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PROJECT RMP5455: SLOWING THE FLOW AT PICKERING

Final Report

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Project RMP5455: Slowing the Flow at Pickering

Final Report

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Executive Summary

This report presents the results of a new project based at Pickering in North Yorkshire designed to look at how changes in land use and land management can help to reduce flood risk. It is one of three pilot projects funded by Defra in response to Sir Michael Pitt's Review of the 2007 floods in England and Wales, which called for Defra, the Environment Agency and Natural England to work with partners to deliver flood risk management involving greater working with natural processes. The overall aim of the project was to demonstrate how the integrated application of a range of land management practices can help reduce flood risk at the catchment scale, as well as provide wider multiple benefits for local communities. Specific objectives were linked to individual management practices and comprised:

1. Agree design, secure funding and establish timeline for the construction of low-level bunds within the Pickering Beck catchment to increase flood storage capacity within the floodplain.
2. Plant 50 ha of riparian woodland within the Pickering Beck catchment and 30 ha of floodplain woodland in the neighbouring catchment of the River Seven at appropriate sites to delay and reduce flood flows.
3. Construct 100 large woody debris (LWD) dams within the Pickering Beck catchment and a further 50 within the River Seven catchment to increase floodplain storage and delay flood flows.
4. Plant 5 ha of farm woodland on sensitive soils within the Pickering Beck and/or River Seven catchments to increase soil infiltration and reduce rapid surface runoff, erosion and sediment delivery to watercourses.
5. Identify and block moorland drains causing rapid runoff and erosion in the Pickering Beck catchment. In addition, establish no-burn buffer zones along main watercourses to retard flood generation.
6. Identify problem drains and restore streamside buffer zones within Cropton Forest to reduce rapid runoff. Amend felling plans to minimise impact on flood risk.
7. Implement farm-scale measures to improve soil infiltration and reduce rapid runoff.

This report describes the approach followed in trying to implement these land management interventions in the Pickering Beck and River Seven catchments. The project benefited from the availability of mapping data and models from a number of previous flood risk management projects, which helped to guide site selection.

Despite the short duration of the project much has been achieved, with five out of the seven flood management measures either implemented on the ground or with firm plans in place to deliver these in the next six months. This includes the construction of two bunds planned to start in summer 2011, 100 LWD dams installed, 13 ha of farm woodland being planted on sensitive soils, a number of problem moorland drains blocked and farm-based measures installed, no-burn buffer zones established and the Forest Design Plan for Cropton Forest revised, with 370 m of streamside buffer zone restored. The greatest challenge has been creating new riparian and floodplain woodland with only 4.1 ha (riparian woodland) being delivered in the Pickering Beck Catchment. Planting of riparian woodland was significantly constrained due to

landscape and biodiversity factors, while financial considerations were key in the lack of landowner interest in floodplain woodland. The project has however been successful in promoting the role of woodlands in reducing flood risk in the wider Yorkshire & The Humber region, with over 90 ha of woodland creation schemes approved in priority forestry and flooding areas.

Modelling predicts that the upstream flood storage bunds will provide protection for approximately 50 properties in Pickering affected by low level flood events (~1 in 25 year flood). The planned riparian woodland planting plus construction of 100 large woody debris dams are expected to assist flood management, although their contribution is predicted to reduce with declining event size. It has not been possible to model the effect of the other measures to date.

An attempt was made to evaluate the ecosystem services provided by the woodland based measures, with the most significant considered to be flood regulation, erosion regulation, habitat provision, social relations, and education and knowledge. The benefit for climate regulation in terms of carbon sequestration, and on the deficit side, the loss in agricultural income resulting from land use change, were also assessed. Combined values for all services gave an estimated mean annual gain of £203,687. Habitat creation and climate regulation were by far the largest benefits, with flood regulation a more distant third, while the loss of agricultural production could be a significant disbenefit. Allowing for the costs of the forestry measures and for the timing of these plus benefits (i.e. their distribution over a nominal 100 year period) gave aggregated net present values (NPV) ranging from around £0.8m to £9.6m, with a central estimate of £4.3m. The positive NPV in each case indicates that from a societal perspective the public benefits from the forestry measures outweigh the costs.

The project has succeeded in fully engaging the local community, who have largely embraced the concept of a whole-catchment approach to flood risk management. Slowing the Flow at Pickering has gained a national profile as a result of efforts in promoting the project in the media, by hosting site visits, by giving presentations at meetings and conferences, and via trade and scientific publications. Of particular note has been the role of the project in helping to guide and integrate the implementation of government policy on flood risk and land use management. A strong foundation has been laid for demonstrating how the integrated application of land management practices can help reduce flood risk at the catchment scale, as well as provide wider multiple benefits for local communities.

Lessons learned and future plans are set out, including the need to:

- secure full implementation of the outstanding planned measures,
- continue monitoring to assess their longer-term effectiveness,
- pursue opportunities to extend existing measures and add new ones to further reduce flood risk,
- build on the success of the project by further communicating and promoting the benefits of a sustainable, catchment-based approach to flood management.

A number of recommendations are made, the main one being to develop and trial a payment system for ecosystem services aimed at securing wider implementation of targeted land management measures to reduce flood risk for affected communities across the UK.

1. Introduction

'Slowing the Flow at Pickering' is a new project based at Pickering in North Yorkshire designed to look at how changes in land use and land management can help to reduce flood risk. The town of Pickering has a long history of flooding, with four floods in the last eleven years (1999, 2000, 2002 and 2007). The 2007 flood was the most serious to date, causing an estimated £7 million of damage to residential and commercial properties. Whilst a flood alleviation capital scheme had been proposed in recent years to alleviate the problem, a cost-benefit analysis showed this to be unaffordable when set against current national cost-benefit thresholds and other priorities.

The Slowing the Flow at Pickering project represents a new approach to flood management that seeks to work with natural processes to help reduce the risk of flooding for affected communities. It is one of three pilot projects funded by Defra under their multi-objective flood management demonstration programme in response to Sir Michael Pitt's Review of the 2007 floods in England and Wales. Recommendation 27 of the review called for Defra, the Environment Agency and Natural England to work with partners to establish a programme, informed by Catchment Flood Management Plans, to deliver flood risk management projects involving greater working with natural processes.

A crucial element of the approach is to understand better how floods are generated in a catchment and how the way the land is used and managed affects the speed and volume of flood flows. The combined effects of past land management practices by humans over centuries are thought to have increased flood risk by promoting rapid runoff and increasing siltation within river channels, although more recent changes, for example planting for upland forestry since 1945, may have partly offset these trends. There are four principal land uses in the *c.*69 km^2 catchment of the Pickering Beck that drains to Pickering, comprising forest, arable, heather moorland and improved grassland. The overall aim of the project was to demonstrate how land use change and improvements in management practices could further help to reverse these trends and restore the catchment's natural flood attenuation capacity.

