Upper Axe Geomorphology Walkover Appraisal

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1 Summary

The study reach extends from Clapton in the east through towards Chard Junction in the west. The river has historically supported salmon, trout, and water vole within these reaches. Salmon were recorded as far upstream as Bere Chapel in 2006 (3), with 5 recorded at Forde Abbey in 2021, with a maximum of 44 in 2010.

Whilst the river has remained reasonably stable in planform over the last century or more, there are now increasing signs of channel instability and bed incision. Paleochannel excavations in 2022 reveal significant rates of floodplain aggradation, with between 0.5 and 1.75m of floodplain raising since 1866 estimated from those works. The combine pressure is seeing mobilisation of former salmonid habitat, loss of marginal habitats and exposed riverine gravels, as well as collapsing riverbanks and riverbank trees.

Intervention is liable to be complex, as full restoration to match historic ecology assemblage habitat conditions would require either significant channel raising or floodplain lowering. In places this may be feasible and may be delivered through paleochannel restoration. In other locations, stabilising the bed with importation of oversized cobbles and gravels, and replacement riparian trees may be the only option. The focus is on providing varied habitats compatible with salmonids, lamprey, water voles and associated invertebrate and aquatic vegetation communities.

2 Introduction

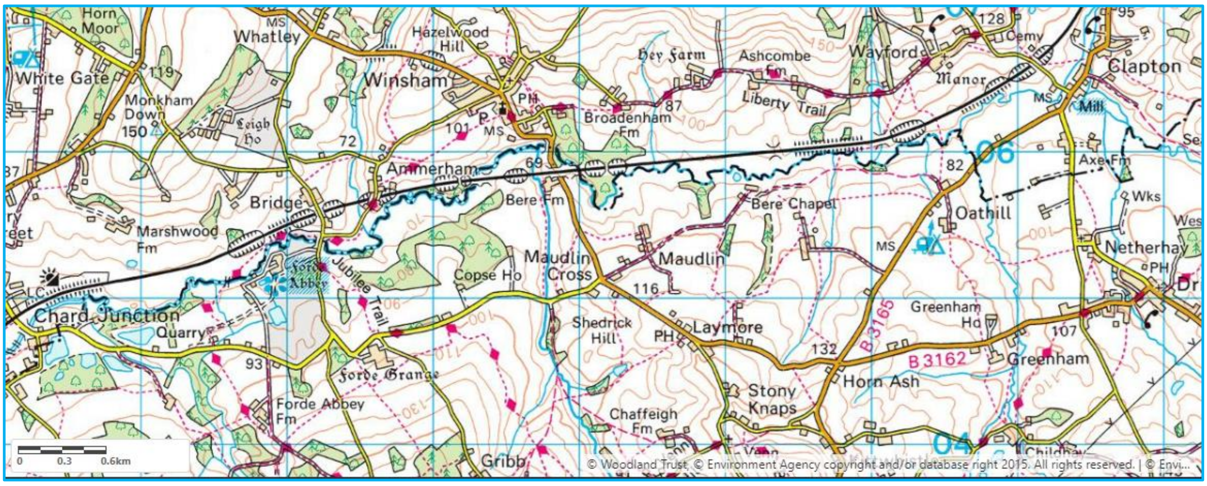

Fig 1. Upper Axe Landscape Recovery Reach

This review covers the River Axe from Clapton through to Hodge Ditch Farm, based on walk over site surveys in May 2023.

The review considers historic evidence on the nature of the river and its ecology. This draws on detailed assessments carried out at Magdalen Farm where paleochannel excavations and trial river restoration measures have been implemented (in June 2021).

A summary of the walkover findings is included in the main document, with detailed photographic notes included in Appendix A.

Recommendations for options for feasibility testing and consultation are also included.

3 History of the Upper Axe river valley

A range of sources of information are available to tease out the history of the River Axe valley and its ecology. These include historical documents, map records, topography reminders seen by eye and aerial surveys, as well academic research into the paleoecological and geomorphological histories in the area.

