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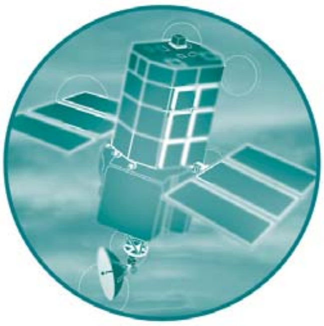

PROJECT SLD2316: RESTORING FLOODPLAIN WOODLAND FOR FLOOD ALLEVIATION

Final Report

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Project SLD2316: Restoring Floodplain Woodland for Flood Alleviation

Final Report

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Executive Summary

This report presents the results of a study designed to evaluate and demonstrate the contribution of floodplain woodland to flood alleviation. It builds on the existing Multi-objective, Defra/EA/EN/FC Pilot Project (Ripon MOP) on the River Laver/Skell in North Yorkshire with the aim of facilitating the establishment of a sizeable area of floodplain woodland (15 ha) to help reduce flood risk. The study had five principal objectives:

1. To appraise the impact of planting floodplain woodland on flood flows and flood risk at Ripon.
2. To investigate the influence of woodland design and management factors on flood flows.
3. To facilitate an application for Woodland Creation Grant under the English Woodland Grant Scheme.
4. To assess the impact of planting floodplain woodland on flood depth, velocity, storage and timing.
5. To demonstrate and communicate the benefits of floodplain woodland for flood alleviation.

The progress made in achieving the objectives is described along with a number of problems encountered. The modelling provided support for the potential of floodplain woodland to alleviate downstream flooding. Model results demonstrated that planting woodland at four sites in the River Laver catchment, totalling an area of 40 ha, delayed the progression of a 1-in-100 year flood by almost one hour. Although this was predicted to have a negligible impact on flood peak height in the River Laver, the time lag had the potential to desynchronise the flood flows from a tributary catchment and so lower the downstream flood peak as the main river flows through Ripon. It was estimated that desynchronisation could reduce the flood peak height by 1-2%, with the possibility of a much greater reduction if the woodland area was expanded.

Despite the positive findings from the modelling work, the landowners proved unwilling to submit an application for planting floodplain woodland at any of the identified sites and a decision was taken to close the project (after 15 months). The main reasons given by the landowners are described, the most important of which was the lack of sufficient payments/incentive to compensate for the perceived reduction in capital value of the land and loss of agricultural income, as well as for the increased risks associated with land use change.

Lessons learnt and recommendations for future work are set out, including the need for one or more replacement demonstration sites to be established to communicate and explain the benefits of floodplain woodland for flood alleviation. There is a strong case for a study in the Yorkshire and the Humber Region, building on recent opportunity mapping work and drawing on the strong regional support for assessing the potential contribution of floodplain woodland to flood risk management.

1. Introduction

The Government's Flood and Coastal Erosion Risk Management Strategy 'Making Space for Water', promotes a whole-catchment approach to flood alleviation, drawing on opportunities provided by rural land use and land management practices. Woodland provides a number of options, principal amongst which is the ability of floodplain woodland to slow down flood flows and enhance flood storage (Nisbet and Thomas, 2006). Research suggests that the greater hydraulic roughness provided by floodplain woodland could make a significant contribution to downstream flood alleviation (Thomas and Nisbet, 2007).

There are increasing opportunities for planting and extending relic areas of floodplain woodland for flood mitigation, but progress is highly constrained by a lack of information on the magnitude of the forest effect and how this is affected by woodland design and management factors. There are also concerns about a possible increased risk of flooding due to the backing-up of flood waters upstream of the woodland, as well as by the wash-out of large woody debris, which could block downstream bridges and culverts. While most of these issues can be investigated by modelling work, a robust assessment requires a demonstration study.

The existing Multi-objective, Defra/EA/EN/FC Pilot Project on the River Laver in North Yorkshire provided an ideal opportunity to establish a demonstration floodplain woodland. A number of potential sites had been identified for planting and local landowners were supportive, in principle. However, planting had not been possible due to insufficient financial support to cover the costs involved with this change in land use.

This project sought to demonstrate the case for using floodplain woodland to reduce flood risk. A positive result would strengthen the evidence base and support for using floodplain woodland as a sustainable method for downstream flood alleviation. This would yield significant socio-economic benefits by helping to tackle the increasing threat of flooding faced by many local communities due to climate change, especially where it is not cost effective to construct engineered defences. The ability of floodplain woodland to benefit water quality and freshwater habitats offers the potential to develop win-win solutions, such as contributing to meeting ecological and chemical quality targets under the EU Water Framework Directive. Finally, the planting of floodplain woodland would help to meet the UK Biodiversity Action Plan Target of creating 2,200 ha of wet woodland in England by 2010. If the project proved successful, the results, models and guidance generated would be used to support better integration of woodland and agriculture for flood alleviation elsewhere in the UK, as well as in the identification and prioritisation of sites for future action.

2. Aims and Objectives

The aim of the project was to facilitate the establishment of a sizeable area (~15 ha) of floodplain woodland in the River Laver catchment to demonstrate and help communicate the benefits of this option for flood alleviation. There were five main objectives:

1. To evaluate the impact of planting floodplain woodland on flood flows and flood risk at Ripon.

Hydraulic models to be applied to the River Laver and available stream flow and high resolution topographic data used to assess the effect of planting floodplain woodland at each of four potential sites on flood flows. The results to be assessed in terms of flood risk at Ripon and the sites ranked by their effectiveness at alleviating flooding.

2. To investigate the influence of woodland design and management factors on flood flows.

The same models to be used in an innovative way to evaluate the effect of varying the design and management of the woodland on flood velocity, depth, storage volume and peak travel time. Factors to be considered included the shape, area, pattern and spacing of tree planting, species choice, woodland structure and establishment methods. The findings to be used to guide the design and management of the planned woodland at the preferred site(s).

3. To facilitate an application for Woodland Creation Grant under the English Woodland Grant Scheme.

The appropriate landowner(s) to be assisted in making an application to the Forestry Commission for grant aid to establish a floodplain woodland at the preferred site(s). The results of the modelling work to be used to supplement the standard scoring system and support the application for funding. Top-up funding to be provided by the project to cover the full cost of establishing the woodland in order to secure planting and allow the potential contribution to flood alleviation to be assessed. Planting floodplain woodland expected to provide additional benefits for society and the environment, including improvements to water quality, fisheries, carbon sequestration, nature conservation, recreation, and landscape.

4. To assess the impact of planting floodplain woodland on flood depth, velocity, storage and timing.

Additional instrumentation to be installed at the selected site(s) to measure the initial effects of the site preparation and planting of the floodplain woodland on flood flows. Monitoring to be maintained by the Forestry Commission beyond the three-year duration of the project to evaluate the longer-term effects on floodplain roughness and flood flows as the woodland becomes fully established and matures. The results to be used to validate and improve existing models, enabling them to be applied with confidence at other UK sites.

5. To demonstrate and communicate the benefits of floodplain woodland for flood alleviation.

The findings from the project to be disseminated via a Forestry Commission Forest Practice Note, Forest Research website and by amendments to the Woodland Creation Grant, Regional Forestry Frameworks, and the Forests & Water Guidelines. Group visits to the demonstration woodland and outreach seminars to help communicate and explain the benefits of floodplain woodland for flood retention to practitioners, planners and policy informers.

The objectives of the project were to be achieved via ten tasks and 12 milestones, as set out in the contract specification. Unfortunately, it proved not possible to complete all of these and the study has had to be closed. This report is structured by objective and describes the results achieved and the issues that have contributed to its closure. Lessons learnt and recommendations for future work are provided.

3. Evaluating the impact of planting floodplain woodland on flood flows and flood risk at Ripon

3.1 Site Selection

The joint agency (Defra/EA/EN/FC) Multi-objective Pilot Project in North Yorkshire had identified three potential sites for restoring floodplain woodland in the River Laver catchment. These were located at Beckmeetings, Ings and Galphay Mill in the middle reach of the River Laver. A fourth site was added at Cow Myers, which incorporated the proposed location for the new flood defence dam at Birkby Nab, in the lower reach of the catchment. This was selected to compare the effects of establishing a floodplain woodland (a ‘green dam’) with that of the traditional engineered construction. Detailed maps and photographs showing the location of each site and the fields identified for potential planting are included in the Appendix. The land use at Beckmeetings and Ings Bridge was grazed pasture while that at Galphay Mill and Birkby Nab was arable (winter wheat or maize). A total of 40 ha of land were potentially available for planting.

3.2 Site topography

Modelling the impact of planting floodplain woodland at the identified sites on flood flows required detailed topographical data for the river channel, banks and floodplain, as well as the physical geometry of any man-made structures such as bridges, culverts and weirs. Cross section and structure data had been collected under the pilot study for the River Laver upstream of Galphay Mill and for the river downstream of Galphay Mill to Ripon from a previous hydraulic modelling exercise by the Environment Agency. High resolution (1-m) LiDAR[1] data were available from a survey of the River Laver and Skell catchments in 2006 and these were used along with supplementary cross section data from the Environment Agency to construct composite cross sections of the channel and floodplain for the selected site reaches. The area of the catchment covered by LiDAR data is displayed in Figure 1.

3.3 Mathematical modelling

A 1-D mathematical/hydraulic model of the River Laver and floodplain was set up for the extended reach between Beckmeetings (SE 207 264) and Ripon (SE 300 710). The selected model was the Infoworks RS[2] river modelling software package, which

[1] LiDAR stands for **Li**ght **D**etection **A**nd **R**anging and is a method of accurately mapping the ground surface profile by an analysis of reflected pulsed laser light.

[2] Infoworks RS stands for Infoworks for **R**iver **S**ystems, developed by Wallingford Software Ltd.

is able to model complex looped and branched networks and provides a comprehensive range of methods for simulating floodplain flows. The Infoworks RS mathematical modelling engine incorporates both unsteady and steady flow solvers, with options that include simple backwaters, flow routing and full unsteady simulation. The engine provides adaptive time-stepping methods to optimise run-time and enhance model stability.

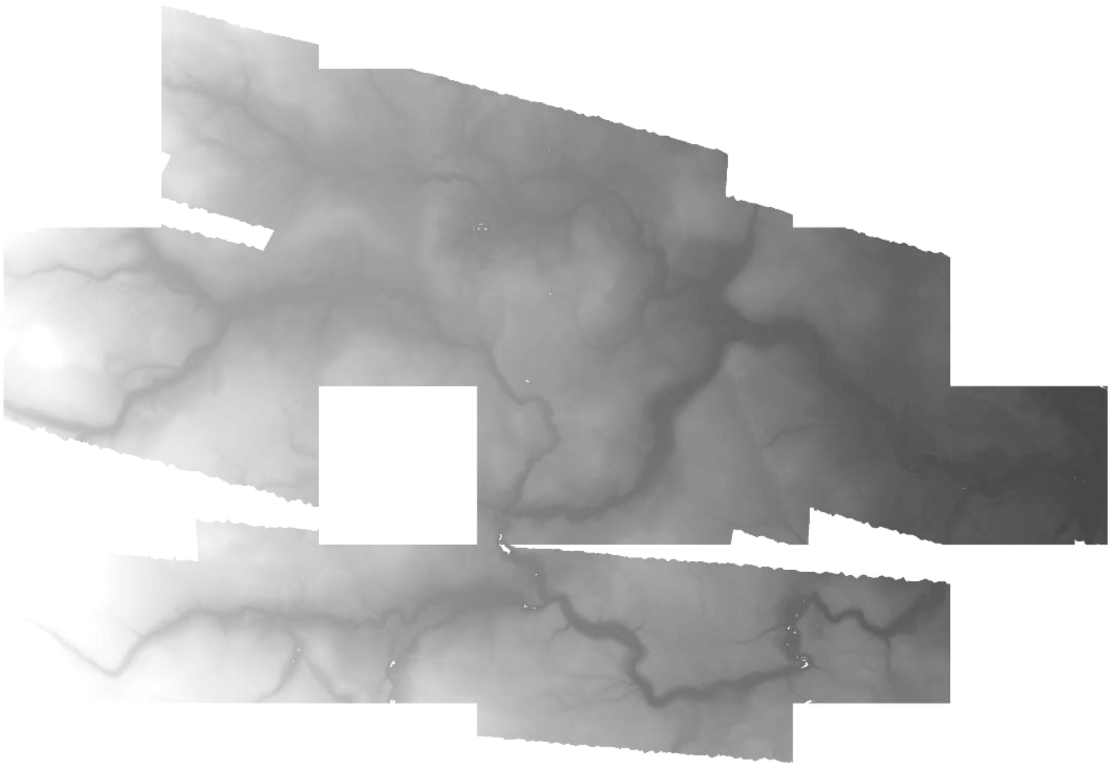


Figure 1 LiDAR image of the River Laver, River Skell and main tributaries (Environment Agency, 2006).

A key feature of Infoworks RS is its ability to model a wide range of hydraulic structures, including common types of bridges, sluices, culverts, pumps and weirs. Reservoirs are included to represent flood storage areas, while junctions permit the modelling of flows and water levels at channel confluences. Wherever possible, standard equations and methods are incorporated into the software to improve the representation of flood level and discharge relationships.

The software provides full interactive views of the model data and results using plan views, long sections, form based editing tools and time series plots. It combines the ISIS Flow simulation engine, GIS functionality and database storage within a single environment, producing flood inundation and extent maps with relative speed, accuracy and ease.

The model requires the input of river cross sections to represent the main channel and the floodplain, including flood bank levels to characterise out of bank flows. It was first constructed using the basic cross sections of the river channel obtained from the topographical survey. Initial conditions were obtained by carrying out a number of simulations using within-bank flows. The model was then developed to include the floodplain sections by extending the cross sections using the LiDAR data. Additional cross sections were added to improve the representation of the watercourse in the modelled reach. A diagrammatic representation of the model, including the LiDAR image is shown in Figure 2.

