Magdalen Farm Paleochannel Exploratory Dig July 2022

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1 Summary

River and floodplain restoration of the River Axe requires understanding of evolution of the river channel form. Countryside Stewardship scheme proposals at Magdalen Farm include options to either enhance the river along its current channel route or restore a former paleochannel.

To inform which option to progress, it was necessary to determine if the paleochannel retained a cobble and gravel riverbed, and whether this was elevated significantly above the current riverbed. Exploratory paleochannel excavations were proposed to:

- confirm the presence of a suitable cobble/gravel bed, and to
- indicate former channel widths and depths

Excavations were carried out at three main locations, providing some evidence on the scale and nature of the paleochannel(s) as well as water table conditions. Works were carried out from 11 to 14th July 2022, using a 3tn excavator.

Excavations indicated paleochannel cobble beds (with a median stone size of 32mm, and maximum of 128mm) at elevations broadly consistent both with remaining cobble and gravel runs in the current channel and exposed cobble strata in the banks at eroded sections.

Combined with the excavation findings, a literature review of the River Axe, Culm and Europe wide geomorphology since the Quaternary period, gives an understanding of a valley wide braided river system existing at the end of the last ice age. This provides a consistent cobble gravel layer that the later river has been founded on. Following the ice age, the river would likely to have evolved into a valley wide wetland with an anastomosed, vegetation controlled, channel system. The advent of large-scale deforestation led to increased rates of sedimentation that smothered these wetland habitats and gradually developed a raised floodplain. The floodplain has become increasingly decoupled from the river channel.

Two of the main excavation trenches suggest floodplain aggradation of 0.58m, 0.98m. The third trench gives evidence of an even greater level of infilling, of at least 1.5m of sedimentation over the former channel. This is comparable to floodplain aggradation rates that have been shown on the nearby River Culm to be up to 4mm per year.

Two trenches revealed signs of blockage by trees, presumably during a major flood, which may have triggered avulsion into the current channel. An historical review suggests that this may have been the 1866 flood that was recorded on the River Exe.

The excavations do suggest a significantly narrower channel than the current one, potentially just 3.9m wide.

These conclusions indicates that restoration of the paleochannel offers no benefits over restoring the existing channel in terms of the elevation of a gravel bed. The excessive volume of cut required, and lack of defined historic banks, make this option unfavourable. The Countryside Stewardship scheme should therefore progress restoration along the line of the current channel.

Restoration options elsewhere on the River Axe should be informed by investigations of the depth of the cobble gravel layer across the floodplain at those locations. Such restoration is required if further deterioration of the river ecology and environment is to be avoided.

2 Geomorphological literature review

A series of papers by Antony Brown (et al) on quaternary rivers, that includes the River Axe and the River Culm, gives a good understanding of the formation of the river and floodplain geomorphology. His work with others also provides a Europe wide context for this.

Brown et al (2015) reveals a valley cut through Upper Greensands (Cretaceous period layers), and into the lower lying early Jurassic and Triassic layers, during glacial periods. Over the last 300,000-400,000 years, this deep valley was then buried with a stacked sedimentary sequence 20-30m thick of fluvial and periglacial sedimentation of near horizontally chert and sand-rich rocks.

Valley slope mapping by Brown et al (2015) indicates thaw-slump scars, related to large hill-slope failures caused by rapid permafrost melting with water pressures and hydraulic fracturing of the Upper Greensand chert layers that provides the source for this infilling material. They propose that over-sized and interlocking chert stones may have prevented incision of the river in interglacial periods until some 14,000-12,000 years before present.

As the area emerged from the Lateglacial Interstadial, a periglacial braided river system extended across the width of the valley. Brown (2015) referenced evidence of the well sorted gravels of this braided system found at the pits and boreholes at Hodge Ditch in Chard Junction Quarry, some 6.5m below surface. This is overlaid by bedded gravels with sand infilled channels, which in turn is overlain by paleosols and glacial related deposits.

Brown & Walling et al (2020) considered combined geomorphological mapping, sediment dating and paleoecology for the nearby River Culm. They chart the evolution of channel forms from a braided state through the last glacial period to an anastomosed form around 5300 years ago.

This pattern is repeated across Europe with Brown et al (2018) referencing work that shows Early Holocene (11,650-9,700 years before present) rivers as "*predominantly multichannel (anabranching) systems, often choked with vegetation"*, with floodplains that *"were either non-existent or limited to adjacent organic filled palaeochannels, spring/valley mires and flushes."* Within these anabranching/ anastomosed systems, the geomorphic processes we largely controlled by the marginal, in channel and valley wetland vegetation.

Around 4,000 to 2,000 years ago, deforestation and arable farming lead to an increase in silt-clay deposits that "*transformed European floodplains, covering former wetlands and silting-up secondary channels"* Brown et al (2018). These deposits created "*cohesive river banks and relatively flat inorganic floodplains."*

From the Roman and Medieval period, there was 'industrialisation' of river channels, for drainage, navigation, and milling.