At the core of the whole-catchment approach being trialled at Pickering is to implement and evaluate a number of land management interventions to help slow down and reduce flood flows. Most of these measures would be targeted to the Pickering Beck catchment but some extend into the neighbouring catchment of the River Seven to help contribute to managing flood risk for the village of Sinnington.

While the focus of the project is on managing flood risk, it is also recognised that the planned measures will deliver wider environmental, economic and social benefits. These were expected to include improved water quality, provision of new habitats and/or an improvement in condition of existing habitats, enhanced carbon sequestration, an enhanced local skill base in estate management, improved recreation/tourism access, and increased public understanding and engagement in land management for flood risk reduction. An attempt would be made to evaluate these ecosystem services so that they can be recognised and factored into future flood risk management planning and related decision making processes.

This report describes the approach followed by the project in trying to implement the planned range of land management interventions in the Pickering Beck and River Seven catchments. It describes the progress made, assesses success against a set of agreed criteria, outlines the lessons learnt, considers future plans and makes a number of recommendations for future action.

2. Aims and Objectives

The overall aim of the project was to demonstrate how the integrated application of a range of best land management practices can help reduce flood risk at the catchment scale, as well as provide wider multiple benefits for local communities. Specific objectives were linked to individual management practices and comprised:

1. Agree design, secure funding and establish timeline for the construction of low-level bunds within the Pickering Beck catchment to increase flood storage capacity within the floodplain.
2. Plant 50 ha of riparian woodland within the Pickering Beck catchment and 30 ha of floodplain woodland in the neighbouring catchment of the River Seven at appropriate sites to delay and reduce flood flows.
3. Construct 100 large woody debris (LWD) dams within the Pickering Beck catchment and a further 50 within the River Seven catchment to increase floodplain storage and delay flood flows.
4. Plant 5 ha of farm woodland on sensitive soils within the Pickering Beck and/or River Seven catchments to increase soil infiltration and reduce rapid surface runoff, erosion and sediment delivery to watercourses.
5. Identify and block moorland drains causing rapid runoff and erosion in the Pickering Beck catchment. In addition, establish no-burn buffer zones along main watercourses to retard flood generation.
6. Identify problem drains and restore streamside buffer zones within Cropton Forest to reduce rapid runoff. Amend felling plans to minimise impact on flood risk.
7. Implement farm-scale measures to improve soil infiltration and reduce rapid runoff.

These objectives were to be achieved via 10 tasks and 18 milestones, as set out in the contract specification.

3. Approach

A key factor in the selection of the Pickering Beck catchment for the project was the nature of land ownership. Experience gained from earlier work in the region (Nisbet *et al.*, 2008) showed that land owners were generally resistant to implementing the identified measures at specified sites due to a variety of reasons, the most important of which was usually the lack of sufficient payments/incentive to cover costs and to compensate for management restrictions, perceived reductions in capital value of the land, loss of agricultural income, or the increased risks associated with land use change. Since the main objective of the project was to demonstrate how land management interventions could work to reduce flood risk, it was essential to achieve changes on the ground and ideally site these at locations where they could be expected to deliver the greatest benefits. The advantage of the Pickering Beck catchment was

that around half of the land was either in public ownership (by the Forestry Commission and the North York Moors National Park Authority) or owned by the Duchy of Lancaster Estates, providing greater flexibility and likelihood of success.

Another important factor in choosing Pickering was the availability of mapping data and models from a number of previous regional flood risk management projects. In particular, a Rural Economy and Land Use (RELU) project had pioneered new ways of incorporating local knowledge into strategic flood risk management, including the development by Durham University of a new hydrological model for the Pickering Beck and River Seven catchments for assessing the role of land management interventions (Odoni & Lane, 2010). Secondly, Forest Research had already identified opportunities for targeted woodland creation within the catchments for flood risk reduction as part of a Regional Forestry and Flooding Initiative by the Forestry Commission and the Environment Agency (Broadmeadow & Nisbet, 2010). These and other projects provided the additional benefit of a ready made, strong regional partnership team that would be crucial to support and secure the necessary land management changes for flood alleviation.

A Programme Board comprising senior representatives from the main partners and funders was established to help steer and oversee the project, while a Programme Delivery Group was formed with representatives of the regulatory bodies and land owners and managers to guide the development and implementation of the agreed interventions. The main partners were:

Lead: Forest Research (FR)

Funding and Regulatory agencies: Defra (lead funder), Forestry Commission England (FC(E)), Environment Agency, Natural England (NE), the Regional Flood Defence Committee and Ryedale District Council.

Major Land Owners: FC(E), North York Moors National Park Authority (NYMNPA), Duchy of Lancaster Estates & North York Moors Railway.

Local Authorities: NYMNPA, North Yorkshire County Council, Ryedale District Council, Pickering Town Council & Sinnington Parish Council.

Community Representatives: Ryedale Flood Research Group (RFRG), Pickering Civic Society & Pickering Flood Defence Group.

Research: FR, Durham University.

4. Methods & Results

This section of the report describes the methods and results for each of the management interventions. It is important to note that the progress made has relied upon a considerable level of match funding in terms of staff time and grant/capital support from partners, details of which are listed in Appendix 12.1.

4.1 Construction of low level bunds

The idea of using low level bunds to provide upstream flood storage was originally proposed by the RFRG as part of the previous RELU project. The RFRG comprised a mix of academics and members of the public and drew on local knowledge to help

develop preferred approaches to reducing flood risk in Pickering. A simple model was developed to evaluate the downstream impact of inserting bunds at different sites in the catchment and to identify optimum locations.

Of an initial list of ten preferred sites, seven had fine resolution topographic data (LiDAR coverage) and were taken forward in this project for further evaluation. The Environment Agency worked with the RFRG to develop a more detailed model to assess the effect of bund construction for upstream flood storage on downstream flood risk. This revealed that the creation of bunds alone would not have the desired effect without additional work to restrict the flow of water in the main river channel. The model indicated that the channel had become too incised/deep such that it had become effectively 'disconnected' from its floodplain, i.e. flood waters were unable to spill out onto the floodplain and thus be retained within any bund.

Fortuitously, data collected during a near-flood event in Pickering in December 2009 allowed the Environment Agency to refine their understanding of the critical flow threshold for the onset of flooding in the town and to rework the corresponding flows and return periods for previous floods. It is now known that the first properties (approximately six) to flood in Pickering lie within the Beck Isle area and are inundated once the flow reaches approximately 12 cubic metres per second (cumecs). Once the flow exceeds 15 cumecs the flood waters extend out across Pickering to affect around 50 properties.