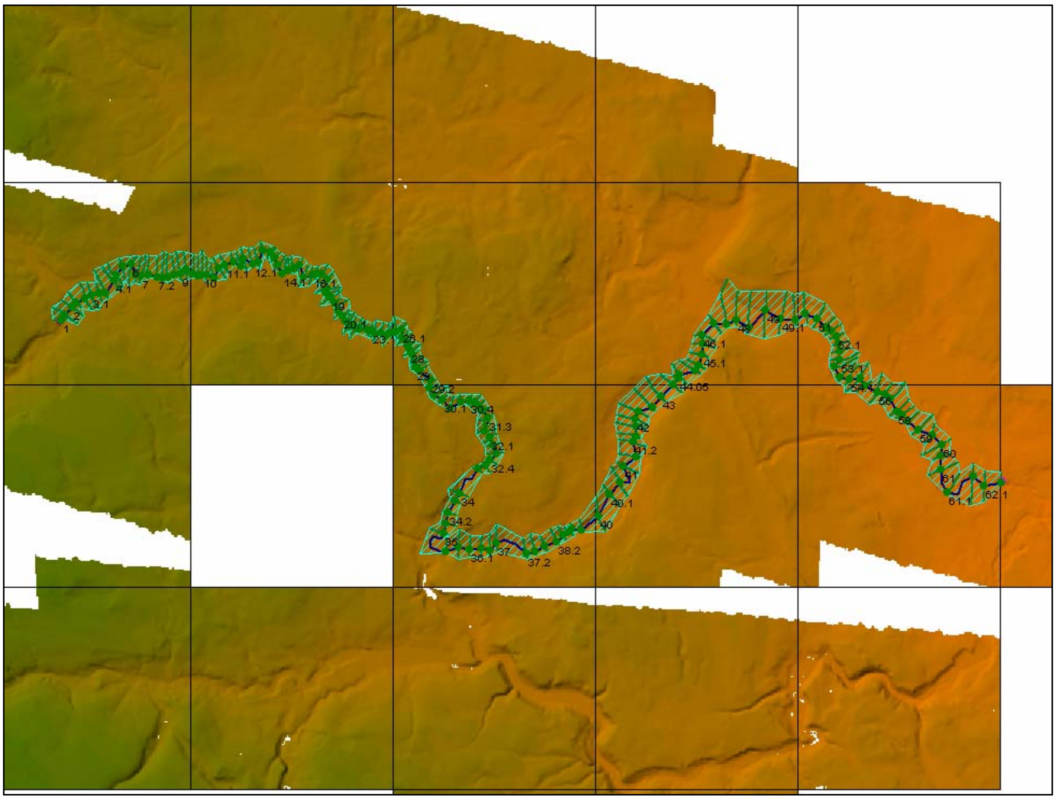


Figure 2 Plan view of the modelled reach of the River Laver incorporating cross sections derived from site-based and LIDAR surveys

The Flood Estimation Handbook's statistical flood frequency analysis was used to generate design hydrographs for the model runs, drawing on the historical flow record for the River Laver at the main gauging station at Ripon. A 1% annual probability event (a.p.e) was selected as the input hydrograph (Figure 3) for the simulations and a number of scenarios then devised to assess the effect on flood flows of woodland placement at the four selected sites.

3.4 Channel and Floodplain Roughness

The principal effect of floodplain vegetation is to increase surface roughness. Modelling techniques in the past have treated vegetation in open channels and on floodplains as an additional flow resistance to be added to the bed roughness. The presence of submerged or non-submerged vegetation along riverbanks and/or across floodplains is often found to be the largest source of resistance.

A roughness coefficient is used to represent the energy lost from flowing water due to channel roughness. One of the most commonly applied uniform-flow formulae for open-channel computations is the Manning's formula, owing to its simplicity and to the satisfactory results that have been achieved in practical applications.

The selection of an appropriate value for the Manning's roughness coefficient (n) is crucial to the accuracy of the computed hydraulic parameters. The value of Manning's n is highly variable and depends on several factors, including: surface roughness; vegetation; channel irregularities; channel alignment; scour and deposition; obstructions; size and shape of the channel; stage and discharge; seasonal changes; water temperature; and suspended material and bedload.

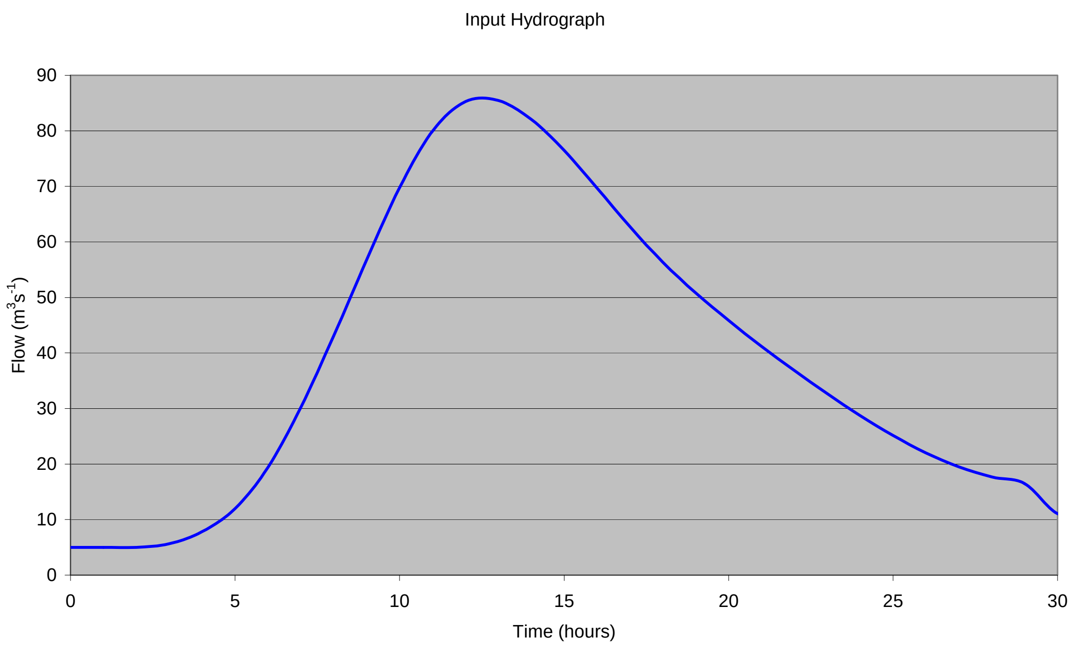


Figure 3 Input design hydrograph based on 1% annual probability event (a.p.e).

There are a number of methods for calculating Manning's n for river channels and floodplains. The channel and floodplain are always treated separately as the degree of roughness can vary considerably between the two. The most important factors affecting channel n are the type and size of the material forming the riverbed and banks, and the channel's cross sectional shape. Floodplain n requires a base value for the natural bare sediment and soils, and a combined measure for surface irregularities, the presence of obstructions, and the nature of the vegetation.

Roughness values of 0.03 and 0.05 were assigned to the channel and floodplain, respectively, to represent the bed roughness associated with the nature of the existing river channel and the baseline grassland or arable land cover (Chow, 1959). The establishment of a cover of native floodplain woodland was represented by increasing the channel roughness to a value of 0.10 and the floodplain roughness to 0.3. The latter is considered to be at the upper limit of possible values for floodplain woodland and to attain such a high roughness the woodland would need to be particularly dense with plenty of undergrowth, low branches and fallen trees. It was thought to be possible to create and maintain this hydraulic roughness by adopting appropriate management practices. Large woody debris forms a very important component of the roughness or flow resistance of both the floodplain and river channel, mainly arising from the formation of debris dams. The formation of multiple channels and pools typical of natural floodplain woodland could also be expected to enhance floodplain roughness and flood storage.

3.5 Model Results: Scenario 1

The model was used to simulate the effect of planting floodplain woodland at each site on the depth, extent and velocity of flood flows in the River Laver. Since funding was only available to support around 15 ha of planting, the results were used to identify which sites would be most effective in reducing downstream flood risk.

Flood depth

The effect of woodland planting on flood depth along the modelled reaches is compared between sites in Figure 4 and in relation to woodland area in Table 1. The results show that the greater roughness associated with woodland increased the flood depth along all planted reaches, with a mean of 0.61 m. Ings bridge produced the greatest average rise of 0.8 m, reflecting the narrow floodplain at this site, while the smallest rise occurred at Birkby Nab. The maximum increase, however, reached 1.31 m at Galphay Mill due to the combined effect of the woodland and the presence of a road bridge. Surprisingly, there appeared to be a negative relationship between flood depth and woodland area. This could be explained by site location, with the woodland area increasing down the catchment. The lowest site at Birkby Nab had the widest floodplain and river channel and therefore shallowest flood flows.

It is notable that the planting of woodland is predicted to create a backwater effect at each site, extending a distance of between 120-330 m upstream of the woodland (Figure 4). The largest effect was at Ings Bridge and smallest at Beckmeetings. The extent of the backwater effect is primarily dependant on the river gradient, as well as the overall increase in water depth. This highlights the need for great care in site selection when planning new woodlands to ensure that the backing-up of floodwaters does not threaten local properties or other assets. The apparent rise in flood depth below the woodland is an artefact of the spacing of the modelled cross-sections.

Scenario	Wooded Area	Average depth change at peak
	ha	m
Baseline	0	0
Beckmeetings	5	+0.76
Ings Bridge	4.3	+0.80
Galphay Mill	11.2	+0.64
Birkby Nab	19.3	+0.44
Combined 4 sites	39.8	+0.61

Table 1 Summary of the change in water level due to woodland planting.

Flood extent

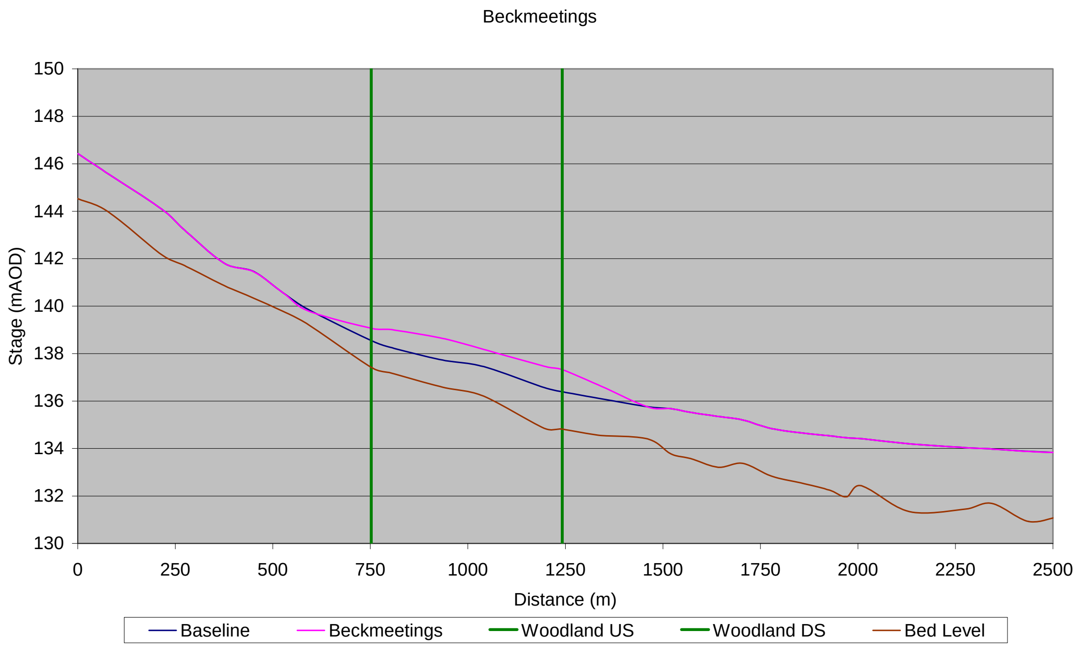
The use of GIS to combine LiDAR topographic and hydraulic modelling data onto an Ordnance Survey (OS) base map is an invaluable tool for assessing the spatial extent and depth of flooding. It is particularly useful for determining whether the backing up of flood waters poses any risk to local properties or will affect neighbouring land. Maps comparing the extent and depth of flooding with and without woodland at each site are presented in Figure 5.

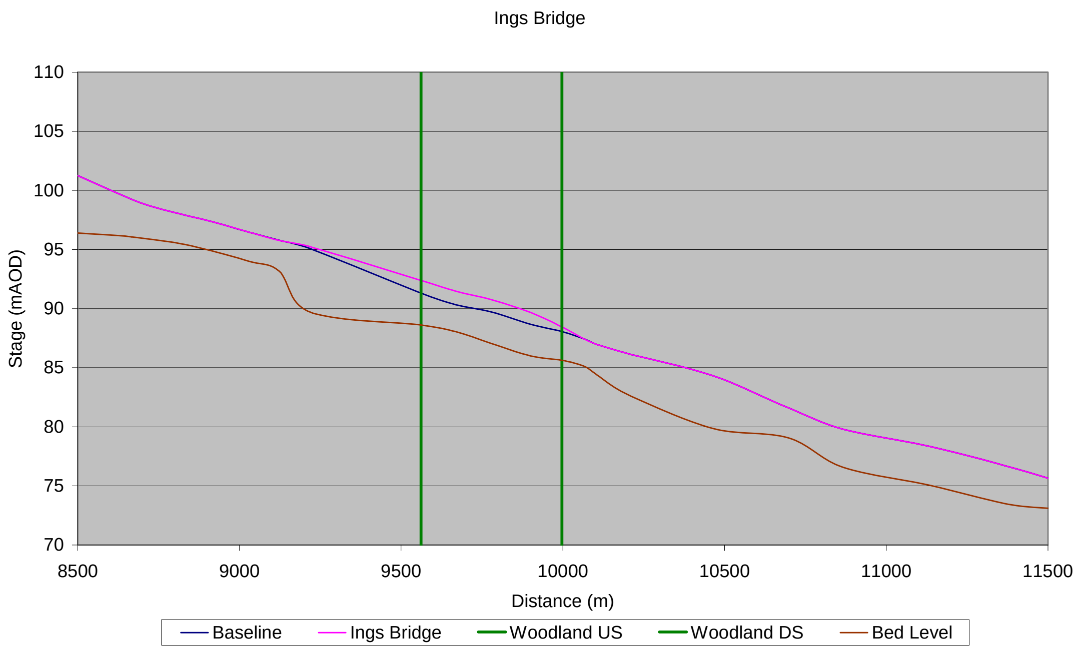
At Beckmeetings, there was little change in the spatial extent of flooding but flood depth increased across both woodland blocks. The backing up of floodwater extended into the upstream field but did not stretch beyond this point and therefore would not affect Beckmeetings Farm. Woodland planting had a greater impact on flood extent at Ings Bridge, almost doubling the affected area and raising flood levels over a longer, wooded, upstream reach. There was a similar response at Galphay Mill, with the flood extending across most of the planted area. The LiDAR data picks out a number of relic channels and the site of a historic pond, which were reclaimed by the flood waters under the woodland scenario. Once again, the presence of woodland upstream meant that the backing-up of floodwaters would present no flood threat. The larger area of planting at Birkby Nab had a relatively smaller impact on flood extent but raised the flood depth across most of the wooded area. Some parts lay outside of the flood envelope and would not benefit from planting. The backing-up effect was somewhat restricted and importantly, did not extend up to Galphay Mill or interact with the upstream site.