The Brown & Walling et al (2020) study of the Culm reveals further details through sediment dating and paleoecology. Their study of the Culm focused on sections of the river that still retain features of the anastomosed system, thought to remain due to the smaller scale and later floodplain and valley slope woodland clearance. Their palaeoecological records show floodplain woodlands dominated by alder and hazel some 5,400 years through to 3,000 years ago. Localised phases of clearances are evidenced around 1,450 to 940 years ago, but with widescale replacement by wet graze pasture by 800 years ago. These are consistent with typical dates of for Southern England and so should be similar for the River Axe. Although, hillslopes on the Culm, persisted as woodland through to 1400 to 1100 years ago, with clearance typically occurring only in the recent period.

For the Culm, coring logs show riffles persisting at intersections of current day and paleo channel routes dating back to between 3030 and 719 years before present. Historic mapping showed little channel change since 1802. "*The combined dating also reveals several later peaks in avulsive activity with the largest peak in the last 400 years, probably forced by the Little Ice Age*"

Brown & Walling et al (2020) showed floodplain aggradation on the Culm to be continuous over the last century except at one location, where there was little aggradation before 1963. Several sites showed increased sedimentation rates in the last 40-50 years, with floodplain rates varying from 0.1 to 4mm/year (with the highest being that most recent).

3 Historical channel development analysis

River channels can develop in different ways, each leaving distinct marks on the landscape. Where a river channel gradually migrates across a floodplain, it leaves a trail of infilling at the inside of bends. This gradual migration itself can be punctuated through phases of pause and acceleration. Oxbow lakes may be left behind as gradual migration cuts off a bend, and then slowly fills. Whereas, when a river avulses, it carves out and moves into a new channel in a single flood. This leaves the former route isolated from the new channel. These landscape scars, combined with historic maps, can reveal the past behaviour of river systems, and indicate either their future or their present condition.

Fig 1. River Exe channel forms

In the aerial photograph of Figure 1, crop marks reveal a series of channel movements of the River Exe. These suggest both phases of more gradual channel migration, as well as discrete channel shifts.

3.1 Aerial Survey LiDAR interpretation at Magdalen Farm

On the River Axe at Magdalen Farm, obvious depressions in the floodplain, analysis of aerial survey data, as well as the county boundary maps, speak of equivalent channel changes.

Figure 2 shows aerial survey data of the floodplain at Magdalen Farm. This suggests a combination of mechanisms. To the east (circled in blue) there is a clear single former channel. This most likely occurred through avulsion in a major flood. To the west (circled in green) are features indicating both gradual channel migration as well as avulsion. Within the woodland to the north, a small area (circled red) shows the more gradual accretion and infilling of a bend as it migrated to the west (with a possible former route shown by the dotted red line).

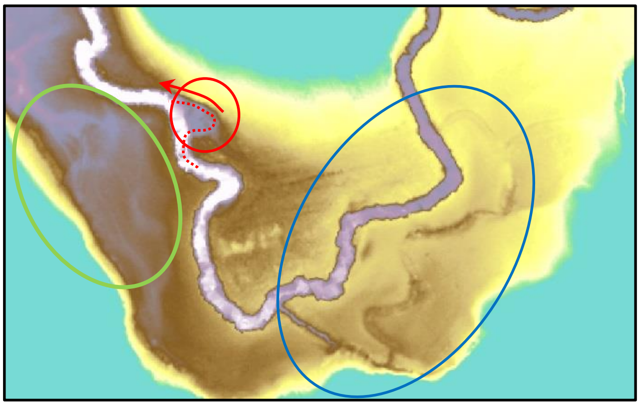


Fig 2. Aerial survey of Magdalen Farm floodplain

Figure 3 shows the range of potential former channels within the Magdalen Farm floodplain area that are suggested by the aerial surveys.

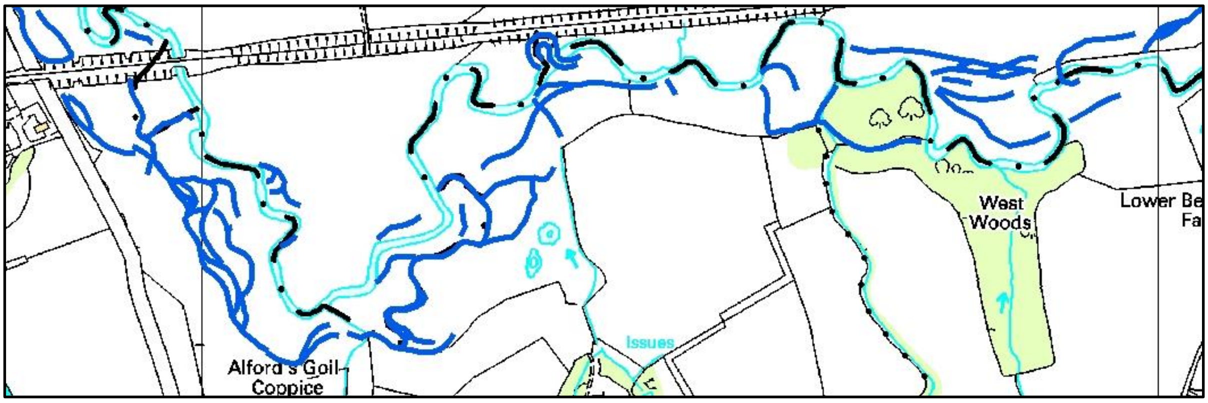


Fig 3. Potential paleochannels of the River Axe through Magdalen Farm

3.2 Historical interpretation at Magdalen Farm

Aerial surveys alone do not reveal the chronology of channel changes. However, County boundary changes, railway construction, historic maps and flood records do provide further evidence to interpret this. The interpretation is shown in Figure 4 by considering these evidence sources.

