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Early Medieval Place-Names and Riverine Flood Histories: A New Approach and New Chronostratigraphic Records for Three English Rivers

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Environmental information from place-names has largely been overlooked by geoarchaeologists and fluvial geomorphologists in analyses of the depositional histories of rivers and floodplains. Here, new flood chronologies for the rivers Teme, Severn, and Wye are presented, modelled from stable river sections excavated at Broadwas, Buildwas, and Rotherwas. These are connected by the Old English term *wæsse, interpreted as 'land by a meandering river which floods and drains quickly'. The results reveal that in all three places flooding during the early medieval period occurred more frequently between AD 350–700 than between AD 700-1100, but that over time each river's flooding regime became more complex including high magnitude single events. In the sampled locations the fluvial dynamics of localised flood events had much in common, and almost certainly differed in nature from other sections of their rivers, refining our understanding of the precise nature of flooding which their names sought to communicate. This study shows how the toponymic record can be helpful in the long-term reconstruction of historic river activity and for our understanding of past human perceptions of riverine environments.

Keywords: chronostratigraphy, early medieval, England, flooding, place-names, rivers, OSL

Introduction

Most English place-names fall into two categories: habitative names which describe aspects of the built or cultural environment (settlements, buildings, enclosures etc.) and topographical names which describe the physical landscape or types of land use (hills, valleys, woodland etc.) (Gelling, 1984; Cameron, 1988: 27–32; Gelling & Cole, 2000). Among the latter, names indicating what must have been, to place-namers, significant local characteristics of rivers, minor watercourses and wet ground are common. Across the country, nearly 2000 major settlement-names contain some reference to river forms and flowing water. Linguistically, the great majority of these names are either Old English or Old Norse in origin (Gelling, 1978: 19–29). Their creation can, thus, be dated to the period when these languages were spoken in England. For Old English, that is (roughly) from the fifth to the eleventh century AD, and for Old Norse, from the ninth to the eleventh. Further chronological precision for certain individual names is provided by attestations in written sources which offer a *terminus ante quem* for their existence. In an otherwise relatively poorly documented period, water-related place-names represent one of the most closely observed, and most extensive, repositories of material informing directly on the physical character of early medieval rivers, their hydrologic regimes, and their floodplains. The value of these names for understanding fluvial processes in the past is enhanced by the richness and variety of the descriptive vocabulary they contain, the possible precision with which particular terms were applied, and the locational tenacity they exhibit across time.

In this article, and for the first time, place-names have been used to guide fluvial geoarchaeologists to specific parts of three English rivers in order to examine their depositional and flood histories. Using this new approach, the early medieval toponymic descriptions of certain localized river behaviours can be set against the broadly contemporary evidence of actual fluvial activity as revealed in the sedimentary records of these places. Here one Old English place-name element, **wæsse*—a term toponomasts have interpreted as indicating a place prone to flooding—has been targeted. Three places with this descriptive term have been investigated: Broadwas (River Teme, Worcestershire), Buildwas (River Severn, Shropshire), and Rotherwas (River Wye, Herefordshire). Analysis of the sedimentary record of alluvial deposition at these **wæsse*-sites, and careful consideration of the magnitude, frequency, and timing of their flood events throws light on key questions relating to when and why **wæsse*-settlements may have acquired their names. It also offers greater precision regarding the nature of the fluvial and geomorphological processes witnessed by their place-namers and which they sought to describe through this term. The period

investigated lies beyond that covered by historical flood data, which typically starts in the later medieval period (e.g. Macdonald, 2013) except in the Classical World (Brown, 1997). Here we use data from an analysis of overbank levee sedimentation proximal to stable channels as suggested by Jones et al. (2010) but extend their approach by over 1000 years.

Names in -*w*æsse* and the Early Medieval Histories of Broadwas, Buildwas, and Rotherwas

The Old English word **wæsse* is preserved only in place-names. Even as a naming element it is relatively rare, appearing in just ten settlement-names and a handful of names of lesser status referring to landscape features. Most of these **wæsse*-names are found in the West Midlands. This restricted geographical distribution may indicate that, during the early medieval period, the term was exclusive to the Anglian varieties of English spoken in the Midlands and North, and may not have been available to place-namers beyond these linguistic communities (Gelling, 1984: 59–60). All these settlements in -**wæsse* are located on significant rivers whose names, without exception, were formed in pre-English languages (Figure 1).

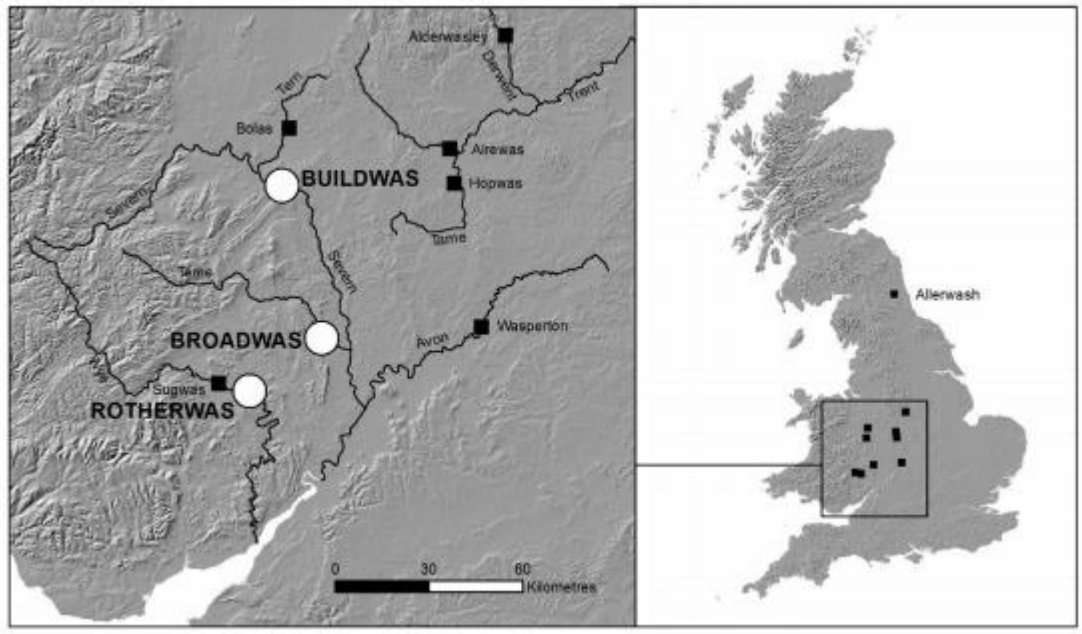

*Figure 1 Location of *wæsse place names.*

The term **wæsse* is closely related to Old English *gewæsc* 'washing, flood' and *wæsce* 'place for washing' but, because it is not on independent record, its precise meaning must be inferred. Since a

low-lying riverine location is shared by all settlements taking this element, a general sense of wetness is fairly secure. Consequently, in early place-name dictionaries, the term was interpreted to mean 'wet place, swamp, marsh' (Smith, 1956, II: 237–38). In some instances, support for the idea that **wæsse* was originally intended to indicate wet ground is found in the terms used to qualify it. For example, Old English *alor*, the water-loving alder tree, is found in Alderwasley (Derbyshire), Allerwash (Northumberland), and Alrewas (Staffordshire) (Cameron, 1959: 515; Gelling & Cole, 2000: 64; Horovitz, 2005: 83–84). Field observations made at Buildwas in the 1970s led Gelling to offer a more precise definition. She witnessed both the inundation of, and subsequent rapid retreat of water from, the floodplain of the River Severn over the space of 24 hours. She proposed the more precise meaning 'land by a meandering river which floods and drains quickly' (Gelling, 1984: 59–60; Gelling & Cole, 2000: 63–64). This definition is now widely accepted, although in some publications it is abridged to simply 'alluvial land' (Mills, 2011). The earliest secure date for the use of **wæsse* is provided by a charter of AD 942 referring to Alrewas (Sawyer, 1968: Charter 479). A charter purporting to date from AD 789x790 for Broadwas is considered a later forgery (Sawyer, 1968: charter 126; Hooke, 1990: 87–90), but it is preserved in a manuscript of the late eleventh century. Two charters relating to Wasperton, dated AD 1043 (Sawyer 1968: charters 1000 & 1226; Hooke, 1999: 104–05), are also forgeries, preserved in manuscripts from the thirteenth century and later. It is in Domesday Book (AD 1086) that Buildwas, Hopwas (Staffordshire), Rotherwas, Sugwas (Herefordshire), as well as Wasperton are first attested (Thorn & Thorn, 1986: 1,7; Harkins & Rumble, 1976: 1,39; Thorn & Thorn, 1983, 25,1; Thorn & Thorn, 1983, 2,37; Plaister, 1976: 6,18); while the name Bolas (Shropshire) is only found from 1198 and Alderwasley no earlier than 1251 (Watts, 2004: 7, 68). While it is entirely possible for these names to have existed long before they were formally recorded, the dates of attestation may suggest that **wæsse* belongs to a relatively late stratum of place-naming. But the existence of the names of the three case-study sites examined here is, at least, confirmed by 1086.

As a precursor to the sedimentological analysis that will follow, consideration must first be given to the situation and early histories of the three **wæsse*-settlements selected for study. Broadwas stands on the River Teme (Figure 2). The river rises in the Kerry Hills of mid-Wales and drains south-eastwards for approximately 100 km to meet the River Severn just south of Worcester. Its drainage system is such that most of its tributary streams feed in from the north with five smaller catchments in the lower reaches the river predominantly on the southern slopes. Broadwas itself is situated at the start of the lower reach of the river, approximately 10 km upstream of its confluence with the Severn at a point where a change in geology has caused a distinctive widening of its floodplain. This valley profile is reflected in the first element of its name, Old English *brād* 'broad'. The present

village stands on a gravel terrace forming the edge of the floodplain on the north side of the river. There is archaeological evidence that the site was occupied in the Romano-British and possibly the immediate post-Roman periods, and that activity at that time may have extended down into the floodplain proper (Hancox pers. comm.). By 1086 Broadwas was already a sizable community and the importance of the Teme and its floodplain to the local economy is made clear from the 20 acres of meadow, two mills, and a fishery noted in the assessment (Thorn & Thorn, 1976: 2,68).

Buildwas lies on the northern edge of the Severn floodplain at the point where it narrows to enter the Ironbridge gorge, where there is a bedrock sill over which a ford existed prior to the construction of the bridge (Figure 2). Here the morphology of the river channel changes from a highly sinuous, meandering form upstream to a straight channel downstream reflecting the significant change in the underlying solid geology and valley constriction. Water passing through the Severn at Buildwas derives from the river's upper catchment of 3717 km^2 , an area which supplies around half of all the water entering the river from its full catchment. Significant alterations to the floodplain at Buildwas are on record. From the twelfth century to the mid-sixteenth century, the floodplain was actively managed by the Savignac, later Cistercian, monks of the abbey founded to the south of the river in 1135. Well-defined earthworks show the presence of fishponds, leats, mill-sites, and fish weirs (Brown, 2002). Archaeological evidence for pre-Conquest activity, however, is entirely lacking. The village first appears in Domesday Book and was clearly a small place although a mill is recorded (Thorn & Thorn, 1986). The first element of the name is difficult. Gelling (1990: 65–66) has proposed an unattested adjective meaning 'swelling, surging', and related to Old English *byldu* 'boldness, confidence' and *gebyld* 'courageous'. Coates (2010) has suggested an unattested Old English noun **bilde* 'exceptional, supernatural power', ultimately related to High German *Bild*. For both, reference to the scale of local floods is assumed.