There is a close match between the location of relic side channels at the Birkby Nab and Galphay Mill sites and the path of the diverted flood waters during the summer 2007 flood and the resulting erosion and sediment deposition. These areas hold great potential for creating an extended area of natural floodplain woodland characterised by multiple side channels, backwater pools and gravel bars. This would help to further increase flood storage as well as to restore an ecologically rich but essentially lost habitat in the UK. Woodland planting in these areas would be particularly effective at diverting flood waters and promoting out of bank flows, even during smaller events, accelerating the restoration of a natural floodplain woodland and flooding regime with multiple associated benefits.

Flood velocity

Figure 6 shows the effect of planting floodplain woodland on the average flood peak velocities along the modelled reach at each site. As expected, the increased resistance resulting from the presence of trees, undergrowth and woody debris caused a significant reduction in the velocity of flood flows, up to a maximum of 2.8 ms^{-1}. The baseline velocity distribution was very heterogeneous along each reach but greatly smoothed by the presence of woodland. The reduction in velocity led to the rise in flood depth and extent within and upstream of the planted woodland. As before, the lower velocities predicted below the woodland were an artefact of the spacing of the modelled cross sections.





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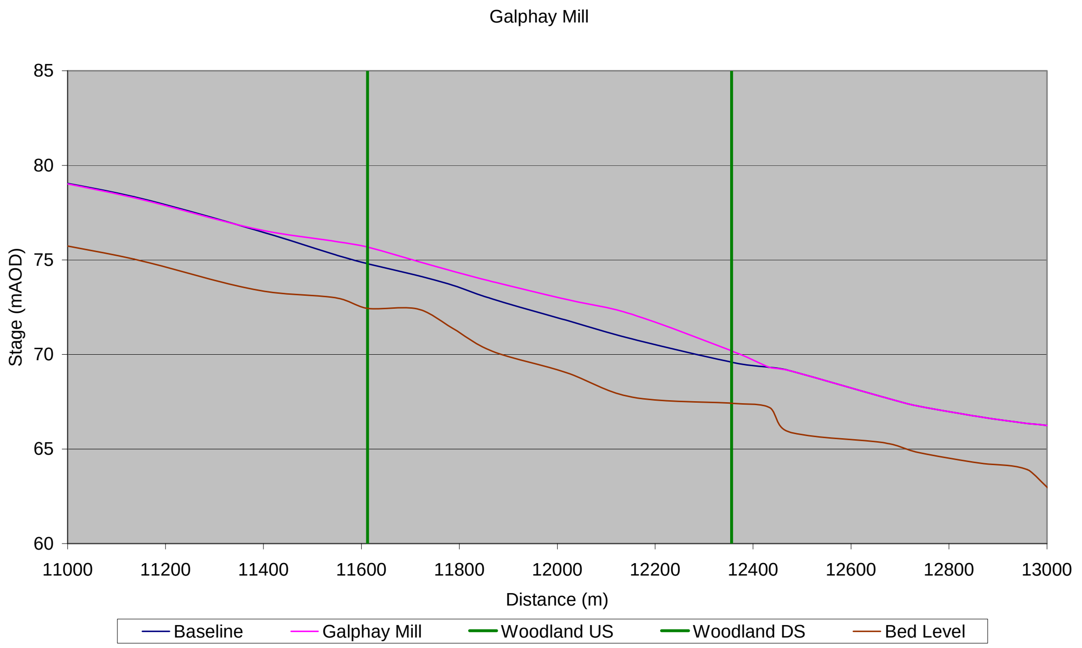


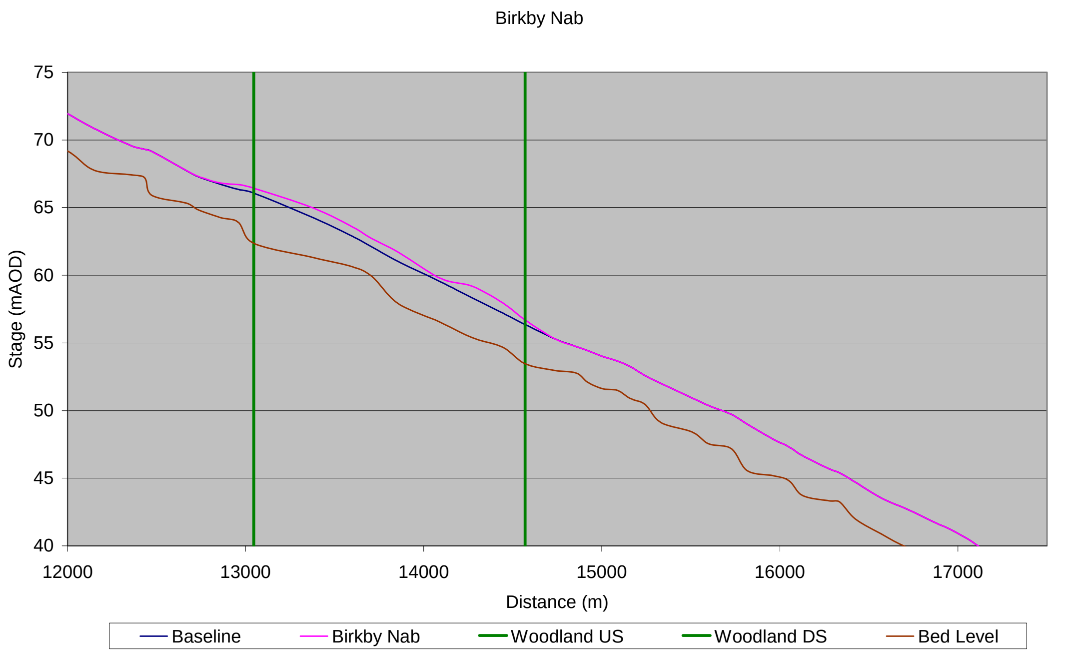
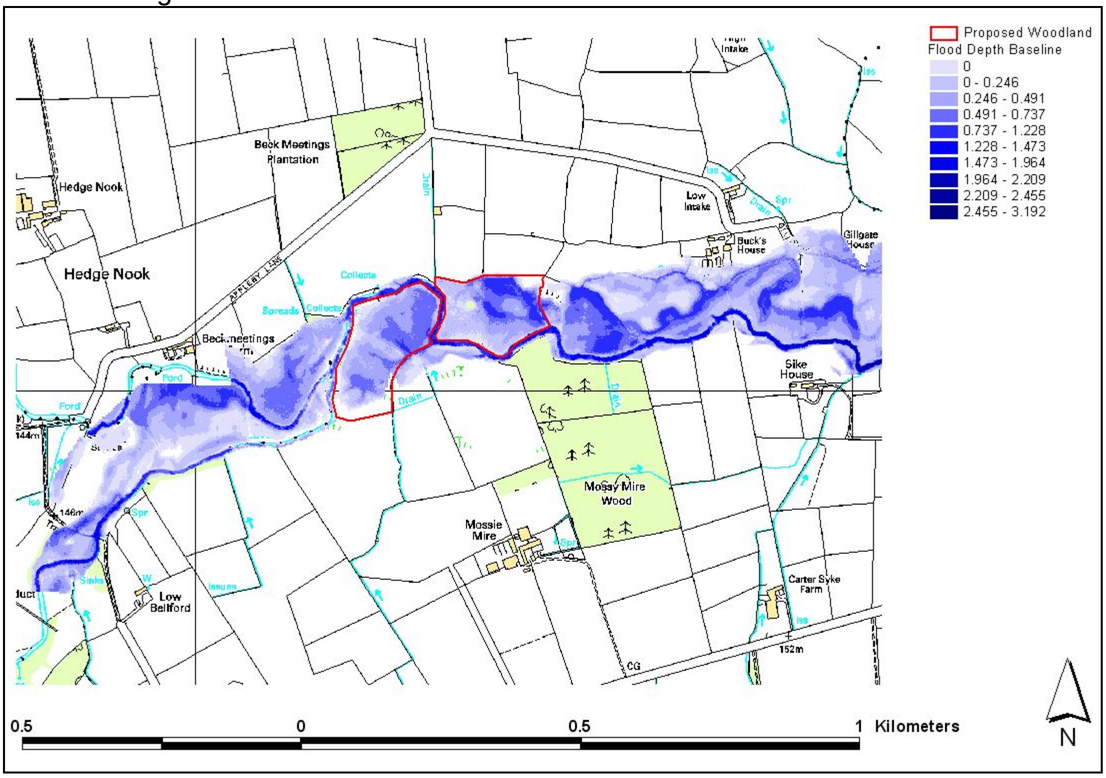


Figure 4 Effect of woodland placement on flood depth along the modelled reach at each site.

Beckmeetings - Baseline



Beckmeetings – With woodland

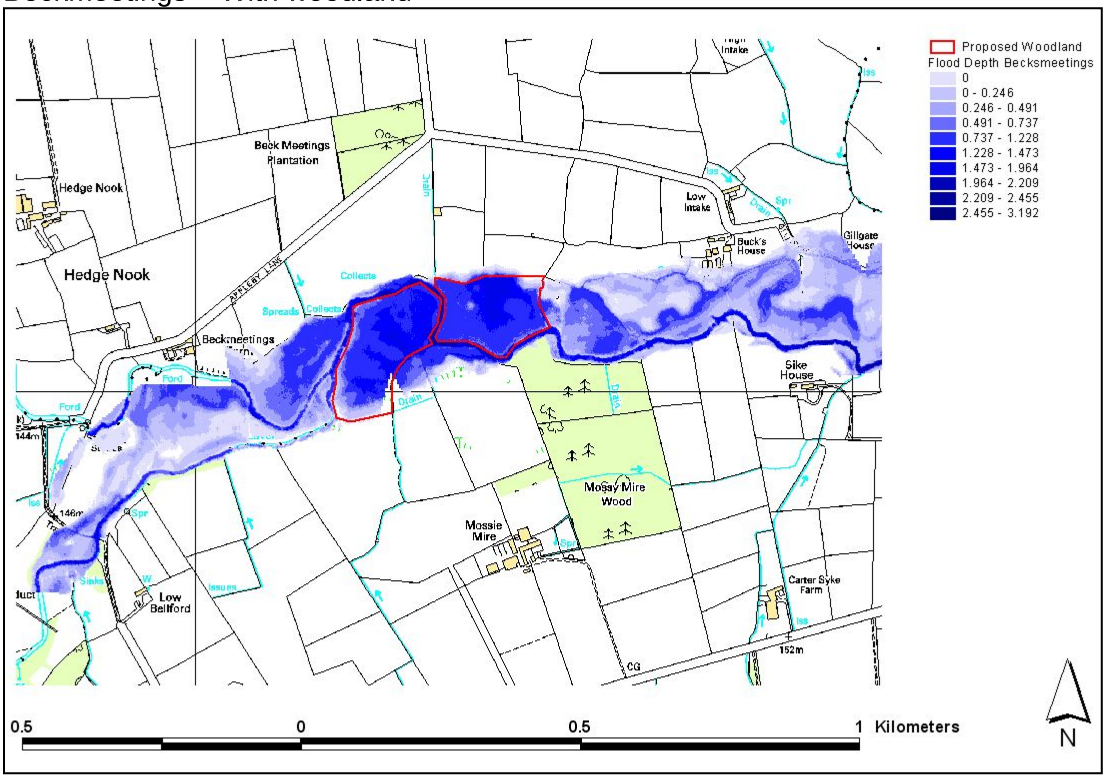
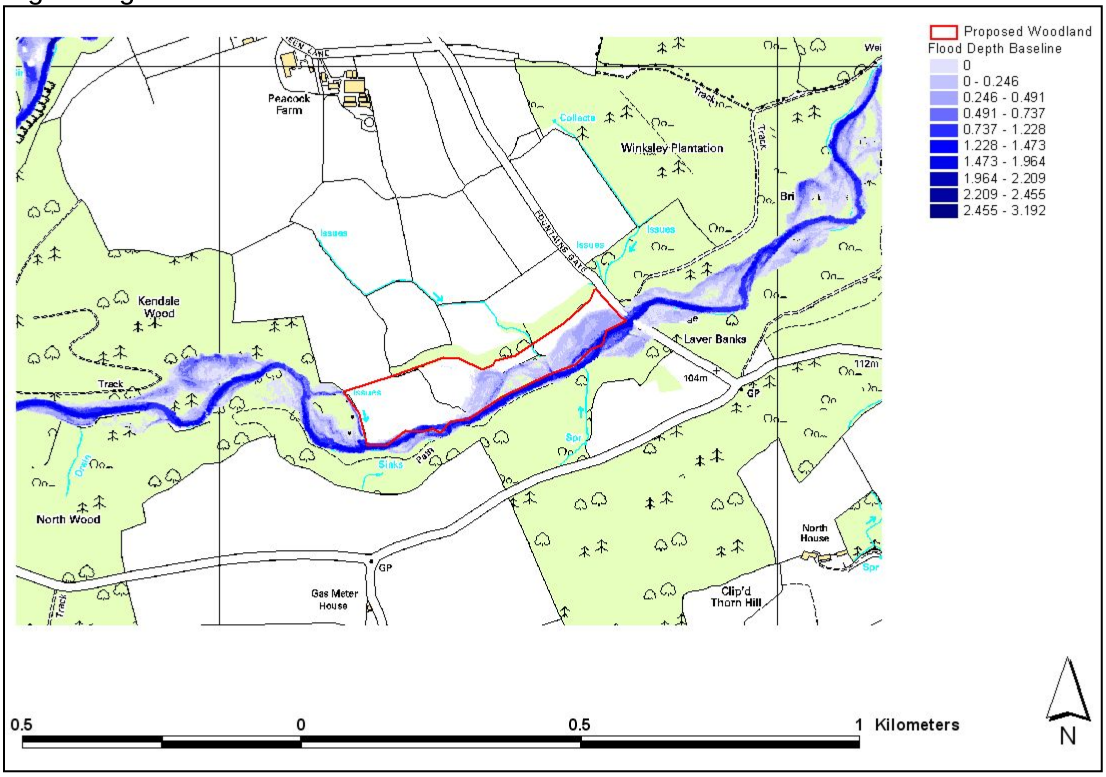


Figure 5 Continued on next page.