Accurate survey maps were first published in 1888, identifying a channel line consistent with the present-day route - marked in green in Figure 4. The earlier 1831 Creighton map is too coarse to use.

The 1832 Parliamentary Constituency and 1844 County Boundary changes, along with the London and South Western Railway construction (between 1859 and 1860), provide information on the next oldest route shown in red.

A much older route running along the southern edge of the floodplain (in blue) is apparent both from Lidar and from wetland vegetation present in the floodplain. This predates the accurate mapped survey data and county boundary changes.

It appears that the river may have been straightened for 1860 railway construction to facilitate the rail crossing. A flood flow culvert is now located where the former channel line is shown. A small meander to the east also appears to have been removed where it ran close to the embankment.

Till 1844 the Somerset County boundary is understood to have used the River Axe. However, this was informed by 1832 parliamentary boundary changes that transferred the Devon enclave of Thorncombe over to Dorset. As such, reference in the Hancock Commission in 1958 to '*that part of Thorncombe lying between the former and present line of the River Axe*' suggests a possible channel avulsion (from the red to green routes) having occurred between then and either 1832 or 1844.

A last piece of potential evidence is given in Macdonald and Sangster's paper on High-magnitude flooding across Britain since AD 1750. This confirms flood rich periods in southern England in the 1780s and 1850s, with a Great Flood on the River Exe in January 1866.

A possible explanation is the shortening of the River Axe through the rail bridge, combined with the 1866 flood, resulted in the avulsion of the channel into the current channel route (red to green).

This leaves a possibility of an earlier avulsion (from the blue to red route) in the 1780s. Such a, shortening of channel may have set up pressure for the later 1860s change, with the intervening time being too short to establish a new stable equilibrium.