Reworking of the model and consideration of the relative effectiveness of each potential bund location and local constraints led to the selection of a site above Newbridge as the preferred area for bund construction. Modelling of this site showed that the construction of two, 1.5 – 2.5 m high, earthen bunds across the floodplain and along the railway (L-shaped bunds), linked to a pipe bridge in the river channel to constrict the flow, would store around 85,000 cubic metres of flood water. Depending on the size of the flow constriction, which is governed by the design of the pipe bridge, this volume of flood storage would be sufficient to protect either approximately six properties in the Beck Isle area from flooding (pipe designed to restrict a flow of 12 cumecs), or 50 properties in the town from flooding (pipe designed to restrict a flow of 15 cumecs).

The flood storage that could be offered by the upstream bunds is typical of the relatively low level, more regular floods experienced in 1999, 2000 and 2002. Larger river flows would not be affected by the bunds as these would already be full, thus leading to flooding of the town. To be able to protect properties from more extreme flood events such as in 2007 would require a much greater volume of flood storage, at ~650,000 cubic metres.

The two options for operating the bunds by constricting the flow were presented to Ryedale District Council's Planning and Resources Committee in June 2010 and the one that protected the larger number of properties was selected as being the most cost-effective. The Council also agreed to consider alternative options for protecting the more vulnerable properties on Beck Isle. Subsequently, they introduced a Householder Flood Resistance Grant Scheme in January 2011 to support flood resistance works by domestic properties affected by flooding in Pickering and elsewhere in the District.

Since the storage volume of the bunds exceeded 25,000 m^3 the design has to meet safety requirements specified by the Reservoirs Act 1975. The Act requires the appointment of a construction engineer to supervise and design the construction work, as well as to assess the risk to lives and property should the bund fail. The bunds were classified as a category A reservoir (highest category) due to the potential impact of a failure on downstream communities. This required further refinements to be made to the bund design to reduce the risk of failure, which added to the cost. Detailed discussions are currently underway with the Reservoirs Engineer to agree the final design.

The cost of designing and constructing the bunds at Newbridge is expected to be ~£1.15m. Ryedale District Council voted unanimously to meet the main part of the cost, contributing £950,000. The Yorkshire Regional Flood Defence Committee has agreed to provide £150,000 through its local levy, with the Environment Agency providing £50,000 from its capital land management programme.

Planning applications were submitted to North Yorkshire County Council and the NYMNPA on 25th February 2011 for the main elements of the scheme and a decision is expected in June 2011. A separate planning permission has already been obtained to import the clay onto the site and it is hoped to start work on building the bunds in June 2011, with possible completion by end October 2011.

Aside from the construction of the main bunds, a trial to assess the effectiveness of smaller 'minibunds' is planned for the River Seven catchment in late summer/autumn 2011, jointly funded by the Environment Agency from the Yorkshire Regional Flood Defence Committee local levy programme and the FC. Two sites have been identified and a design agreed for building two minibunds made from 'leaky' timber walls linked to a LWD dam. The timber walls will extend out from the dam for a distance of 10-20 m on both sides of the floodplain, with the aim of creating between 1,000-3,000 m^3 of flood water storage. This is a relatively new and inexpensive technique, which if shown to be successful could potentially be rolled out at a larger number of sites across both catchments, subject to available funding.

4.2 Planting riparian and floodplain woodland

Woodland can contribute to flood risk management in a number of ways, principal amongst which is the ability of riparian and floodplain woodland to slow down flood flows and enhance flood storage (Nisbet & Thomas, 2006). Research suggests that the greater hydraulic roughness provided by these types of woodland in the form of the trees, undergrowth and woody debris have the potential to reduce downstream flood risk (Thomas & Nisbet, 2006). Woodland can also aid flood management by reducing sediment delivery from the adjacent land, as well as through tree rooting stabilising and strengthening riverbanks, so reducing bank erosion and siltation. The presence of the North Yorkshire Moors Railway, the narrow valley floor and existing woodland or other important habitats in the Pickering Beck floodplain limited the scope for creating new floodplain woodland in the catchment but there was significant potential for extending riparian woodland.

Opportunity mapping work identified around 400 ha of riparian land (defined as land within 30 m of any watercourse) comprising 96 individual stream reaches as being potentially available for planting (Broadmeadow & Nisbet, 2011). Woodland has been cleared from some of these areas (especially in the southern part of the catchment) in the past for agriculture and the wetness of the ground made it very vulnerable to damage by trampling, inappropriate cultivation and cropping practices. These areas can be expected to respond rapidly to heavy rainfall and make a significant contribution to flash floods. Restoration of riparian woodland would remove existing agricultural pressures on the soil and so enhance soil infiltration and water retention. In due course, the woodland would help to trap and add LWD to stream channels, creating LWD dams, which could further reduce the flood response (see section 4.3).

The target was to plant a total of 50 ha of riparian woodland in the Pickering Beck catchment. Durham University's 'Overflow' model was used to assess all of the potential sites and identify where planting would be best targeted to reduce flood risk (Odoni & Lane, 2010). A particular strength of the model was its ability to separate sites where planting would have a beneficial effect (flood reducing) from those where it could be damaging (flood increasing) by assessing whether slowing the flow synchronised or desynchronised tributary responses.

In addition to aiding site selection, the model was used to calculate the combined effect that the planting of 50 ha of riparian woodland plus the construction of 100 LWD dams at positive sites in the catchment would have had on two previous flood events (November 2000 and June 2007). The results are written up in an accompanying report (see Appendix 12.2 and Odoni *et. al.* (2010)) but the main findings are summarised as:

- The best/most positive sites for planting were located in the upper half of the catchment and the least suitable in the lower third.
- Planting along main Beck sites had a greater positive effect in terms of reducing downstream flood risk than planting along tributaries.
- The effectiveness of planting was greater for the larger (2007) flood event than the smaller one (2000) studied.
- Peak flow reductions for 50 ha planting plus 100 LWD dams ranged from 2.2 cumecs for the 2007 event to 0.8 cumecs for the main peak in the 2000 event. These figures translate into reductions in flood volume of 53,000 m^3 and 15,000 m^3, respectively.

Unfortunately, out of the total of 398 ha of potentially available land for planting riparian woodland that was originally identified by mapping work, only between 49 and 144 ha was predicted to have a positive effect on reducing flood flows at Pickering, depending on the magnitude of the flood event. This presented a much greater challenge for reaching the planting target, especially since most of the positive sites lay in the more sensitive, upper half of the catchment.