Ings Bridge – Baseline



Ings Bridge – With woodland

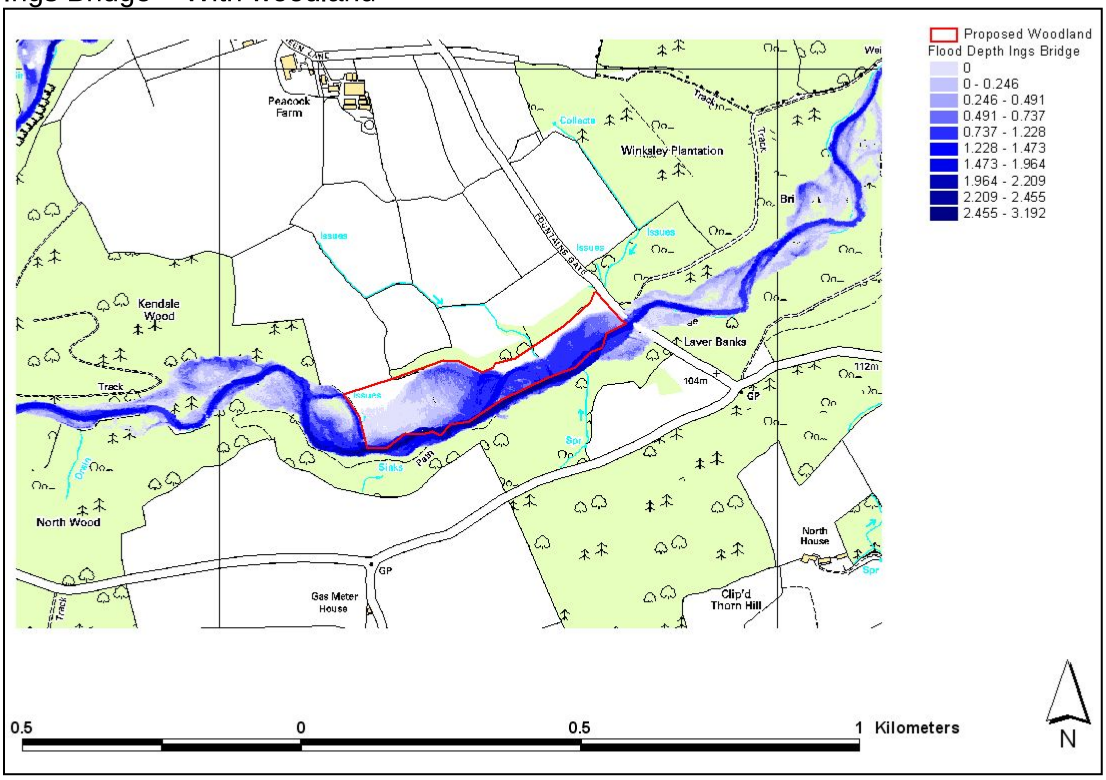
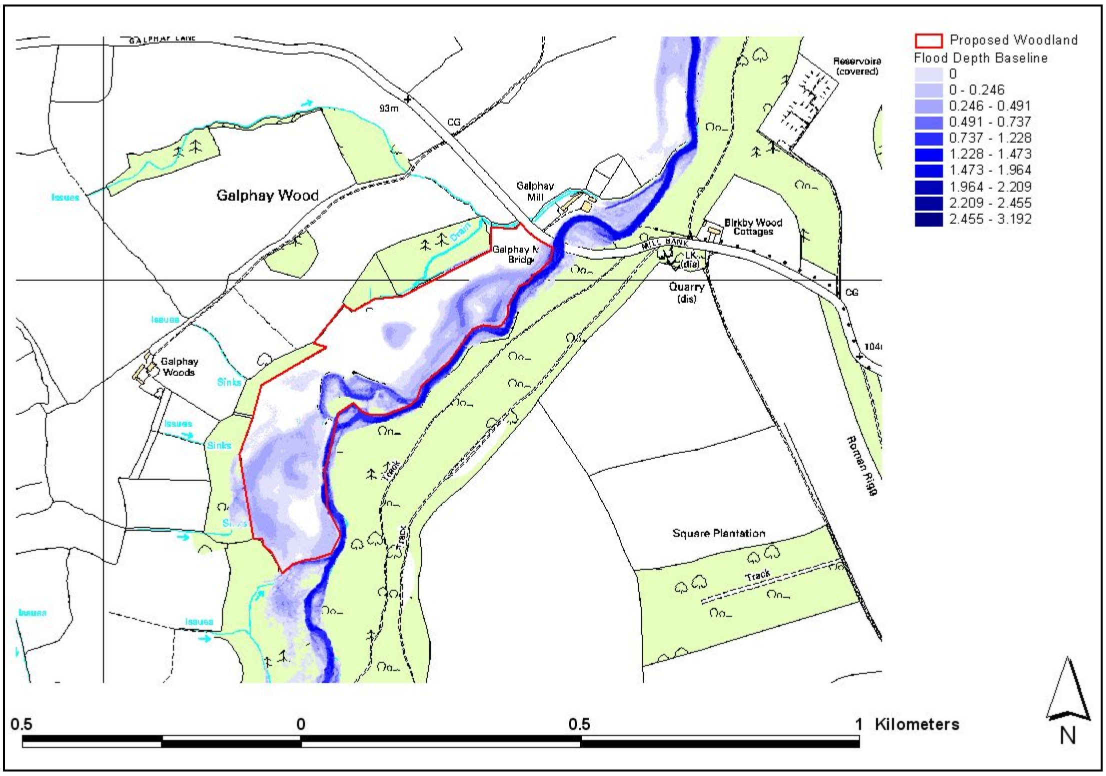
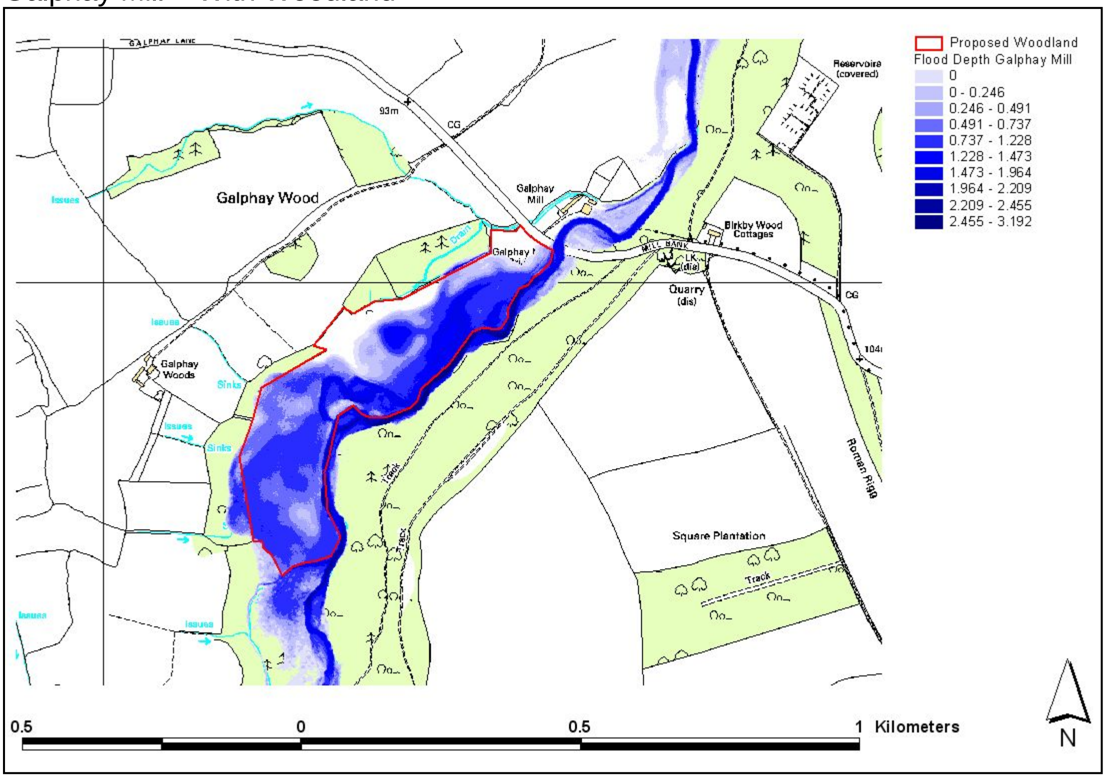


Figure 5 Continued on next page.

Galphay Mill – Baseline



Galphay Mill – With Woodland



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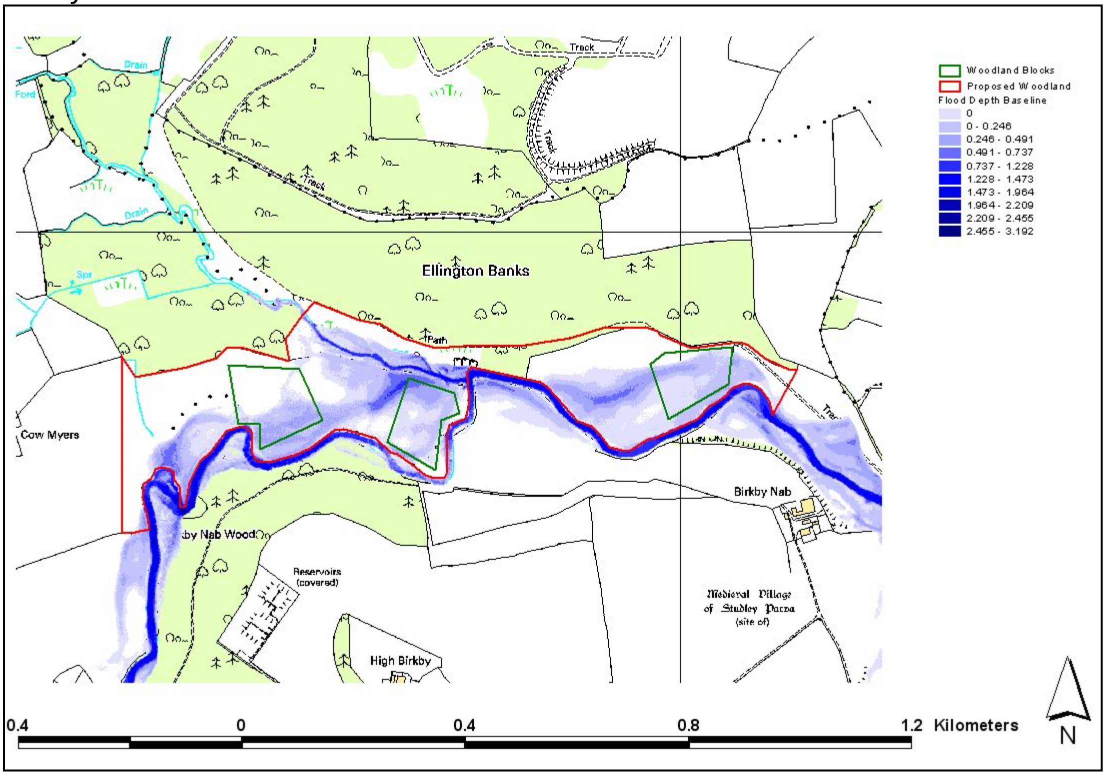
Birkby Nab – Baseline



