

**River Babingley – River Restoration and Maintenance
Proposal**

**Prepared for King’s Lynn Internal Drainage Board by Emily long, MSc,
Norfolk Rivers Trust**

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Glossary of Terms

Bank height – height of the river bank from mean water level

Bank width – width of the river at mean water level.

'Dig and dump' – A method of creating berms in the channel by excavating a pool and building the side of the channel up either side before it to create a pinch point.

Large Woody Debris/LWD – features of wood staked into the river, can either be created from smaller pieces tied together or whole branches/trees installed. These are usually installed with the root ball (if present) facing into the centre of the channel. These are staked in and tied using twine or wire to hold in place.

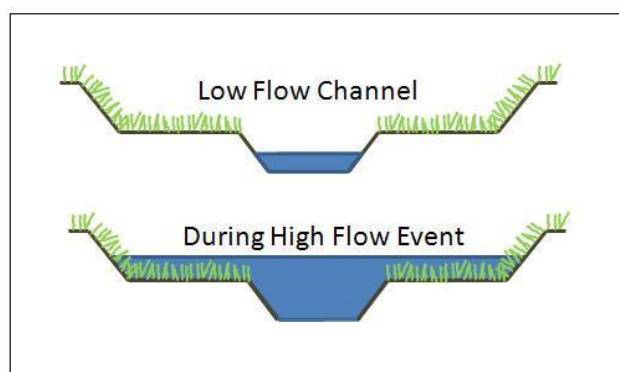
Riparian edge – the interface between the land and river/stream.

Sinuosity - is the ratio between distance covered by the meander and the straight line distance covered by the meander. It runs from 1.0 for a completely straight **river**, to 1.5 for a typical meandering **river**, up to 3.0+ for a twisting course

True left hand bank/Left hand bank - The left hand bank of the river when looking down stream

True right hand bank/Right hand bank – The right hand bank of the river when looking down stream

Two-staged channel – shape of channel allow a narrower low flow channel and wider high flow channel. See diagram below.



Woody faggots – bundles of branches tied together, usually made of hazel.

1. Introduction

1.1 Background

The boards area of the River Babingley runs from West Newton Mill to the outfall structure at Wooton Marshes, covering around 19Km of river channel. The upper 13Km of the Boards operating district displays more natural chalk stream habitats, whilst the lower 6Km are more characteristic of lowland drains being heavily modified for land drainage.

The Babingley is a chalk river being predominantly fed by the chalk aquifer rising near the village of Flitcham. Chalk streams are internationally rare habitats characterised by their unique array of fauna and flora and are considered priority habitats under the UK Biodiversity Action Plan.

The river was classified as a low consequence system by the Environment Agency (EA) due to the low risk of flooding to people or properties (Environment Agency, 2015) but forms an important function for the surrounding arable land use.

1.2 Current Status

The Babingley is designated as a **heavily modified waterbody** for flood protection measures under the Water Framework Directive, currently achieving an overall status of **Moderate**, (Environment Agency, 2009). The waterbody fails for fish, with other chemical and biological parameters reaching high. This is summarised in Table 1.

Water Framework Directive Status	Current River Status (2009)	Predicted by 2015
Bad		
Poor	Fish	Fish
Moderate	Overall status	Overall status
Good		
High	Invertebrates, Dissolved oxygen, Ammonia, PH Phosphate	Invertebrates, Dissolved oxygen, Ammonia, PH Phosphate
	Hydrology supports good ecological potential	

Table 1 The current Water Framework Directive status as published in the 2009 Anglian River Basin Management Plan, and the proposed status for the Second River Basin Management Plan to be published later this year.

Current monitoring on the Babingley is undertaken by the Environment Agency's standard monitoring programme. Within the IDB's catchment this includes two water chemistry points, one invertebrate (Biological) monitoring point, one flow gauge and one fisheries monitoring site. A map of these points is shown in Appendix 1.

These are currently sampled on a yearly basis for WFD monitoring. It is suggested that further monitoring be undertaken around any restoration measures that are put into place to monitor change. Further to this, any changes in maintenance regime should also be monitored for impact. Where monitoring relates to a discrete restoration project, pre and post monitoring should be included in the budget. Monitoring impacts of maintenance regime could be funded by the board.

1.3 Objectives

The objective of this report is to outline a plan of restoration and maintenance methods to increase the ecological diversity of the river, whilst ensuring appropriate drainage and flood risk management. This includes traditional mechanical maintenance activities and proposals to restore and increase the rivers natural processes with the aim to reduce the need for mechanical maintenance.

Proposals to satisfy the mitigation measures required to allow the river to reach Good Ecological Potential are underlying the proposals put forward. These have been outlined in the River Basin Management Plan and are seen as necessary for the river to reach the best ecological state possible under its modified state. These are summarised in Table 2.

Mitigation Measure	Status
Sediment management strategies (develop and revise)	In Place
Retain marginal aquatic and riparian habitats (channel alteration)	In Place
Appropriate techniques (invasive species)	In Place
Appropriate timing (vegetation control)	In Place
Selective vegetation control regime	In Place
Appropriate channel maintenance strategies and techniques – minimise disturbance to channel bed and margins	Not in place
Structures or other mechanisms in place and managed to enable fish to access waters upstream and downstream of impounding works	Not in Place
Improve floodplain connectivity	Not in Place
Set-back embankments	Not in Place
Increase in-channel morphological diversity – bank re-profiling and dig and dump.	Not in Place

Table 2. Mitigation measures set out to achieve Good Ecological Potential under the Water Framework Directive, as set by the Anglian River Basin Management Plan, 2009. Measures which are deemed to be in place and therefore satisfied are stated so.

1.4 Considerations

Walkover surveys were carried out in December 2014 and January 2015 to inform this report. This time of year allows more of the channel morphology to be assessed as plant growth is at a minimum, however, this does not allow for a full consideration of macrophyte growth within the channel. Desk based surveys were undertaken, alongside consultation with landowners, the Environment

Agency and other conservation bodies to gain information on macrophyte abundance and diversity. Therefore these recommendations take into account all available information but are subject to review throughout the growing season.

At present there is no hydraulic model of the river. It is proposed that full hydraulic modelling is carried out throughout the IDB's area to fully assess the proposed measures and ensure positive changes to flood risk are seen before any measures are put into place.

It should also be noted that whilst some consultation has been undertaken with landowners with regards to these plans, no formal commitment has been given to allow restoration works to take place. Therefore these proposals highlight the best outcomes for the river, but do not necessarily reflect an agreed outcome.

