying digital content package.

TEXTUAL AND GRAPHICAL CONVENTIONS

The basic unit of reference throughout the archive that supports this report is the context number. This is a unique number given to each archaeological event on site whether it was a layer, a pit cut, fill material, a wall, a surface, a recut or any other archaeological feature or deposit. Modern intrusions and natural features were generally excluded. Context numbers in the text are shown thus: Q[100], denoting Site Q, context [100]. The site code prefix is included where ambiguity may exist with the reader. This may occur where, for the purposes of compiling an orderly site archive without confusion in the field, the use of site codes permitted each site to run on an independent set of registers. This means that each site has its own context index attached to a letter, overriding the occurrence of duplicate numbers.

This report employs the use of group numbers for features or land-use entities where evidence has a direct physical, spatial and/or chronological association. Terms that may employ group numbers and are considered land-use entities include, and are not limited to; buildings, structures, wells, enclosures, pit clusters, trackways, funerary groups and similar themed complex site features. Whilst the components of these will be referred to by context number, usually the cut, or perhaps specifically a fill or layer, the group numbers will employ the site code letter followed by a number for the site feature. This number will not appear in brackets. These numbers have been generated to support the dissemination of information within this report, they are generally sequential within their respective chapters and do not relate to any previous documentation.

Numbers given to individual registered finds within the site archive are most commonly objects sent for X-ray and artefacts with special conservation considerations

Table 1.2: Summary of archaeological discoveries in chronological order

Periods	Relevant evidence	Relevant sites
late Neolithic, Bronze Age and early Iron Age (c.4000-450BC)	prehistoric worked flint polished stone axe (Site G) finds prehistoric pits pit alignments palaeochannel pit clusters	residual on various sites Site G Site C Site H Site M Site P Site L Sites D and G Site K
middle Iron Age (c.450-100BC)	farming settlement field systems dispersed roundhouses and pits storage pits and nearby boundaries	Site G Sites D, G, M Sites G Sites K and N
late Iron Age (100BC-AD43)	ditches draining into a marshland trackways and enclosures boundary ditches and enclosures isolated cremation burials Period 1 of cremation cemetery stone cairn and funerary pyre trackways and enclosures urned cremation cemetery (initial) funerary enclosure unurned cremation cemetery and pyres	Site G Site J Site H Site Q Site Q Site M1A Site M1B Site H Site F Site H Site H
Roman (AD43-300)	boundary ditches enclosure, boundary ditches and burials funerary enclosure unurned cremation cemetery and pyres urned cremation cemetery (main) Periods 2-4 of cremation cemetery trackways and enclosures	Site P M1 Junction 12 (all sites) Site Q Site H Site H Site F Site M1A Site H
late Roman (AD300-450)	charnel pit and scattered human bone	Site F
Anglo-Saxon (AD450-850)	inhumation cemetery isolated pits and pottery sherds	Site H Site F
late Saxon (AD850-1066)	isolated pit pottery sherds, comb and loomweights residual pottery	Site F Site F Site Q
Saxo-Norman (AD1066-1150)	enclosure, pits and possible buildings boundary ditch and residual pottery	Site F Site Q
medieval (AD1150-1540)	buildings and enclosures timber frame building and boundaries pottery waster midden boundary ditch	Site F Site Q Site M1C Site M1B
post-medieval and industrial (AD1540-1900)	building remains bridle path historic hedgerow historic hedgerow historic hedgerow embankment field boundary ditches material dumped beside a trackway	Site M1C Site E NGR TL 00500 25320 NGR TL 01300 25660 NGR TL 01883 29738 Site S Sites G and Q Site F

or that are of a delicate nature with intrinsic artefactual interest. Such finds have been given catalogue numbers with a prefix denoting their category. The number refers to the catalogue, derived from the field register with additions following Stage 2 analysis and reporting. Note that this means that where there are two apparent

duplicates, they are from different sites. The prefix is by material type, and may have a letter outside of the bracket for the site code, if this is not obvious through context. For these reasons the numeric series does not run sequentially through the report. Registered finds are presented thus:

- <A1> antler or worked bone artefact no. 1;
- <C1> ceramic artefact no. 1 (spindle whorls, loomweights etc.)
- <CN1> coin no.1;
- <Cu1> copper-alloy artefact no. 1 (excluding coins);
- <DS1> decorated samian artefact no. 1;
- <Fe1> iron artefact no. 1;
- <G1> glass artefact no. 1;
- <P1> pottery artefact no. 1 (specific sherds, vessels and funerary urns);
- <Pb1> lead artefact no. 1;
- <S1> stone artefact no. 1;
- <SS1> samian stamp no. 1.

An important distinction is drawn between early/middle or middle and late, and earlier-middle or later-middle. The former is intended to mean either/and/or, whilst the latter is a sub-division of the period in question. This approach is used throughout but particularly where the work breaks down the existing knowledge of middle Iron Age pottery into forms and decoration of distinctly earlier or later date within the middle Iron Age.

This publication employs recognised fabric codes for prehistoric pottery, developed by specialists working in the Bedfordshire region (Wells 2008b).