Birkby Nab – With woodland

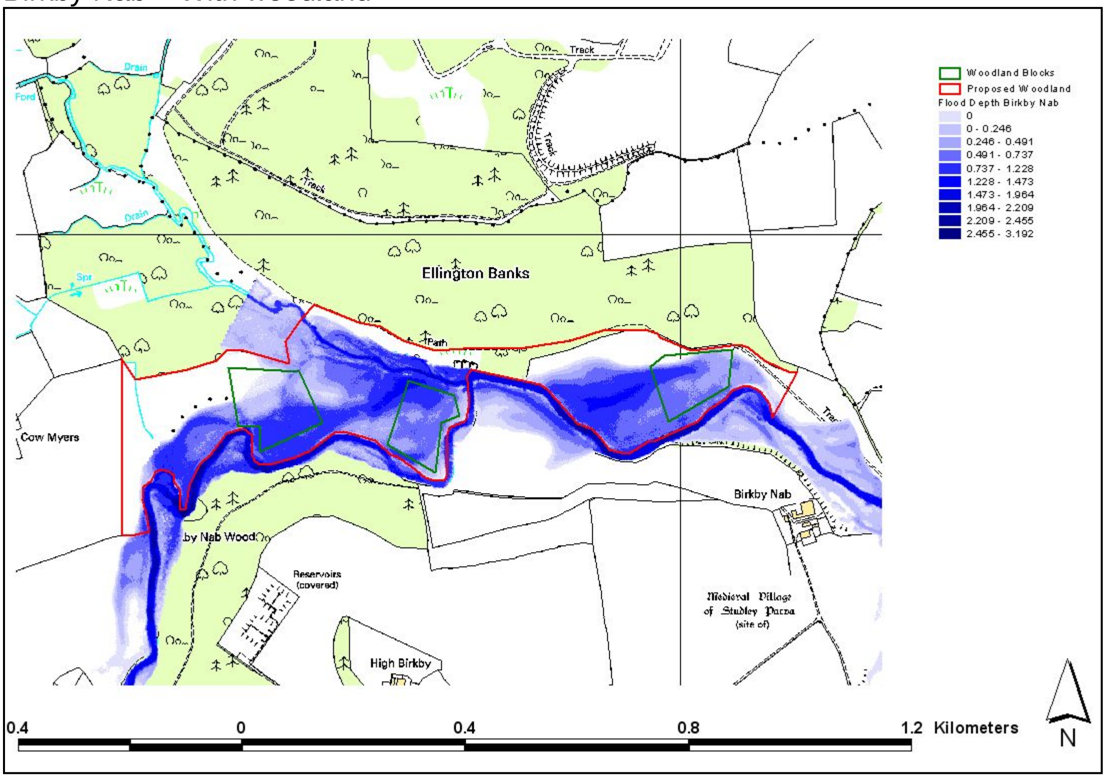
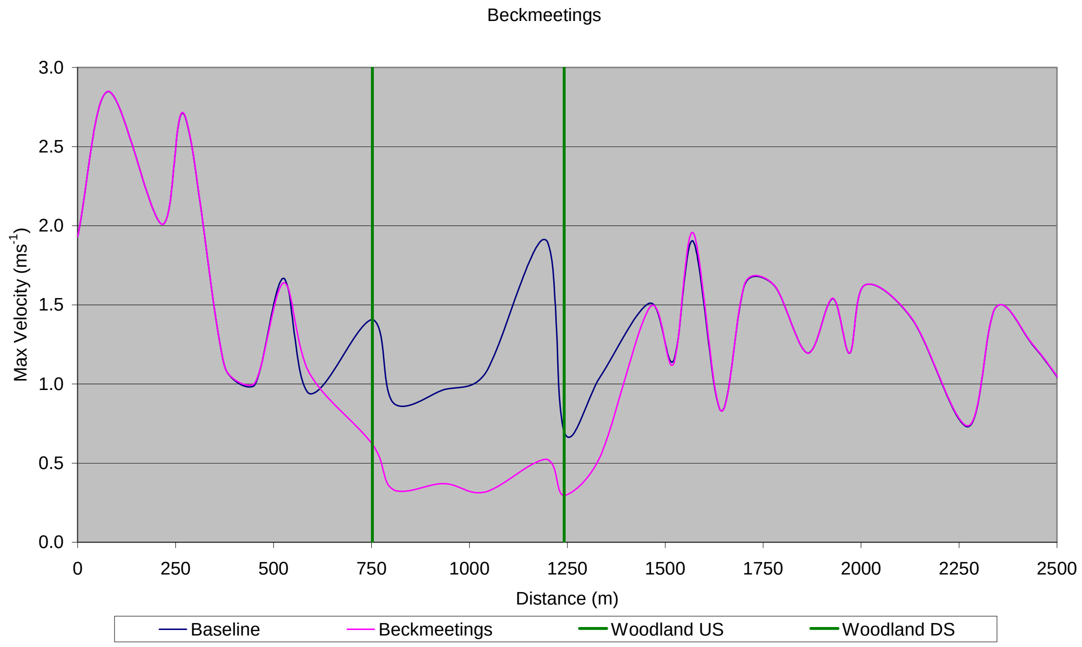
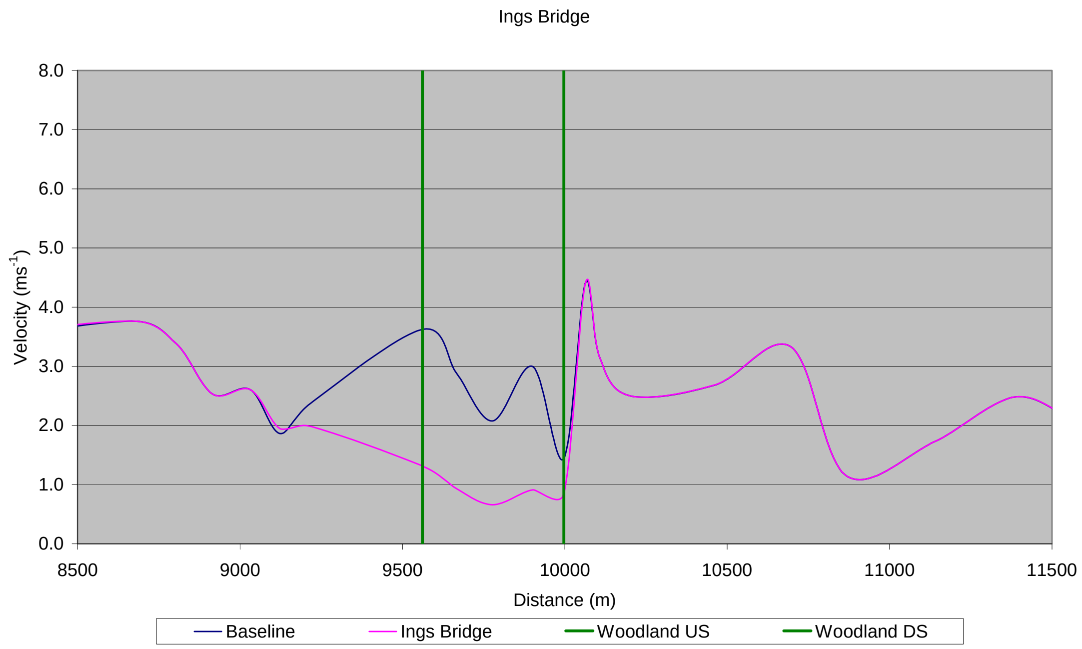


Figure 5 Maps showing the spatial extent and depth of flooding for baseline and floodplain woodland scenarios at each site.





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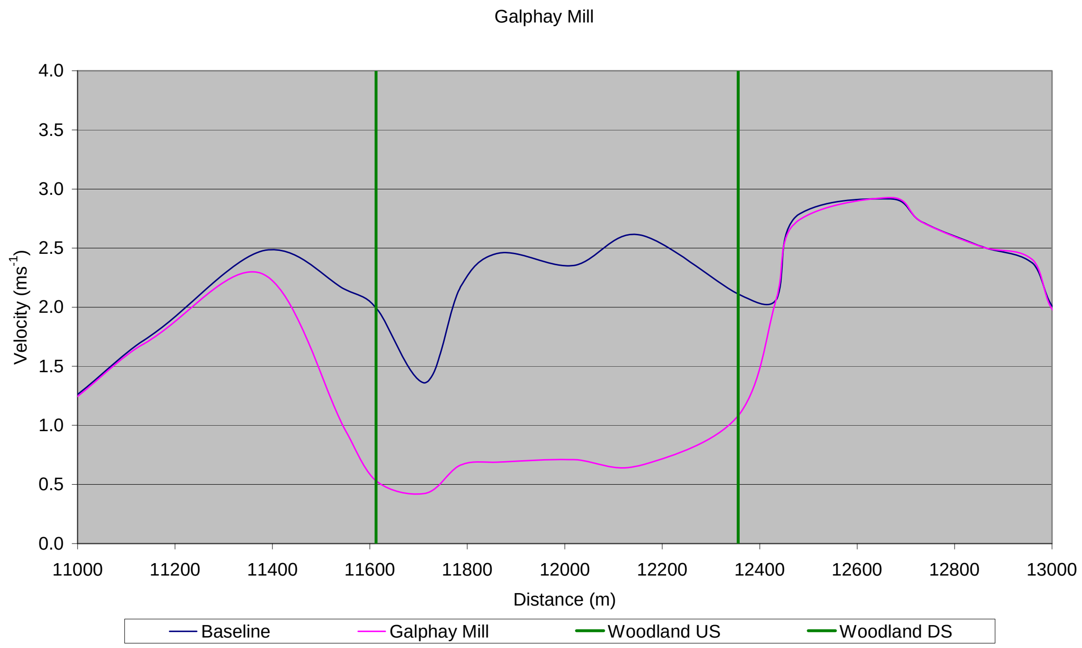

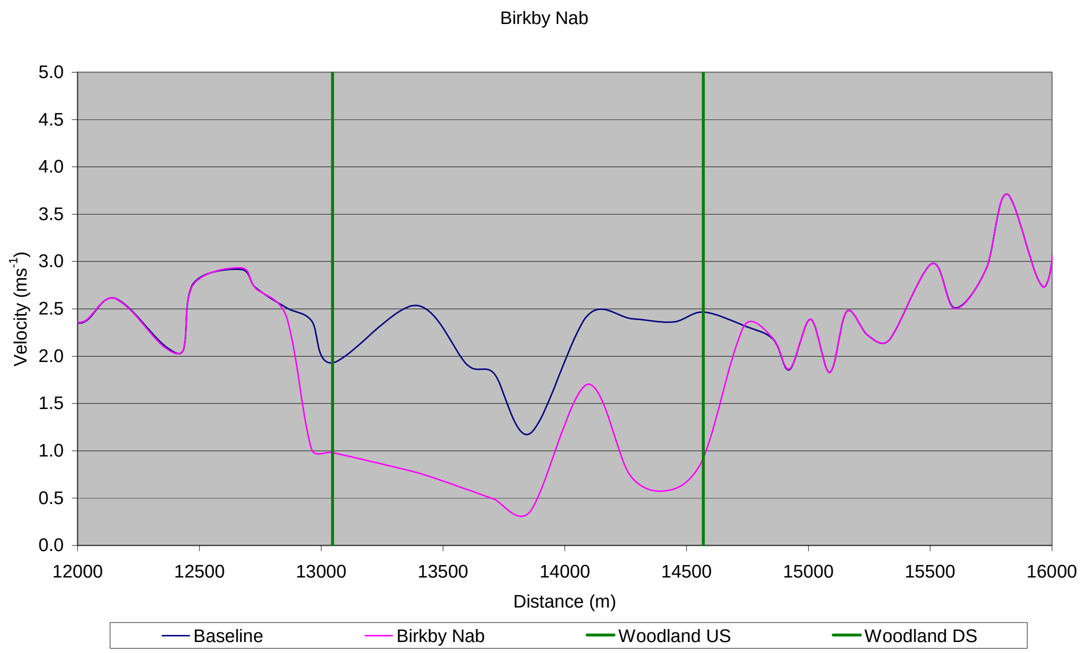

Figure 6 The effect of woodland planting on average flood peak velocities along the modelled reaches.

Peak flow timing

The impact of planting floodplain woodland at each site on the outflow hydrograph for the 1% a.p.e flood for the River Laver at Ripon is displayed in relation to the input hydrograph in Figure 7. Changes to the timing and size of the peak discharge are provided in Table 2, along with the combined effect of planting at all four sites. There was a negligible effect on peak flow, which reached a maximum of only 0.3% for all sites. In contrast, the presence of woodland caused a significant delay in the timing of the flood peak, with the lag ranging between 15 and 20 minutes between sites. The lag was greatest for the sites with the largest wooded area, although the effectiveness of the woodland was highest for the smallest sites, ranging between 1 min/ha at Birkby Nab to 3.5 min/ha at Ings Bridge. This was partly influenced by the significant proportion of the wooded area that lay outside the flood envelope at Birkby Nab.

The effect of the individual sites was not additive and the combination of all four resulted in an overall lag in the flood peak at Ripon of just under one hour, equivalent to 1.4 min/ha of woodland. This was considered significant in terms of flood warning, with the travel time of the 1% a.p.e estimated at around three hours from near the source of the River Laver to Ripon. Figure 7 shows that the lag was greatest during the early part of the flood event, reflecting the greater effect of the woodland in holding back and spreading flows across the floodplain when the flood levels are shallowest. The frictional resistance tends to be greatest nearer the ground surface due to the influence of dead wood, tree stumps and ground vegetation, although it can also be enhanced at height by the presence of densely branched, low shrubs and young or stunted trees, particularly conifer.

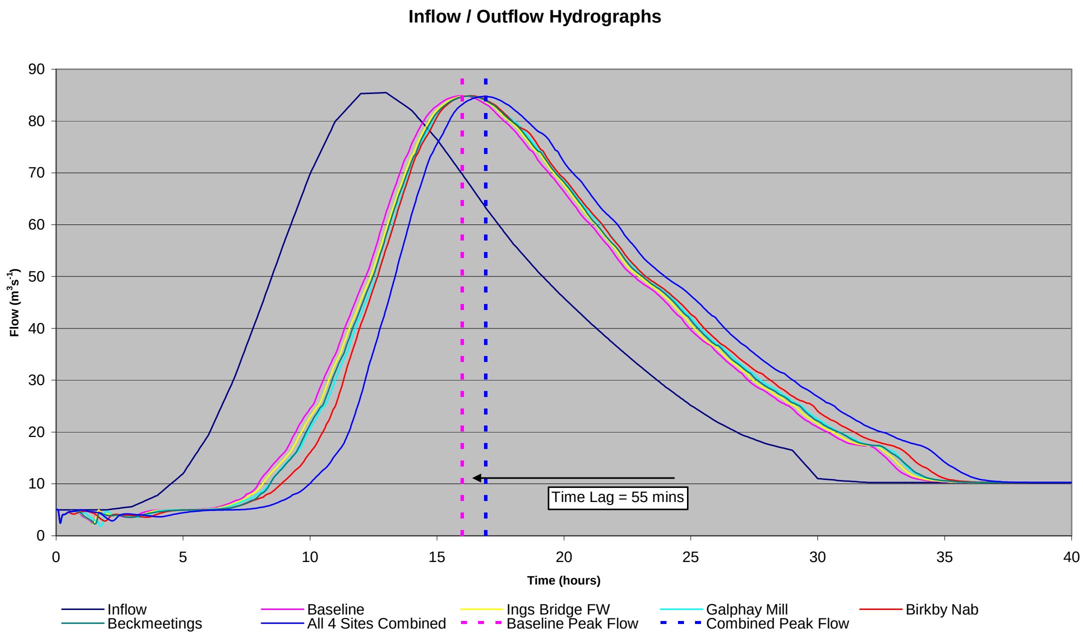

Figure 7 The impact of planting floodplain woodland on the timing of the 1% a.p.e. flood hydrograph at Ripon.