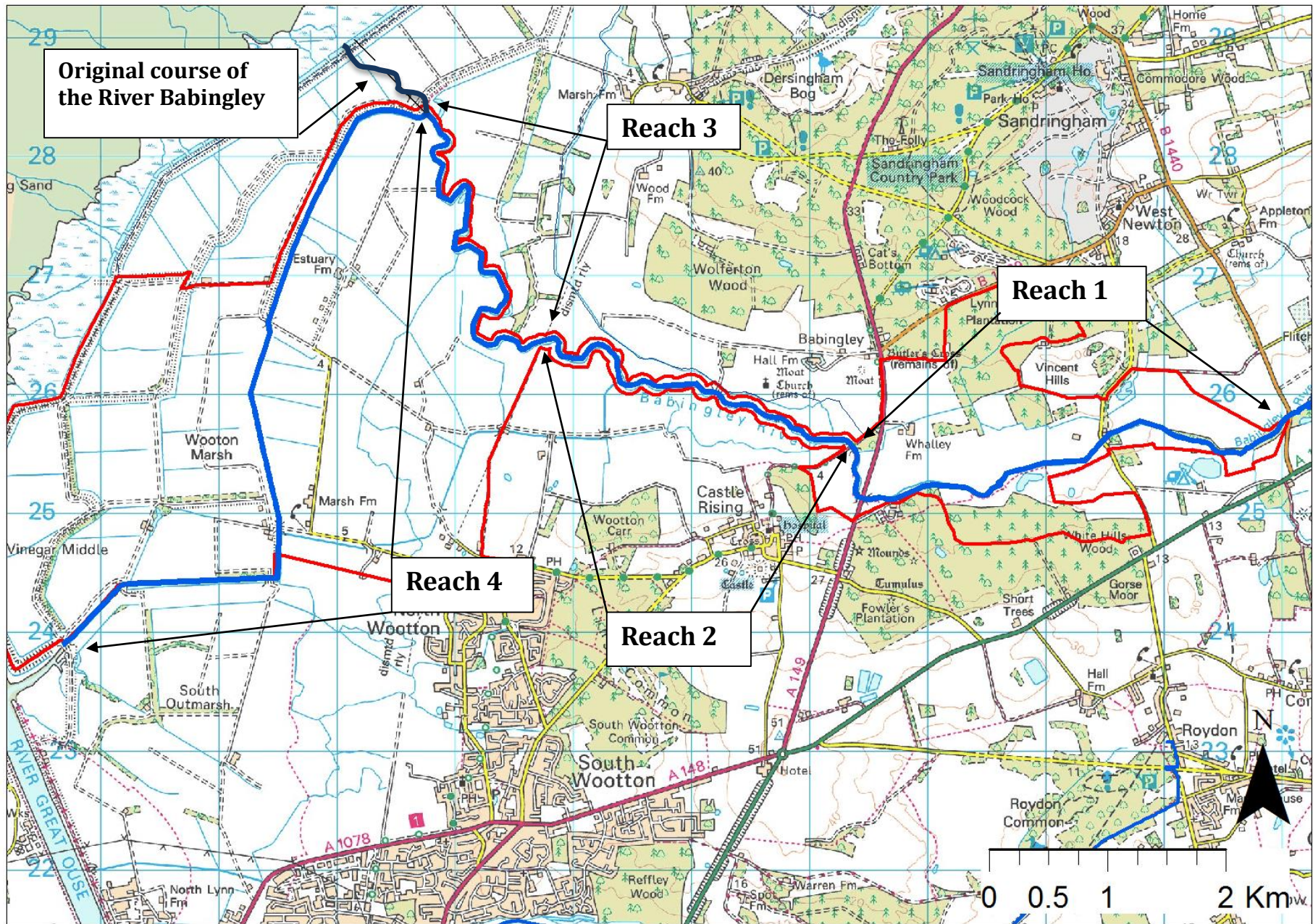


Figure 1 Map showing selected reaches of the Babingley as outlined in this report.

2. River Plans

The river has been split into 4 reaches of similar character, shown in Figure 1. The current condition of the reach is described followed by proposed restoration and maintenance plans. These are summarised as maps at the end of each section, and linked to the text below by the corresponding text box numbers as stated. Bank heights are given as height from mean water level, and with is given as the distance between banks at mean water level.

2.1 Reach 1 -B1153 to Babingley Bridge

2.1.1 Current state

This section of the River Babingley is largely natural. Flow rates vary, being faster flowing in the east over gravel and cobble substrates, with areas of slower flow and a predominantly sandy substrate scattered throughout the reach. The width varies between 4-7m wide with banks between 1-2m high. The banks in places are steep, particularly to the western end. Channel depth varied with the bed visible along the majority of the stretch, particularly across the riffled sections where the flows are higher. The top 2Km is largely wooded on the northern, right hand bank until West Newton Mill, whilst the left hand bank is arable and pasture fields.

Arable farming lines the river to the east, below West Newton Mill, of the reach on both banks, with 8-10m buffers on both sides. Moving west both banks become pasture with evidence of sheep grazing on the northern bank (right hand bank).

The upper most eastern section is quite natural and has recently had restoration works completed by Norfolk Rivers Trust, reducing bank height and creating a backwater.

The channel is most modified at the most eastern and western ends of the reach with water mills present at both ends. The western mill at the end of the reach is now redundant with the old mill channel operating as a backwater habitat, Photo 1, BOX 8. These more modified areas display and over wide channel and disconnected floodplain. The western extend, just below the mill have an Environment Agency gauging station sited on the river causing a small impoundment and localised widening of the channel.



Photo 1 Old mill leat operating as backwater channel

A more natural morphology is displayed through the middle section. Some restoration efforts are seen through this stretch, with fish passage easements seen below a weir, 'dig and dump' channel narrowing, and logs crossing the channel, Photo's 2 and 3, BOX 6. These have added to the habitat diversity seen through this section and are concentrated through the middle and western end of this section. In addition to this some evidence of natural recovery is seen through the deposition of silts causing natural channel narrowing and emergent macrophyte growth. Some erosion is also seen through this section, most likely from historic poaching, some remnants of bank protection are seen lining the old river bank.



Photo 2 'Dig and dump' berm creation on near (left hand) bank. Now vegetated.