A map was made showing the location of all of the positive planting sites and the individual reaches numbered. All sites lay within the National Park and were jointly assessed with the NYMNPA for their suitability through a series of meetings and site visits. A number of the sites had an existing open tree cover and most lay within designated areas (e.g. SSSI and Scheduled Monuments), the majority of which were

eventually discounted for various public interest reasons (see Appendix 12.3), including:

1. The need to maintain iconic open moorland landscapes in the upper parts of the catchment.
2. The need to conserve locally important wetland flushes and water vole habitat along the riparian zone.
3. The need to protect sites of national archaeological importance.

New planting was considered to be acceptable at only four of the positive sites, comprising a total area of 4.1 ha of riparian woodland. An application was made by the NYMNPA in autumn 2010 to FC(E) for a Woodland Creation Grant (under the English Woodland Grant Scheme (EWGS)) to help meet the costs of the planting, which was approved. The total grant aid received amounted to £15,618, comprising the basic grant rate of £1,800/ha for native broadleaved woodland plus an additional contribution of £2,000/ha to support planting in areas contributing to flood risk management. Tree planting was completed by various NYMNPA volunteer groups. Due to issues of landscape, livestock management, common land and difficulty of access, planted areas were not fenced but instead protected against grazing by using strong, staked tree shelters, which is a method used successfully elsewhere in the Park.

While the potential for additional new planting of riparian woodland in the Pickering Beck catchment is severely constrained, there may be scope for enhancing relic areas of existing open riparian woodland. A number of positive sections of stream are tree lined or have occasional trees that could benefit from 'infill' tree planting or appropriate management to aid natural woodland regeneration. EWGS could provide a grant to contribute towards additional tree planting and appropriate management works along stream sections where opportunities are of a suitable scale.

In terms of floodplain woodland, attention concentrated on the River Seven catchment where there was perceived to be much greater opportunity for planting, which could help to reduce flood risk for the village of Sinnington. A total area of 40 ha of floodplain was identified as being potentially available and an ambitious target of creating an extended 30 ha demonstration floodplain woodland along the main watercourse was set by the project. All of the potential land lay in private ownership and was in agricultural use, comprising improved grassland or arable cropping. A total of six main landowners were identified and canvassed for their willingness to consider woodland planting, of which two expressed significant interest, two were uncertain and the remaining two were not interested.

To encourage support for planting, the effect of creating floodplain woodland on flood flows at the two sites with landowner interest was evaluated using a 1-D hydraulic model (HEC-RAS). Application of the model required detailed topographic data for the identified 6.5 km reach and therefore a cross section survey was commissioned. The model was used to simulate the effect of planting a total area of 5.8 ha of floodplain woodland on the depth, extent and velocity of flood flows for a 1 in 100 year flood event. The results are reported in Appendix 12.4 and showed that the additional roughness created by woodland planting would raise water levels within the planted reach by 0.45 m and increase the volume of flood water

temporarily stored by 14%. This had little effect on the size of the flood peak but delayed its downstream progression by 20 min. A side effect was to cause flood waters to back-up for a distance of 740 m upstream of the woodland, although this did not impinge on any dwellings.

While the very small nature of the proposed planting in relation to catchment size (0.07% of the River Seven catchment of 90 km^2) greatly constrained its effectiveness in slowing flood flows, the findings indicate that the creation of a larger area of floodplain woodland or a series of similar-sized woodlands could make a significant contribution to flood risk management at Sinnington, especially if targeted to sub-catchments where the lag effect could be exploited to desynchronise tributary contributions.

The results were used to try and secure landowner interest in planting but unfortunately both of those that expressed an initial interest have preferred not to proceed to date. The main reasons given for their reluctance to plant were essentially financial, particularly the fact that despite the enhanced rate of grant available, planting would represent a net loss in terms of forestry costs and loss of agricultural profits from the planted area. Another key factor was the reduction in the enhanced rate of grant that could be offered (from an intended additional contribution of £4,000/ha to £2,000/ha) due to the formal withdrawal of funding following the closure of the Regional Development Agency (Yorkshire Forward). Similarly, none of the other landowners have shown any renewed interest in woodland creation in the floodplain.

4.3 Construction of large woody debris dams

LWD dams are a prominent feature of native riparian and floodplain woodland and known to enhance flood storage and slow down flood flows (Thomas & Nisbet, 2007). However, concerns over interference with fisheries and the washout of material blocking downstream structures have historically led to most LWD being actively removed from river systems. Methods have been developed in North America to promote the restoration of managed watercourses by artificially constructing LWD dams. The construction of an open framework of logs at appropriate locations and spacing will gradually develop into a network of effective dams as wood inputs from adjacent woodland are captured. These dams can raise water levels within upstream reaches and allow streams/rivers to reconnect with their floodplains, so increasing potential flood storage.

The project set a target of constructing 100 LWD dams within the Pickering Beck catchment and a further 50 in the River Seven. All were to be located within watercourses draining the FC's Cropton Forest using local deadwood and thinnings based on a proven design. The results from the OVERFLOW model were used to select four 'positive' channel reaches within the Pickering Beck catchment for dam building. It was decided to concentrate the dams along a relatively small number of reaches to provide a stronger basis for monitoring their impact on flood flows.

Studies show that LWD dams typically occur at a spacing of one every 7 to 10 channel widths in naturally wooded rivers (Linstead & Gurnell, 1998) and so this was adopted as a general guide for the construction work. Dams were confined to river

channels <5 m wide to reduce the risk of failure and washout of debris, which could potentially cause flooding problems downstream if it led to the blockage of bridges and culverts. A more open design was used on larger stream reaches to reduce the risk of affecting fish movement, while closed dams were built on forest drains to promote rewetting and out of bank flows. Following receipt of consent from the Environment Agency, dam construction work began in June 2010 using the NYMNPA team of Modern Apprentice estate workers. Around 20 dams were built along one stream over a two-week period, followed by another 30 along a different stream in a second two-week period in November 2010. The remaining 50 were constructed by FC workers spread between a further two streams in February-March 2011.

It is planned to build a further five to ten larger dams in the main channel of the Pickering Beck during summer 2011. The OVERFLOW model indicated that LWD dams would be particularly effective at retaining flood flows in the main channel, however the close proximity of the railway to the river greatly constrained the number of suitable sites. Survey work identified three potential reaches of <5 m width where there is an opportunity to construct dams without affecting the railway line or posing a risk of flooding upstream properties. Construction is scheduled for the forthcoming summer when flows should be lower permitting easier access and working.

Identifying suitable reaches for the 50 dams in the River Seven catchment was initially hindered by the absence of OVERFLOW data, with the application of the model confined to the Pickering Beck catchment. However, an MSc student at Durham University was able to extend the model application to the River Seven in summer 2010, allowing reaches to be identified where dam construction would make a positive contribution to reducing downstream flood risk at Sinnington. Two streams have now been selected for dam construction, with work expected to be carried out by the team of apprentice estate workers in May 2011.