Scenario	Wooded Area	Peak Q	Peak Time	dQ	dQ	dt	dt
	ha	m^3s^{-1}	min	m^3s^{-1}	%	min	hr
Baseline	0	84.98	960	0.00	0.00	0.0	0.00
Beckmeetings	5	84.79	975	-0.19	-0.22	15.0	0.25
Ings Bridge	4.3	84.85	975	-0.13	-0.15	15.0	0.25
Galphay Mill	11.2	84.82	980	-0.16	-0.19	20.0	0.33
Birkby Nab	19.3	84.86	980	-0.12	-0.14	20.0	0.33
All 4 Sites	39.8	84.73	1015	-0.25	-0.29	55.0	0.92

Table 2 Changes in peak discharge and timing for the 1% a.p.e. flood hydrograph at Ripon due to planting floodplain woodland.

While one might have expected the delay in peak timing to bring about a larger reduction in peak height, the discrepancy between the two measures reflects the way the model handles woodland roughness. The woodland acts as a porous barrier, raising the flood level and delaying the downstream passage of the flood peak but having little affect on the volume of flood storage. Although flood velocity is reduced, flood discharge is maintained by the raised flood depth/height in the river channel and across the floodplain. As noted above, the 1-D model is unable to allow for the increased flood storage that would be expected to result from the creation of multiple channels and depressions characteristic of natural floodplain woodland. Similarly, there is no allowance for any tree canopy interception, increased water use, or enhanced soil/ground water storage capacity, although this would be limited during the winter leafless period.

Despite the negligible impact on flood peak height of the River Laver at Ripon, the ability of the floodplain woodland to delay the passage of the flood peak leaves open the possibility of reducing downstream flood risk. The River Skell joins the River Laver just above Ripon and an analysis of the flood hydrographs for a 1% a.p.e using the Revised FEH Method shows that the Skell contributes around half of the flood volume of the River Laver and peaks slightly earlier (Figure 8). Consequently, by delaying the flood response in the River Laver, the floodplain woodland could help to further desynchronise the peak flow contribution from the River Skell and thereby achieve a significant reduction in the flood peak passing through Ripon.

The magnitude of the reduction depends on the shape of the respective hydrographs and the degree of offsetting that can be achieved. Based on the hydrograph analysis, the 55 minute lag generated by Scenario 1 was predicted to reduce the combined 1% a.p.e. flood by 1-2%. Although this margin is relatively small, it is sufficient to reduce a 1-in-100 year flood to a 1-in-95 year event. It is also worth noting that the potential reduction in peak height becomes increasingly sensitive to the length of the lag as the offset shifts to the steeper part of the hydrograph. A possible downside of de-synchronisation, however, is that by extending the flood hydrograph there is a risk of consecutive flood events contributing to higher flood peaks if they coincided with the delayed recession limb of the flood hydrograph.

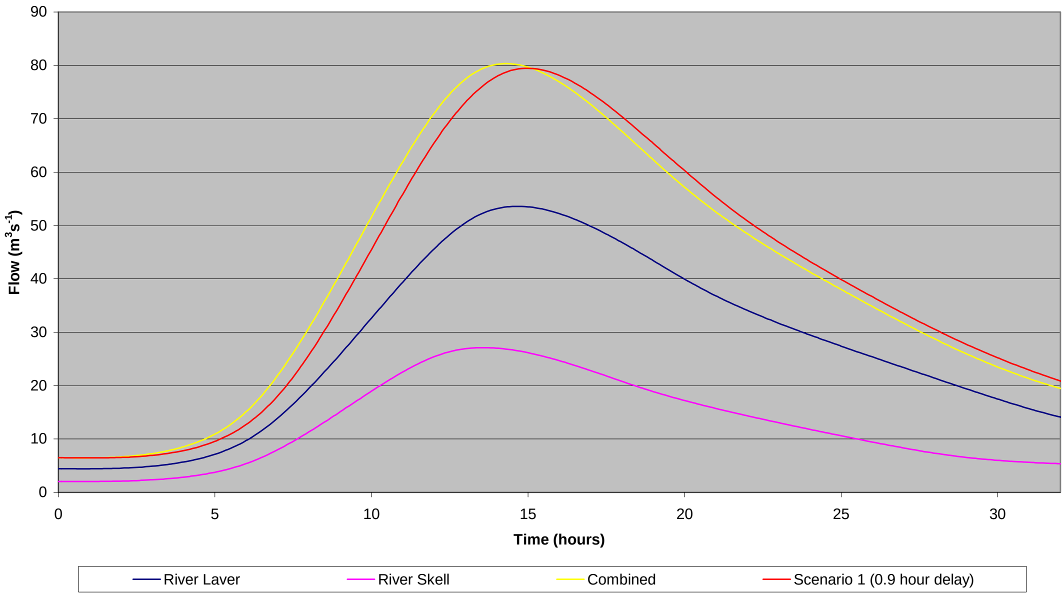

Figure 8 The impact of planting floodplain woodland on the synchronisation of the 1% a.p.e. flood hydrograph for the River Laver and River Skell at Ripon.

3.6 Model Results: Scenario 2

The original plan was to use the results from the first model scenario to determine the most effective locations for siting the proposed 15 ha of floodplain woodland. In the end, however, the landowners dictated where and how much woodland would be acceptable and the potential area for planting was reduced to around 8 ha. It was therefore agreed to repeat the modelling exercise for the smaller area of woodland to determine whether it would have a significant impact on flood risk at Ripon.

Figure 9 shows the results of the second scenario in terms of the phasing of the flood hydrograph, while details of the changes in the timing and size of the peak discharge are given in Table 3. It is clear that the reduced area of floodplain woodland would have a small impact on the flood response, with a maximum lag of 22 minutes for the combined 8.1 ha of planting at Beckmeetings, Galphay Mill and Birkby Nab. In terms of individual sites, the floodplain woodland at Beckmeetings exerted the greatest impact, reflecting the creation of a complete cover of woodland across the width of the floodplain. The response was the same as for the larger area of planting at this site under the first scenario (5.0 ha vs. 2.2 ha), highlighting a local throttle effect. This is an important finding since it demonstrates that targeted planting of specific locations could be more effective at flood alleviation.

While a 22 min lag was unlikely to yield a significant desynchronisation effect on the flood peak at Ripon, it was still felt to be worthy of study. Establishment of the reduced area of woodland would allow the direct effects on flood flows at the individual sites to be determined and the model predictions to be tested. If confirmed, the sites would provide a good demonstration of what could be achieved if a larger area of floodplain woodland were planted within the catchment.

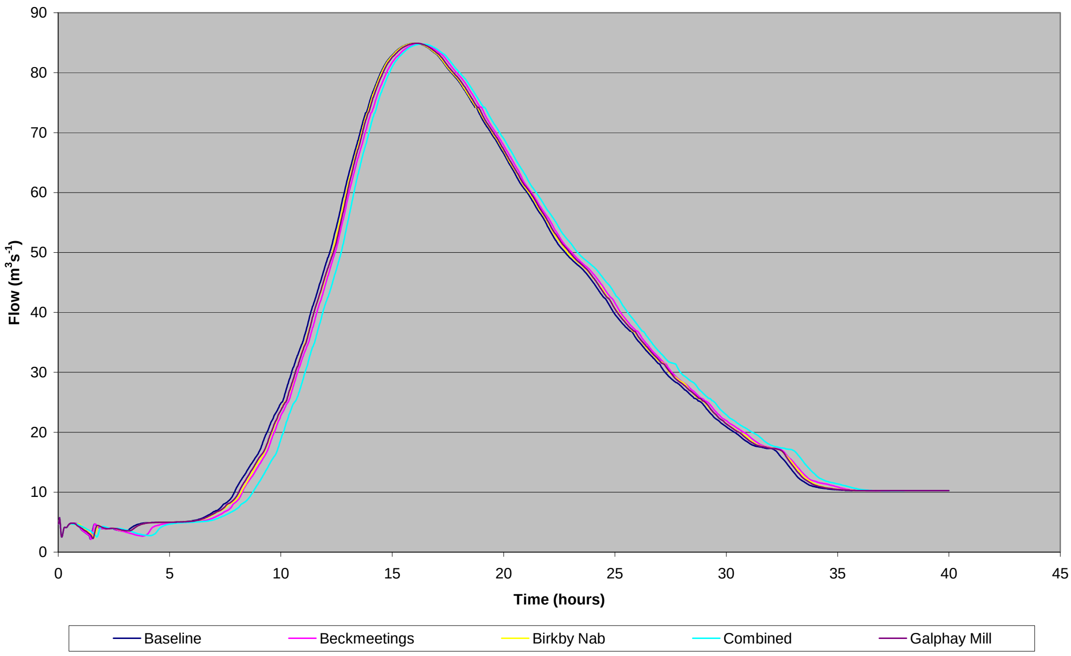

Figure 9 The impact of the reduced area of woodland planting on the flood hydrograph at Ripon.

Scenario	Woodland Area	Peak Q	Peak Time	dQ	dQ	dt	dt
	ha	m^3s^{-1}	min	m^3s^{-1}	%	min	hr
Baseline	0	84.91	959	0.00	0.00	0.0	0.00
Beckmeetings	2.2	84.79	974	-0.12	-0.14	15.0	0.25
Galphay Mill	2.1	84.90	966	-0.01	-0.01	7.0	0.12
Birkby Nab	3.8	84.91	962	0.00	0.00	3.0	0.05
Beckmeetings & Birkby Nab	6.0	84.80	975	-0.11	-0.13	16.0	0.27
Combined (with Galphay Mill)	8.1	84.79	981	-0.12	-0.14	22.0	0.37

Table 3 The impact of woodland planting on flood peak discharge and timing.

4. Investigating the influence of woodland design and management factors on flood flows

Since the timing of the flood response is a good integrator of the effect of woodland planting on flood depth, extent and velocity, this was selected as the best measure for evaluating the influence of woodland design and management factors. The larger Birkby Nab site was chosen to investigate the effect of changing the woodland area, shape and location. Insufficient information was available to assess the influence of species choice or spacing, which merits further experimental work.

Figure 10 presents the relationship between the width of woodland across the floodplain and the resulting time lag in the passage of the flood peak. This suggested a curvilinear response, with the woodland exerting the greatest effect over the first 80 m, equivalent to a 1 min lag for every 4 m of woodland. However, the relationship is strongly influenced by the topography of the floodplain cross section and the modelled response for Birkby Nab reflected a rise in ground level across the second half of the floodplain. The decline in the lag time between 80 m and 100 m is probably due to the woodland diverting floodwaters into a relic side channel, while the subsequent more gradual rise in lag verses width reflects the shallower flood depth. Interestingly, the results indicate that even a 20 m wide (smallest width assessed) stretch of woodland generated a lag effect, implying that a series of separate small blocks across the floodplain could have a similar effect to an equivalent single, wider block. As expected, the most effective placement for enhancing the lag effect was within the lower lying, wettest part of the floodplain.

The effect of varying the length of woodland along the modelled reach is displayed in Figure 11. This shows an approximate linear relationship between woodland length and flood lag, with a gradient of 1 min per 90 m. There is no evidence of an upper threshold over the 1800 m reach, although the response was more erratic along the upper half of the section. As with floodplain width, this probably reflected the variation in local topography, especially in terms of gradient. This highlights the need for care in site selection.

The final exercise was to assess the effect of an incremental number of 1.0-1.5 ha woodland blocks along the floodplain. Figure 12 shows the location of the three woodland blocks used in the assessment and the results in terms of peak discharge and lag time are given in Table 4. The individual blocks had a similar effect, each contributing to a 2-3 min time lag in the downstream passage of the flood peak. In terms of total area, the size of the time lag was in line with that expected from the general relationship with length and width, indicating that separate blocks were as effective as an equivalent larger area of woodland cover.

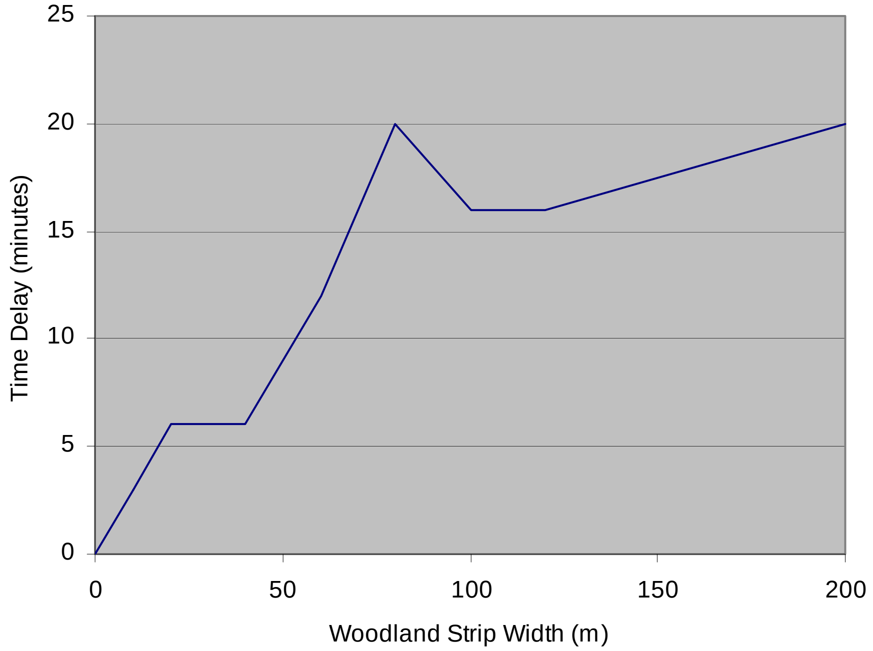

Figure 10 The effect of varying the width of woodland across the floodplain on peak flow lag time.