Photo 3 Restoration measure - log across channel

Sections of the reach are wooded, with infrequent coarse woody debris and shade, but there are long lengths with no cover. The survey was undertaken through December and January reducing the ability to assess the aquatic vegetation. However, some species were evident including: water cress, fools water cress, lesser water parsnip, and branched burr reed, *Sparganium erectus*, on the margins. Localised patches of starwort, *Callitriche agg.* and Mare's tail, *Hippurus vulgaris*, are seen mid channel, with the banks dominated with sedges

and willow herb, *Epilobium hirsutum*. The stretch would benefit from a full macrophyte survey through the summer months. Previous surveys conducted by Norfolk Wildlife Trust demonstrate an abundance of aquatic and marginal vegetation throughout this stretch.

The most western section, below A149 – Cromer Road, shows an over wide section of river with a high southern bank (left hand bank). The right hand bank is heavily vegetated with a range of trees and scrub, Photo 4.



Photo 4 over wide section between the by-pass and Babingley Bridge. Beds of starwort seen.

At the very end of this section a drain comes into the watercourse from the north. Evidence of high sediment inputs from this drain is evident.

2.1.2 Proposed restoration options

The most eastern section of the reach would benefit from some light canopy thinning and large woody debris installations, BOX 1. As the left hand bank becomes open, the reach would benefit from some narrowing, either via 'dig and dump' and bank re-profiling, BOX 2.

West Newton Mill is currently a barrier to fish passage, preventing migratory species, such as sea trout and eel, to reach the available habitat above. Norfolk Rivers Trust has commissioned a feasibility report looking for options to increase fish passage around the structure. Once completed, this will be submitted to the board separately, BOX 3.

The reach, below West Newton Mill, would benefit from the creation of berms or pinch points, adding to the morphological diversity and breaking up the uniform flow. This section has high macrophyte growth, predominantly branched burr-reed, which could be managed by increasing the flow diversity, BOX 4.

The middle section has already had some restoration efforts completed, however, this section would benefit from some floodplain connection and bank height reduction, BOX 5 and 6. This would increase the wetted edge, creating a

refuge area for small fish/fry as well as a range of invertebrates. This could also be achieved through the creation of a two-staged channel, additionally adding to the sinuosity of the reach, with the introduction of large woody debris features to increase flow diversity. A small weir is present within this section, Photo 5. It is proposed that this is removed allowing naturalised flow reducing the impoundment upstream.



Photo 5 Small weir present through the section - propose to remove it to reduce impoundment upstream.

The lower section, above the A149, which is largely wooded would benefit from some canopy thinning to increase light penetration to the river, BOX 7. This would increase macrophyte growth within the channel adding to the flow diversity. Coppiced material could be used upstream as LWD features to increase flow diversity through this reach and the stretch above.

Below the A149-Cromer Road the river is over wide and heavily embanked. This section would benefit from some berm creation to narrow the channel, BOX 9. Berms could be created in a number of ways, either using the 'dig and dump' method, creating pools in channel to win the material, or by constructing the berm out of woody faggots and coir rolls. A combination of the techniques could also be used. Investigations into the sediment input from the drain would also be beneficial. This is likely resulting from high sediment inputs from the plantation at the top end of the drain.

The restoration measures listed above are detailed in the map shown in Figure 2.

2.1.3 Proposed maintenance regime

There is no annual maintenance regime suggested through this reach. There is a low flood risk to agricultural land or property. If imposed, the restoration options will increase flow diversity allowing the channel to self-regulate vegetation control. This would be confirmed by the outputs of the proposed modelling.

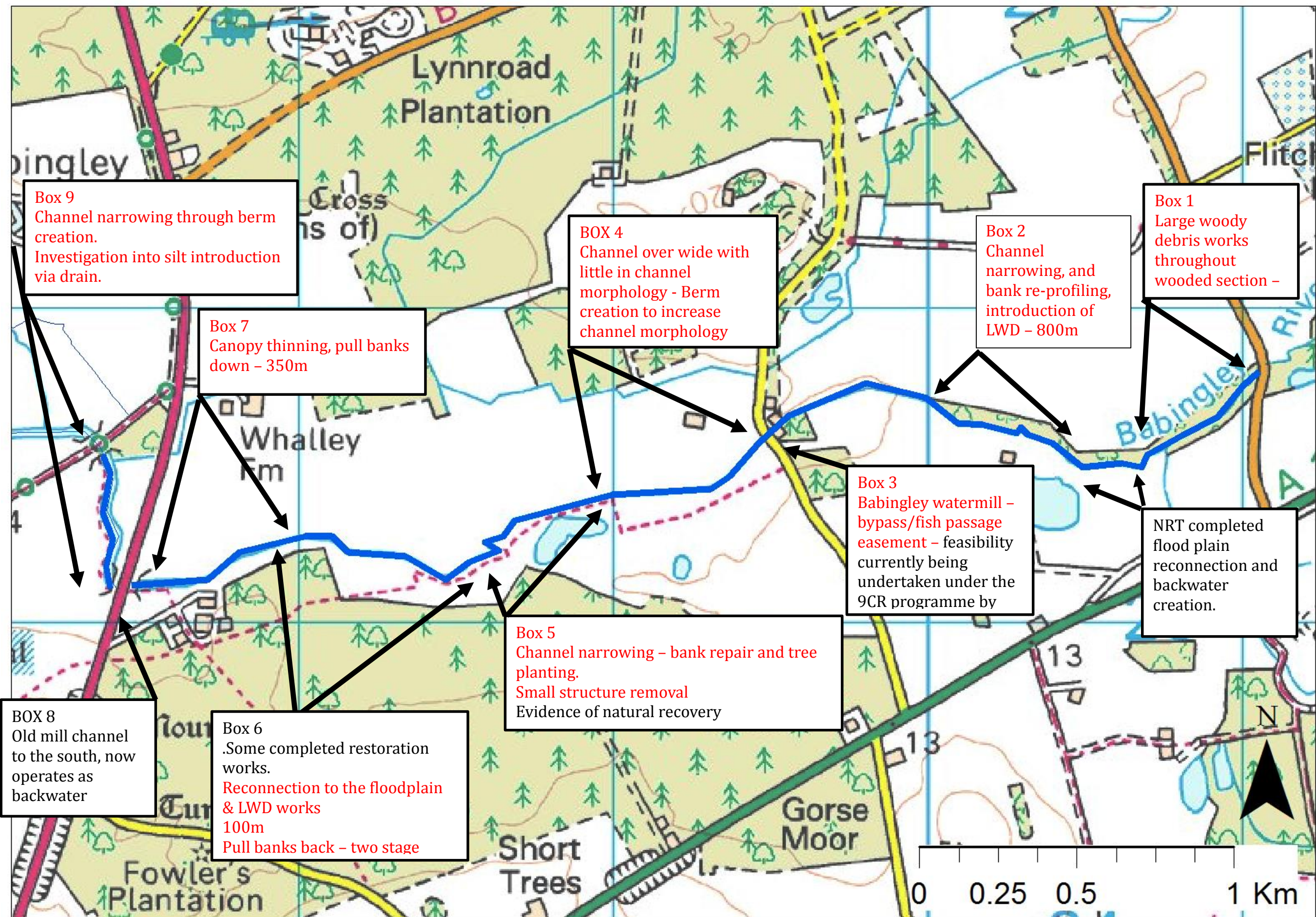


Figure 2 Proposed restoration measures for Reach 1. Black text indicates current features/state, red text indicates proposed measure.