Like our other sites, Rotherwas is recorded in Domesday Book as a small settlement (Thorn & Thorn, 1983, 25,1). The first element of the name is considered to be Old English *hrȳðer* 'ox, cattle' (Coplestone-Crow, 1989: 82). It is located to the south-east of Hereford in an area of wide floodplain of the River Wye (Figure 2). The morphology of the river channel in the middle Wye reach is typically sinuous, with numerous large meanders and a relatively shallow gradient. The Wye has fifteen major tributaries, the largest of which, the River Lugg, meets the Wye 6 km downstream of Rotherwas. Prehistoric and Romano-British settlement has been identified 500 m south-west of Rotherwas at the edge of the floodplain (Duncan & Jones, 2003; Sworn & Jackson, 2014). Much of this early activity appears to have been located close to large palaeochannels on the floodplain, the sedimentation of which continued into the medieval period (Sworn & Jackson, 2014: 30). To the south of the village, a curvilinear boundary ditch and posthole dated to the sixth or seventh century

AD, associated with a rectilinear feature possibly of the same date, provides the first evidence for early medieval activity (Miller, 2011). Rotherwas lay within the medieval ecclesiastical parish of neighbouring Dinedor and appears to have been dependent on it. Although no mill is recorded at Rotherwas in Domesday, one is returned for Dinedor manor (Thorn & Thorn, 1983, 8,7). The location

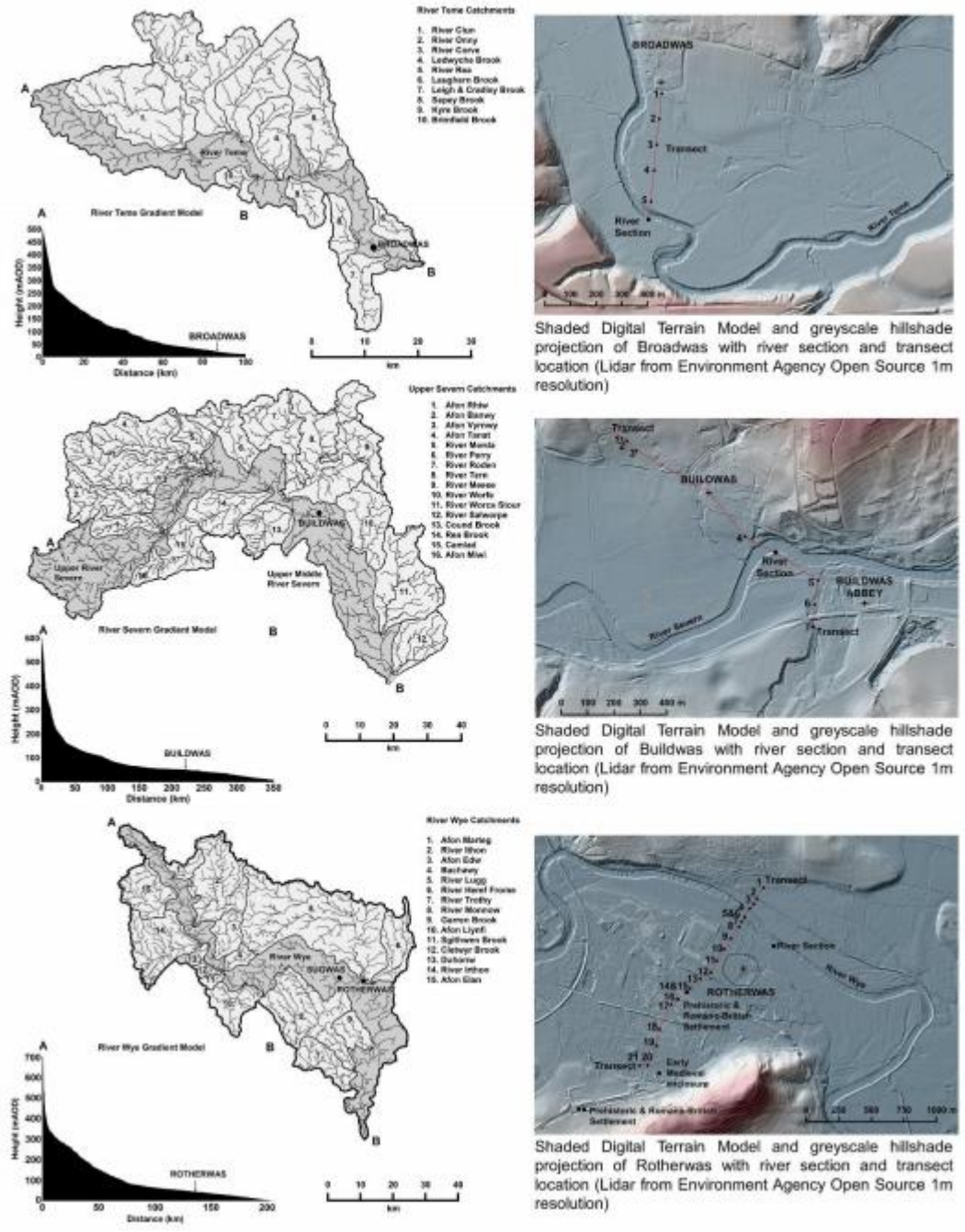

Figure 2 Catchments, river gradients, local topography, and transect locations at Broadwas, Buildwas, and Rotherwas.

of a small islet on the northern edge of the manor, which has a form typical of islands associated with mills, strongly suggests that a mill and/or weir occupied this site at an early date (Atkinson & Cadbury-Simmons, 2013).

Site Geomorphology and Channel Stability

The geology of the three site catchments is similar, dominated by Mesozoic lithologies of sandstone, mudstones, and clays in their lowlands with Palaeozoic sedimentary lithologies in their headwaters. This is important for two reasons: first, it allows a full range of sedimentary size-fractions to be available for transport and deposition—allowing grain-size variation to be used as a measure of flood velocities rather than simply reflecting availability; and second, the quartz content has similar and rather predictable (stable) qualities for sediment dating of all three sequences.

Whilst detailed geomorphological studies are not included here (see Pears et al., forthcoming), all three sites have stratigraphic and archaeological evidence that shows that the channel has remained fixed at, or very close to, its current location for the last 2000 years. Coring and long bank exposures provide the confidence that the stratigraphy sampled was representative of the reach and could be traced along and away from the channel. At Buildwas, the channel location has been fixed by the gorge, its sill, and the terrace upon which the abbey and its associated outworks sit. Essentially, it is confined to this location and the large meander to the north has no scroll bars or palaeochannels and is inherited from an earlier meandering planform. At Broadwas, again the channel immediately to the north is confined by a bedrock gorge section. The dated sample site is located immediately downstream, before significant meandering could have occurred. At Rotherwas, the channel is also in a confined reach, with the village (which includes Romano-British archaeological remains, see Rouse, 2009) on a terrace separating it from the tributary brook (Figure 3). At all three sites, the upper unit (the buff-red silty clay *sensu* Shotton, 1978) that was deposited over the last 2000–3000 years contains no channel deposits and was vertically accreted, with the channel in approximately its present location. This is a phenomenon well known for the lower Severn and its lowland tributaries (Shotton, 1978; Brown, 1983, 1995; Marriott, 1992; Brown et al., 2013) that has been caused by a combination of low gradients (reaches under 0.001 m/m-1) and high rates of levee and overbank sedimentation. This is the basis of the Stable Bank relative incision model under which rapid rates of vertical accretion over the last 2–3 millennia have confined the river channel (Brown, 1997; Brown et al., 2018); although, before the deposition of the superficial unit, channels were mobile and multiple. This has been demonstrated by the identification of buried palaeochannels and, even more dramatically, by the discovery of a Neolithic–Bronze Age monumental landscape preserved under

the upper silty clay at Ripple downstream of the Teme-Severn junction (Jackson, 2008). As discussed by Brown et al. (2018), the situation here is a meandering pattern that has been preserved by rapid levee/overbank deposition which has created incised stable channels with width:depth ratios (α) below α =7. This is characteristic of bedrock rather than alluvial channels (Finnegan et al., 2005). The similar but relatively uncommon geomorphological position of the three sites investigated here, all demonstrating confined stability, may be one reason for the relative rarity of the **wæsse* place-name element and may offer clues to its specificity, given that all alluvial floodplains flood regularly in this region.

Methodology

At all three sites, river sections between 3 and 3.5 m of undisturbed alluvium were identified. After cleaning back, sediment colour, texture, consistency, inclusions, and depositional boundaries were recorded, and *in-situ* sediment samples were taken using u-channels for high-resolution laboratory analyses. Summaries of laboratory methods are given here with full details given in the Supplementary Material. All physical analyses were conducted at 1– 2 cm resolution and included Loss on Ignition (LOI) to determine the percentage moisture, organics, and carbonate essential to determine micro-variations in sediment texture. Percentage moisture has an inverse relationship to particle size and can thus be used to differentiate between high- and low-energy depositional conditions. Organic content offers a measure of the potential development of soils during non-flood periods and their later burial, alongside possible deposition from flood events. Carbonate content can be used to indicate the rapidity of sediment burial and thus frequency of flood events since, if left exposed, carbonate content in the deposited alluvium will reduce through the processes of dissolution, leaching, and soil formation.

The magnetic susceptibility (MS) of the alluvial sediments was established using a Bartington MS analyser. Peaks in MS are created by high levels of Fe and other metallic compounds in the sediment. Since these are present in higher quantity in finer rather than coarser sediments, spikes in the MS graphs can be used as indicators of low-energy depositional conditions or extended periods of waterlogging.