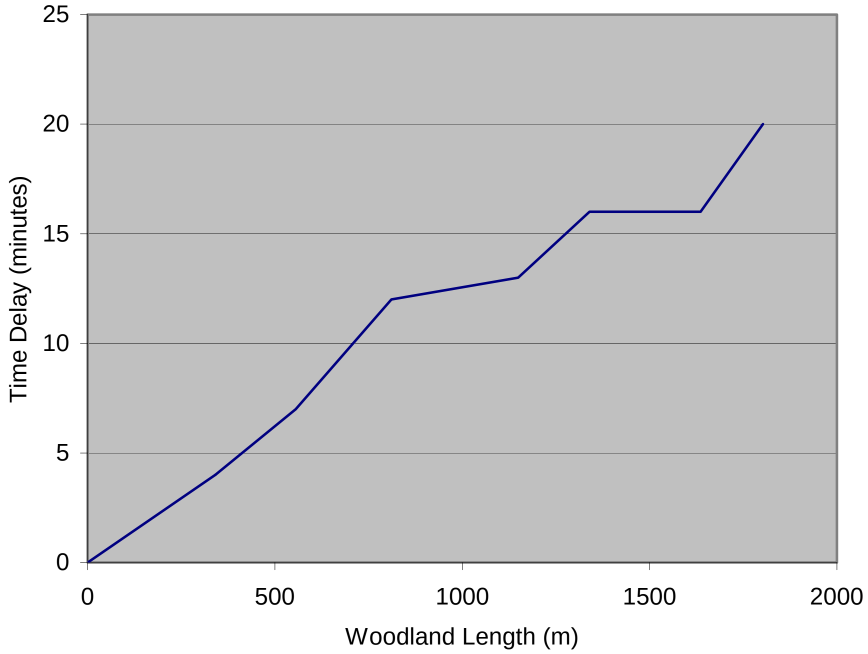

Figure 11 The effect of varying the length of woodland along the modelled reach on peak flow lag time.

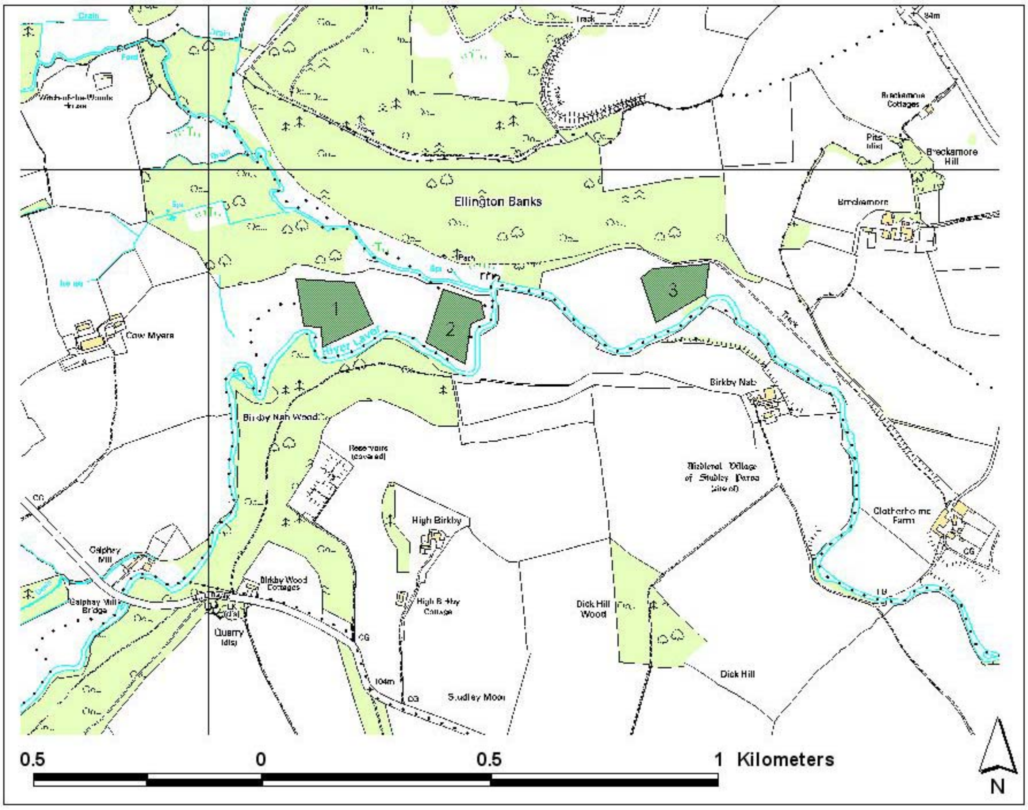

Figure 12 Location and orientation of woodland blocks at Birkby Nab used to assess the effect of woodland design on peak flow lag time.

Scenario	Total Area	Peak Q	Peak Time	dQ	dQ	dt	dt
	ha	m^3s^{-1}	min	m^3s^{-1}	%	min	hr
Baseline	0	84.91	959	0.00	0.00	0.0	0.00
Woodland Block (1)	1.6	84.89	962	-0.01	-0.01	3.0	0.05
Woodland Block (1+2)	2.8	84.89	964	-0.01	-0.01	5.0	0.08
Woodland Block (1,2 + 3)	4.0	84.89	967	-0.02	-0.02	8.0	0.13

Table 4 Summary of the impact of woodland block placement on peak flow discharge and lag time.

5. Facilitating an application for a Woodland Creation Grant under the English Woodland Grant Scheme or its successor

The success of the project relied on establishing one or more demonstration floodplain woodlands in the River Laver catchment. All of the land identified for possible planting at the four sites was privately owned. A large estate owned three of the sites while the fourth belonged to a dairy farm. The landowners expressed an interest in planting floodplain woodland when the project was being formulated, providing that funding was sufficient to compensate for the reduction in value of the land and lost agricultural income. Forestry Commission England's Woodland Creation Grant was worth £1800 per ha, which could be expected to cover 40-50% of the cost of establishing the woodland. To secure an application, it was thought that as a minimum, a large part of the establishment cost would have to be met. Thus the project budget included an additional sum to allow for a doubling of the Woodland Creation Grant to £3600/ha. Based on discussions with landowners, it was hoped that around 15 ha of floodplain could be released for planting. The total budget for top-up funding was therefore set at £27,000.

When the project was being formulated the Forestry Commission's Woodland Creation Grant (WCG) was closed but it was expected to be renewed or replaced under the 2007 Rural Development Plan for England. A meeting was held with the Forestry Commission's local Conservator in York on 31/01/07 to discuss the way forward. A decision on the new grant scheme was anticipated in May 2007 with applications for planting open in June and closed by September. Competition for WCG funds is intense and success depended on achieving a sufficient score based on how an application met national and regional priorities in terms of rural development, economic regeneration, recreation, conservation and landscape enhancement. Benefits for flood alleviation are not included but it was agreed that an allowance would be made for this if required to secure grant support. Applications for the project sites were likely to score highly for environment and conservation, size and landscape, as well as for recreation if the applicant could be persuaded to allow public access. Forestry Commission England were keen to support the applications in view of the national significance of the project and the fact that they would contribute to one of the key Priority's for Action under the Yorkshire and The Humber Regional Forestry Strategy: 'Regional flood risk is reduced through increased woodland creation on the floodplain'.

Separate site meetings were held with the two landowners on 03/04/07 to explain the project and determine whether they remained interested in planting floodplain woodland at the proposed sites. Both confirmed their willingness to support the project and to consider submitting an application should the new grant scheme go forward. Some concerns were raised about the impact of woodland planting but it was felt that these could be resolved by attention to woodland design/landscaping and limited additional funding. The main concerns were:

> <u>Beckmeetings</u>: loss of productive land and restricted access to fields on other side of floodplain

Birkby Nab, Galphay Mill, Ings Bridge: loss of productive land, reduced land value, diminished local views (especially at Birkby Nab) and increased capture of rubbish by floodplain woodland.

The landowners acknowledged the support offered under the Farm Woodland Payment Scheme (FWPS) to compensate for the lost agricultural income but were discouraged by the fact that payments were limited to the first 15 years after planting. Payments of £200/ha were available from the Forestry Commission for improved grassland at the Beckmeetings site (within LFA)[3] and £300/ha for arable land at the other sites (outside LFA). These compare with annual payments of approximately £200/ha for arable land under the Single Farm Payment Scheme (current scheme ends 2012) and £315/ha (for 10 years) under HLS[4].

The site visit to Beckmeetings identified a small larch copse (~1 ha) in the centre of the floodplain that had the potential to be converted to native floodplain woodland. The trees were relatively mature and widely spaced thus presenting limited resistance to flood flows. Since the project would benefit from its inclusion in the proposed area of new planting it was decided to explore its felling and restocking with the owners, Yorkshire Water.

Forestry Commission England confirmed in July 2007 that they were prepared to fast track the planting schemes and therefore they would not need to go through the normal scoring round. This reflected the increasing interest in using woodland for sustainable flood management and the priority given to this action in the new England's Trees, Woods and Forests Strategy (Defra, 2007).

Following the completion of the modelling work, another round of site meetings were held with the two landowners on 02/08/07 to discuss the results and reach agreement on drawing up the planting applications. The farmer at the Beckmeetings site was encouraged by the results and expressed a desire to submit a planting application but only for one small field amounting to less than 1 ha. This comprised a very wet piece of ground on the edge of the farm that was less valuable to the business. Unfortunately, he ruled out planting on a more extensive area of the floodplain in the centre of the farm due to the significant loss in agricultural income and subsidy (Single Farm Payment). Grazing land was in short supply in the locality and conversion to woodland would require him to try and rent land from a neighbour at increased cost (local rental values very high).

Although the farmer was only prepared to plant one small field the site was considered to be potentially significant for flood management since it would link two adjacent areas of proposed new native floodplain woodland (the larch copse and an HLS on a downstream neighbouring property) and provide a bridge with an existing area of native woodland on the opposite bank of the floodplain. In total, an area of around 3 ha of continuous floodplain woodland would be formed straddling the full width of the River Laver floodplain. The farmer agreed to work with Forestry Commission England in drawing up the planting application but requested more details on planting practice and the costs involved.

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[3] LFA stands for **L**ess **F**avoured **A**rea and relates to land designated as being less-favoured for farming.
[4] HLS stands for Higher Level Stewardship under the Environmental Stewardship Scheme and is aimed at delivering significant environmental benefits in high priority areas

The second land owner was also interested in the modelling results but remained concerned about the effect of woodland planting on local views. A walk-over survey suggested that the impact could be minimised by restricting planting to the lower-lying wettest parts and avoiding areas of raised ground. While this limited the area of planting to around 6 ha it would comprise the best ground for flood mitigation and thus was still worth pursuing. His main concern, however, was the loss in capital value of the planted land. This was despite the fact the recent summer floods had led to the River Laver changing course at both the Galphay Mill and Birkby Nab sites and exploiting relic side channels. These cut across main fields and resulted in major soil erosion and gravel deposition. The field drainage system had been seriously disrupted and sizeable areas of winter wheat crop lost, necessitating major restoration work. The landowner felt that he would still be better off restoring the land to wet grassland and applying for HLS grant than converting to floodplain woodland. A grassland cover would preserve the capital value of the land and the option of switching back to cereal cropping at a later date. He did not completely rule out woodland planting but wanted compensation for any loss in value and acknowledgement for any flood mitigation provided to downstream beneficiaries. The funding offered for woodland planting would barely cover his costs but more importantly, the farm woodland payments would cease after 15 years.

It was agreed that the modelling work would be repeated for the revised areas of proposed planting and consideration given to raising the amount of available funding. This would be guided by an assessment of local agricultural and woodland capital values.

Land values were rising due to general increases in cereal and timber commodity prices, as well as strong demand from home buyers for recreational pursuits. It proved difficult to come up with values for native wet woodland but prices for broadleaved woodland in north England ranged from £12-20k/ha, with less productive woodlands towards the lower end of this range. Prices for farmland appeared to be at the upper end of the range and significantly exceeded it locally, with prices as high as £30k/ha. However, an allowance had to be made for the flood damaged nature of some parts of the land identified for the proposed planting and data from the Northeast region gave a lower value of £6-7k/ha (three year old figure). Thus land values for native floodplain woodland could be similar to that of damaged/eroded poor quality farmland, depending on the extent to which the value of the latter has risen over the last three years (no figures available).

In the end, the decision on offering additional funding to the landowners had to be guided by experience and the project budget. Since there was strong regional demand for WCG at the official grant rate (albeit not for floodplain or good farmland), which was half that offered by the project, their was a reluctance to offer much more. Another complicating factor was EU limits on State Aid for afforestation. The increased funding support for the proposed planting was close to the maximum permissible contribution of 70% of eligible costs for woodland establishment (standard cost for native woodland is £5800/ha) and any further increase was likely to breach this. However, a case could be made to justify State funding of up to 100% of eligible costs for afforestation to promote biodiversity, combat erosion or promote a comparable protective function (e.g. flood reduction), although this would require State Aid notification and could involve a significant delay.

Since £27,000 had been identified in the budget for top-up funding of the WCG and the maximum available land for planting in the catchment had reduced to around 8 ha, it was decided to use the spare funding to increase the offer by another £1,000/ha. This would give a total grant of £4,600/ha, meeting the full expected cost of the woodland planting. Enquiries were made about the need for State Aid notification and initial feedback suggested that this could be waived on the grounds that the aid was to support research work.