The NYMNPA also plans to build a network of LWD dams along a number of positive stream reaches on its own land within the Pickering Beck catchment. Environment Agency consent has been given and work will be undertaken by NYMNPA Apprentices during 2011. The Forestry Commission will provide logs from Cropton Forest for the work and the dams built where access and local constraints permit.

4.4 Planting farm woodland

Pre-project mapping identified a number of opportunities on farmland within both the Pickering Beck and River Seven catchments for woodland planting to help intercept surface runoff from fields and retain or slow down its passage to streams. The most effective locations are thought to be across hillslopes at field boundaries or along runoff pathways, as part of infiltration basins. It was expected that relatively small areas of woodland targeted to key sites could make a local difference, both in terms of reducing flood runoff and sediment delivery to watercourses. Consequently, a low target of 5 ha was set for planting farm woodland under agri-environment agreements, spread between both catchments.

Efforts by FC and NYMNPA staff to seek woodland planting applications have mainly succeeded in the River Seven catchment. A large scheme of 13 ha has been

approved for planting in 2011 on farmland identified as a high priority for reducing surface runoff and sedimentation, with other areas expected to follow. In contrast, less progress has been made in the Pickering Beck catchment, although 1650 oak trees have been planted as part of woodland habitat restoration work by the NYMNPA. Planting extended over a total area of 11.5 ha within a number of steep sided, bracken covered valleys, known as 'The Griffs' in Levisham Moor. The work was done by a local contractor and funded by the NYMNPA, with the trees planted in staked shelters rather than fenced.

4.5 Blocking moorland drains and establishing no-burn buffer zones

Although the main moorland areas in the Pickering Beck catchment comprising Levisham and Fen Moors have not been extensively drained, there were known to be a few drains that would benefit from restoration work. Modelling and site surveys identified five drains that appeared to be discharging too much run-off resulting in localised erosion and drain deepening.

Three of these have been blocked using the well-established technique of inserting heather bales at intervals along each drain to raise water levels, slowing down runoff and allowing water to spill out and spread over adjacent ground. A specialist local contractor was employed by the NYMNPA to undertake the work using 200 small heather bales cut from Fen Moor. Restoring the other two drains is more problematic due to their relatively large size and sensitive locations (one alongside a main footpath and the other forming habitat for water voles) but discussions are ongoing to try and find an acceptable solution.

Heather burning was also recognised as a potential flood management issue as burning temporarily removes the vegetation cover and can make the surface of the soil more hydrophobic, speeding up surface runoff. The main actions were identified as limiting the extent of burning and in particular, to try to avoid burning the vegetation close to watercourses. Five metre 'no-burn' buffer zones have therefore been established along all watercourses to help protect the vegetation, which is important for improving soil infiltration and providing 'roughness' to slow down runoff. The moorland is all designated SSSI and heather burning is controlled through NE land management agreements.

Other work identified includes the reseeding of areas of bare peat in the Hole of Horcum to promote heather regeneration. This was planned for last November/December using a local specialist contractor but was curtailed by the heavy snowfall and has had to be rescheduled for late autumn 2011.

4.6 Blocking forest drains, restoring streamside buffer zones and amending Forest Design Plan

This measure focused on the need to take stock of how the design and management of Cropton Forest can influence flood flows and to take action to minimise risks and enhance benefits. All FC woodlands are managed under an agreed Forest Design Plan (FDP), which lays out detailed felling and restocking proposals for the area covered by the plan in order to achieve a set of pre-determined objectives. The plans are reviewed every five years and work on the Cropton FDP revision began in early 2008.

While protecting soil and water resources is a fundamental requirement of sustainable forestry management, it was recognised that there was scope for being more proactive in trying to reduce flood generation. Thus a specific objective of aiding flood risk management was added to the plan in 2009.

The new objective incorporates a number of important elements designed to slow the flow. Firstly, trees and conifers in particular, are known to use/evaporate more water than shorter crops, which can help to reduce the volume of runoff. This benefit is temporarily lost when forest crops are harvested and thus there is a need to manage the scale of such work so that the risk of increasing runoff is minimised. Felling plans were therefore checked to ensure that no more than 20% of the catchment area of main tributary streams would be felled in any three year period; research shows that it is difficult to detect any effect on flows when the rate of felling is below this threshold.

Secondly, the structure of the forest was amended to create wider riparian buffer zones alongside main watercourses draining the forest. Increased light levels following programmed conifer clearance will promote the development of ground vegetation and a shrub layer, which will increase hydraulic roughness and slow flood flows. The future development of native riparian woodland within these zones will further enhance water retention and flow attenuation, as well as form an important forest habitat network to aid the movement of wildlife.

A third element was to help guide felling and restock operations to recognise and secure local opportunities to slow the flow within the forest. To start with, an extensive survey of the condition of all watercourses and drains was undertaken to identify any eroding stretches discharging excessive volumes of water, or drains directly flowing into streams. These are flagged for restoration when felling of the adjacent crop allows access. The North York Moors operational planning procedure (Ops 1) was amended to facilitate this process, ensuring that the work will be incorporated into future restock cultivation and drainage plans. Consideration is also given to opportunities to extend the use of LWD dams within incised watercourses draining felling sites to help raise water levels and reconnect floodplains, subject to consent from the Environment Agency.

The revised plan was approved in July 2010 and will be reviewed again in 2015. To date, mature conifer crops have been cleared from approximately 2.1 ha of riparian zones across two sites and 370 linear metres of streamside buffer areas restored. So far there has not been a need to install any LWD dams in cleared reaches. Outside designated riparian areas, 12 ha of restocking has been completed in accordance with the revised FDP, involving no drainage work.

4.7 Implementing farm-scale measures

A range of agricultural practices is associated with potentially damaging the soil and promoting rapid surface runoff to watercourses. Overstocking, overgrazing, inappropriate cultivation and poor runoff management are all recognised contributory factors to downstream flooding. These are also responsible for generating diffuse pollution, which is a major issue in the Pickering Beck catchment and thought to be the cause of local water bodies failing to meet good water status (as defined by the EU

Water Framework Directive). This had led to the area being designated as a Priority Catchment under the England Catchment Sensitive Farming Delivery Initiative.

The above designation provided an opportunity for integrating action to address both diffuse pollution and flood risk by accessing funding from the Catchment Sensitive Farming Capital Grant Scheme and Environmental Stewardship. Two workshops and a number of farm visits were held during the project to raise awareness among farmers of the availability of grants to help tackle these issues. The second workshop included a farm walk to demonstrate a new soil aeration technique for improving soil infiltration.