Together these paint a changing landscape, built on past geology, and then set in motion during the last glaciation period. At the end of the glaciation period, thawing lead to collapse of hillslopes and the spread of chert cobble and gravel layers across much of the lower and mid valley floors. Valley wide wetlands, rich in wildlife, persisted through till at least the Iron Age, with a clean flowing cobble and gravel river running through it, possibly in multiple channels.

However, woodland clearance for farming on the valley tops is likely lead to the release of sediments into the valley and the gradual development of floodplains through the Roman and medieval periods. In the 1500s and 1600s ecclesiastical estates increased the intensity of farming, clearing woodlands, riparian corridors, increasing grazing. By the 1850s very little riparian woodland remained. Milling, with leat construction also increased.

The increase in sedimentation from this farming also lead to aggradation of floodplains, with over 1.75m of sediment accumulation on the floodplain since probably 1866 at one location in Magdalen Farm.

3.1 Historical records

The Book of the River Axe (Pulman, 1854) whilst not a rigorous scientific study, provides valuable indications of catchment conditions and ecology. Fish are listed as: salmon, trout (parr, bull, sea, and common), roach, dace, lamprey, flounder, three varieties of common eel, minnow, stone loach, and stickleback. Pulman notes falling numbers of May flies and reduced catches of salmon and trout (with high levels of poaching being identified). Though the wooded tributaries of the River Synderford, Kit (Chardstock) Book and Blackwater retained high fish stocks. He also notes changes in flood hydrology resulting from recent land drainage across the catchment.

The channel bed appeared intact at that time, being described as having uninterrupted gravelly riffle and pool sequences, with occasional sandy berms sloping into the channel. These are particularly noted by Pulman downstream of Clapton Bridge for their quality where 'its crystal waters ripple on their pebbly bed in a series of delightful pools and stickles to the sea'. Although it is notable in the illustration that the right bank meadows are devoid of trees, unlike the left; and there is no encroachment of the channel from the right bank.

Reach descriptions by Pulman and the included illustrations (dating back to 1669) confirm a scarcity of riparian woodlands and widespread cattle grazing access to the watercourse. He identifies few sections of wooded corridor along the entire river. There was a 2-mile heavily wooded section upstream of Seaborough, and a 'greatly bush-encumbered' mile down to Clapton. Much of the reach between Clapton and Winsham (above and below Bere Chapel) was considered unfishable due to overhanging alders, and with wooded valley slopes. Through Forde Abbey estates he describes a gradually widening stream, within a torturous course, and a profusion of scattered trees.

By contrast, Pulman reflects on the valley at the beginning of the 1600s as having wooded hillsides throughout (with oak, elm, sycamore, and beech), with only 'openings to view the crystal stream', and of hedgerow elms that were later removed. This correlates to intensification of farming in the

Blackdown Hills from the 1500s to 1600s associated with ecclesiastical estates and seen in radiocarbon dates of floodplain deposits in the Culm catchment (Brown et al, 2013).

A more consistent source of information can be seen in historical OS maps. The National Library of Scotland holds digital copies of maps along the Axe. The OS Six Inch 1888-1913 map represents the earliest accurate mapping on their records, with later mapping for 1937, 1945-1965, and 1949-1972. These maps include the County Boundaries which were based on the river course prior to the 1860 construction of the Waterloo to Exeter Rail Line. Mapping is of course, however, limited to showing planform condition of the river and riparian corridor, within condition of the bed being unrecorded.

The construction of the rail line can be seen to have resulted in the rerouting of the river in a few locations. Between Chard Juntion and Hodge Ditch Farm, two meanders were cut through, shortening the river by over 250m. Between 1886 and 1949 this led to the elongation of the meander immediately upstream. The instability of this appears to have worked its way upstream to the two meanders in front of Hodge Ditch Farm between 1937 and 1949. This section is now heavily reinforced by mass stone bank protection, showing the 200 year lag between impacts of the rail line construction on the steepening of the river and resulting bank instability upstream on the other side of the valley.