Roman fabrics from the A5-M1 link road follow the Warwick and Oxford system (Booth 2000) and fabric series in Evans *et al.* (2017). Roman fabrics at M1 Junction 12 draw on published references for Bedfordshire (Slowikowski 2001; 2004; 2005), and are coded following the National Roman fabric reference collection (Tomber and Dore 1998).

All of the medieval pottery wares are recorded using the conventions of the Bedfordshire County Type Series (Baker and Hassall 1979). Associated with these are alphanumeric codes prefixed “F” that relate to the medieval pottery database and tables. An explanation of these codes is provided early in the text of the relevant finds report.

Ceramic building materials are described and classified by type rather than being allotted to a fabric type series, as no such published coding system exists for Bedfordshire.

The following abbreviations are used within the text and in tables or catalogue entries: aOD (above Ordnance Datum); BE (base equivalent); CBC (Central Bedfordshire Council); CCJV (Costain-Carillion Joint Venture); CP (ceramic phase); EMS (early to middle

Saxon); EVE (estimated vessel equivalent); FADD (further archaeological design document); HER (Historic Environment Record); LS (late Saxon); MOLA (Museum of London Archaeology); MNI (minimum number of individuals); MNR (minimum number of rims); MNV (minimum number of vessels); MSW (mean sherd weight); MPR (mean percentage of rims); NA (Northamptonshire Archaeology); NGR (national grid reference); OS (Ordnance Survey); RE (rim equivalent); Sh (sherd count); SN (Saxo-Norman); sqm (square metres); UKPN (United Kingdom Power Network); UPD (updated project design); WSI (written scheme of investigation); Wt (Weight, usually given in grams).

The graphical conventions used in the site plans and illustration for this report are shown in Fig 1.21.

ARRANGEMENTS FOR THE ARCHIVES

The archives for each of the projects have been offered to Luton Culture, upon completion of the publication (Accession no. LTNMG 2010.67 for M1 Junction 12, and Entry no. LTNMG 1093 for the A5-M1 link road).

The archives will be retained at the MOLA offices in Northampton while the museum is closed for refurbishment. OASIS forms were completed for the project upon the issue of each grey literature report as part of standard company procedure and each report will be submitted to the Archaeological Data Service (ADS). There is no requirement for the archive to be digitised and the National Archaeological Record is no longer receiving microfilm copies of site records. The archive will be prepared according to professional standards and guidelines, together with the specific requirements for Luton Culture (Walker 1990; MGC 1992; SMA 1993; Watkinson and Neal 2001; Duncan 2011; CiFa 2014e-f; LC 2013).

The archive comprises all written, drawn and photographic records, and all material finds and processed sample residues recovered from the excavation. The site archive is accompanied by the research archive, which comprises the text, tabulated data, the original drawings and all other records generated in the analysis of the site archive. The archive is fully catalogued and prepared for deposition. Copies of the project background information: WSIs, FADDs, evaluation reports, watching brief reports, building recording reports, topographic surveys, assessments and UPDs are included, along with a copy of the present publication. Any material requiring special curation was handled under the recognised guidelines prior to deposition (Watkinson and Neal 2001).

COMMUNITY ENGAGEMENT AND PUBLIC DISSEMINATION

The archaeological remains discovered during construction of both the M1 Junction 12 and the A5-M1 link road were reviewed, assessed, analysed and reported upon following the relevant archaeological guidance provided in the *Design Manual for Roads and Bridges* (HA 2001). Dissemination of the information was conducted for both schemes together, where possible. MOLA produced 500 copies of a popular brochure for distribution including 120 copies that were lodged with the local authority. A public lecture presented the findings of the excavations along the road scheme to the Council for British Archaeology South Midlands conference in 2017 where attendees received a copy of

the brochure. Subsequent requests by local societies for talks and presentations were honoured by MOLA. The present volume represents the Stage 2 report upon the post-excavation analysis and has been compiled to meet a more academic audience, in keeping with other comparable road schemes delivered by Highways England. This volume is accompanied by a bank of digital content, hosted by Archaeopress, and accessed by QR matrix barcode. This digital content package comprises project documentation and archaeological data, together with minor elements of the archaeological recording that were excluded from this publication (i.e. detailed specialist data sets, unstratified finds reports, topographic surveys of post-medieval features, building recording of motorway overbridges etc.).

	middle/late Bronze Age (excavated section is lighter shade)		Saxo-Norman, late 11th to early 12th century AD
	late Bronze/early Iron Age		medieval, early to mid-12th century AD
	early-middle Iron Age		medieval, mid to late 12th/13th centuries AD
	later-middle Iron Age		late medieval
	late Iron Age, 1st century BC to AD0		post-medieval
	pre-conquest, late Iron Age, BC to mid-1st century AD		undated
	post-conquest, early Roman, mid-1st to early 2nd century AD		area of interest
	Roman, early to mid-2nd century AD		geophysical anomaly
	late Roman		limit of excavation
	post-Roman, late 4th to 5th centuries AD		section line
	early/middle Saxon, 5th to 8th centuries AD		illustrated section
	Saxon, 7th century AD		pot with burial
	late Saxon, 9th to late 11th centuries AD		pyre debris

Fig 1.21 Graphical conventions used in this report