Particle size analysis was conducted to determine the micro-variation in sediment texture throughout the sequences by sieving for the coarse fraction above 2 mm, and a DigiSizer Laser Granulometer for the <2 mm fraction. Since the size of particles within suspended sedimentary loads is positively correlated with flow velocity (the higher the flow velocity, the larger the sediments that

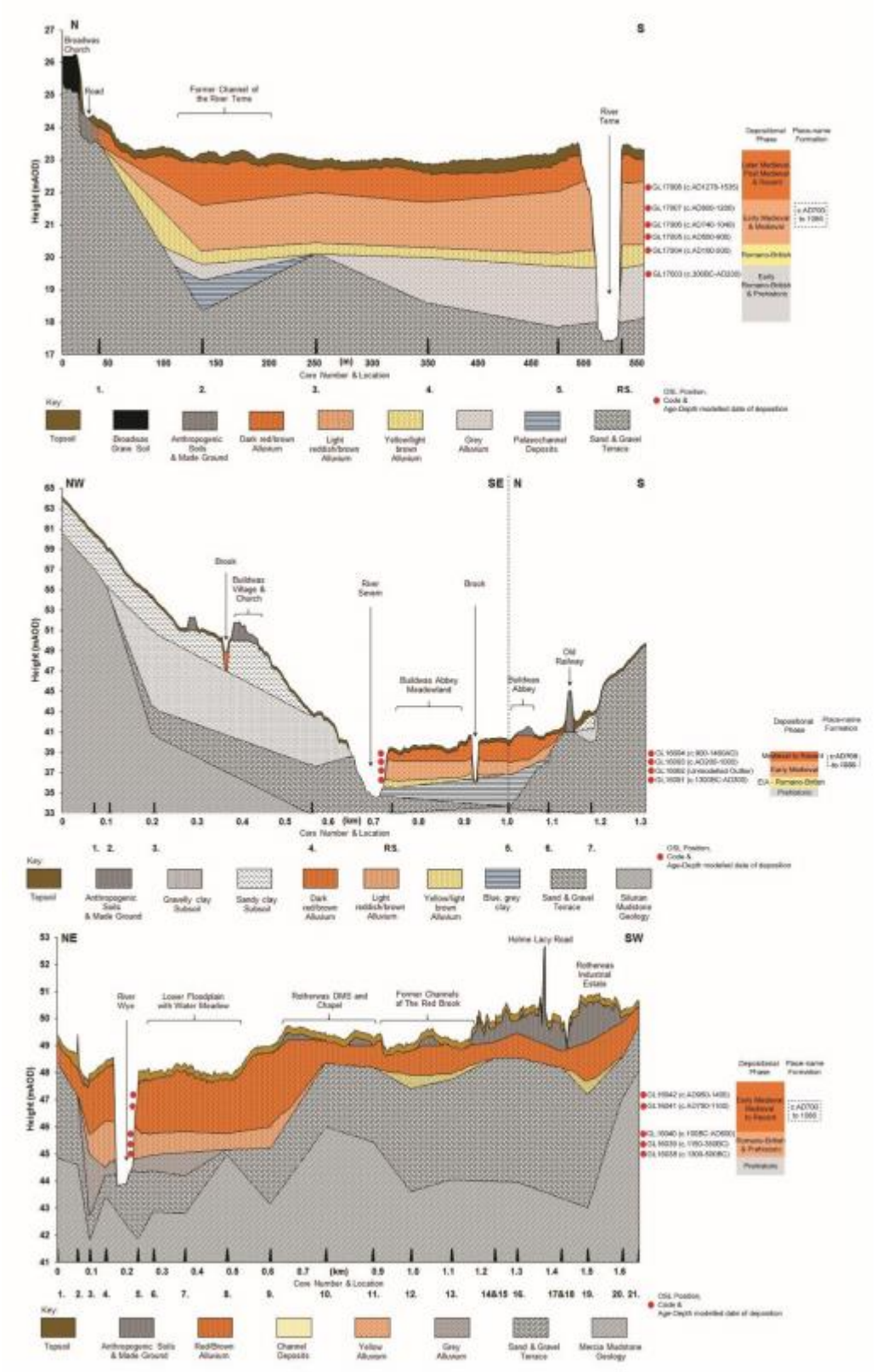

Figure 3 Floodplain sedimentary profiles from Broadwas, Buildwas, and Rotherwas.

can be transported), relative differences in particle size enable interpretations to be made regarding the depositional energies responsible for the creation of each sedimentary lamination. Alongside the physical analyses, high-resolution multi-element analysis was also undertaken using ITRAX XRF spectrometry. A total of 39 elements were analysed at a resolution of 2 mm and the results were used to conduct mineragenic ratio analyses providing additional information on grain-size, depositional conditions, waterlogging, elevated water tables, and heavy metals.

Each sequence was dated by OSL to determine the time that has elapsed between the burial of mineragenic sediments and their exposure to solar radiation. A total of 15 dates were obtained from the three sites. These were carefully located at specific points in the sedimentary sequence which were representative of the stratigraphy but contained higher sand concentrations in order to increase the quality of potential dateable material. An even spread of dates throughout each section was maintained to improve the quality of the chronostratigraphic modelling of the calculated OSL dates (Table 1).

From these dates, Bayesian age-depth models have been calculated to determine the vertical accretion rates of the alluvial deposits as well as the likely date of major flood events, with the period AD 300-1150 illustrated as the grey shaded area (Figure 4). The accumulation rates at all

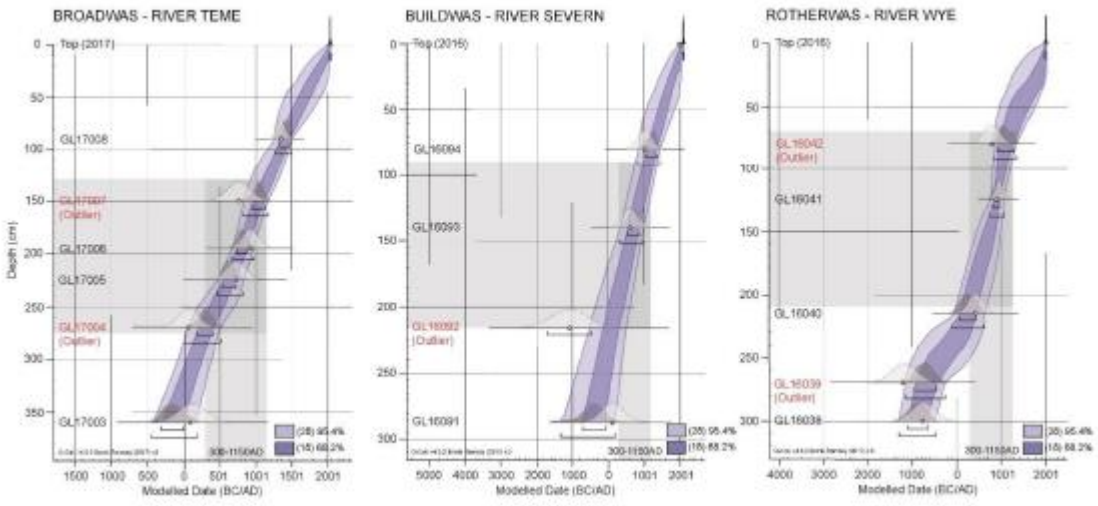

Figure 4 Age-Depth models from Broadwas, Buildwas, and Rotherwas modelled using OxCal (4.3). Outliers in red, date ranges in white, and statistical calibration in dark grey.

three locations investigated are curvilinear, as would be expected from near-channel overbank sedimentation. This is typical of rapidly accreting overbank sedimentation near stable channels (Brown, 1997). Bayesian modelling also enabled the identification of possible age reversals and

outliers within the sequences (highlighted red in Table 1), and the resultant 'acceptance' or 'rejection' of those dates. The accepted dates were subsequently converted into calendrical chronostratigraphic Bayesian models using OxCal, version 4.3 with IntCal13 program (Bronk Ramsey, 2008, 2009). The statistical precision of these calendrical dates can be calculated to, on average, 340 years at 2δ (95.4 per cent confidence) and 169 years at 1δ (68.2 per cent confidence). The dates that are quoted in the discussion of the results have been estimated to 100 years at 52–55 per cent confidence.

Depositional and Flood Chronologies

The stratigraphy at all three sites showed laminations to variable degrees indicating that the sedimentary flux exceeded the bioturbation flux. It is therefore possible to derive flood histories at all three locations that extend back to the prehistoric period and forward to the present day. Here only those parts of each sedimentary record relevant to understanding the behaviour of these rivers during the early medieval period, and of potential relevance to the interpretation of the place-name element **wæsse*, are presented and discussed. Each chronology begins with a brief discussion of Late Roman depositional conditions to provide context for the early medieval flooding and floodplain development witnessed at these sites from c. AD 400 to c.1150.

The Teme at Broadwas

During the late Romano-British period (BRD-1 to 3, 275–258 cm), the physical characteristics of alluvial deposition at Broadwas indicate gradually changing conditions (Figure 5). Subtle decreases in moisture, organic, and carbonate accompanied by increases in grain size, total sand, and elemental particle size proxies suggest a shift from frequent low-energy floods to higher energy events.

By the start of the early medieval period (BRD-4 to 5, from 258 cm), these higher energy depositional conditions increased further. A distinct coarsening of the alluvium and much higher sand content and a shift in elemental particle size proxies point to an extended phase of higher energy flooding lasting until the latter end of the sixth century AD (233 cm). During this phase there is evidence for a short but marked change in depositional character. Between 241 and 238 cm, there is a very sharp increase in magnetic susceptibility and paralleled decreases in sediment texture and coarse inclusions. This record potentially corresponds with the AD 536 climatic event, and certainly bears witness, irrespective of the precise trigger, to a distinct episode of flooding and floodplain waterlogging around this time. Throughout most of the seventh century (BRD-6, 232–218 cm), fluvial activity at Broadwas appears to have calmed somewhat, but nevertheless remained more pronounced than that seen during the Romano-British period. Increased variability in the elemental

indicators prove that the Teme flooded regularly and with varying magnitude. After c. AD 630 (226 cm), an increase in average alluvium accumulation rate from 1.3 to 1.7 mm/yr indicates a more rapid build-up of sediments. An accompanying gradual increase in carbonate, the indicator of less dissolution in the alluvium, points to clear flooding events, and the retention of water on the floodplain for extended periods.

Throughout the first half of the eighth century AD (BRD-7 and 8, 218–207 cm) evidence of high-energy deposition is apparent, with clear increases in alluvial texture and most significantly in the sediment power index. This distinctive phase of deposition appears to have abated by the latter half of the eighth century (BRD-9, 206–194 cm), but occasional higher energy flash flooding continued throughout most of the ninth century (BRD-10, 194– 179 cm).