Within Westmills Plantation a small meander appears to have elongated slightly between 1886 and 1949. More significantly, upstream of Westmills Plantation, the meander to the north has cut through its neck. This appears to have occurred after the 1949-72 mapping. The major instabilities in channel form that this has caused can be readily seen playing out today (Appendix A). It is notable the different course the county boundary demonstrates existed prior to 1888, which demonstrates this area to be particularly susceptible to change (see Figure 2).

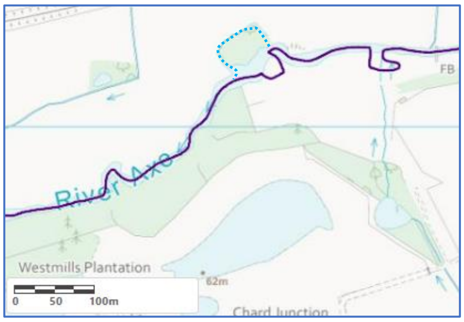

Fig 2. Former channel along the County Boundary, and meander cut off around the north of the woodland

A further meander has been lost upstream of this, where the southern tributary joins from Westmill Cottages. This represents the largest planform change shown within Forde Abbey estate. The other change being meander migration that has developed at Sawmill Cottage since 1949-72. Given the proximity of these two changes, and the comparable response time of change at Hodge Ditch Farm, the meander development at Sawmill Cottage may well have been in part triggered by bed level changes resulting from the downstream, shortening of the river.

The channel planform appears reasonably stable up till Ammerham Mill where some minor elongation of meanders have developed between there and the Rail line over the period of the 1886 survey to now.

Whilst the river was straightened for the rail line upstream of Ammerham Mill, there does not appear to have been any significant adjustment in planform since then, according to the map data. The 1888 map does show the remains of a meander some 200m upstream of the railbridge. This remains evident in the landscape today, and is noted in photo record notes presented in Appendix A.

More significant changes have occurred at Magdalen Farm and are addressed in detail in Section 3.3. these appear to reflect both impacts of rail line channel alterations but also channel changes in response to major flooding, which may have occurred in 1866.

Further upstream at Bere channel, there has been some slight rotation of a couple of meanders, through from 1888 to present day. The river remained reasonably stable in planform from there through to Oathill Farm.

More significant change has occurred from between 200m upstream of the Temple Brook to within 250m of Clapton Bridge. The country boundary follows the floodplain edge for some of this section, rather than the 1888 river route to the north. A small double meander has straightened out between 1888 and the 1937-61 map, towards the downstream end of this section. A meander has developed with what had been woodland in 1888 towards the upper section of this reach. This appears to have occurred since the 1949-72 map. Throughout, channel migration and instability are apparent in the plan form of the current mapping. This includes meander development within the mill channel tributary from the north at the downstream of Clapton Bridge. Significant channel shifts are also apparent upstream of the road bridge since 1972.