There was limited take-up of the 2010 Capital Grant Scheme in the catchment, which focused on measures to improve farm infrastructure. The project was able to exert a stronger influence on the 2011 Grant Scheme, which offers grants of up to £10,000 for a range of measures aimed at better management of runoff and drainage waters, and reducing soil poaching and sediment delivery. This includes installing sediment ponds, swales and check dams, cross drains on farm tracks, and providing drinking troughs to preclude the need for livestock accessing watercourses. It is uncertain what the final take-up will be as the application window only opened on 1 March 2011 and is not due to close until 30 April 2011.

5. Evaluating multiple benefits

This section summarises efforts to conduct a preliminary economic evaluation of the ecosystem services provided by the land management interventions (a full report is provided in Appendix 12.5). The approach followed the draft Environment Agency guide 'Ecosystem services assessments: How to do them in practice'. As a first step, the Wider Programme Delivery Group undertook a qualitative assessment by determining the 'likelihood of impact' of the planned interventions across the full set of ecosystem services. The Group scored the impact using the recommended UN Millennium Ecosystem Assessment (2005) classification scheme, which groups services into four main categories: provisioning, regulatory, cultural and supporting services. An additional service was added to the list of cultural services in the form of 'education and knowledge'.

The Group met on 21 January 2011 to score the impacts of the project measures, which were grouped into four categories: bund construction, woodland creation, drain/stream channel restoration, and farm-based measures. Each category was scored individually and then a combined score was agreed for each service for the project as a whole. Overall, the measures were considered to provide potential significant positive effects for six services (flood regulation, erosion regulation, recreation & tourism, social relations, education & knowledge, and habitat provision), with none yielding any potential significant negative effects.

The next step was to carry out an economic valuation of the significant positive impacts. In view of limited time and resources, efforts focused on evaluating the services provided by the woodland creation (floodplain, riparian and farm woodland) measures plus LWD dams. Climate regulation was added to the list of significant positive effects and recreation & tourism was deleted to reflect the Group scores for these measures. A reduction in food provision from the loss in agricultural production

was included as a potential negative impact. The objective was not to estimate definitive values but to provide some conservative estimates to serve as the foundation for a more robust future valuation of ecosystem services. Although the woodland is likely to be established in perpetuity, a 100-year time horizon was selected for the purposes of the assessment.

Minima, maxima and means for each of the indicative central estimates for each of the impacts are summarised in Table 1 below. The estimates suggest that habitat creation and climate regulation are by far the largest benefits, with flood regulation a more distant third, while the loss of agricultural production could be a significant disbenefit.

Table 1: Indicative annual ecosystem service values based on central estimates for the woodland creation (85 ha) and LWD dam (150 dams) measures

	Minimum (£/yr)	**Maximum (£/yr)**	**Mean (£/yr)**
Habitat creation	£0	£138,514	£121,524
Flood regulation	£4,200	£6,000	£5,964
Climate regulation	-£18,241	£317,943	£107,035
Erosion Regulation	£0	£221	£205
Education and knowledge	£10	£60	£14
Community development	£549	£549	£549
Agricultural production	-£32,056	-£3,771	-£31,604
Total	**-£42,653**	**£431,180**	**£203,687**

The benefit calculations are gross values and do not allow for the costs of the forestry measures implemented or for the timing of both these and the benefits to accrue (i.e. their distribution over the 100 year period considered). These aspects are accounted for in Table 2 where each 100 year flow of annual values has been converted into a present value by discounting based upon the Treasury Green Book protocol. Aggregating gives net present values (NPV) ranging from around £0.8m to £9.6m, with a central estimate of £4.3m.

The positive NPV in each case indicates that from a societal perspective the public benefits from the forestry measures outweigh the costs. However, it is important to note that it is unlikely to be cost effective to implement the forestry measures solely for flood regulation, highlighting the need to factor in other ecosystem benefits. The calculations show that the greatest benefits would arise from habitat creation and climate change mitigation. It should also be noted that the indicative estimates suggest that it is unlikely that the benefits will outweigh the costs for private landowners. For example, based upon Treasury Green book discount rates, the present values of expected woodland grant payments (ranging from £4,515/ha to £6,780/ha) would only partly cover the forestry costs (£4,200/ha to £8,200/ha) and that of lost agricultural production (£3,600/ha to £13,100/ha).

Table 2: Indicative ecosystem service present values (£k at 2011 prices) for the woodland creation (85 ha) and LWD dam (150 dams) measures

	Low (£k)	**Central (£k)**	**High (£k)**
Habitat creation	£1,630	£2,773	£4,459
Flood regulation	£88	£175	£292
Climate regulation	£923	£2,800	£5,464
Erosion Regulation	£0	£5	£10
Education and knowledge	£0	£1	£6
Community development	£0	£16	£62
Agricultural production	-£1,113	-£911	-£306
Forestry Costs	-£710	-£539	-£369
Net Present Value	**£819**	**£4,321**	**£9,618**

6. Measuring success of project against agreed set of criteria

Twelve criteria were agreed early on in the project as a way of judging success. These are listed below and the performance against each summarised.

1. Developed an agreed plan for a combination of measures that aspires to reduce flood risk and provide protection for Pickering for a 1-in-25 year event (protecting approximately 50 properties).

Two flood storage bunds have been designed to reduce flood risk and provide protection for ~50 properties affected by low level flood events (equivalent to ~1 in 25 year flood). The contribution of riparian woodland planting plus construction of 100 large woody debris dams to flood management is predicted to reduce with declining event size and lower the peak discharge at Pickering by <0.8 cumecs for a 2000 type event and by 2.2 cumecs for a 2007 type event (see Appendix 12.2).

2. Community engagement plan in place and local residents and landowners kept informed about the project and feel that their views have been adequately aired.

A community engagement plan is in place and has been regularly updated (see Appendix 12.7). The local community has been kept informed through two Community Engagement days (28/09/09 & 11/11/10), via their representatives on the Programme Delivery Group, via the project website and through the local media. The project has also strongly engaged with the wider community at regional and national levels through the media (including a slot on BBC Breakfast TV), by hosting site visits, by giving presentations at meetings and conferences, and via articles in the trade press and scientific papers. A list of these is included in Appendix 12.6.

3. Practical advice on what to do before, during and after a flood provided to all properties and businesses at risk of flooding in the catchments of the Pickering Beck and the River Seven.

A representative from the National Flood Forum attended the Community Engagement day on 11/11/10 and hosted a display on flood resistance and resilience. Ryedale District Council approved an initial £50k budget for a householder flood resistance grant scheme for the District, which was launched in January 2011.