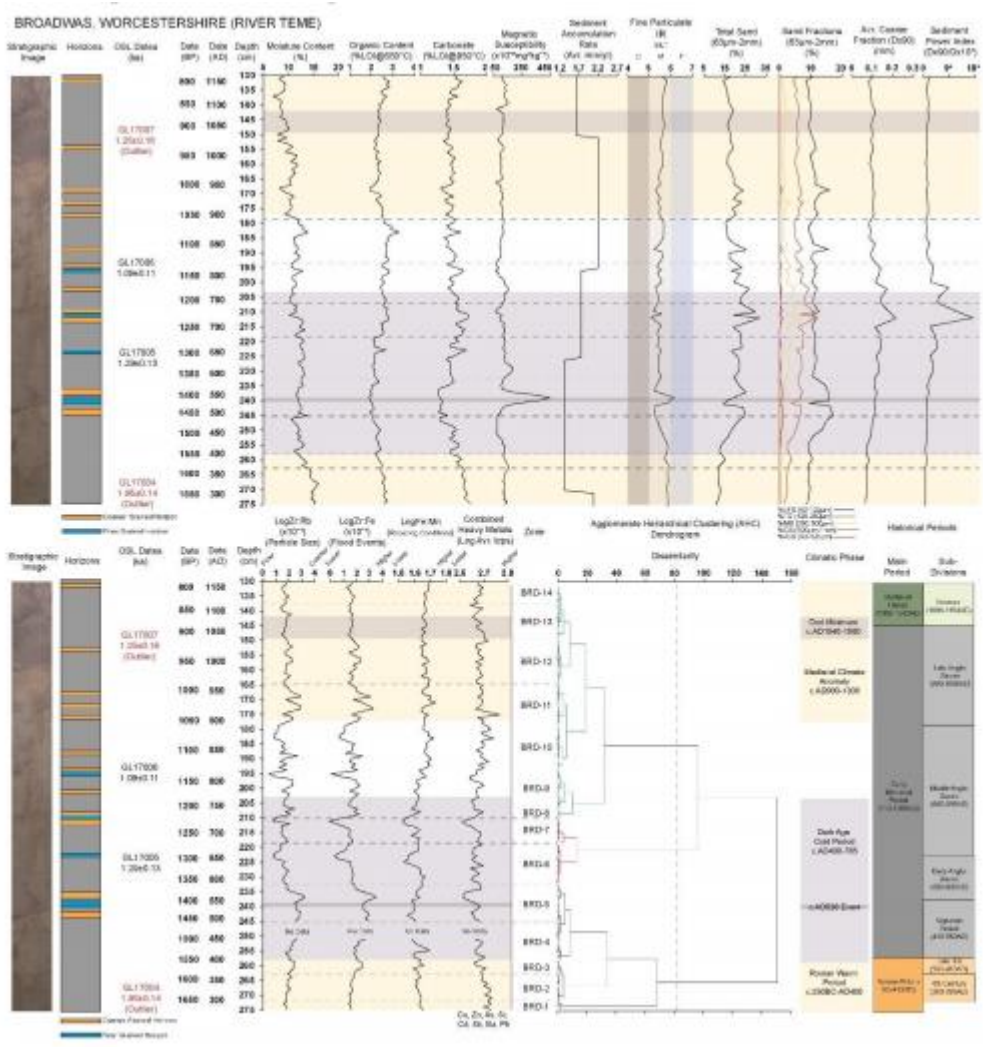

Figure 5 Chronostratigraphic model for the Teme at Broadwas, c. AD 300–1150.

From the late ninth to mid-tenth century (BRD-11, 178–165 cm), further coarsening of the alluvial texture, alongside a significant rise in elemental indicators, suggests an increase in fluvial activity and depositional conditions. These higher-energy flood signatures may represent the Teme's response to overarching climatic variations brought on by the start of the Medieval Climate Anomaly.

After *c*. AD 950, the sedimentological record reveals a reduction in depositional energy which continued for an extended time up to *c*. AD 1150 (BRD-12 to 14, 167–130 cm). During this period, there is a gradual decrease in coarse-grained components, a decrease in the elemental indicators, and, after *c*. AD 1035, a clear decrease in average sediment accumulation rate to 1.6 mm/yr. Together this evidence demonstrates a calming of riverine depositionary conditions in the Teme by the end of the early medieval period and the start of the medieval period. Flooding at this time would have been less frequent and of lesser magnitude.

The Severn at Buildwas

Initially river activity in the late Romano-British period at Buildwas appears to have been dominated by low-energy deposition, with the nature of the alluvium betraying relatively low energy fluvial conditions (BUI-1, 215–211 cm) (Figure 6). During the fourth century (BUI-2, 211–197 cm), however, depositional conditions changed rapidly so that by the end of the Romano-British period the alluvial texture was dominated by a coarse silt fine fraction with a major increase in coarse components. Together these indicate an increase in the magnitude and intensity of flooding at this point on the Severn. The sedimentological evidence suggests that throughout the fifth century AD (BUI-3, 197–182 cm) this high-energy flooding persisted and indeed increased further, leading to a century of coarse alluvial deposition with significant levels of coarse components.

The depositional characteristics of the river began to change from the start of the sixth century and lasted until the mid-eighth century (BUI-4 to 6, 182–145 cm). During this prolonged period there was a significant decrease in alluvial texture and coarse inclusions, alongside increases in other fine-grained sediment proxies. Together, these suggest a marked reduction in flooding intensity and magnitude, and generally more benign river conditions characterized by low-energy, long duration floods.

After I. AD 750, the sedimentary characteristics suggest that the Severn rapidly reverted back to higher energy deposition (BUI-7, 145–137 cm) which intensified throughout the ninth century (BUI-8,137–127 cm). During the latter part of this phase, the significant change to the alluvial texture suggests a major intensification in frequency and magnitude of flooding on the Severn. From the late

ninth to the mid-twelfth century (BUI-9 to 13, 127– 90 cm), the sediment character is typically composed of coarse silts with steadily increasing sand inclusions suggesting an extended period of high-energy deposition. Distinctive increases in Zr:Rb and Zr:Fe reveal ever-increasing flood magnitude, with the Severn at its most energetic since the fifth and sixth centuries.

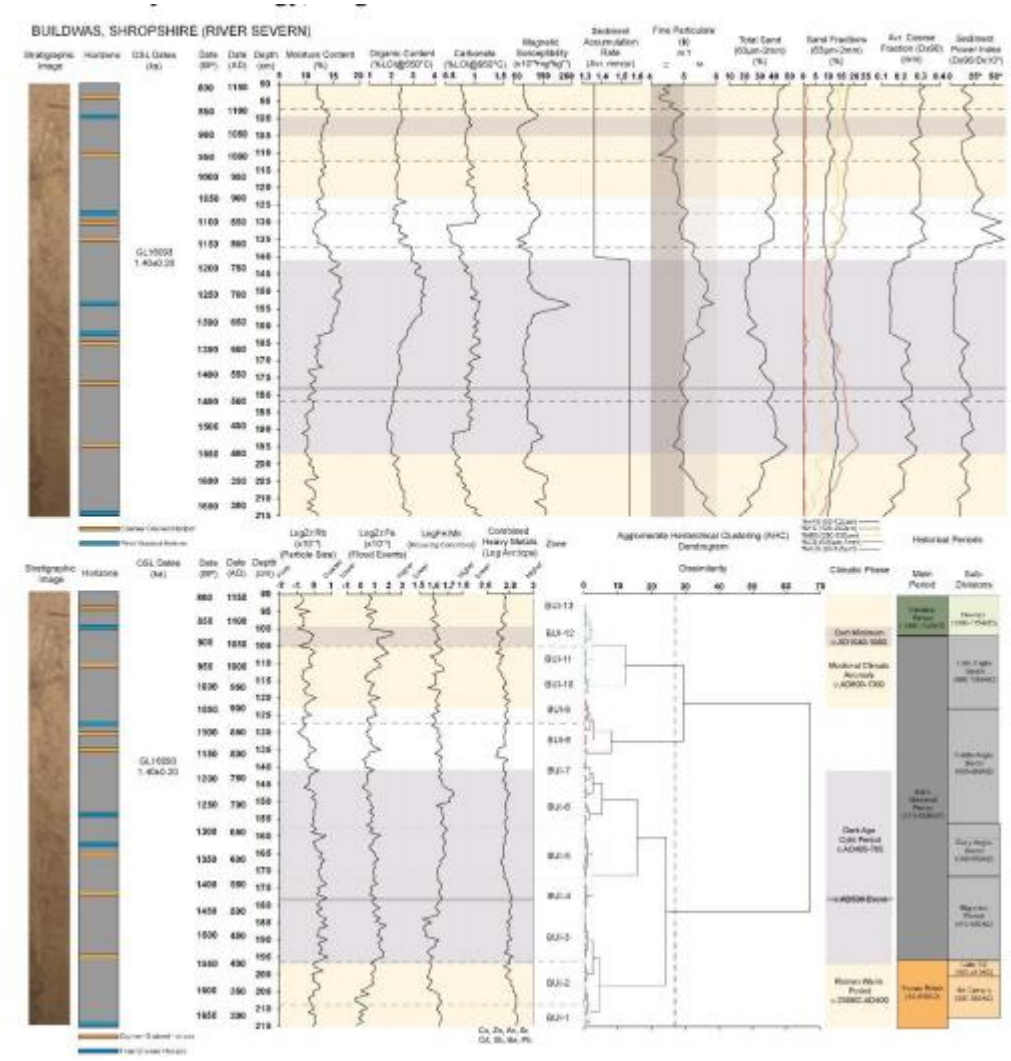

Figure 6 Chronostratigraphic models for the Severn at Buildwas, c. AD 300–1150.

Despite the general high-energy deposition at this time, evidence of very short lower energy floods can still be determined in the sediment sequence. The enhanced magnetic susceptibility and decrease in grain size at the end of the eleventh century possibly reflects a very brief change in depositionary conditions associated with extended waterlogging, possibly linked to climatic deterioration brought on by the Oort Minimum (c. AD 1040– 1080).

The Wye at Rotherwas

During the late Romano-British period (ROT-1 to 2, 210–194 cm), analytical results from the sedimentary record for the Wye at Rotherwas indicate a period of decreasing flood intensity and magnitude (Figure 7). The presence of a significant peak in magnetic susceptibility and drop in Zr:Rb suggests a clear phase of lower energy fluvial conditions in the late fourth century. At the beginning of the early medieval period, fluvial conditions appear to have continued as before. Through the fifth to the late sixth century (ROT-3 to 5, 195–170 cm,) the general texture of the alluvium continued to decrease alongside the coarse components, suggesting a further reduction in fluvial conditions and flood intensity.

After the late sixth century, the Wye demonstrates a significant change in depositionary characteristics marked by a clear change in the sedimentology. Between *c*. AD 580–640 (ROT-6, 170–162 cm), a distinctive coarse silty sand with fine gravels dominates the sequence, the physical signature left by a period of very intensive, high-energy flooding. This must have had a significant impact on the floodplain landscape given the relatively benign conditions of the previous three centuries. No historical records exist which describe the extent and effect that this period of flooding had on the local populations but it is clear from the sedimentological record that the sudden change in river dynamics would have dramatically altered how people occupied and used the floodplain for many years.

This episode of extreme deposition, however, was short-lived. From the mid-seventh to the late ninth century (ROT-7 to 10, 162–130 cm), the river returned to much lower-energy depositional conditions. Throughout this period, medium to fine silt alluvium dominates the sequence with considerably fewer coarse inclusions, suggesting lower energy flood events. Within this phase, however, several coarser-grained horizons point to very occasional higher energy floods between *c*. AD 750–850, but, on the whole, these appear to have been rare events.

From the tenth to the mid-twelfth century (ROT-11 to 14, 130–70 cm), the heterogeneous sedimentary characteristics of the alluvium suggest regular alternation between high- and low-energy depositional conditions. More generally, the gradual shift to coarser alluvium with greater concentrations of coarse inclusions and a distinctive increase in average accumulation rate (from 1.7 to 2.3 mm/yr) indicate increasingly higher-energy deposition over time associated with more frequent and greater intensity floods. Occasional shorter phases of low-energy deposition do occur at this time, marked by clear increases in magnetic susceptibility and carbonate, but, on the whole, these events are rare.