2.2 Reach 2 – Babingley Bridge to the dismantled railway.

2.2.1 Current State

The river is very uniform throughout this section with uniform flow and little in-channel features, Photo 6. The surrounding land use is mainly arable with some semi-improved and some rough grassland on to the west of the stretch. The old sea wall follows the channel for part of its length, with a line of scrub (mostly hawthorn). Localised areas of scrub and trees are also seen where adjoining drains/ditches joining the channel. There are good buffer strips along both banks. Channel widths vary on average between 3-7 m wide, with banks between 1-3m high, disconnecting the river from the floodplain. In a few sections the embankments are slightly lower. The substrates, where visible, are largely sandy and silty.



Photo 6 Uniform channel throughout reach

The upstream, or eastern extent shows an over widened river, with large beds of common reed, *Phragmites australis*, Photo 7. This is typical of over wide-deep and silty sections. Some evidence of natural recovery is seen throughout the section, with material being deposited on the in-side of bends and beds of emergent vegetation growing on the margins. These beds narrow the channel to 2-3m wide.



Photo 7 Large beds of *Phragmites australis*

A bridge crosses the river through the middle of the section and there are remnants of older bridge structures or bank revetments. The disused railway bridge marks the end of the reach, the bridge has been removed, but the brick supports still remain lining the channel. The western end of the reach shows evidence of heavy poaching, particularly on outside of the bend prior to the dis-used railway bridge, Photo 8.



Photo 8 heavy poaching near dis-used railway

Some restoration efforts have been completed through this section with 3 areas of channel narrowing constructed out of coir rolls, Photo 9. One of these is situated on the inside of a bend creating a shallow berm, another on a straightened section, and one low berm on the outside of a bend at the lower end of the stretch. One field to the north of the site has a large scrape created in it, there are reports of good numbers of avocets that use this feature.



Photo 9 Previous restoration works, creating low berm.

Despite the survey being conducted in winter there is evidence of starwort, *Callitriche agg.* growing within the channel. The margins are marked by reed sweet-grass, *Glyceria maxima*, common reed, *Phragmites australis*, and branched

burr-reed, *Sparganium erectus*, willow herb, *Epilobium hirsutum*. Local areas of bulrush, *Typha latifolia*, are also seen.

Through some sections where the banks are steepest the lower sections are bare showing a large number of burrows. Whilst no formal water vole survey was carried out through this stretch as part of this report the Environment Agency has confirmed records of water voles through this stretch (pers. comms).

2.2.2 Proposed restoration measures

The current channel is over-wide and disconnected to the floodplain, to restore some of the natural function, whilst maintaining channel capacity it is proposed to pull back the banks in places to create a two-stage channel, BOX 1. This would allow a pseudo flood plain to be created, allowing silt to settle out on the lower ledge in the shallow slow flowing water allowing a wetted berm to become established, whilst maintaining a clear channel for normal flows and an increased channel area for high flows. Modifying the channel in this way allows the overall capacity to be increased, with the creation of a narrower average flow channel.

The accentuation of berms on the inside of meander bends is also proposed in selected places in conjunction with some pool features. This will create important lacking fish habitat.

Where poaching is prevalent to the west of the reach it is proposed to re-grade the banks and create specific cattle drink areas. These could be created via backwater features bringing water off the channel into the field for access, allowing the river bank to be fenced, BOX 2.

Throughout this section there are two areas proposed in a joint project by the EA and Norfolk Rivers Trust. These are two out of three areas that have been selected for further investigation into the feasibility of creating flood storage areas to hold water out of the channel in times of high flow, BOX 3. Selection was undertaken by the Environment Agency by looking at LiDAR data (land heights), location and current land use. These are shown in Figure 3. To date topographic surveys have been undertaken to help determine the feasibility of each area and initial landowner discussions have taken place.

Proposed measures are seen in Figure 3.

2.2.3 Proposed maintenance regime

Although there is some anecdotal evidence of high macrophyte growth through the section it is proposed that changes to channel morphology to increase flow variation is the preferred control method. This in conjunction with the proposed flood storage areas will increase the flood capacity whilst increasing the ecological diversity and meet WFD objectives.

Formal surveys of macrophyte abundance is proposed in the optimum survey window, with results used through various determination tools for channel

management and conveyance. This will determine the need for short-term management prior to morphological changes throughout this section.