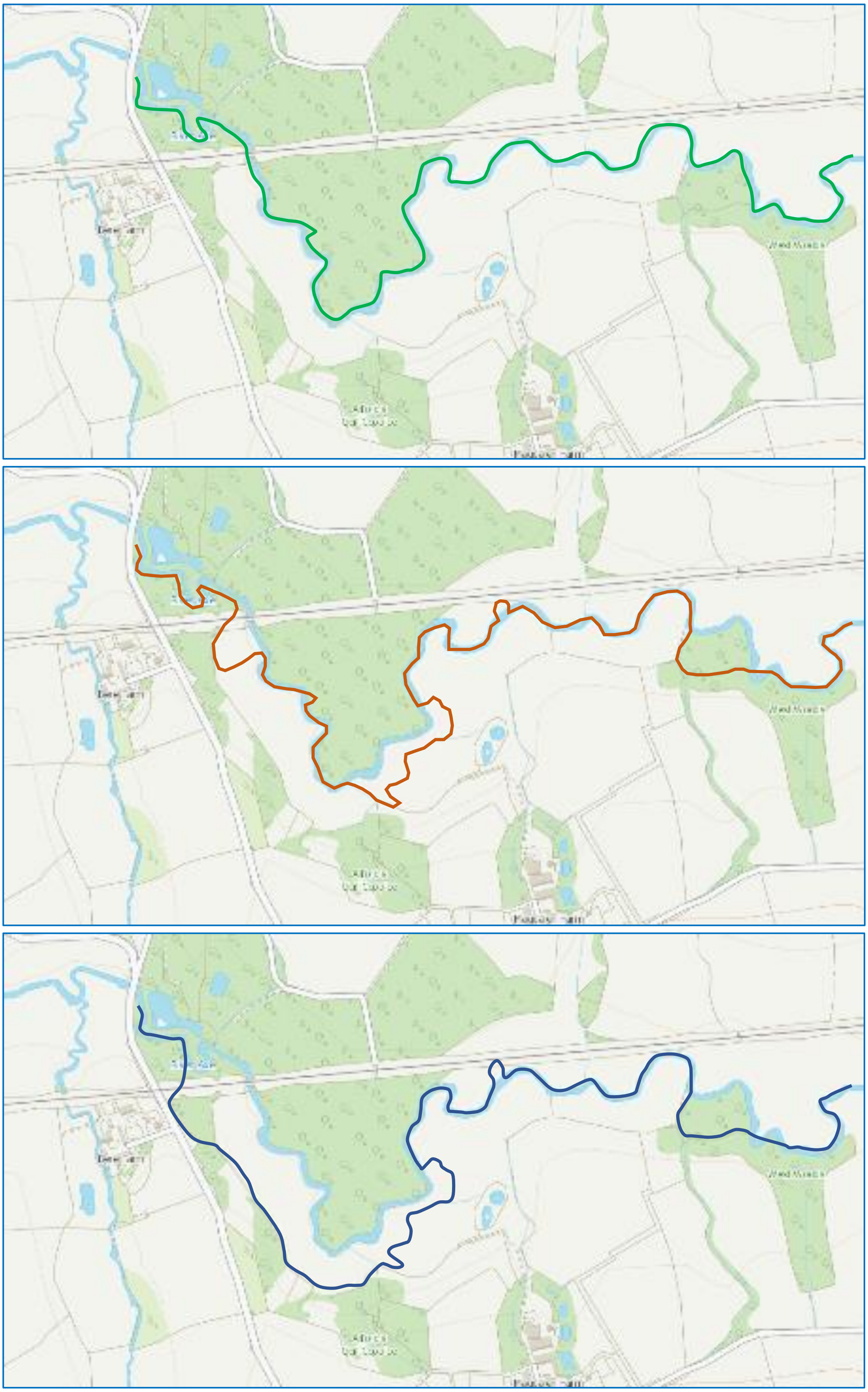


Fig 4. Historic evidence of River Axe channels

4 Paleochannel Excavation

4.1 Approach and methodology

Prior to this investigation, the expectation was that the paleochannels would have retained their cobble and gravel riverbeds, and that these would potentially be elevated significantly above the current riverbed levels. If this proved to be the case, then restoration of the reach could achieve by excavating down to the retained bed, to create a narrow and shallow channel that was well connected to the current floodplain. Removed material would then have been used to construct dams across the existing channel, effectively creating a series of ‘ox-bow lake’ style habitat features.

The excavation objectives were therefore to:

- confirm the presence of a suitable cobble/gravel bed
- indicate former channel widths and depths
- inform floodplain tree planting

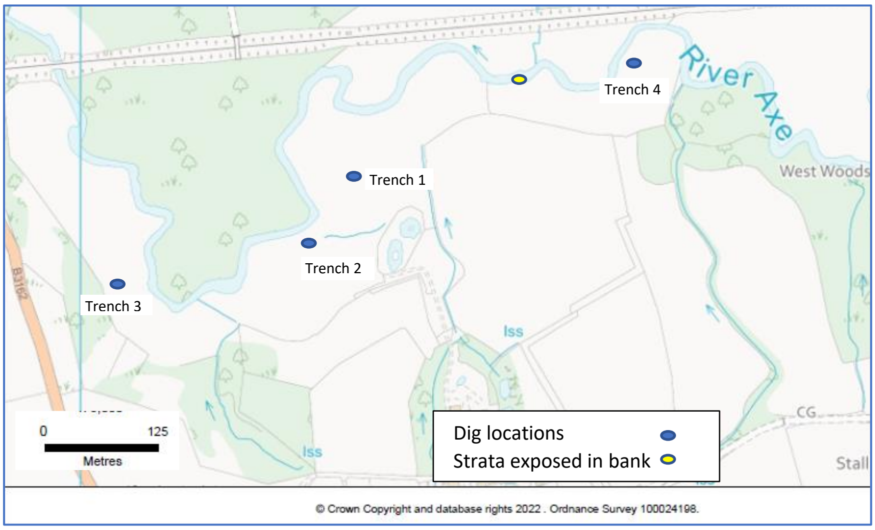
With limited time and resource, trench cuts were focused on providing the key information rather than establishing detailed channel profile sections. The expectation was, however, that clear soil characteristics would be found that reveal paleochannel cross sections and former floodplain levels.

Trench 1 was cut across the county boundary route, close to the potential off take from the main channel. This was selected as: it would confirm the route of the paleochannel at this location; it was in a location of known floodplain wetness and ponding; and was in an area remote from known past drainage works. A concern was the proximity to tight bends in the former paleochannel which had the potential to create an incised and heavily asymmetrical cross section.

Trench 2 offered a location where the paleochannel remained well defined, and on a reasonable straight section of former river. A well-defined symmetric channel was anticipated here. Concerns with this location were impacts of past drainage works on this a functioning drainage channel, and for any crossing structures.

Trench 3 looked to the older paleochannel route, with a focus on confirming the cobble/gravel bed layer.

Trench 4 was a brief exploration to confirm former paleochannel bed levels at the location of possible backwater feature.



Full details of trench excavations are given in Appendix A.

Fig 5. Locations of the excavation trenches, and identified cobble/gravel layer in the riverbank

4.2 Excavation key findings

i. Gravel bed layers in the paleochannel were found in 2 of 3 sites at 2.3m below field levels.
   a. This is broadly consistent with remaining gravel cobble bed runs within the channel
   b. In the incised channel section with gravel stratum exposed in the bank, the stratum is to 2.16m below field level, extending 0.65m to bed level and below.