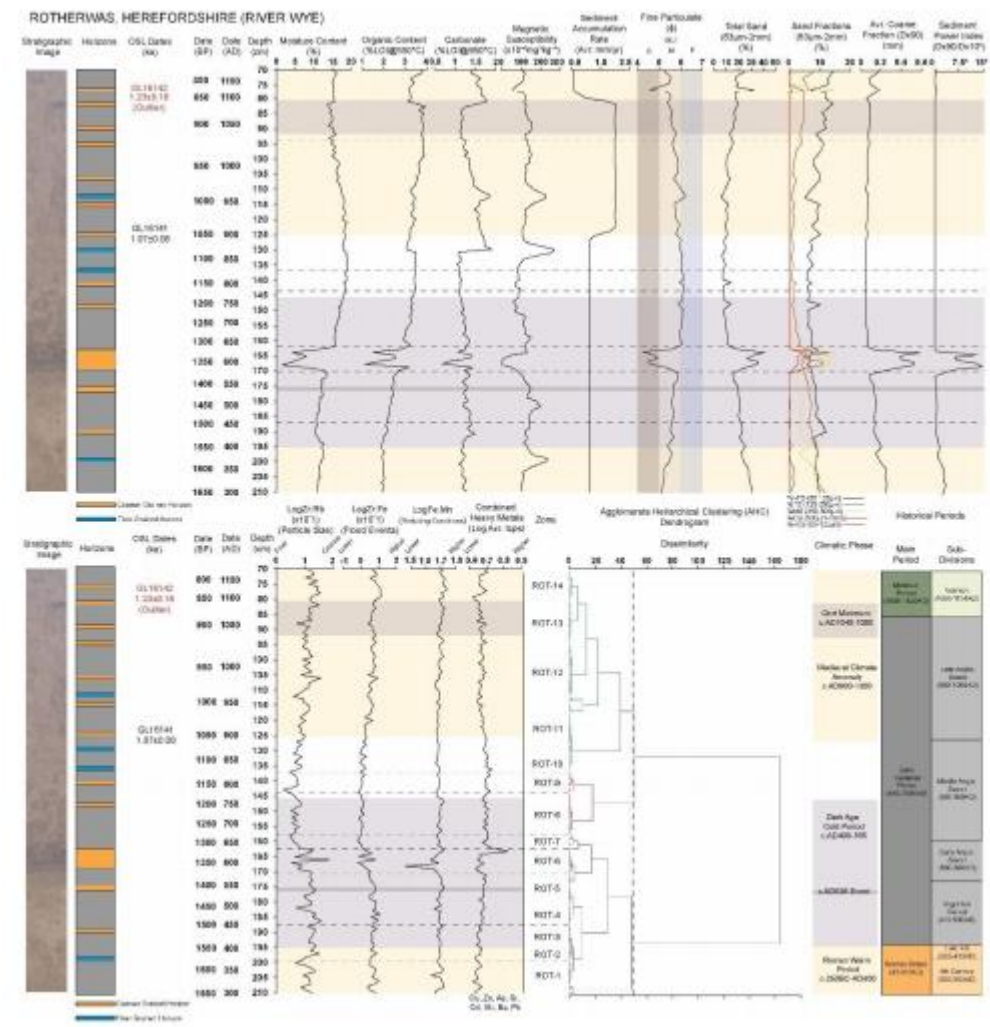

Figure 7 Chronostratigraphic models for the Wye at Rotherwas, c. AD 300–1150.

Discussion

These new chronostratigraphic sequences serve to extend significantly our understanding of the fluvial dynamics of the Severn, Teme, and Wye during the early medieval period. When compared against each other, these rivers display a degree of synchronous behaviour, but not uniformity, perhaps reflecting the individual traits of their respective catchments' characteristics and histories (Figure 8). There are broad similarities in the patterns of sedimentation across the three sites. All three sequences show, for instance, more frequent and more energetic flooding in the earlier part of their sequences than in later periods. More specifically each of the sites shows a higher degree of riverine activity in the immediate post-Romano-British period between the fifth to the seventh centuries. After *c*. AD 650, all the records demonstrate a decline in flood intensity; this is most apparent at Broadwas and Rotherwas, but at Buildwas only to a lesser extent perhaps due to its

larger catchment. The period between the mid-seventh to the mid-ninth century exhibits the most variability in fluvial activity across the three sites. The Severn and Teme appear to have been much more active than the Wye, but at all the sites rhythmical extremes between larger and smaller flood events can clearly be seen implying greater flood variability. In short, these rivers appear to have been behaving in a more erratic manner. Those living close to these rivers would have been only too aware of their unpredictable nature and the challenges they then posed to the full exploitation of both the rivers themselves and their rich floodplains. In contrast, there is broad synchronicity between the tenth and mid-eleventh centuries when there is a distinct increase in riverine activity and flood magnitude on all three rivers, albeit at different scales. The Teme and Wye demonstrate further continuity into the mid-twelfth century, whereas on the Severn there is a marked decrease in activity.

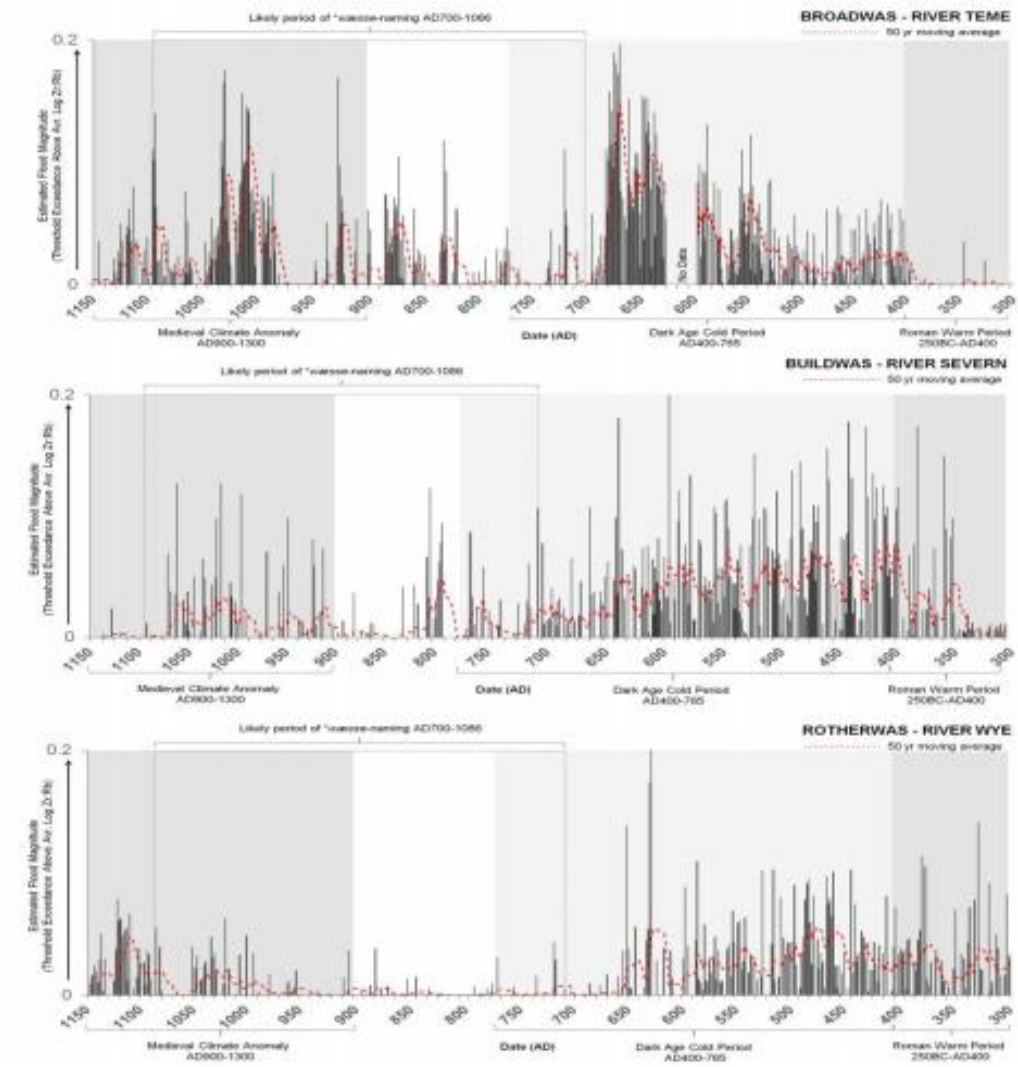

Figure 8 Estimated flood magnitude models for Broadwas, Buildwas, and Rotherwas.

Some correspondence in the behaviour of these three rivers would be expected. All are adjacent, and their catchments fall predominantly within the southwest England precipitation area defined by Gregory et al. (1991); but the flood histories of basins will always vary due to a combination of topographic, geological, and land use variables. The flood histories of the **wæsse*-sites that have been presented here appear to correspond to Macklin et al.'s (2005) study of major riverine flood probability within this precipitation zone. They isolated two phases of elevated flood activity, between *c*. AD 250-500 and *c.* AD 750-1100, and the results from the **wæsse*-sites broadly follow this model. Both they and others (Jones et al., 2010, 2012) have correlated these periods with wetter climatic phases identified, for example, in the Irish bog oak record between *c*. AD 750-850 (Leuscher et al., 2002) and in the coterminous evidence for very elevated water-levels in northern British peatlands (Charman et al., 2006). These wet phases have also been correlated with solar minima (Larsen et al., 2008). Nevertheless, it would appear that specific fluvial responses at Broadwas, Buildwas, and Rotherwas to these climatic episodes varied. This is perhaps best explained by the different scales of their respective river catchments: the Teme at 1640 km^2 , Wye 4136 km^2 , and Severn (excluding the Wye) 11,420 km^2. During wetter periods, the carrying capacity of the Severn was much more likely to be exceeded than along the Teme and Wye as a result of the collection of greater quantities of water from its more extensive catchment with a greater area of upland. This is borne out in the sedimentary record which reveals the Severn to have been more prone to higher magnitude and more frequent flooding than the others.

For the most part, it is now accepted that while the flood behaviours of British rivers are principally driven by climate (Macklin et al., 2010, 2012), their sedimentary flux is also a product of land-use history (Brown et al., 2013). In general, anthropogenic landscape change appears to have been a less significant factor in flood records, at least until *c*.950AD, after which the rates of accumulation of fine silts rise rapidly nationwide. This is considered to represent the signature of the expansion of arable farming and the delivery of greater sedimentary loads to rivers through the erosion of exposed soils (Macklin et al., 2010; Brown et al., 2013). Across the whole period covered by the new sequences, however, overbank rates of alluvial accumulation at all three sites appear to vary very little but remain high (see below). This appears to indicate a relatively stable catchment environment, and this interpretation is supported by palynological and archaeological evidence. Aggregated data from upland Wales, where all three of these rivers originate, indicate a consistent if small increase in woodland across the early medieval period. Arboreal pollen also indicate that in the western lowlands, relevant for an understanding of the middle and lower courses of all three rivers, woodland cover was again largely preserved for most of the period and may have actually increased in the immediate post-Roman period before declining after AD 850 (Rippon et al., 2015). Signs of any

expansion of arable cultivation are negligible in both regions. Such landscape continuity may help to explain the relatively constant rates of flood sedimentation at the **wæsse*-sites which remained, over the whole of the early medieval period, between 1.19-2.31 mm/yr. That said, for English lowland rivers, such rates are relatively high. Certainly, on the three sites examined here, the accumulation of alluvium was sufficiently rapid not to allow bioturbation and reworking of flood laminations, explaining why sediment preservation is so good in these places.