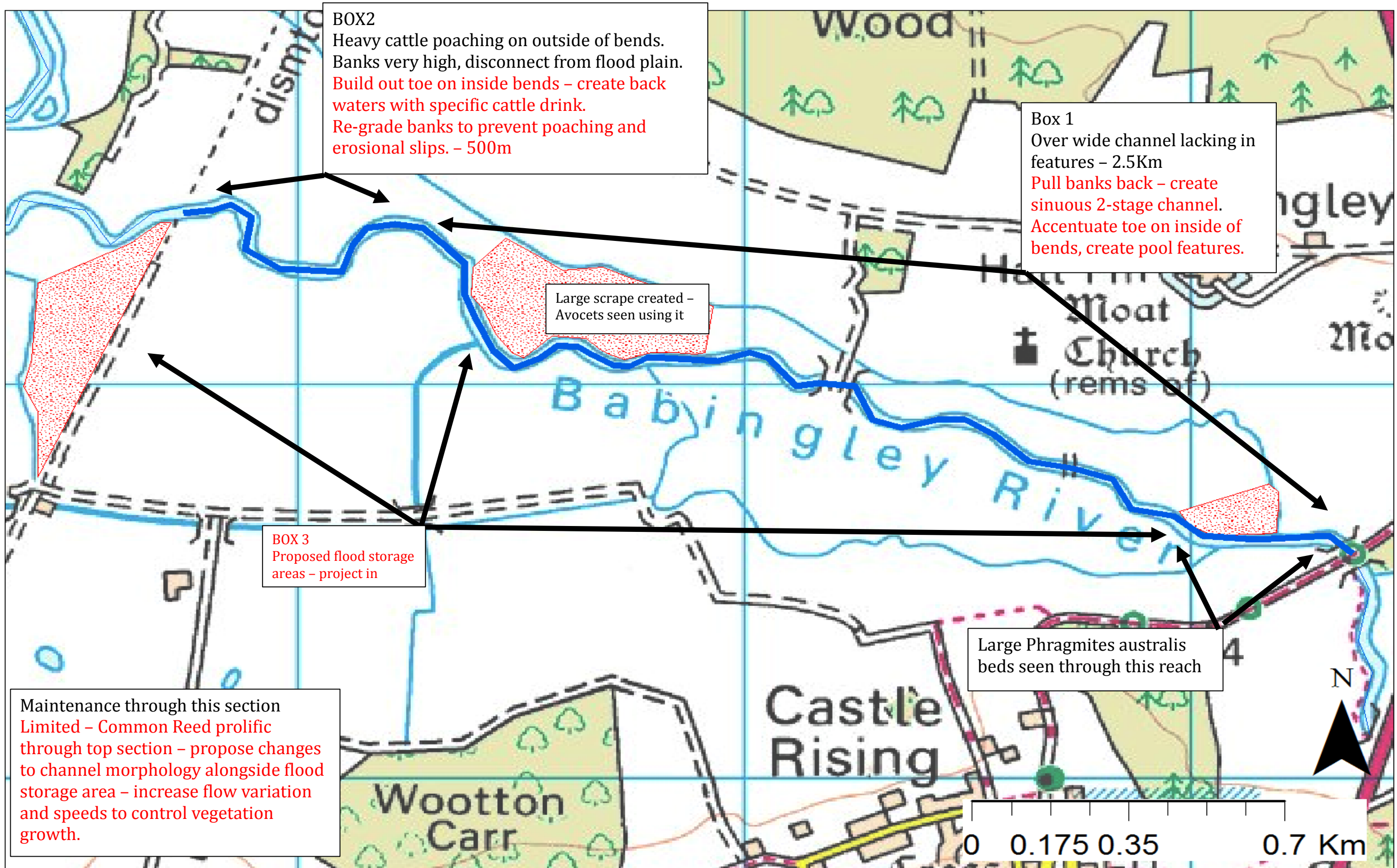


Figure 3 Proposed restoration options for Reach 2. Black text highlights current features. Red text indicates proposed measure.

2.3 Section 3 – Dismantled railway to northern extent.

2.3.1 Current state

This reach of river, although sinuous, has a wide uniform channel, uniform slow flow with sparse aquatic vegetation, Photo 10. The river is on average 5-6m in width with high steep banks ranging from 1 – 2.5m high, disconnecting the river from its floodplain. The banks are well vegetated, with wide buffer strips present on both banks. The land is largely arable, with a few pasture fields to the eastern extent.



Photo 10 Wide uniform channel, wide uniform flow. Rippled surface is the result of wind.

To the western and northern end of the reach there are several field corners that have been set aside, BOX 2. Some evidence of natural recovery is seen through the deposition of sediments on the insides of bends throughout the section. The substrate, where visible, is sands and silts.

There are two small concrete structures seen on the north bank, highlighting where water flows into and out of lakes on the northern side, Photo 11. Sections of this reach are lined by the historic sea wall, constraining the channel. Some areas of scrub are seen along these boundaries.



Photo 11 Showing concrete structures allowing water management of lake on right hand bank.

The wetted edges are heavily vegetated with reed sweet grass, *Glyceria maxima*, and common reed, *Phragmites australis*. There is little in channel vegetation with limited localised patches of starwort, *Callitriche agg.* The top of the banks and buffer strips are vegetated with coarse species, with remnants of great willow herb, *Epilobium hirsutum*, present. Anecdotal evidence suggests that growth of branched burr-reed, *Sparganium erectus*, can be quite prolific throughout this reach. No shading or cover is seen.

Where the banks are steepest there is little vegetation growth, exposing the bare banks. These are heavily burrowed, Photo 12. Whilst no formal wolver survey was conducted through the survey for this report populations have been confirmed by the Environment Agency. The steep banks present good burrowing habitat, with abundant cover and food source.



Photo 12 Exposed banks, highlighting burrows.

Anecdotal evidence of field drains failing to drain as a result of high river levels has been given for the fields on the southern side. This will be taken into account and investigated further.

2.3.2 Proposed restoration options.

Throughout this section the river is overly wide with little variation in width or flow, therefore, where space allows the majority of this reach would benefit from the creation of a two-stage channel allowing the channel capacity and maximum conveyance to be achieved or increased, whilst allowing a smaller channel for lower flows, BOX 1. This could be created by using the 'dig and dump' method, creating in channel pools, or re-profiling the river bank widening top of the bank and narrowing the base, or importing woody fagots. A combination of the techniques could also be used. This lower channel with wetted berm area would allow flows to be locally increased, diversifying habitat and allowing natural vegetation management. It should be noted that this measure could be used throughout this reach where space allows, but smaller feasible areas would need to be determined with landowner consent before taking the measure forward.

To the western edge of the reach there are several large areas set aside as field corners within the apex of meander bends, BOX 2. These could be lowered to allow inundation of water on a 3-5yr return period. This would increase capacity during high flow events, and create an area of pseudo-flood plain. This measure would need to be agreed with Natural England to ensure these areas would still remain within their respective Environmental Stewardship schemes. These measures can be seen in Figure 4.

This reach holds the third proposed flood storage area as described in Reach 2, BOX 3.

Drainage problems have been highlighted through this area by the land managers, with field drains sometimes failing to drain in high flows. This will need to be carefully considered throughout any proposal, ensuring average water levels aren't adversely impacted impeding drain flow.

2.3.3 Proposed maintenance regime

With limited shade and slow uniform flows this reach has the potential, and is anecdotally known, to have high volumes of macrophyte growth (anecdotally known to be burr-reed, *Sparganium erectus*). Whilst the measures proposed above are intended to increase flow diversities to increase the self-maintenance properties of the river it is accepted that immediate regular maintenance of this reach would be beneficial. It is proposed that this reach is cut annually removing in-stream vegetation and one bank, leaving a riparian fringe.

The cutting regime should be undertaken between mid-July and mid-September, leaving it as late in the season as reasonable to ensure wolver populations are at their maximum, with a reduced number of young (the breeding season running from March-October).

It is proposed that a full macrophyte survey is undertaken through the survey season (May-July) to record growth and determine full required extent of cutting requirements. This is proposed to be reviewed on a regular basis to ensure that unnecessary maintenance isn't carried out and natural processes allowed to develop around the proposed restoration when implemented. Consideration for field drainage will also be made throughout this process to ensure ample drainage.