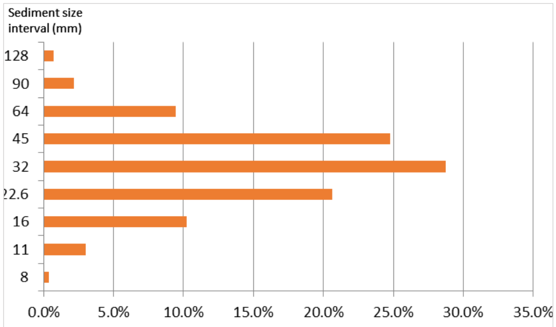
ii. There is evidence of at least 0.4m, but up to 0.98m, of alluvium deposits across the floodplain since the paleochannels were active. A depth of 1.5m is possible above one of the infilled channels.

iii. The water table, 2 days after excavation in the downstream excavation, was 1.17m below field level.

iv. Evidence of former riverbanks is minimal. One trench suggested a paleochannel width of 3.9m.

v. Stone size counts were carried out at two trenches (Figure 6), with a median stone size of 32mm and maximum 128mm.

Clast size	Count	Percent
8	3	0.4%
11	25	3.0%
16	86	10.3%
22.6	173	20.6%
32	241	28.7%
45	208	24.8%
64	79	9.4%
90	18	2.1%
128	6	0.7%



Clast size	Count	Percent
8	1	2.4%
11		0.0%
16	5	12.2%
22.6	9	22.0%
32	12	29.3%
45	8	19.5%
64	5	12.2%
90	1	2.4%
128		0.0%

Fig 6. Cobble and gravel size distributions at trench 3 and 2

5 Geomorphological interpretation

Paleochannel excavations on the River Axe at Magdalen Farm correlate to findings on the River Culm, River Frome and rivers across Europe. Interpretations of these are informed further by detailed reviews of the late Quaternary origins of the Axe valley landscape.

Research points to there being a valley wide braided river system. This braided river flowed across chert and sandstone clasts released from large hill-slope failures in the Upper Greensand chert layers caused by rapid permafrost melting at the end of the last ice age.

Following this, the river would likely to have evolved into an anastomosed multi-channel river system within a wetland valley. Woodlands, marsh and mires would have produced biological controls to channel movement. Fine sediment and organic layers would have built up within this wetland system, overlying the former braided river form. The valley would likely to have been dominated by alder and hazel woodlands, with a rich river and marginal aquatic ecosystem including now rare riffle beetles that require clean flowing stony rivers.

Following the Roman Britain period, woodlands were locally cleared, with widescale replacement to wet graze pasture in the early Medieval period. This large-scale deforestation, led to increased rates of sedimentation which smothered the wetland habitats and caused creation of a raised floodplain. This ever more elevated floodplain has become increasingly decoupled from the river channel whose riverbed remained at the level of the post-glacial braided river system.

Figure 3 shows the array of likely paleochannel across the floodplain that is revealed by aerial surveys. What is not clear is if these represent various single thread channel routes or whether any of these indicate earlier concurrent multi-channel conditions.

However, early mapping for parliament and country boundaries suggests that only a single thread channel was present by the early 1800s. This single thread channel does appear to have avulsed in certain reaches in the late 1800s, with a likely cause being the 1866 flood.

The two excavation trenches within the suspected early 1800s channel both revealed large timbers lying lengthwise down this channel. This would be consistent with blockage of the channel to prompt avulsion (although whether this was to an entirely new channel, or the recutting of a former route, isn't known). The early 1800s channel appears to have infilled with clay deposits, which were later overlain by silt and sand floodplain accretions. At these two trenches this subsequent floodplain aggradation was some 0.98m and 1.5m deep. This relates to aggradation rates of between 6.2 and 9.6mm per year. This is higher than the 4mm per year calculated from deposits on the River Culm floodplain, but as this is located within the depression of the former channel where rates might be higher than across the wider floodplain.

The presence of loam within the base of the older paleochannel, of trench 3, in notably distinct from the first two trenches. The age of this paleochannel might provide answers to this, such that it has the potential to date back either to medieval wet grazing pasture conditions, or to even earlier Iron Age anastomosed river valley wetland conditions.

In the most recent decades, channel and riparian management combined with the increased in-channel concentration of flood flows, has resulted in the destabilisation of the post glacial braided river system cobbles and gravels. In places the riverbed is eroding beneath this stony stratum to less resistant material. Without management this suggests the start of a new phase in channel and floodplain evolution.

6 Conclusions

The paleochannel excavations reveal former channels that retained their cobble and gravel beds. The elevation of these former riverbeds is consistent with those of the current channel where the bed remains intact, and the level of exposed cobble and gravel strata in riverbanks where bed erosion has occurred. This supports the understanding of a gravel cobble layer having been formed at the end of the ice age as a braided river channel across the valley bottom, with subsequent accretion of floodplain deposits.

The review of historical records suggests the last avulsion from the paleochannel may have occurred in 1866, with a subsequent accretion of floodplain sediments of up to 1.5m in depth.

The results indicate that restoration of the paleochannel offers no benefits over restoring the existing channel in terms elevation of gravel bed. Along with the lack of defined banks, the excessive volume of cut required to restore the paleochannel makes this option unfavourable compared to restoration on the current channel route.