3.2 Aerial Survey LiDAR

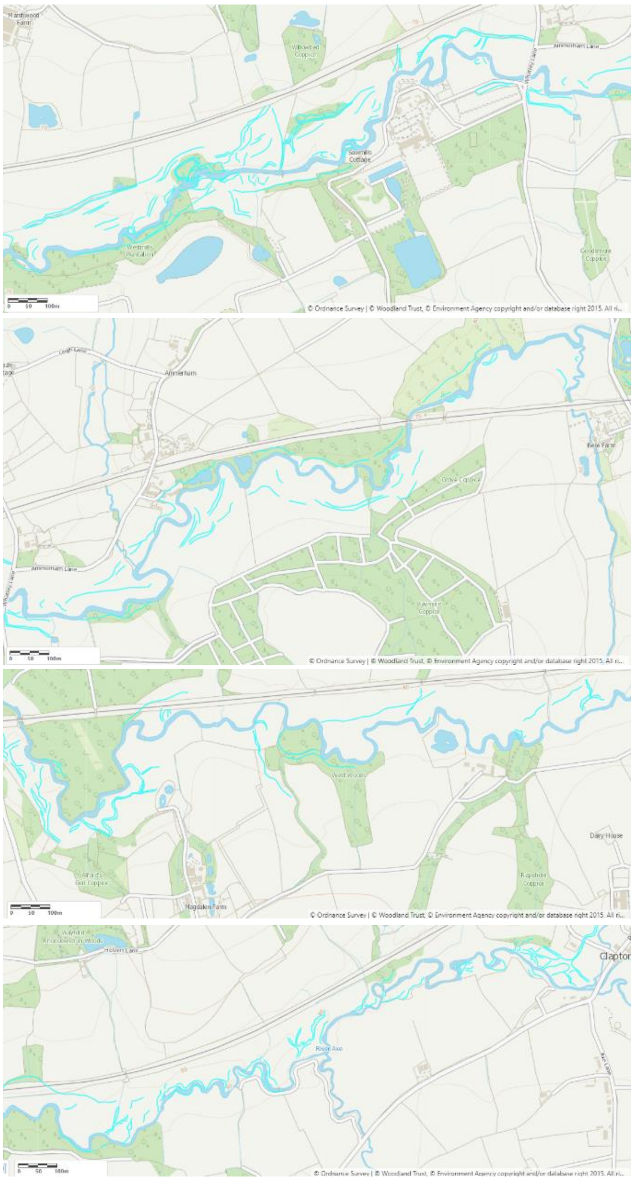

Fig 3. Potential paleochannels and drainage features

Aerial Survey is available throughout the River Axe catchment at 2m grid resolution. This reveals indications of previous channel routes (including scarp edges to the valley sides potentially dating back before the last ice age), drainage channels and leats.

Many of the features pre-date the when the river followed the County Boundary. A notable example if a meandering channel to the north of the current channel and the cut off meander north of Westmills Wood. This is past channel is alluded to by contours shown on the 1888 map.

Some features match those described in Section 3.1. An example of this are signs of the meander that was shortened downstream of Sawmill Cottage, in the Forde Abbey Estate. Leats and other drainage channels associated with the original Abbey are also apparent from this data.

Between Clapton and the Temple Brook, the section of County Boundary southeast of the current channel is also reflected in the survey data. More significant and earlier channel changes, including the original route of the mill stream entering at Clapton Bridge are also revealed.

A more detailed aerial survey analysis has been carried out for the land at Magdalen Farm (Figure 4). This shows both historic channel migration, and channel avulsion, which is described in detail in Section 3.3.

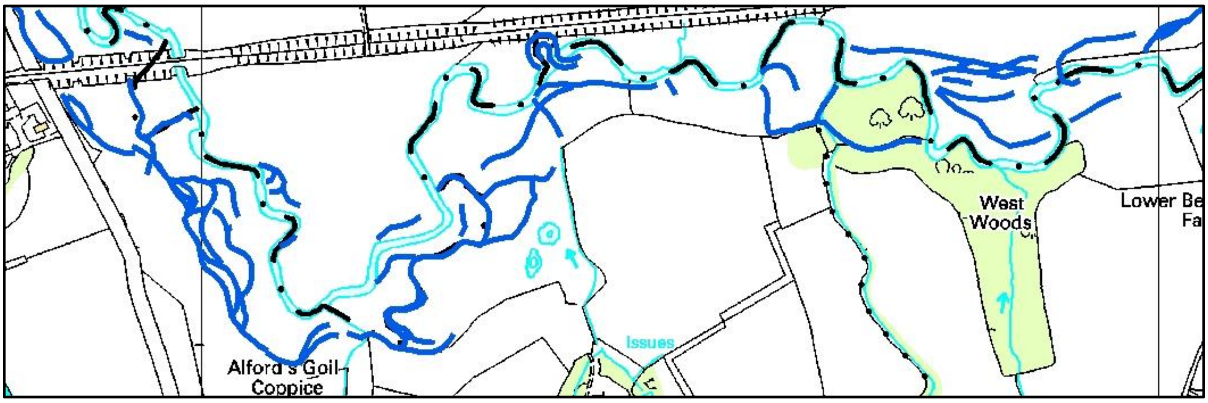

Fig 4. Potential paleochannels of the River Axe through Magdalen Farm

3.3 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.