4. Design agreed, funding secured and timeline established for the construction of low-level bund(s) and associated works within the Pickering Beck catchment.

The design has been revised, funding secured, the main planning application submitted (on 25/02/11; the planning application for the import of construction materials has already been obtained) and a timeline is in place for the construction of two bunds within the Pickering Beck catchment, with work hoped to commence in June and be completed by October 2011.

5. 100 large woody debris dams constructed along preferred reaches within the Pickering Beck catchment and a further 50 within the catchment of the River Seven.

Work is ongoing with 100 dams constructed to date along reaches within the Pickering Beck catchment where modelling predicted that their construction would have a positive effect on reducing downstream flood risk. The remaining 50 dams within the River Seven catchment are due to be built by end May 2011. Additional larger dams will be constructed along two main reaches of Pickering Beck during a period of low flow in summer 2011. Two timber-based mini-bunds linked to LWD dams are due to be constructed and trialed in the catchment of the River Seven in autumn 2011, funded by the Yorkshire Flood Defence Committee Local Levy.

6. 50 ha of riparian woodland restored/planted or subject of an application to plant within the Pickering Beck catchment.

The original target was set in the context of an estimated 398 ha of potentially available land in the catchment that was suitable for planting riparian woodland. The results of the OVERFLOW modelling reduced this total to between 49 and 144 ha of riparian land where planting was predicted to have a positive effect on reducing flood flows at Pickering, depending on the magnitude of the flood event. Most of this land lay in the upper half of the catchment, where potential constraints were greatest. A total of 4.1 ha of riparian woodland within the Pickering Beck catchment have been planted in target areas. There is limited scope for further new planting due to local constraints, primarily linked to landscape and biodiversity issues, but also to the presence of existing remnants of native woodland along several reaches (see Appendix 12.3). The latter sites could be improved by in-fill planting or by encouraging natural regeneration.

7. 30 ha of new floodplain woodland planted or subject of an application to plant within the River Seven catchment.

No floodplain woodland has either been planted or is currently the subject of a planting application in the River Seven catchment due to lack of interest by landowners, primarily due to financial considerations. However, there is significant scope for riparian woodland planting, with one application approved for 1.8 ha and a second larger scheme of around 8.4 ha in progress.

8. 5 ha of new woodland planted on farmland on soils vulnerable to rapid surface runoff and erosion within the Pickering Beck catchment.

Efforts are ongoing to encourage land owner interest in planting farm woodland. 1650 oak trees have been planted across an area of 11.5 ha in the Pickering Beck catchment as part of native woodland restoration. There is greater willingness to plant new woodland within the River Seven catchment, where a total of 13 ha of vulnerable land have been approved for planting.

9. Moorland drains surveyed on Saltergate and Levisham Moor, and problem drains either restored or a work plan in place to block these. No-burn buffer zones established along main watercourses.

The condition of the moorland drains has been assessed and three problem drains on Levisham Estate blocked using heather bales. Restoration of two other drains is under consideration. Five-metre wide no-burn buffer zones have been established along all watercourses.

10. Watercourses and drains within Cropton Forest surveyed and work to establish appropriate riparian buffer areas timetabled and incorporated within the revised Forest Design Plan. Plan checked to ensure that no more than 20% of the catchment will be clearfelled in any three-year period.

Main watercourses and drains have been surveyed within Cropton Forest and the Forest Design Plan revised. The plan limits the scale of clearfelling to meet the 20% threshold in any three-year period and highlights the need for an operational site assessment prior to felling to identify opportunities to restore and enhance riparian habitats and increase flood water storage, e.g. by constructing LWD dams.

11. Ten additional water level gauges installed to measure the effectiveness of the measures on flood flows and flood risk.

Seven water level recorders have been purchased and six installed within the Pickering Beck catchment to measure the effectiveness of LWD dams and riparian woodland planting in reducing flood flows.

12. Implemented measures generated wider environmental benefits including for water quality and biodiversity.

A qualitative assessment has been completed of the impacts of the project measures on ecosystem services, yielding potential significant positive effects for water regulation, erosion regulation, recreation and tourism, social relations, education and knowledge, and the provision of habitat, and no potential significant negative effects. A limited quantitative assessment has been completed for the impacts of the woodland creation and LWD dam measures, which give total indicative annual values ranging from a loss of £42,653 to a gain of £431,180, with a mean estimate of a gain of £203,687. The results of the ecosystem services assessment are described in Appendix 12.5.

7. Lessons learned

The main lessons learned can be summarised as:

1) Two years is too short to execute a demonstration project, which is the main reason why the project has fallen short in achieving some of the success criteria. This was compounded by the delay in signing off the contract, which reduced the time period to 21 months. Longer time is needed for securing changes on the ground, which can involve a lengthy process of data gathering, modelling, ground truthing of model results, designing, consultation, persuading landowners, and making supplementary funding bids and a formal planning application. Less would have been achieved if the project had not been able to draw on the preliminary modelling and community engagement work by the RFRG, as well as the opportunity mapping undertaken by FR. While two years may be sufficient for planning and case study work, a minimum of three years is recommended for implementing such a project and ideally five years.
2) A short duration project is also problematic for monitoring and evaluation work. Monitoring equipment cannot be installed until final sites are selected for the measures, leaving limited time for baseline data collection if implementation is to be achieved within the project time line. Evaluation of the impact of woodland creation necessitates long-term monitoring.
3) To be successful, partners need to adopt a 'can do' attitude and not be risk averse. Good communication is also vital to ensure that plans are understood by all and incorporate local knowledge. In this regard, it is important to adopt the 'Engage, Deliberate and Decide' model, rather than one based on 'Decide, Announce and Defend'.
4) There is a need to carefully manage community expectations, with the community naturally impatient to see things implemented on the ground. Measures such as including community representatives on the Programme Delivery Group, drawing up a community engagement plan as part of the EA's 'working with others' approach, and holding two community engagement days, all assisted in this regard. The local community also now better understand the working procedures and constraints affecting regulators when making land management decisions.
5) Local communities appear ready to embrace the concept of a whole-catchment approach to flood risk management. The concept 'makes sense' and fits the green agenda. However, there is a need to be clearer in communicating flood risk.
6) Decision making over the selection and siting of flood management measures often relies on good data and robust models. It is also important to undertake ground truthing to check results. Where deficiencies are found and subsequently improved, great care is required in communicating changes to minimise the risk of confusion and loss of confidence.
7) Modelling work predicts that land management measures can reduce downstream flood risk, underpinning the concept of a whole catchment approach to flood management. Confidence is greatest for the role of the low level earthen bunds but the modelling work also provides further support for the positive contribution of woodland creation and large woody debris dams in particular. Unfortunately, it has not proved possible for the modelling to integrate the effects of the different measures, mainly due to lack of time/resources. It would have helped if agreement had been reached at the outset on data requirements and on the preferred modelling framework, including which flood events should be modelled.