Finally, the results indicate that without intervention, the elevating floodplain levels and concentration of in-channel flood flows, will lead to deterioration of the river habitats and drying of floodplain habitats.

7 References

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Appendix A - Excavation survey details

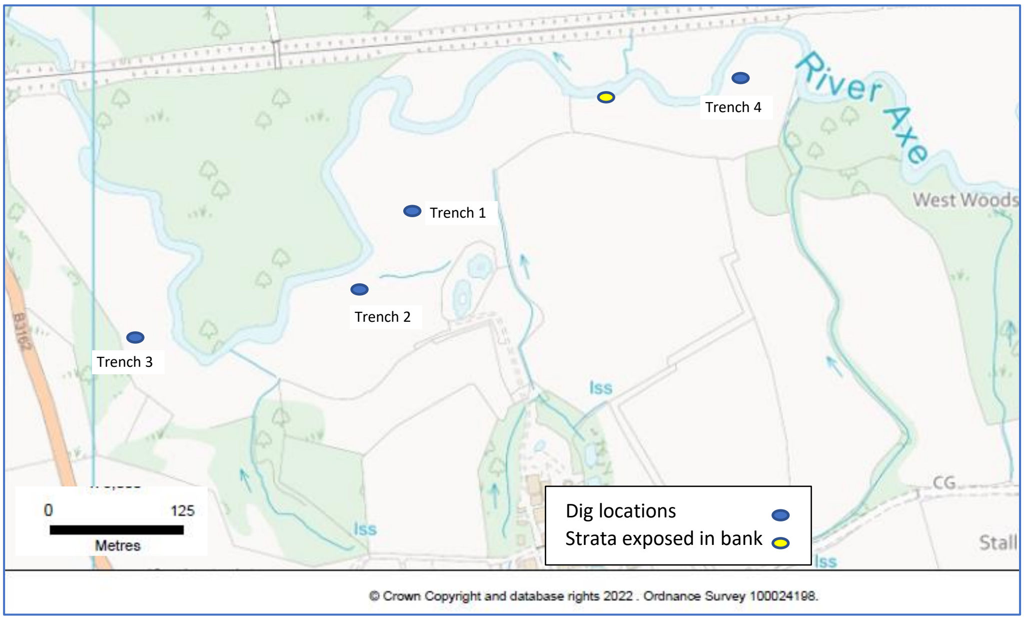

Fig A1. Excavation survey locations and exposed cobble strata in the riverbank

Trench 1 – evidence of clay infilling and large woody material channel blockage

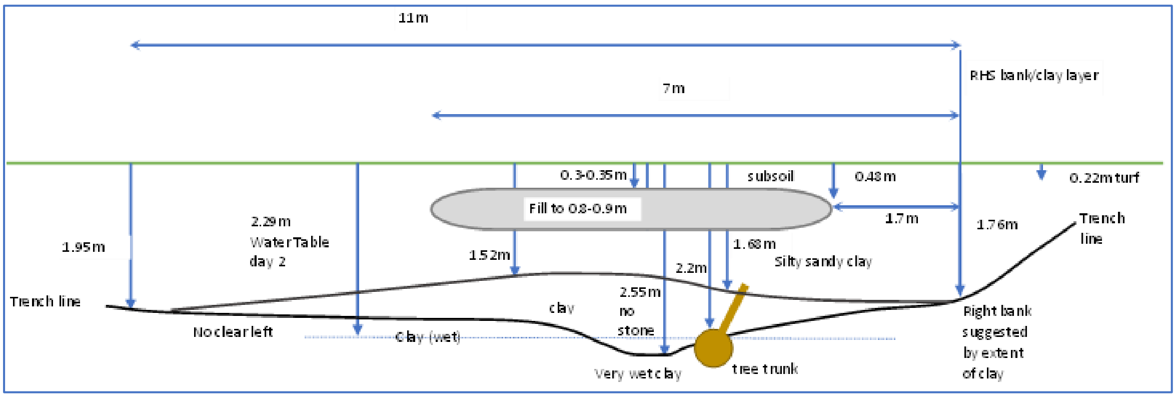

Fig A2. Trench 1 excavation (surface elevation approx. 71.6mAOD)

The trench was excavated from both north and south sides (right hand side).

At shallow depths previous farm fill material was found – stone, rubble, brick, twine. This was evidently used for a crossing point across the wetter paleochannel.

Subsoil transitioned imperceptibly to a red brown silty sandy clay. One pocket of grey clay was found encasing a woody fragment.

Below the silty sandy clay was a distinct change to grey clay. This was interpreted as the infilled channel (or perhaps underlying alluvial clays). The clay started at between 1.52m and 1.7m below ground level.

Focused single bucket width excavation on the south side revealed remains of a large tree trunk lying inline within the former channel, some 2.2m below the ground surface. Further excavation located the lateral limit of the clay, which was interpreted as the right-hand side paleochannel riverbank.