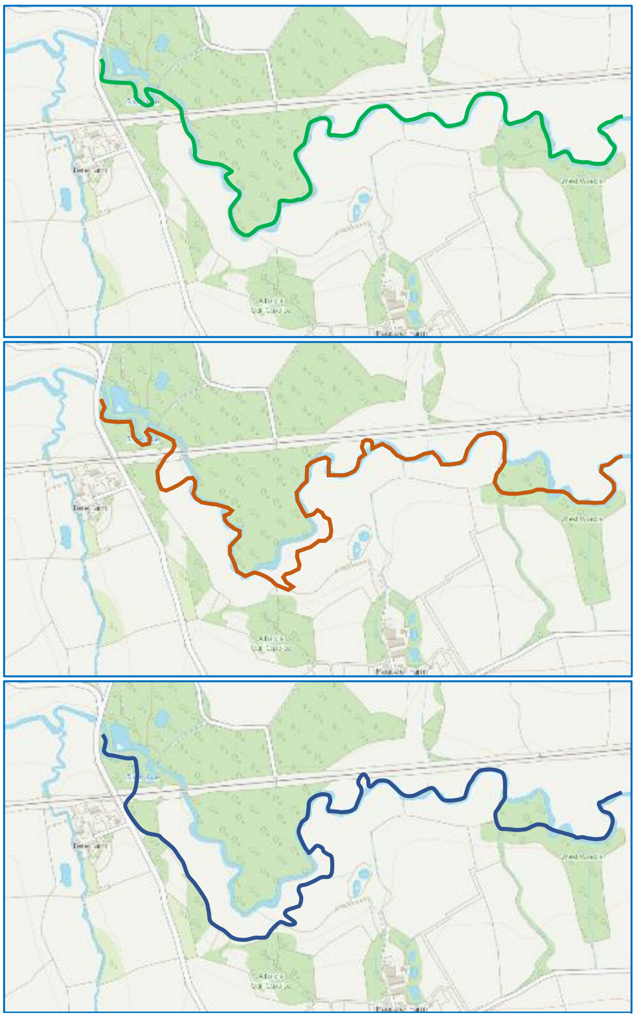

Fig 4. Historic evidence of River Axe channels

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.

3.4 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.

Brown et al (2015) reveals the main Axe 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 Axe valley. Brown & Walling et al (2020) chart the evolution of such channel forms for the nearby River Culm from this braided state through to an anastomosed form around 5300 years ago. This pattern is repeated across Europe with rivers dominated by vegetation, having no significantly raised floodplain, but wetland mires and flushes extending across the valley floor (Brown et al, 2018).

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). Pulman (1854) looks back to the beginning of the 1600s: when Axe valley hillsides were wooded throughout (with oak, elm, sycamore and beech); there were only 'openings to view the crystal stream'; and the presence of hedgerow elms that were later removed. This landscape change correlates with intensification of farming in the Blackdown Hills from 1500 to 1600s that is associated with the ecclesiastical estates, and the effects reflected in radiocarbon dates of the increasing floodplain deposits in the Culm catchment (Brown et al, 2013).

4 Walk over description

The River Axe was walked from the Hodge Ditch Farm to Ammerham Mill, and Winsham to the downstream rail bridge on 11 May 2023, Magdalen Farm to Clapton on 10 May 2023, Ammerham Mill to the upstream rail bridge on 25th April 2023, and through Magdalen Farm at various times from 2019 to 2023, and Forde Abbey in April 2019 and July 2022. Reach by reach notes and photographic descriptions are given in Appendix A. A summary of findings are presented below.