The material deposited was generally relatively coarse, being dominated by silts and sand. This reflects the regional geology and nature of the floodplain, particularly the fixed location of the river channels. Of course, the nature of flooding at **wæsse*-sites need not necessarily mirror what was happening elsewhere in these river catchments. Indeed, the adoption of a unique term to describe the phenomenon may point to the fact that flooding in these locations was recognised as being substantively different from that observed in other places. What each of the sequences unequivocally demonstrates is that all three **wæsse*-sites were located on reaches with high-unit stream power but also with channel stability. Such river reaches were of fundamental importance to the early medieval economy, providing excellent conditions for the placement of mills as well as weirs and fords.

The sedimentary sequences at these **wæsse*-sites provide new data that help to refine previous models developed for river behaviours and floodplain development across the early medieval period, both in terms of flood chronology and sediment accumulation. These have previously been difficult to build securely from radiocarbon-dated sequences (Brown et al., 2018). Beyond their general value, however, the results are of particular relevance for the interpretation of the unique conditions which might have been being described by the term **wæsse* in riparian settlement-names.

It is sensible to assume that, wherever deployed, **wæsse* was intended to describe the same natural process or set of characteristics. However, if we also assume that the three west midland names—Broadwas, Buildwas, and Rotherwas—came into existence at about the same time, it is difficult to identify a period when all three sites were subject to the same specific riverine behaviours. It is tempting to assign the names to the period before the mid-seventh century AD, when all three rivers flooded regularly. It is, however, extremely unlikely that Old English was sufficiently well established at that date, this far west, for **wæsse*-names to have arisen then (Bassett, 2000).

The degree of fluvial variability in river behaviours evident after the eighth century thus presents a challenge to the interpretation of the name and the fluvial phenomenon it describes. Yet despite the variability in their later detailed flood chronologies it is the case that certain types of flooding event

were shared in common at each **wæsse*-site. They all underwent both higher-energy, shorter-duration events and smaller, more prolonged flooding during the centuries when we might expect the names to have arisen (perhaps from *c.*AD650- 950). In these circumstances, it is difficult to be confident that Gelling's (2012: 103) definition of **wæsse* as a highly specialised term for land by a river which floods and drains with dramatic swiftness is the one that specifically applies, even if the sedimentary data does broadly support this interpretation. If the term were indeed linked to high-energy flood events, then we might note the extended period of the most intense fluvial activity at Buildwas during the late-eighth century as one likely context in which the name might have been adopted. Similarly, the intensification of flood activity on the Teme from the mid-ninth century might account for the Broadwas name. However, comparable conditions on the Wye which might explain Rotherwas are entirely lacking before the eleventh century AD. These non-synchronous chronologies do not, in themselves, pose a problem since the names and the places to which they were attached need not have been necessarily or strictly contemporaneous with one another.

Rather than trying to identify a shared chronology for the naming of **wæsse*-sites, it is perhaps better to consider how individual flood events may have physically manifested themselves on the ground during the latter part of the early medieval period, since an equally likely origin of **wæsse* might lie in the precise fluvial dynamics of floods common to all locations taking this name. In all instances examined here, downstream obstacles to the free flow of water exist. At Buildwas, it is the constriction of the Severn's floodplain as it enters the Ironbridge Gorge. When heavy rains occur in the upper catchment, the Severn's flood pulse is able to move downstream unhindered until it reaches the Gorge. If this pulse exceeds the capacity of the Gorge, then water backs up causing floods at Buildwas. At Broadwas, the same effect is observed when water travelling down the Teme is unable to enter the Severn. This is particularly true when the Severn is in flood, an event which last occurred in 2007. The same phenomenon occurs on the Wye at Rotherwas when the River Lugg is in spate. The effect of this pooling is a rapid rise in river levels at all three **wæsse*-sites leading to extensive overbank flooding as downstream flows meet the blockage. Equally, once the obstruction clears, there comes a moment when water previously standing on the floodplain is syphoned off, causing the floodplain to drain rapidly too.

All of which brings us back to Gelling's observations and her extended meaning of **wæsse* as 'land by a meandering river which floods and drains quickly'. Implicit in her model is that individual flood events were of short duration (from her field observations, 24- hour events). The sedimentological record, however, suggests that, in reality, some flood events might be of long duration and the geoarchaeology explains why. What is clear is that, in all three locations, it is both the onset of flooding and its conclusion that occur rapidly even if water might cover their floodplains for

considerable periods between times. It would appear, then, that it was not only the tendency of these places to flood and the frequency with which this happened that place-namers sought to communicate by using the **wæsse* element in place-names, but also the alarming speed at which these floods might rise and the comforting speed at which they receded. If these specific riverine characteristics might, from time to time, threaten the communities who lived and worked in these locations, they might also be exploited, thus explaining, perhaps counter-intuitively, why permanent settlements might be established in such places. River reaches with high stream powers and fixed channels, as found at these **wæsse*-sites, provided the most effective locations for the construction of on-stream watermills as well as weirs (e.g. fish weirs) and fords. Given such economic potential, it may be significant that two, and possibly all three, of these **wæsse*-sites possessed watermills by the late eleventh century.

Conclusion and Wider Implications

This paper has offered a new methodology for conducting fluvial geoarchaeological research and the first OSL-based early medieval flood chronology in the UK. It has demonstrated the value of using place-names to target particular river sections where the fluvial processes described in these names can be tested against the physical evidence of sedimentary records. Here, only one place-name element, Old English **wæsse*, has been examined in detail. It is suggested that Old English speakers recognised **wæsse*-sites as unusually high-energy locations: prone to flooding, yet still suitable for permanent settlement, river crossings, and the development of economic assets such as mills (Brown et al., 2018). There is great potential to extend this methodology further. Other English place-name elements that potentially describe locations where distinctive signatures of fluvial activity may have been left include: *botm* 'flat alluvial area, restricted in size, moist and often easily flooded' (Cole, 1987–88); *flēot* 'shallow water coming and going' (Cole, 1997); *halh*, variously seen to refer to 'low-lying land higher than its surroundings but still liable to occasional flooding' or 'lowlying land liable to (infrequent) flooding' (Stiles, 1997; Kitson, forthcoming); *hamm*, with potentially multiple senses including 'land in a river bend; river-meadow', 'piece of valley-bottom land hemmed in by higher ground' and the more general implicit sense 'land liable to flooding' (Gelling & Cole, 2000: 46–49); and *wisce*/*wixe* 'a piece of land in the bend of a river liable to floods' (Smith, 1956, II: 270). The method might also profitably be used to examine the behaviour of rivers based on the names they carry. It might be expected, for instance, that the River Tove 'slow, dilatory, laggardly one' will have left a different sedimentological profile than the River Swale 'whirling, rushing river' (Ekwall, 1928; Watts, 2004). Finally, since the two dominant languages, Old English and Old Norse,

from which English place-names and to a lesser extent its river-names were formed are both Germanic branches of the wider family of Indo-European languages, this is a methodology that should find potential application beyond the British Isles in the examination of the geomorphological and geoarchaeological character of rivers across Europe, including Scandinavia.

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Table 1 Summary table of OSL dates obtained from the sequences at Broadwas, Buildwas, and Rotherwas (outliers in red). (Full detailed table in supplementary material).

Site, County	Location NGR	River	Depth (cm)	OSL date & error (ka)	Code	cal. BC/AD date (δ95.4%)	cal. BC/AD date (δ68.2%)	Age estimate
Broadwas, Worcestershire	SO 375466, 254599	Teme	90	0.67±0.06	GL17008	cal. AD 1278–1535	cal. AD 1353–1497	Accepted
			150	1.25±0.16	GL17007	cal. AD 610–930	cal. AD 687–847	Accepted
			195	1.09±0.11	GL17006	cal. AD 743–1041	cal. AD 814–961	Accepted
			225	1.29±0.13	GL17005	cal. AD 563–907	cal. AD 645–814	Accepted
			270	1.95±0.14	GL17004	73 cal. BC–cal. AD 207	3 cal. BC–cal. AD 137	Accepted
			360	1.89±0.19	GL17003	287 cal. BC–cal. AD 355	158 cal. BC–cal. AD 166	Accepted
Buildwas, Shropshire	SJ 363945, 304508	Severn	80	1.00±0.20	GL16094	cal. AD 826–1494	cal. AD 1082–1424	Accepted
			140	1.40±0.20	GL16093	cal. AD 420–1074	cal. AD 624–944	Accepted
			216	3.10±0.50	GL16092	1584–590 cal. BC	830–334 cal. BC	Rejected
			287	1.90±0.30	GL16091	780 cal. BC–cal. AD 431	492 cal. BC–cal. AD 107	Accepted
Rotherwas, Herefordshire	SO 353864, 238488	Wye	80	1.23±0.18	GL16042	cal. AD 606–966	cal. AD 696–876	Accepted
			125	1.07±0.08	GL16141	cal. AD 834–1094	cal. AD 902–1030	Accepted
			215	1.59±0.17	GL16140	cal. AD 6–501	cal. AD 117–346	Accepted
			270	3.20±0.29	GL16139	1474–894 cal. BC	1329–1039 cal. BC	Accepted
			300	2.77±0.26	GL16138	912–184 cal. BC	680–345 cal. BC	Accepted

Supplementary Material

Flow Regimes

Flow regimes for the three rivers have been taken from the National River Flow Archive (https://nrfa.ceh.ac.uk) created by the Centre for Ecology and Hydrology, using the nearest station upstream of the sample sites: Knightsford Bridge Station (54029) for Broadwas and the Teme; Buildwas Station (54095) for Buildwas and the Severn; and Belmont Station (55002) for Rotherwas and the Wye. Mean flows are quoted, together with Q95 (5 percentile flow)—the flow in m3 /s equalled or exceeded for 95 per cent of the flow record—and Q10 (90 percentile flow) equalled or exceeded for 10 per cent of the flow record, which, when compared, provide an index of the variability or flashiness of the flow regime.

Teme: mean flow: 18.163m^3/s. Q95 2.02 m^3/s. Q10 42.2 m^3/s. The Teme is considered a natural catchment.

Severn: mean flow: 59.74 m^3/s. Q95 11.6 m^3/s. Q10 146 m^3/s. The modern flow regime of the Severn has been significantly modified as a result of upstream reservoir construction.

Wye: mean flow: 48.344 m^3/s. Q95 6.428 m^3/s. Q10 115.6 m^3/s. The current flow regime is moderately affected by high levels of water abstraction for agriculture.

Topographic, Gradient & Sedimentological Modelling

Topographic modelling at each site was conducted using high-resolution LiDAR datasets available from the Environment Agency. Initially a Digital Terrain Model (DTM) at 50m resolution was created for the UK and central England and overlain by major rivers (Figure 1). Detailed DTMs at 1m resolution were then created for c. 2.5–3km^2 areas across each of the floodplains at the three sites and overlain by a colour-shaded elevation model with major watercourses. River gradient models were calculated using the raw elevation data combined along the lengths of the Teme, Severn, and Wye at 50m intervals (Figure 2). In order to contextualize the sequence stratigraphies at each site across the wider floodplain landscape, existing core data held by the British Geological Survey (https://www.bgs.ac.uk/data/bmd.html) was gathered and remodelled with the new data in cross sections. At Broadwas, where no existing core data were forthcoming, a programme of coring at 100m intervals using a mechanical percussion auger was undertaken to record the sediment sequence and collect samples from the settlement to the river section (Figure 4). The ground surface topography across each transect was extracted from the raw LiDAR data at 10cm resolution.