Excavation to 2.55m revealed no stone, but continued clay – which was increasingly wet. This was the limit of safe excavation depth.

Excavation from the north side aimed to chase the clay layer bank towards a left bank. No bank line was located even after 11m length of excavation. The dig was abandoned at this point.

Photos charting the excavation are given below.

Trench 1 - Conclusions

Based on the probably right bank, and the width of fill over the channel depression, the paleochannel was at least 7m wide. It extended to at least 2.55m below current ground levels.

The likely asymmetric, outer bend location of the trench may explain the excessive bed depths, and the lack of defined inner bend riverbank.

The presence of the tree aligned with the channel suggested possible obstruction of the paleochannel leading to its infilling consistent with channel avulsion.

The lack of any riparian woody remains from the former paleochannel was notable.

Photo 1 View towards River Axe along line of Paleochannel

Photo 2 Initial excavation

Photo 3 excavation through turf, subsoil and fill

Photos 4 through fill to silt sandy clay (inset)

Photo 5clay pocket and removed wood fragment (inset) in silty sandy clay layer

Photo 6 grey clay layer with upright of large woody material

Photo 7 Large wood material in line with channel

Photos 8 detail of wood in situ, inset removed sections

Photo 9 Right bank transition from grey clay

Photo 10 chasing left bank for end of clay

Photo 11 full trench from north

Photo 12 Ground water egress

Trench 2 -confirmation of paleochannel width and large woody material blockage

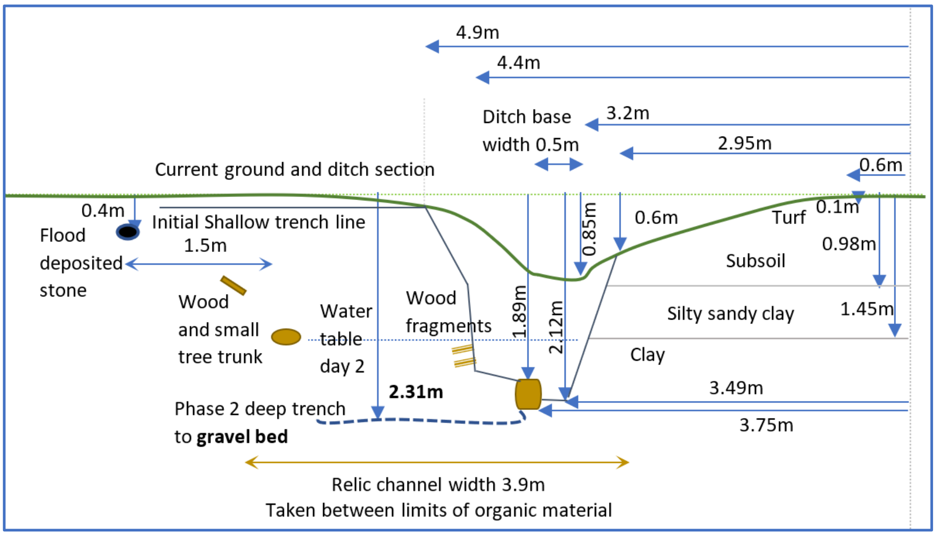

Fig A3. Trench 2 excavation (surface elevation approx. 71.35mAOD)

The initial excavation was started from the south side (left hand side), quickly revealing greyish silty sandy clay below brown sandy clay subsoil.

As grey clays were reach, wood fragments were exposed, and seepage was noted. At a depth of 1.89m below ground level, a large timber lying in-line with the channel was unearthed. Excavation to the north of the timber extended to 2.12m without reaching a stone bed.

With the expectation of reaching a shallow cobble gravel bed not being met, and concerns of possible recent drainage ditch improvements having potentially disturbed this, further excavation in trench 2 was paused to allow a focused attempt at trench 3 to unearth a cobble/gravel bed.

The second phase of excavation involved cutting an access ramp to allow a single bucket trench to extend down to at least 2.5m below ground level on the southern side.

A cobble and gravel layer was located at 2.31m depth. Forty-one stones (and a large bone) were recovered. The stone size ranged from 8mm to 90mm, with average of 32mm.

The single bucket trench was cut back at about 1.5m below ground level to try and chase back an end to the grey clay layer. After extending back more than 5m with no clear end, this was stopped. On closer inspection there was a notable darker zone of clay with organic fragments within a couple of metres of the buried large timber. This suggested the extent of debris infilled channel on the left-hand side.

A 50mm cobble was noted some 400mm below ground level, set back southwards of the organic grey clay extent. This was interpreted as a possible overland flood deposit.

In the third phase, excavation was carried out from the north side. This was taken down to at least 1.5m below ground level and was chased back to find a possible right hand-side riverbank. As on the left side, presence of dark organic material indicated the extent of the channel.

Trench 2- Conclusions

The paleochannel appeared to be 3.9m, with a stone riverbed at 2.31m below ground level.

Infilled clay layers were to within 1.45m of the surface, with evidence of flood deposited stone at 0.4m below ground level.