4.1 Summary

Throughout the length of the surveyed river, the Axe is showing signs of instability. Much of this is being driven by bed incision, revealed by deep holes cut into the underlying clay geology, and entire trees, their root balls and associated bank/floodplain material, slumping into the channel.

In some reaches, cattle access is chronically exacerbating the channel's decline. But in many cases, where the channel is too deep, or well fenced, once channel instability has begun, this is accelerating uncontrollably regardless. Downstream of Forde Abbey, from the most upstream cut off meander, right past Hodge Ditch Farm, the scale and rate of channel change is very great. The channel here is very oversized, both in depth and overall width. The effect of this appears to be extending upstream and may well have triggered the changes seen over the last decade at Sawmill Cottage, Forde Abbey.

There are very few sections with straight runs of cobble and gravel bed, that are not excessively mobile. Ranunculus is retained in these sections, along with in patches of less stable coarse substrate bed.

More often, coarse bed load accumulations are highly mobile, evident in sidebar shoals, and weak riffle forms. The size of bedload increases downstream. This appears to be linked to inputs from hillslope ditches and streams. Those entering from the south tend to provide a coarser range of stone material than those from the north of the valley – the exception being the stream from Cricket St Thomas.

In some places, cobble gravel strata are evident within the banks. However, at the times of survey, much of the exposed bank material was sandy silts and underlying clays. It is not clear how representative this is, and whether lower water levels will reveal deeper stone layers. Soil coring is proposed throughout the floodplain of the reach to provide more evidence on this.

There are a range of paleochannel features evident in the landscape. The more recently abandoned forms of these suggest much shallower channel depths.

For much of the reach, the deep cleaned out channel acts as a flume, allowing little marginal habitat to develop, and providing limited ranges of habitat conditions. There are sections, where following excessive channel migration or cut-offs of meanders, and where dense instream tree growths have persisted, then greater ranges of in-channel habitats have developed. This includes the section at Magdalen Farm where dense tree jam works have led to the establishment of marginal vegetation, clean riffles, flow diversity and sediment accumulations.

Clapton represents an area of what appears to be well connected floodplain and river, although, even here, the channel is now incising a short way downstream. In the floodplain to the south of Amerham Mill, as well as in small sections at Magdalen farm, wet grassland habitats persist in what appear to be paleochannel routes – even though these are now disconnected from the main river.

Comparison with the historic mapping data, reveals that the developing lateral erosion changes through the reach are distinctly at odds with past channel change processes and speeds. This no doubt reflects the tipping point that has occurred with floodplain aggradation and channel incision. Unchecked, rapid channel deterioration might be expected throughout the river here.

5 Recommendations for Restoration Feasibility Assessment

Stable coarse cobble and gravel beds remain present in a few locations, and occasionally where the bed has incised significantly there is some evidence of cobble and gravel strata in the riverbanks. The presence and extent of this strata across the valley, and its depths below current floodplain levels is critical for determining practical river and valley restoration options. Soil profile cores are therefore proposed to be taken along the study reach at both persistent floodplain and potential paleochannel locations.

A scale of restoration options might then be considered for locations along the study reach:-

1) **Channel stabilisation**. Through augmentation of coarse bed load with oversized stone mix, and planting of the riverbanks using for instance live willow stakes at water line, willow and alder planting/staking at mid-bank height, and tree planting at the bank top and riparian zone.

2) **Channel stabilisation and roughening**. This would build on the above option, but include introduction of large woody material, to reduce in channel velocities and introduce habitat cover and flow diversity. This might be through creation of reaches with multiple large tree jams and or laying willow/alder/hazel along the riverbanks.