Field Sampling

In order to analyse the sedimentary sequences at Broadwas, Buildwas, and Rotherwas, river sections were excavated at strategic locations along the banks of the rivers Teme, Severn, and Wye. The sample areas were cleaned, photographed, and recorded, revealing between 3 and 3.75m of alluvium down to the present river level, with terrace gravels identified at the base of each. From each section *in-situ* sediment samples were collected using 30–50-cm-long u-channels with 5-10cm cross-over to enable <1cm to 1cm resolution analysis; these were complemented by larger bulk sediment samples (c. 20–50g) collected every 5cm.

Optically Stimulated Luminescence (OSL) Sampling

Sample Preparation

Fifteen sediment samples were collected in opaque plastic tubing from excavated sections and submitted for optical dating at the University of Gloucestershire Luminescence dating laboratory (Toms, 2017; Toms & Wood, 2018a, 2018b) (Table 1 [main article] and Table S1 [Supplementary Material]). To preclude optical erosion of the datable signal prior to measurement, all samples were opened and prepared under controlled laboratory illumination provided by Encapsulite RB-10 (red) filters. To isolate material potentially exposed to daylight during sampling, sediment located within 20mm of each tube-end was removed. The remaining sample was dried and then sieved. Depending on each sample's modal grain size, quartz within the fine sand or fine silt fraction was segregated.

Samples were then segregated and subjected to acid and alkaline digestion (10 per cent HCl, 15 per cent H_2O_2) to attain removal of carbonate and organic components respectively. For fine sand fractions, a further acid digestion in HF (40 per cent, 60 minutes) was used to etch the outer 10–15µm layer affected by α radiation and degrade each sample's feldspar content. During HF treatment, continuous magnetic stirring was used to effect isotropic etching of grains. To remove acid soluble fluorides, 10 per cent HCl was then added. Each sample was dried, re-sieved and quartz isolated from the remaining heavy mineral fraction using a sodium polytungstate density separation at 2.68 $g.cm^{-}$. Twelve 8mm multi-grain aliquots (c. 3–6mg) of quartz from each sample were then mounted on aluminium discs for determination of D_e values. Fine silt sized quartz, along with other mineral grains of varying density and size, was extracted by sample sedimentation in acetone (5µm in 21 mins at 20°C). Feldspars and amorphous silica were then removed from this fraction through acid digestion (35 per cent H_2SiF_6 for 2 weeks, Jackson et al., 1976; Berger et al., 1980). Following

addition of 10 per cent HCl to remove acid soluble fluorides, grains degraded to <5μm as a result of acid treatment were removed by acetone sedimentation. Twelve multi-grain aliquots (*c.* 1.5mg) were then mounted on aluminium discs for D_e evaluation. All drying was conducted at 40°C to prevent thermal erosion of the signal.

D_e Measurements

All minerals naturally exhibit marked inter-sample variability in luminescence per unit dose (sensitivity). Therefore, the estimation of D_e acquired since burial requires calibration of the natural signal using known amounts of laboratory dose. D_e values were quantified using a single-aliquot regenerative-dose (SAR) protocol (Murray & Wintle, 2000, 2003) facilitated by a Risø TL-DA-15 irradiation-stimulation-detection system (Markey et al., 1997; BøtterJensen et al., 1999). Within this apparatus, optical signal stimulation is provided by an assembly of blue diodes (5 packs of 6 Nichia NSPB500S), filtered to 470±80nm conveying 15mW.cm^{-2} using a 3mm Schott GG420 positioned in front of each diode pack. Infrared (IR) stimulation, provided by 6 IR diodes (Telefunken TSHA 6203) stimulating at 875±80nm delivering ~5mW.cm^{-} , was used to indicate the presence of contaminant feldspars (Hütt et al., 1988). Stimulated photon emissions from quartz aliquots are in the ultraviolet (UV) range and were filtered from stimulating photons by 7.5mm HOYA U-340 glass and detected by an EMI 9235QA photomultiplier fitted with a blue-green sensitive bialkali photocathode. Aliquot irradiation was conducted using a 1.48 GBq ^{90}Sr/^{90}Y β source calibrated for multigrain aliquots of 5–15μm, 125–180μm and 180–250μm quartz against the 'Hotspot 800' ^{60}Co γ source located at the National Physical Laboratory (NPL), UK.

The propensity of feldspar signals to fade and underestimate age, coupled with their higher sensitivity relative to quartz, makes it imperative to quantify feldspar contamination. At room temperature, feldspars generate a signal (Infrared Stimulated Luminescence; IRSL) upon exposure to IR whereas quartz does not. The signal from feldspars contributing to OSL can be depleted by prior exposure to IR. For all aliquots the contribution of any remaining feldspars was estimated from the OSL IR depletion ratio (Duller, 2003). If the addition to OSL by feldspars is insignificant, then the repeat-dose ratio of OSL to post-IR OSL should be statistically consistent with unity, as is the case in this study for the majority of the samples. The exception is sample GL16138, which returns a post-IR OSL ratio of 0.78±0.03 and, thus, the associated age should be treated as a minimum estimate.

Preheating aliquots between irradiation and optical stimulation is necessary to ensure comparability between natural and laboratory-induced signals. However, the multiple irradiation and preheating steps that are required to define single-aliquot regenerative-dose response leads to signal

sensitisation, rendering calibration of the natural signal inaccurate. The SAR protocol (Murray & Wintle, 2000, 2003) enables this sensitisation to be monitored and corrected using a test dose, here set at 5 Gy preheated to 220°C for 10s, to track signal sensitivity between irradiation-preheat steps. However, the accuracy of sensitisation correction for both natural and laboratory signals can be preheat dependent.

The Dose Recovery test was used to assess the optimal preheat temperature for accurate correction and calibration of the time dependent signal. Dose Recovery attempts to quantify the combined effects of thermal transfer and sensitisation on the natural signal, using a precise lab dose to simulate natural dose. The preheat chosen for each sample was that where the ratio between the applied dose and recovered De value was consistent with unity. Further thermal treatments, prescribed by Murray and Wintle (2000, 2003), were applied to optimize accuracy and precision. Optical stimulation occurred at 125°C in order to minimize effects associated with photo-transferred thermoluminescence and maximize signal to noise ratios. Inter-cycle optical stimulation was conducted at 280°C to minimize recuperation.

Murray and Wintle (2000, 2003) suggest that ratios from repeat-dose measurements indicate the success of sensitivity correction, whereby ratios ranging across 0.9–1.1 are acceptable. However, this variation of repeat-dose ratios in the high-dose region can have a significant impact on De interpolation. In this study, these ratios are based on repeats of low and high dose measurements. Most repeat-dose ratios are consistent with the range 0.9–1.1, though some data are relatively scattered owing to poor signal to noise ratios. However, the recycling ratios for sample GL16092 from Buildwas are not consistent with the range 0.9– 1.1; the corresponding age estimate is therefore rejected.

D_r Measurements

Lithogenic D_r values were defined through measurement of U, Th and K radionuclide concentration and conversion of these quantities into α, β and γ Dr values (Table S1). Contributions of α and β were estimated from sub-samples by laboratory-based γ spectrometry using an Ortec GEM-S high purity Ge coaxial detector system, calibrated using certified reference materials supplied by CANMET. Rates of γ dose were estimated *in situ* with an EG&G μNomad portable NaI gamma spectrometer (calibrated using the block standards at RLAHA, University of Oxford); these reduce uncertainty relating to potential heterogeneity in the γ dose field surrounding each sample. The level of U disequilibrium was estimated by laboratory-based Ge γ spectrometry. Estimates of radionuclide concentration were converted into Dr values (Adamiec & Aitken, 1998), accounting for D_r modulation forced by grain size (Mejdahl, 1979), present moisture content (Zimmerman, 1971) and,

where D_e values were generated from 5–15 μm quartz, reduced signal sensitivity to α radiation (a-value 0.050 ± 0.002). Cosmogenic D_r values were calculated on the basis of sample depth, geographical position, and matrix density (Prescott & Hutton, 1994). No samples exhibited pronounced ($^{226}Ra/^{238}U$>50 per cent) U disequilibrium.

Age-Depth Modelling

The determination of the OSL dates allowed detailed age-depth modelling of the alluvial sequence (Figure 3). This was conducted using OxCal, version 4.3 with IntCal[13] program (Bronk Ramsey, 2008, 2009). Outliers were identified by running statistical analyses on all the dates, including reversals, and analysed against a run without reversals (Figure 3, in red). This demonstrated that all but one of the dates (GL16092) were statistically viable for the calculation of precise calendrical dates at 2δ (95.4 per cent confidence) and 1δ (68.2 per cent confidence). The development of a sequence chronology then enabled the calculation of the average sediment accumulation rate at each of the sites.

Loss on Ignition

Alongside the chronological determination, samples were also subjected to a range of sedimentological analyses to interpret the depositional history of the sequence (Figures 5, 6, and 7). Loss on Ignition (LOI) at 1cm resolution was conducted by combusting samples at 105°C for 12 hours to determine moisture content, an additional particle size proxy. A second burn at 550°C for a further 2 hours provided the percentage organics, conducted to determine the presence of *in-situ* soil horizons and/or sudden deposition from flood events. A final burn at 950°C for 4 hours determined the calcium carbonate ($CaCO_3$) content, essential for further elucidation of the fine-sediment fraction through the preservation of flocculated structure, and the binding of organics to the fine particulate in alluvium (e.g. Bullinger-Weber et al., 2007).

Magnetic Susceptibility

Magnetic susceptibility (MS) was measured in order to identify high-resolution variations in texture, and changes in depositional conditions, possibly as a result of flooding events (Figures 5, 6, and 7). The process was also used to determine variations in landuse on the floodplain. This has previously been shown to demonstrate changes in anthropogenic activity on archaeological sites (Tite &

Mullins, 1971). MS was undertaken with a Bartington MS2 meter using the MS2B dual sensor equipment at 1cm resolution. Volume magnetic susceptibility in SI unit (κ) was determined using a fixed frequency of 3.41kHz and a periodicity of 15 seconds, and precision was determined with randomly selected repeatability of samples. The methodology and interpretation of results followed Dearing (1999).

Particle Size Analysis

Further analysis of micro-variant sediment texture was conducted using particle size analysis (Figures 5, 6, and7), following the methodology set out by Konert and Vandenberghe (1997). To remove organic material, 2–5g of sediment was heated to 550^{o}C for 2 hours in a furnace and the remaining sediment sieved through a <2-mm sieve and then mixed with a deionized water and Calgon solution to disaggregate remaining components. A subsample of this was then placed in a petrie dish with more Calgon and gently agitated with a pestle before being added to a Malvern Digisizer until an optimal obscuration of 5–20 per cent had been achieved. Background and sample measurement time was set to 90 seconds and each sample was analysed five times in order to get a good statistical dataset as determined by the international standard ISO-13320-1. All samples analysed had a standard deviation lower than 2 per cent for the fine-grained percentile (<Dx10), less than 3 per cent for the median percentile (<Dx90).