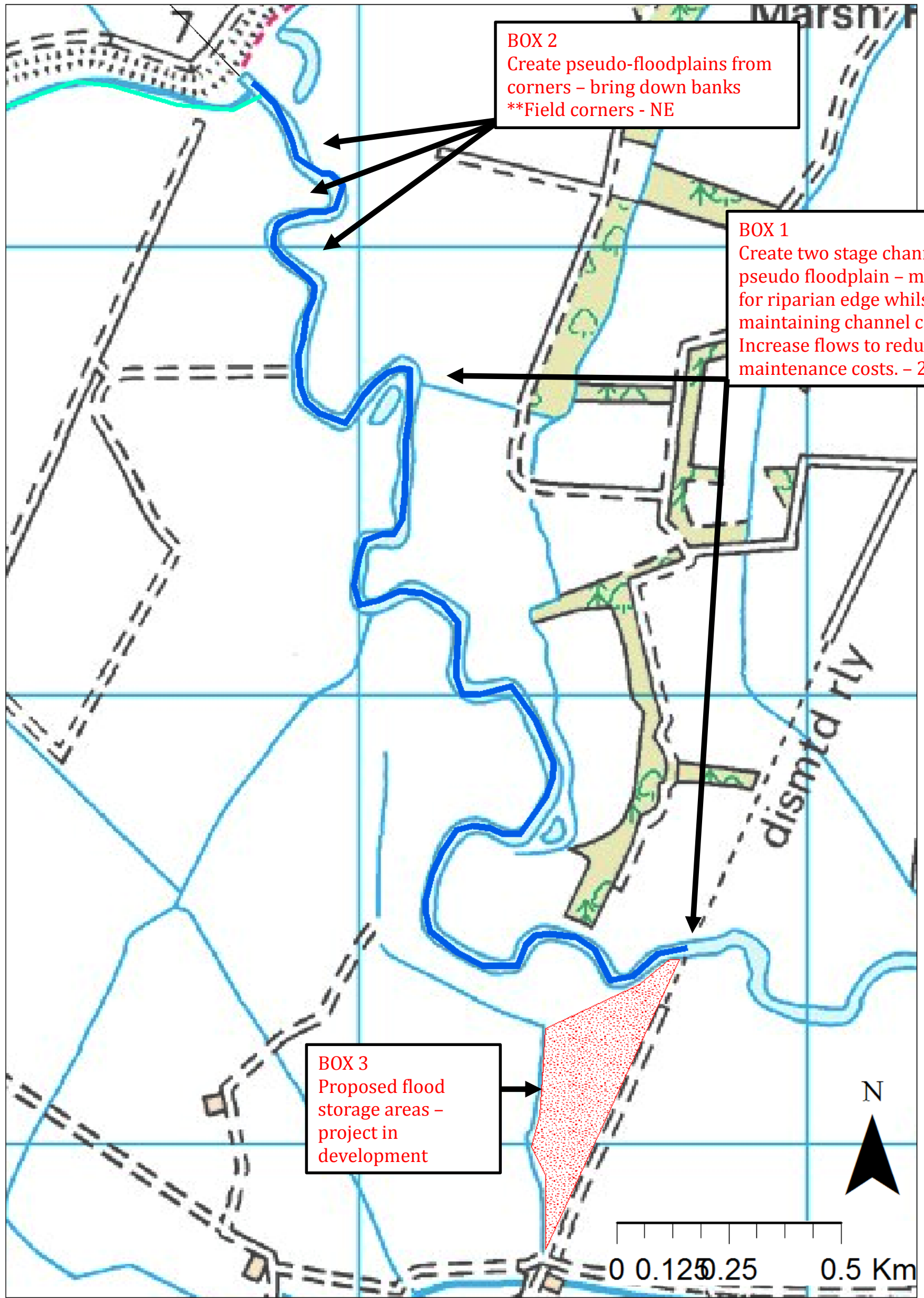


Figure 4 Proposed restoration and maintenance measures for Reach 3. Black text states current features/state, red text states proposed measure

2.4 Reach 4 – Most northerly extent to outfall

2.4.1 Current state

This reach of the Babingley is the most intensively modified with the channel showing a straightened un-natural course. The river originally discharged at the boundary between 3 and 4, as indicated in Figure 1, being altered through a series of reclamation works that took place around 1850. At the beginning of the reach the river changes direction from running west to running south-southwest for 4.5Km before kinking sharply to the west to the outfall. The river width varied between 3-10m, the narrowest point seen in the upper extent of the reach where the river is pinched between the historic sea wall and a bund separating the river from a drain. Bank heights vary dramatically through the reach, from 5m where the sea wall marks the river edge, to 1-1.5m. This section of the Babingley is more typical of a lowland drain with drainage being its main form and function.

The land is intensive arable farming through this stretch, with buffer strips present throughout its length. The intensive farming through this reclaimed land requires a high level of drainage which is visible throughout the section, Photo 13. Several drains enter this stretch of the river collecting water from field drains. Some of these join the channel via an open channel, whilst others drain via gravity outfalls. The outfall above Kilham's Bridge has been reportedly failing to drain at times due to high river levels. This will be investigated and taken into account through the next subsequent sections.



Photo 13. Showing the agriculture extent of the reach, with ploughed field and a field drain connection.

The river drains through three 1.2m wide sluice gates Wooton Marsh, Photo 14, two of which have been fitted with fish friendly 'pet flaps' elongating the available time for migrating species such as trout and eels to pass between the river and estuarine section. During high tide the river becomes tide locked, backing up throughout this section, draining again on the outgoing tide.

Several crossings are seen throughout the stretch allowing vehicle access, the first of these is two-thirds of way through the southern flowing stretch, with

another half way down and a third on the bend where the river branches to the west. This central bridge, Kilham's Bridge, houses a gauging station.



Photo 14 Babingley outfall gates

The channel is uniform, with no flow variation and no evidence of in channel vegetation. Anecdotal evidence suggests that that burr-reed, *Sparganium erectus*, and blanket weed can be prevalent. Bank side vegetation is also sparse,

mostly consisting of grasses. These had been recently cut, so species could not be identified. Buffer strips display coarse grass and rush species such as great willow herb, *Epilobium hirsutum*. Brambles are present in places along the eastern, right hand bank, particularly to the north of the reach on the bund between the river and drain. The northern most extent, on the north bank (right hand bank) shows a shelf covered in scrub between the sea wall and river. Scrubby vegetation and small trees are currently growing throughout this area.