Subsequent discussions and a site meeting with Yorkshire Water secured their interest and willingness to support the project by felling the larch copse at Beckmeetings and planting this with native floodplain woodland. Assistance was provided in drawing up an application for a Felling Licence and designing the restocking plan. Costs would be reduced by avoiding the need to replace part of the fencing by linking the woodland directly to the new planting in the adjacent field, although the project was asked to cover the cost of the restocking grant (£1100/ha).

The larger landowner was contacted in early September and offered the enhanced grant support but this was rejected. He remained concerned about the potential loss in land value, the lack of any long-term support and altered vistas. At a scientific level, he was also sceptical that the relatively small scale of the proposed planting would make a difference in terms of flood risk at Ripon. Overall, there was insufficient incentive for him to make the change in land use, at least for the time being.

The second land owner at Beckmeetings also proved reluctant to proceed with submitting a planting application. Details of planting costs and grant support were provided and considered by his ADAS agricultural advisor, who concluded that he was likely to lose money compared to the status quo. The shortfall in income was estimated to be about £200/ha/yr (pers com), requiring a doubling of the Farm Woodland Payment. This proved not possible since the Forestry Commission had no flexibility in varying the value or term of the payments. Opportunities to replace the lost agricultural income were likely to be limited, especially in the short-medium term. Income from native floodplain woodland would be restricted to fire wood and possibly shooting for several decades until the trees were large enough to generate more valuable wood products. However, the need to maintain a shrub and ground layer and in due course inputs of dead wood from old aged trees to maximise hydraulic roughness, would limit the scope for the woodland to eventually yield high quality timber.

Contact was made with the ADAS advisor to explain the background to the project and further discussions held with the landowner. Despite the offer of the raised planting grant, he declined to proceed with submitting an application, even for the small field involved. Once again, there was insufficient incentive to persuade him to change land use, which was not helped by his lack of experience with managing woodland. Other lesser issues included the risk of losing the trees and having to replant them (at his own cost) if they were washed out or damaged by flooding, possible loss of fencing due to enhanced flooding and impacts of woody debris, and perceived difficulties with providing supplementary drinking water for his cattle due to restricted access to the river.

Efforts were made to identify other potential planting sites in the River Laver or Skell catchments, including contacting the National Trust. Unfortunately, no opportunities were identified. Finally, Forestry Commission England raised the possibility of applying to Yorkshire Forward to fund the purchase of the four original sites in the River Laver catchment. Initial feedback was positive but before submitting a formal application the land owners were approached to assess their willingness to sell. Both declined to either sell any sizeable areas of their land or enter into a long-term lease on the grounds that the sites involved were core areas of their estate/farms and effectively land-locked. Having exhausted all options the decision was taken to close the project at the end of March 2008. Yorkshire Water was notified that that the felling of the larch copse was no longer required.

6. Assessing the impact of the planting of the floodplain woodland on flood depth, velocity, storage and timing

A limited monitoring programme was established in 2005 under the Multi-Objective Pilot Project to provide baseline data for assessing the impact of future planting of floodplain woodland on flood flows. Seven water level recorders (pressure transducer type) and gauge boards were installed above and below the three original sites identified as having potential for planting. These instruments were supported by occasional manual water velocity measurements using a handheld current meter. Water velocity was recorded at fixed cross sections along the river under a range of flow conditions. A recording rain gauge was also installed within the River Laver catchment. The intention was to purchase and install an additional set of six water level recorders and a specialised high resolution current profiler at the selected sites but this was dependent on the woodland planting going forward. Details of the seven instrumented sites are given in the Appendix, including site maps and photographs.

The sites were visited at monthly intervals by Forest Research Technical Support Unit staff operating from Wykeham Forest in the North York Moors to download data from the loggers and maintain equipment. Data capture has been good with few breaks in the river level or rainfall records. The plan was to conduct additional short campaigns of intensive measurements during periods of flood flows but the timing of the events made it impracticable. Since it has not been possible to secure woodland planting the proposal is to cease monitoring when the project closes at the end of March 2008. The preference is to remove the equipment and hopefully install it at another site where there is a greater likelihood of planting floodplain woodland, ideally in the Yorkshire and the Humber region.

7. Demonstrate and communicate the benefits of floodplain woodland for flood alleviation

Presentations on the model results and the potential benefits of floodplain woodland for flood alleviation were given to a total of eight regional forestry seminars in England and one in Scotland during the summer of 2007. The results were also presented to a joint EA/FC/JBA Consulting meeting in York on 01/08/07 and to a

Scottish Government Flood Summit in Perth on 10/09/07. A short paper describing the project was submitted and presented to the Flooding, Water and the Landscape Conference in Sheffield on 17-20/03/08. The project also features in a FC England Regional Briefing Note 'Forestry & Flooding' and is cited as a case study in the England's Trees, Woods and Forests Strategy. Copies of these papers are included in the Appendix.

8. Conclusions and Recommendations

The project provides further support for the potential of floodplain woodland to alleviate downstream flooding. Model results show that planting of four sites in the River Laver catchment, totalling an area of 40 ha, could delay the progression of a 1% a.p.e. flood by almost one hour. Although this was predicted to have a negligible impact on flood peak height in the River Laver, the time lag had the potential to desynchronise the flood flows from the tributary River Skell catchment and so lower the downstream flood peak as the main river flows through Ripon. It was estimated that desynchronisation could reduce the flood peak height by 1-2%, with the possibility of a much greater reduction if the woodland area was expanded. The modelling showed that the time lag tended to increase linearly with the width and length of floodplain woodland. This suggests that a number of smaller woodland blocks may be just as effective in delaying flood flows as an equivalent larger block.

Despite the positive findings, the landowners proved unwilling to submit an application for planting floodplain woodland at any of the identified sites. The main reasons were:

- The resulting reduction in the capital value of the land and permanent nature of the land use change.
- The loss of agricultural income and likelihood of minimal income from floodplain woodland.
- The loss of agricultural subsidies (SFP) and time bound nature of replacement woodland subsidy (FWPS).
- Lack of knowledge and experience of woodland management and fear of the unknown.
- Risk of flooding damaging newly planted trees and landowner having to fund replanting at his own expense.
- Change in landscape and perceived loss of vista.
- Restricted access to neighbouring fields and loss of direct access to drinking water for livestock.
- Increased capture of rubbish and other debris by woodland, requiring landowner to arrange removal at own cost.
- Increased cost of replacing fencing damaged by larger quantities of woody debris trapped during flood events.
- Scepticism that planting floodplain woodland would be effective at reducing downstream flood risk and could be relied upon to provide the necessary flood protection.
- Concern that woodland planting would be used as an excuse for cancelling the proposed flood defence scheme at Ripon and let local authorities 'off the hook'.

- Even if the floodplain woodland was effective at reducing downstream flood risk, concern at the length of time it would take for this to become established.
- Increased upstream flooding due to a backwater effect, affecting land quality and management, as well as posing a risk to local properties.
- Perceived unfairness of landowners having to take action and face risks without recompense or acknowledgement by downstream beneficiaries.

Overall, while the funding on offer in the form of the Woodland Creation Grant and project top-up payment would meet most of the cost of planting the floodplain woodland, there was no incentive/payment to cover the expected losses in capital value and agricultural income, nor to compensate for the perceived risks associated with land use change.

The main lessons learned can be summarised as:

- Landowners are generally resistant to land use change, especially where there is a perceived loss of income or land value and increased risks.
- Although the current value of woodland grants and farm woodland payments are sufficient to promote wider woodland planting, they are generally insufficient to secure woodland planting on higher valued agricultural land, for example within the floodplain.
- Where planting needs to be targeted to a particular location to derive a specific benefit, landowners will need a much greater incentive to achieve land use change.
- The current scoring systems underpinning the Woodland Creation Grant fails to acknowledge any water benefits, such as potential flood reduction. However, while action to remedy this situation would be helpful, it will not be sufficient on its own to secure planting in the right place.
- A sizeable area of floodplain woodland will be required to deliver a significant reduction in downstream flood risk. While this could be achieved by a single large landowner, more often it will rely on co-ordinated action by a number of smaller landowners.
- Woodland planting in certain locations in the floodplain, e.g. within lower lying, wetter sections and where relic side channels and other features remain, would be more effective in retarding flood flows.
- It is not necessary to plant a continuous stretch of floodplain woodland either across the full width or an extended length of the floodplain; a series of smaller blocks spread out along or across the floodplain will be just as effective at flood attenuation and may be easier to achieve in practice. Results indicate that even a 20 m wide block of woodland would generate a lag effect.
- Achieving the required scale of woodland planting within the floodplain will require a much higher level of grant support than is currently offered. One option would be to introduce a special challenge fund or locational premium to target the most effective locations for planting.
- The case for such a fund should not be limited to a flood reduction benefit. Floodplain woodland offers a range of benefits, including for water quality, carbon storage, nature conservation, fisheries and recreation. These should be better quantified and factored into the level of grant support.

- There remains a need for a sizeable demonstration study to help communicate and explain the benefits, risks and nature of floodplain woodland to stakeholders, especially landowners. This would promote understanding of what was involved and how sites could be best managed to control risks and maximise benefits. The importance of such exemplar sites should not be underestimated and thus warrants additional support to secure their establishment. The selection of a publicly owned site would have a number of advantages, including providing greater flexibility over design and management factors, and securing long-term monitoring work.
- The restoration of natural floodplain woodland with multiple channels and backwater ponds is likely to offer the greatest value for flood alleviation, as well as nature conservation. However, this will lead to a marked reduction in the capital value of the land, resulting in a ‘flood damaged’ landscape with disrupted land drainage and significant erosion and deposition. Landowners would need to be adequately compensated and effort spent ‘educating’ them of the resulting benefits.
- Persuading landowners of the case for planting floodplain woodland and assisting them in submitting a planting application takes significant time. Additional resources will be required to support this process, especially if it was to be extended over a wide area.
- More research is required to quantify the contribution of floodplain woodland to downstream flood alleviation. This would help to strengthen the evidence base and persuade landowners, practitioners, planners and policy makers of the case for land use change.
- It is important to manage expectations. While floodplain woodland can contribute to downstream flood mitigation, it will not prevent future flooding. The benefit of the lag effect for increasing the time for issuing and responding to flood warnings should not be overlooked.
- Floodplain woodland offers a no-regrets option for flood management, especially where it is not cost effective to install engineered defences. Model results suggest that it will reduce flood risk but if this fails, it will still succeed in delivering a range of other environmental and social benefits.
- If the impact of floodplain woodland is limited to delaying the downstream passage of the flood peak, its contribution to flood alleviation will be restricted to those sites where there is the potential to desynchronise flood flows from tributary systems. This will require care in site selection to ensure that planting does not have the opposite effect of increasing the flood peak by synchronising flood flows from individual tributaries.
- Floodplain woodland is not suitable for all sites and in many cases will be rejected by landowners for a range of reasons.

The main recommendations are:

- One or more replacement, sizeable, demonstration sites should be established to communicate and explain the benefits of floodplain woodland for flood alleviation. There is a strong case for a study in the Yorkshire and the Humber Region, building on recent opportunity mapping work and drawing on the strong regional support for evaluating the potential contribution of floodplain woodland to flood risk management. Effort should focus on publicly owned sites to secure planting and provide greater flexibility and control over the design, management and testing of the impact on flood flows. It would be helpful to have at least two demonstrations, one with a larger, central block of floodplain woodland and a second with a series of smaller areas of woodland planting, to compare the advantages and disadvantages of these contrasting designs.

- Planting should target the lowest lying, wettest and most flood prone sections of the floodplain, especially where relic features remain, such as side channels, backwater pools and gravel bars. Woodland can be particularly effective in these locations at diverting flood waters and promoting out of bank flows, even during smaller events, accelerating the restoration of a natural floodplain woodland and flooding regime. Work is needed to identify such sites within potential demonstration areas.
- A demonstration site should include a trial of the impact of short rotation coppice (SRC) or short rotation forestry (SRF) on flood flows. SRC, and to a lesser extent SRF, offers a quick way of ‘growing’ hydraulic roughness for testing model predictions. The crop would also be more economically attractive to landowners and provide wider benefits for biofuel and carbon sequestration.
- The demonstration sites should be underpinned by research and long-term monitoring studies to quantify the impact of woodland establishment on flood flows and test model predictions; this would hopefully strengthen the evidence base and improve confidence in using floodplain woodland for flood alleviation. There is also a need to evaluate the risk of large woody debris being washed downstream and how this could be managed to reduce the risk of blocking critical structures such as bridges and culverts.
- There should be a review of existing land management subsidies and locational premiums to determine the best way of achieving the planting of floodplain woodland in desired locations. Consideration should be given to introducing a special challenge fund or locational premium to target the most effective locations for planting. This should reflect the potential marked reduction in land value and loss of income where natural floodplain woodland with multiple channels and backwater ponds is restored.
- Consideration needs to be given to the longer-term management of floodplain woodland sites, including dealing with deposited rubbish (e.g. responsibilities and costs).
- The scoring system used for prioritising applications for Woodland Creation Grant should be amended to reflect the contribution to flood risk management, as well as other water benefits.
- An attempt should be made to quantify the economic value of the potential flood reduction benefit associated with floodplain woodland, as well as other ecosystem services, such as improved water quality, carbon storage, nature conservation, fisheries and recreation. These benefits should be factored into an evaluation of grant support to promote the targeted planting of floodplain woodland.
- Suitability mapping work should be extended to other regions to identify where floodplain woodland could be best planted for flood risk management. Care will be required in site selection to ensure that planting does not have the opposite effect of synchronising flood flows.
- Guidance should be drawn up to assist land managers and landowners on how best to design and manage floodplain woodland for flood mitigation.
- Effort should be spent on raising awareness among agricultural advisers of the benefits of woodland for water, including flood reduction.

9. References

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