Multi-element ITRAX Analysis

Multi-element determination was calculated using an ITRAX XRF scanner (Croudace et al., 2006). *In-situ* sediment samples were collected in 30–50cm-long 'u channels' from the river section and scanned at 0.2cm resolution using 30kV, 30mA settings and a 15-second count time at the British Ocean Sediment Core Research Facility (BOSCORF) at the National Oceanography Centre, Southampton (NOCS). In total, 39 elements were identified including lithogenic indicators (Si, Al, K, Ti, Zr, Rb) and anthropogenic and heavy metal indicators. The resultant elemental intensities, measured in counts per second (cps), were vetted to remove unreliable results which occurred at the boundaries of samples, in particular within exceptionally coarse sediment horizons. The resultant dataset was then scrutinized and specific combinations of elemental ratios created in order to determine proxy coarse-grained indicators (Zr:Rb) (Thompson & Oldfield, 1986; Jones et al., 2010, 2012), flood events and depositional conditions (Zr:Fe) (Wilhelm et al., 2013), redox conditions, waterlogging and/or elevated water tables (Fe:Mn) (Vepraskas, 2002), and combined heavy metals

(Cu, Zn, As, Sr, Cd, Sb, Ba, Pb) in the fine and coarse sediment fraction (Croudace & Rothwell, 2015). Results from the multi-element ITRAX analysis are presented in Figures 5, 6, and 7 as logratios following the work of Aitchison (1981), Weltje and Tjallingii (2008), and Weltje et al. (2015).

Sediment Power Index

In order to further understand the variations in sediment concentration, size, distribution, and presence/absence of void space within the alluvium at the three sites, a Sediment Power Index was calculated (Figures 5, 6, 7). This was achieved by dividing the coarse sediment fraction (Dx90) by the finest sediment fraction (Dx10) to the power 3. The organic fraction was initially removed from the calculation; however, the LOI@550 results were so negligible that in the end this was not calculated in the equation.

Agglomerate Hierarchical Clustering (AHC)

To analyse statistically sedimentological variations within the alluvial sequences from the three sites, a programme of Agglomerative Hierarchical Clustering (AHC) analysis was conducted using the XLStat, which enabled the detailed zonation of horizons (Figures 5, 6, 7). For each site, series dissimilarity was determined of data z-scores at 1cm resolution using the Euclidean distance between six variables, percentage organics, percentage carbonate, magnetic susceptibility, fine particulate, percentage sand, and Zr:Rb. Agglomeration was calculated using Ward's Method (Ward, 1963). The results were presented in horizontal dendrograms demonstrating cophenetic distance between variables and horizons, with major classes defined by class colour variation and individual horizon zonation defined by changes at the most similar level.

Flood Magnitude Models

Flood magnitude models were created for each of the sites using the coarse-grained sediment indicators Zr:Rb determined during the ITRAX multi-element analysis, detailed by Jones et al. (2012: 91 & 93). This methodology was chosen because the original work had also been conducted in the River Severn catchment where comparable basal geologies exist. The original ITRAX data were statistically tested using polynomial regression, which enabled the determination of a flood threshold value, and remodelled where there was threshold exceedance above average LogZr:Rb (Figure 8). The filtering out of 'noise' from the original dataset and addition of a 50-year moving

average, enabled the identification and refinement of flood-rich phases of deposition at each site between AD 300 and 1150.

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Table S 1 Dr, De and Age data. Age estimates expressed relative to 2016 for Buildwas and Rotherwas and 2017 for Broadwas. Uncertainties in age are quoted at 1σ confidence and reflect combined systematic and experimental variability. Blue text denotes rejected age estimate, owing to poor repeat dose ratios. Red text indicates sample age should be considered a minimum estimate, owing to significant feldspar contamination.

Site, County, NGR & River	Lab Code	Overburden (m)	Grain size (μm)	Moisture content (%)	NaI γ-spectrometry (in situ) γ D_r ($Gy.ka^{-1}$)	Ge γ-spectrometry (*ex situ*)			α D_r ($Gy.ka^{-1}$)	β D_r ($Gy.ka^{-1}$)	Cosmic D_r ($Gy.ka^{-1}$)	$^{226}Ra/^{238}U$	Total D_r ($Gy.ka^{-1}$)	Preheat (°C for 10s)	Low Dose Repeat Ratio	High Dose Repeat Ratio	Post-IR OSL Ratio	D_e (Gy)	Age (ka)	cal. BC/AD date (1σ, 68.2%)
						K (%)	Th (ppm)	U (ppm)												
Broadwas, Worcestershire, SO 375466, 254599, Teme	GL17008	0.90	125-180	13 ± 3	0.90 ± 0.11	1.61 ± 0.10	9.32 ± 0.57	1.88 ± 0.14	-	1.39 ± 0.14	0.18 ± 0.02	1.01 ± 0.14	2.47 ± 0.17	260	0.97 ± 0.02	1.00 ± 0.01	0.96 ± 0.02	1.6 ± 0.1	0.67 ± 0.06	cal. AD 1290 – 1410
	GL17007	1.50	125-180	14 ± 4	0.88 ± 0.11	1.63 ± 0.10	9.39 ± 0.57	1.77 ± 0.14	-	1.36 ± 0.15	0.16 ± 0.02	0.88 ± 0.13	2.40 ± 0.18	220	0.97 ± 0.03	1.03 ± 0.02	0.94 ± 0.03	3.0 ± 0.3	1.25 ± 0.16	cal. AD 610 – 930
	GL17006	1.95	125-180	16 ± 4	0.86 ± 0.11	1.67 ± 0.10	9.35 ± 0.57	1.77 ± 0.14	-	1.35 ± 0.15	0.15 ± 0.01	1.23 ± 0.19	2.36 ± 0.19	260	0.98 ± 0.03	1.00 ± 0.02	0.97 ± 0.03	2.6 ± 0.1	1.09 ± 0.11	cal. AD 820 – 1030
	GL17005	2.28	125-180	16 ± 4	0.81 ± 0.10	1.36 ± 0.09	9.22 ± 0.56	1.83 ± 0.14	-	1.17 ± 0.13	0.14 ± 0.01	0.84 ± 0.11	2.12 ± 0.17	280	0.95 ± 0.04	1.00 ± 0.03	0.93 ± 0.04	2.7 ± 0.2	1.29 ± 0.13	cal. AD 590 – 860
	GL17004	2.70	5-15	20 ± 5	0.85 ± 0.08	1.56 ± 0.10	10.16 ± 0.60	2.01 ± 0.15	0.39 ± 0.04	1.37 ± 0.14	0.13 ± 0.01	1.13 ± 0.17	2.75 ± 0.17	240	0.99 ± 0.08	0.99 ± 0.06	0.95 ± 0.08	5.4 ± 0.2	1.95 ± 0.14	80 cal. BC – cal. AD 200.
	GL17003	3.55	125-180	19 ± 5	0.85 ± 0.11	1.67 ± 0.11	9.40 ± 0.59	1.96 ± 0.14	-	1.32 ± 0.16	0.12 ± 0.01	0.95 ± 0.12	2.28 ± 0.21	260	1.02 ± 0.02	1.02 ± 0.01	1.00 ± 0.02	4.3 ± 0.2	1.89 ± 0.19	50 cal. BC – cal. AD 320
Buildwas, Shropshire, SJ 363945, 238488, Severn	GL16094	0.82	180-250	15 ± 4	0.60 ± 0.09	1.35 ± 0.09	5.78 ± 0.44	1.03 ± 0.12	-	1.01 ± 0.12	0.18 ± 0.02	0.64 ± 0.11	1.80 ± 0.14	220	0.95 ± 0.05	1.00 ± 0.04	0.93 ± 0.05	1.8 ± 0.4	1.0 ± 0.2	cal. AD 800 – 1250
	GL16093	1.40	180-250	19 ± 5	0.72 ± 0.10	1.63 ± 0.10	7.72 ± 0.50	1.37 ± 0.13	-	1.16 ± 0.14	0.17 ± 0.02	0.71 ± 0.11	2.05 ± 0.19	240	1.02 ± 0.07	1.00 ± 0.04	0.95 ± 0.06	2.8 ± 0.4	1.4 ± 0.2	cal. AD 400 – 890.
	GL16092	2.16	180-250	20 ± 5	0.84 ± 0.11	1.79 ± 0.11	9.19 ± 0.57	1.77 ± 0.14	-	1.31 ± 0.16	0.15 ± 0.01	1.10 ± 0.16	2.29 ± 0.21	260	1.13 ± 0.06	1.07 ± 0.04	1.10 ± 0.06	7.0 ± 0.8	3.1 ± 0.5	1510 – 610 cal. BC
	GL16091	2.85	180-250	18 ± 4	0.74 ± 0.11	1.67 ± 0.11	7.27 ± 0.50	1.50 ± 0.13	-	1.22 ± 0.14	0.13 ± 0.01	0.83 ± 0.12	2.09 ± 0.18	240	1.01 ± 0.04	0.98 ± 0.03	0.97 ± 0.04	3.9 ± 0.4	1.9 ± 0.3	120 cal. BC – cal. AD 380
Rotherwas, Herefordshire, SO 353864, 238488, Wye	GL16142	0.80	125-180	19 ± 5	0.86 ± 0.11	1.48 ± 0.10	10.54 ± 0.61	2.03 ± 0.14	-	0.86 ± 0.11	0.18 ± 0.02	0.93 ± 0.12	2.27 ± 0.20	260	0.96 ± 0.02	1.01 ± 0.01	0.96 ± 0.02	2.8 ± 0.3	1.23 ± 0.18	cal. AD 610 - 970
	GL16141	1.25	5-15	22 ± 5	0.91 ± 0.09	1.74 ± 0.11	10.96 ± 0.63	2.29 ± 0.15	0.41 ± 0.05	1.47 ± 0.16	0.17 ± 0.02	0.87 ± 0.11	2.96 ± 0.19	260	0.97 ± 0.06	1.01 ± 0.05	0.96 ± 0.06	3.2 ± 0.1	1.07 ± 0.08	cal. AD 860 – 1030

	GL16140	2.15	180-250	15 ± 4	0.94 ± 0.11	1.49 ± 0.10	11.66 ± 0.64	1.90 ± 0.14	-	0.94 ± 0.11	0.15 ± 0.01	0.95 ± 0.14	2.37 ± 0.18	260	0.96 ± 0.03	1.02 ± 0.02	0.95 ± 0.03	3.8 ± 0.3	1.59 ± 0.17	cal. AD 250 – 600
	GL16139	2.70	180-250	17 ± 4	0.88 ± 0.11	1.57 ± 0.10	9.87 ± 0.59	2.00 ± 0.14	-	0.88 ± 0.11	0.13 ± 0.01	1.01 ± 0.13	2.28 ± 0.19	240	0.98 ± 0.02	0.99 ± 0.02	0.97 ± 0.02	7.3 ± 0.3	3.20 ± 0.29	1470 – 890 cal. BC
	GL16138	3.00	180-250	17 ± 4	0.83 ± 0.10	1.38 ± 0.09	9.99 ± 0.60	1.89 ± 0.14	-	0.83 ± 0.10	0.13 ± 0.01	0.73 ± 0.10	2.11 ± 0.18	260	0.98 ± 0.03	1.00 ± 0.03	0.78 ± 0.03	5.8 ± 0.2	2.77 ± 0.26	1010 – 490 cal. BC