The river is at its widest point half way through the stretch where it opens out to a very wide ponded area. This area shows a large area of open water with abundant reed growth. The river narrows to the north of the stretch.

Some erosion was evident through the north of the reach where the river is pinched. The channel is narrower here, with steep banks on both sides.

2.4.2 Proposed restoration measures

Due to the limited space and intense agriculture throughout this stretch limited restoration measures are possible without compromising the flood risk to agricultural land.

One opportunity for restoration lies on the northern most bend, where a shelf exists between the sea wall and river, BOX 1, Photo 16. This area is currently covered with small trees and scrub with banks around 2m in height. Some light scrub clearance and bank re-profiling to drop the banks in areas to create a lower berm and seasonally in-undated area of water is proposed. This would create a connected backwater environment which could provide refuge for small fish and eel. Partially dropping the banks to allow inundation would also provide a storage area for water during higher flows, this is shown in Figure 4.

The first stretch running south has limited restoration opportunities as the river is pinched between the old sea wall and a bund separating the river from a drain. This stretch does however present an opportunity for bank stabilisation, with the bund, right hand bank, being eroded in places. It would be suggested that this is achieved using geotextiles or coir matting, BOX 2.

Where the river is wider, below Kilham's bridge, opportunities may exist for the creation of low berms, creating a two stage channel, BOX 4. This could be done through the variety of methods including 'dig and dump', bank re-profiling and woody faggot installation. This would help speed up flows when the river is free flowing, helping to control the growth of blanket weed and common reed. Restoration options are shown on Figure 4.

One alternative measure for the reach would be to re-direct the outfall to its original course as indicated in figure 1. This would benefit the river from putting into a more natural alignment, encouraging more natural processes, allowing the more constrained, modified section of the current river to continue as a drainage channel, but not part of the main water course. Before modification this area would have been large salt marsh and mud flats, therefore no remnant channel is obvious through an analysis of LIDAR data. One smaller channel can be seen to

the south, but this is likely one of many that would have fed through the marsh system.

This proposal would be costly, requiring a new outfall structure to be constructed, and the sea wall to be cut through allowing a route out. However, it could have substantial economic and ecological benefits for the river and surrounding land. If the more heavily modified section of the river were to be bypassed, land drainage could be more efficiently undertaken without compromising the watercourse or ecological corridor. Due to the scale and significance of this proposal, and the likely cost this would be proposed over a long-term time-scale and be considered against current and future policy on sea defence and the capital programme. An extensive Environmental Impact Report would also be required to assess impact on The Wash which is heavily designated with European and national status. It is proposed that discussions are started with all relevant bodies to explore the feasibility of this idea.

2.4.3 Proposed maintenance regime

This reach of the river would benefit from an annual cutting regime, removing the in-channel vegetation and one bank. An emergent buffer should be left on one side. It is proposed that cutting take place from the left hand bank at the top of the section and the from Kilham's bridge down to the outfall. If possible this will be alternated to improve watervole habitat. Due to the high number of waders known throughout the catchment, it is suggested that cutting should take place between mid-July and mid-September, preferentially leaving till late August where possible to allow the majority of breeding to occur un-disturbed.

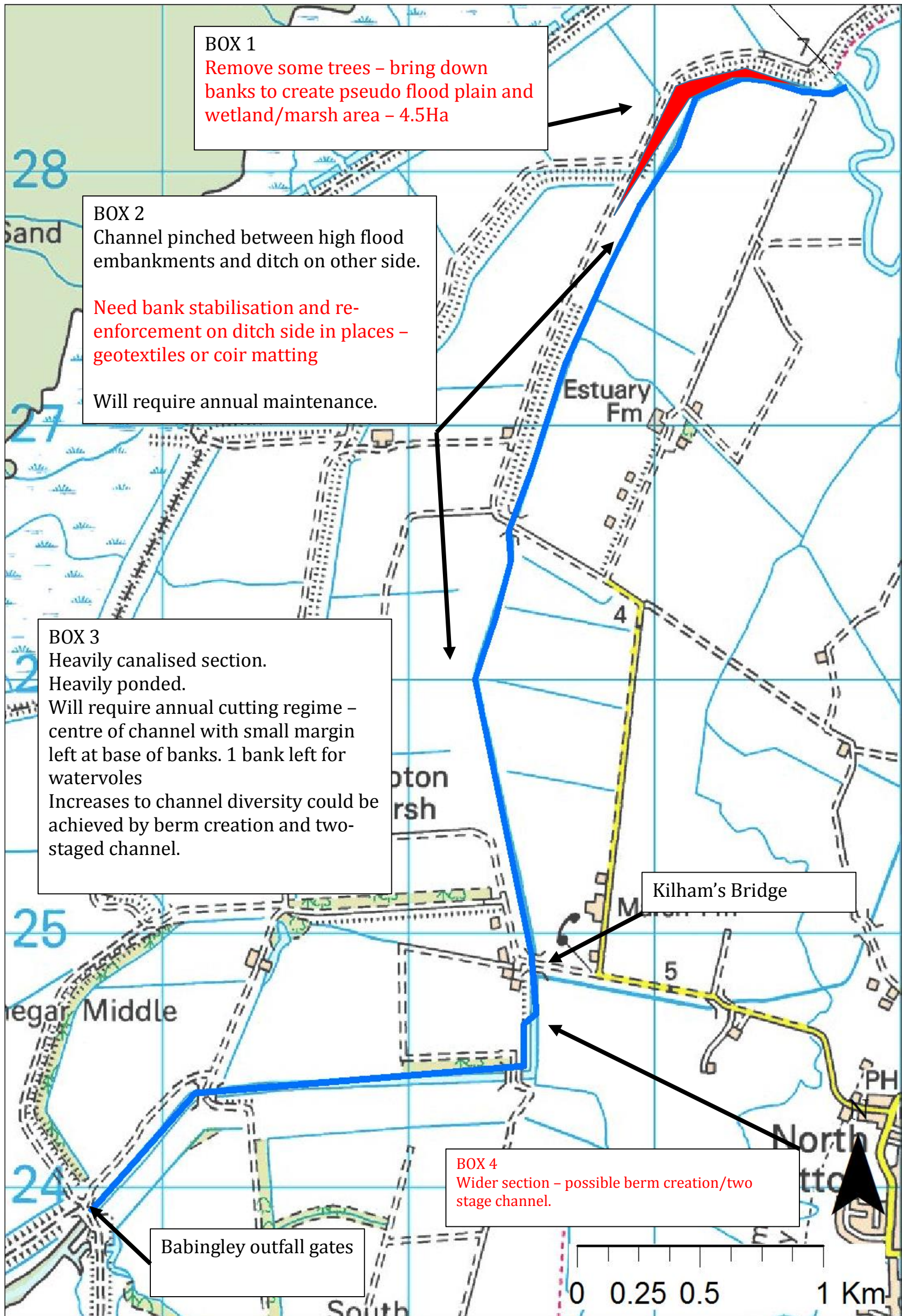


Figure 5. Proposed restoration and maintenance options for the lower end of Reach 4. Black text outlines current features, red text indicates proposed actions.