Photo 1 View of trench from the east

Photos 2 Phase 1 dig, with water egress at organic matter (inset)

Photo 3 From right bank, showing ‘in channel’ organic material and tree trunk longitudinal on the ‘bed’, inset of removed wood fragment

Photos 4 Section through base clay layer, silty sandy clay, and overlying subsoil

Photo 5 Phase 2 dig of left bank (south)

Photos 6 Dig to stone bed. Inset – excavated gravel and bone

Photo 7 Transition from dark organic matter clay (lower) to pure grey clay (top & inset))

Photos 8 Potential flood deposited stone

Photo 9 Phase 3 dig of right bank (north)

Photos 10 Transition from dark organic matter clay (left and inset) to pure grey clay (right and top of inset)

Photo 11 Water table after 4 hours

Photo 12 Water table after 24 hours

Trench 3 - Bed load exploration

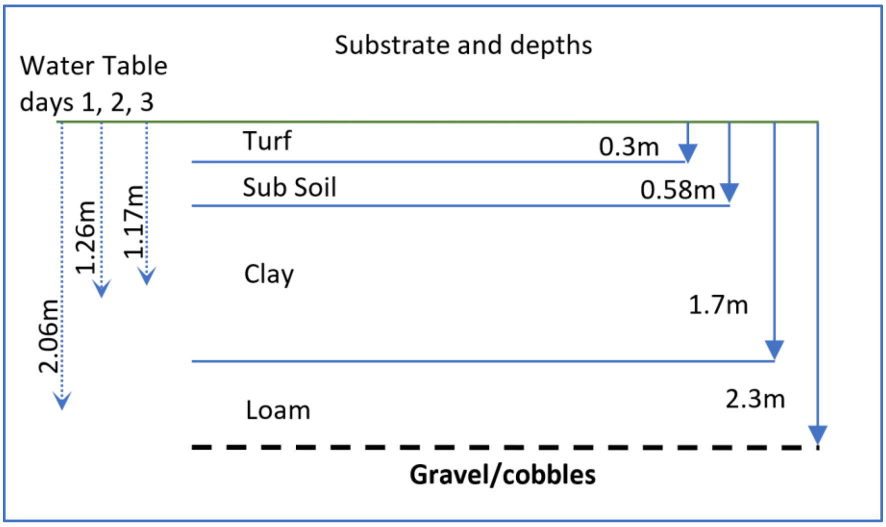

Fig A4. Trench 3 excavation (surface elevation approx. 70.3mAOD)

The third trench was located within the western field. The avulsion from this section of paleochannel predate that from the trench 1 and 2 channel. The line of channel is evident from wetland vegetation. If the paleochannel was not to be restored, this would be a potential location for creation of a wetland scrape/'oxbow lake' creation.

With the intent of the excavation focusing on finding the paleochannel bed, excavation was carried out from one side only (the north) and formed to provide a safe access route for the excavator that ensured an excavation depth to at least 2.5m below ground level.

Recording focused on substrate material qualities and depths below surface, no horizontal dimensions were considered.

Within 600mm clay was located below the subsoil at a clear boundary layer.

From just over 1m depth the clay became increasingly wet. Excavated clays transitioned to a loam at around 1.7m depth and increasingly included organic fragments up to 20mm diameter.

Persistent water level was met at 2.06m, with a clayey stone bed layer located below this at 2.3m below surface level. 839 clasts ranging in size from more than 5.6mm to 128mm were separated from the clays. A near normal distribution of stone was found, with a median of 32mm, and with 74% between a 22mm to 45mm range.

Water table levels rapidly increased to 1.26 the following day, and 1.17m the day after.

Trench 3 - Conclusions

A paleochannel bed was located at 2.3m below current floodplain levels.

The bed was formed of clasts typically between 22mm and 45mm, with a maximum size of up to 128mm and a median of 32mm.

The channel may well have been infilled with organic matter, creating a loam 0.6m deep, but with overlying clays 1.1m deep some 0.61m below current ground levels.

Photo 1 View west

Photo 2 Subsoil

Photo 3 Clay layer (inset detail)

Photo 4 Transition to clayey loam

Photo 5 clayey waterlogged stone layer (15:58)

Photos 6 Loam with wood fragments

Photo 7 Water level by 16:50, day 1

Photo 8 Water level 08:56, day 2

Photo 9 Extracted stone (32/45/64) (90/128)

Photos 10 sub soil to clay, and clay to clayey loam layer

Trench 4 – Upstream backwater location investigation

A final excavation was carried out in the approximate position of a possible backwater creation location in the far eastern field. This was located on a potential paleochannel route of either the River Axe (predating the channels of trenches 1 t0 3) or the tributary draining the east of Magdalen Farm.

Coarse sediment deposits were again found at approximately 2.3m below field level, although this time these were predominantly sandy. Given time limitations, this trench was not investigated further.

Exposed cobble gravel strata in riverbank

Downstream of Trench 4 location, approximately at ST 3848 0585, a distinct cobble/gravel strata is evident in the river bank. This served as a comparator to the excavation trenches.

The layer starts at 2.16m below floodplain level. It extends to at least 650mm where the current riverbed is located.