3) **Brushwood riverbed rehabilitation (optionally with channel roughening).** Where excessive scouring has occurred, riverbed levels may be restored towards former levels by installing a brushwood mattress. As well as raising bed levels, the brushwood matrix would aim to trap fine sediments, to eventually be incorporated into the bed.

   Where bed raising is greater than around 200mm, or where lengths of mattress are greater than around 50m, then intermittent impermeable bed check weirs should be formed within the mattress. This might be through a staked coir curtain, or preferably a cobble bed check weir. These are required to ensure the mattress is submerged along its length in low flow conditions, such that fish passage is not impeded.

   Brushwood mattresses may need to be secured in place with wiring or weighted down with large stone. Overtime, once sediment has accumulated it would be preferable to augment a cobble gravel bed over the top of this layer.

   Alternatively, a coarse bed load layer of cobbles and gravels (at least 300mm deep) might be added at the time of installation but would be expected to reduce the fine sediment accumulation capacity.

   Where increasing flood depths is acceptable, large woody material should be included to reduce flood flow velocities and increase flow diversity. This will encourage sediment accretion, increase durability of the mattress, and enhance habitat and refuge functions.

4) **Riverbed rehabilitation with channel roughening**. Where certainty of design bed conditions and resilience are required, the riverbed would be restored fully with an oversized cobble and gravel bed layer (at least 500mm deep). This would rapidly create salmonid spawning and run habitats.

Where there has been extreme bed scouring, especially in localised pools, an underlying clay or sand fill might be appropriate to reduce stone quantities.

As above this might include introduction of large woody material, to reduce in channel velocities and introduce habitat cover and flow diversity. This might be creation of reaches with multiple large tree jams and or laying willow/alder/hazel along the riverbanks.

5) **Riverbed rehabilitation, channel roughening, and floodplain lowering**. The intent of this option is to increase floodplain connectivity by reducing levels of the floodplain across all or part of its width.

   The greater the reduction in difference between riverbed and floodplain level the wetter the floodplain habitats will become, with increased biodiversity, biomass, and carbon sequestration.

   Floodplain lowering should more readily dissipate flood flows across the valley form (including for more prolonged periods), reducing pressure on the river channel and bed. The floodplain flow capacity created will offset any reduced flood conveyance in the main channel that results from the bed raising and channel roughening. This should be designed to ensure no increase in flood risk to any local properties or infrastructure.

   Consideration should be given for future floodplain aggradation and the need to manage upstream land management to avoid adverse long-term impacts. Soil disposal will be a key consideration for this option.

6) **Paleochannel restoration, with possible floodplain lowering**. Where a resilient paleochannel riverbed is present, and the current channel is significantly incised or lacking in coarse cobbles and gravels, this option might avoid excessive engineering and importation of stone that would be required to restore the existing channel (as in option 5).

   Restoration of a well vegetated river riverbank and riparian strip would be required. Lowering of the floodplain might also be required to ensure a balance channel/floodplain flow split and low flow floodplain connectivity.

   The existing channel might be partially infilled to provide wetland scrape/ox-bow lake habitat features, as well as to intercept and store suspended solids and nutrients from flood flows.

All but the first option, especially where combined with floodplain tree planting, should result in a net increase in flood attenuation for the benefit of property and infrastructure downstream. However, options 2-6 have the potential to increase flood depths locally if this is not explicitly designed out.

There are a few reaches where local increases in extreme flood depths will need to be avoided. These relate to flood risks to Sawmill Cottages, Forde Abbey, Whatley Lane road bridge, The Old Granary Amerham Mill and both properties and the road bridge at Clapton. Winsham Bridge and the mainline railway embankment at various locations may also need to be considered in terms of increased flood risk.

Option feasibility assessment should consider river and floodplain habitat restoration potential, wetting/drought impact avoidance of floodplain farmland, constructability, carbon impacts/benefits, sediment and nutrient capture benefits, and maintenance and management requirements.

6 References

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Appendix A – Walkover photo records