3. Summary and future considerations

3.1 Summary

The River Babingley is a small chalk stream on the North Norfolk coast that flows into The Wash. The 19Km which are currently managed by the King's Lynn Drainage board can broadly be categorised into three sections:

1. Reach 1 - The top section showing more naturalised features and natural processes that present a wide range of restoration options and limited requirement for annual maintenance. Restoration options include the installation of large woody debris, two stage channel creation, berm creation and canopy thinning.
2. Reaches 2 & 3 - The middle section which, whilst still highlighting semi-natural sinuosity and some natural processes, are more modified, over wide and embanked. A range of opportunities are proposed through this section which could be undertaken in isolated areas or in combination with a larger reach scale project. These include two-stage channel creation, flood plain storage areas, bank re-profiling and height reduction, cattle drink creation and fencing. Some maintenance is required through Reach 3 whilst other measures are put into place, with a review thereafter.
3. Reach 4 – The lower section is heavily modified, straightened and heavily embanked. Little restoration opportunity exist due to the intense agriculture surrounding it. Where space is available berm creation causing localised narrowing would be beneficial to control growth of common reed, particularly through the middle section. A regular, annual cutting regime is suggested. A long-term aspiration to move the outfall could also be explored, improving the river system and drainage abilities of the land.

The measure proposed, which are briefly highlighted above would decrease the need to mechanical maintenance of the river system and increase the ecological biodiversity. This in turn works to satisfy the mitigation measures placed on the water body under the water framework directive allowing it to reach **Good Ecological Potential**, as outlined in Table 2. Mitigation measures set out to achieve Good Ecological Potential under the Water Framework Directive, as set by the Anglian River Basin Management Plan, 2009. Measures which are deemed to be in place and therefore satisfied are stated so. Table 2. A summary of the proposed restoration measures are seen below in Table 3.

Restoration measure proposed	Opportunity to implement measure (Km/Ha)	Reach opportunity is present within
Large woody debris installation – increase in-channel morphological diversity	1.3Km	1
Channel narrowing/two-stage channel creation	6Km	All
Bank re-profiling	2.5Km	1,2,3
Flood plain connection/set back of embankments	20Ha identified – only 1 of three areas to be taken forward	2 and 3

Table 3 Summary of restoration measures and areas identified.

The measures proposed can be both undertaken as part of general maintenance where possible and run as part of a larger restoration scheme. Funding would need to be secured between the Board and Norfolk Rivers Trust to ensure to success and completion of this proposed plan.

3.2 Future considerations

3.2.1 Water level management

As already mentioned, one consideration into the management of the river could be to move the outfall, this is discussed above. Additionally to this, in the short term, alternative water level management could be considered to keep water levels at an appropriate level for the ecology and abstraction, whilst allowing the required drainage in the lower reaches. At present water levels are managed by manually opening and closing the sluice gates in response to local rainfall events. Due to the size of the gates, minor changes in height can have a dramatic difference in river levels creating a challenging and time intensive management situation. Options to overcome this challenge to be explored include the introduction of a tilting weir to the lower reaches or a fixed level more natural weir structure, such as a rock ramp further up the river.

The benefits of a tilting weir structure include the reduction in need for manual operation of the gates by having an automated level control on the gate allowing more constant levels which would benefit bank stabilisation and the ecology. However, installing a tilting weir through the lower reaches of the river has significant environmental impacts, impeding fish and eel passage and reducing the natural transport of sediment. It also has the potential to decrease drainage potential and increase flood risk. Therefore this option would need to undergo a rigorous feasibility and environmental impact assessment before being taken forward. Fish passage mitigation measure would also need to be met.

The introduction of a fixed weir structure would allow water levels to remain set at a minimum level through the more naturalised areas, allowing the lower levels to be managed more effectively for drainage. This would benefit the ecology of the river and drainage of the surrounding land below. However, the location of this feature would need to be carefully determined, not allowing flexibility in water levels and reducing flexibility of levels above its position. Investigations may therefore reveal that in order to ensure no negative impact to flood risk the feature would need to be placed too high in the catchment to allow the water level management below to be altered considerably without impacting on the ecology of the lower river.

It is proposed that both options are explored further with other relevant regulatory bodies to identify a solution to water level management.

3.2.2 Climate change

Other considerations for the Babingley in the future will be tree cover and water temperatures. With expected rise in air temperatures through climate change it is expected that water temperatures in rivers will also rise. This poses a

significant risk for the river life, most notably fish species such as trout whose egg survival rate is significantly impacted upon by small changes in temperature. Therefore, a consideration to the river would be the need to add cover, allowing shade to help regulate temperatures. As well as being important for spawning fish, it will also ensure resilience of the whole ecosystem to climate change and help regulate plant growth and habitat connectivity. Long stretches of river with no cover can pose a significant barrier to migrating species.

Current concerns around bankside planting in the lower reaches are centred on access requirements, potential threats to flood risk and ongoing maintenance issues. Planting has therefore not been suggested as part of this plan through the lower sections. It will however need to be considered in the future, with aspirations to increase tree cover added to the mitigation measures for the second River Basin Management Plan. It is hoped that some cover will be added in the upper sections where management requirements are less intensive.

3.2.3 Population growth

Population growth and the increased need for water, both for domestic and agricultural use is a growing concern for chalk streams. Being predominantly aquifer fed, an increase in abstraction from the aquifer and instream agricultural abstraction can act to drop water levels in the river impacting on flows and available habitat. The restoration proposals above aim to introduce channel narrowing, both in the form of berm creation and two-stage channel creation would help mitigate against reduced flows. This will aid the resilience of the system, but will need to be regularly addressed.

4. References

Environment Agency, 2009. 'River Basin Management Plan – Anglian District - Anglian Water River Basin Management Plan

Environment Agency, 2015. 'Anglian (Central) Regional Flood and Coastal Committee'.

Accessed at:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/419505/CRFCC_Final_Full_Pack_150115_reduced_size.pdf

5. Appendix 1 – Environment Agency monitoring points on the River Babingley.