8) Slowing the flow at some sites can increase rather then decrease flood flows as a result of synchronising catchment contributions. In general, siting measures closer to flood prone locations is more likely to increase flood risk. Measures are expected to be most effective when placed in the upper half of a catchment (with the exception of large flood storage bunds).
9) While public ownership of land can smooth decision making over woodland creation, a range of barriers still exist. Planting in the Pickering Beck catchment was hampered by the sensitive nature of the landscape, especially by its existing high biodiversity and landscape values. While it was originally hoped that there would be greater support for an expansion of native riparian woodland, this was largely curtailed by the desire to maintain the openness of the landscape and to protect important areas of wetland habitat. Decisions were also influenced by the perceived narrower benefit for flood management from planting existing wetland compared to more intensive farmland.
10) LWD dams can exert a stronger effect on flood flows than woodland vegetation, although both are complementary. LWD dams are particularly valuable for raising water levels within incised river channels and reconnecting floodplains. They offer a useful measure for slowing the flow in river reaches where there are constraints on planting woodland, although will need active management to maintain their effectiveness in the absence of natural inputs of dead wood.
11) Demonstration projects should include a formal ecosystem services assessment, which needs to be carefully planned from the start of the project. An initial qualitative assessment of the expected costs and benefits would help to guide data collection, assisting a final quantitative evaluation. The exercise also needs to be properly costed and resourced, as well as include protocols for handling sensitive data.
12) The ecosystem services assessment suggests that it is unlikely to be cost effective to implement forestry measures solely for flood regulation, highlighting the need to factor in other ecosystem benefits such as for habitat creation and climate change mitigation. However, while the wider public benefits appear to greatly outweigh the costs, the opposite applies to private landowners. Consequently, landowners remain reluctant to plant floodplain woodland and to a lesser degree riparian woodland due to financial considerations. The greater costs associated with these types of woodland reflect the need for higher planting densities and the use of tall tubes or long lengths of fencing. This is compounded by the higher value of the land and lost agricultural income and subsidy payments.
13) To be most effective, land management measures need to be carefully targeted. This is often problematic for land owners, who have their own site preferences. To secure change requires a higher incentive/compensation.
14) It remains a challenge to persuade farmers to implement slowing the flow/diffuse pollution measures, with limited take-up of Catchment Sensitive Farming Capital Grants.

8. Future work, including monitoring and evaluation

While much has been achieved during the period of the project, a lot remains to be done if the original aims and objectives are to be fully realised. Future work can be split into four main components:

1) **To secure full implementation of the outstanding planned measures.** Project partners have plans in place to achieve most of the outstanding measures within the next 6-12 months, including providing grant support to help protect the Beck Isle properties. The main exception concerns the planting of riparian and floodplain woodland. There appears to be little opportunity for further new planting of riparian woodland within the Pickering Beck catchment but some scope for restoring such habitat by encouraging natural regeneration or possible in-fill planting. The remaining challenge is to encourage private landowners in the River Seven catchment to plant floodplain woodland, which will be strongly influenced by future changes in agricultural incomes and subsidies, as well as the value of the woodland creation grant. Increasing the additional contribution to £4,000/ha for the latter may help to secure interest, although this may be very difficult in the current financial climate. In contrast, there appears to be significant potential to increase the extent of riparian woodland planting in the River Seven catchment. The Programme Delivery Group have agreed to continue to meet at six-monthly to annual intervals to help guide the future development of the project, while the Programme Board will reconvene in spring 2012 to take stock of progress.
2) **To monitor the longer-term effectiveness of the implemented measures at reducing downstream flood risk.**
   It is essential that monitoring continues to capture and demonstrate the effects of existing and future measures. This relies on the continued operation of the Environment Agency's main river gauging stations in both catchments, supplemented by the seven additional water level recorders in the upper Pickering Beck catchment installed by FR to separate out the effects of the riparian woodland planting and LWD dams. Monitoring includes the downloading, quality control and analysis of water level data, as well as regular assessments of the condition of the LWD dams and the performance of the low level bunds. The impact of the bunds and constructed large woody debris dams should be established in the medium term (5-10 years), depending on future flood frequency. In contrast, the effects of the new riparian woodland will take much longer to fully establish (50+ years).
3) **To extend existing measures and investigate new ways to further reduce flood risk at Pickering.**
   The planned measures are expected to protect ~50 properties from a 1 in 25 year flood event, but Pickering will remain vulnerable to larger floods. It is expected that partners will continue to seek opportunities to implement additional, small-scale measures, including further woodland planting (FC), more LWD dams (FC & NYMNPA), restoring greater areas of riparian woodland and peatland habitat (NYMNPA & FC) and extending the number of farm-scale measures (NE/EA/Defra). Securing funding for another large bund is likely to prove extremely difficult but there is scope for creating a larger number of 'minibunds', as originally proposed by Durham University. The Environment Agency and FC have agreed to fund a mini bund trial within the River Seven catchment in autumn 2011, the results from which will help determine the effectiveness and wider applicability of this innovative technique.

4) **To build on the success of the project and further promote the benefits of a sustainable, catchment-based approach to flood management.**
Much has already been achieved in promoting the project but this task will need to continue if the project's full potential and value is to be realised. The partnership plans to hold a follow-up dissemination event in autumn 2011 to show the local community and others what has been achieved on the ground. FR will continue to host the webpages on the project on its own website and endeavour to keep these up-to-date. Partners will write up the results for publication in the wider literature (including revising existing guidance) and continue to use the sites for demonstration and training days. It is also planned to further develop and refine the ecosystem services assessment, raising the projects profile as a major case study for evaluating the flood, water quality and wider benefits provided by a catchment-based approach to flood management.

9. Conclusions and Recommendations

The project has succeeded in a number of important respects. Most of the success criteria have been largely achieved or firm plans are in place to deliver these in the next 6 months. The local community have been fully engaged and largely embraced the concept of a whole-catchment approach to flood risk management. Slowing the Flow at Pickering has gained a national profile as a result of efforts to promote the project via the media, by hosting site visits, by giving presentations at meetings and conferences, and via trade and scientific publications. Of particular note has been the role of the project in helping to guide and integrate the implementation of government policy on flood risk and land use management. A strong foundation has been laid for demonstrating how the integrated application of land management practices can help reduce flood risk at the catchment scale, as well as provide wider multiple benefits for local communities.

Despite these successes, more remains to be done if the project's full potential and value is to be realised. The main recommendations are summarised as follows:

1. Partners continue to work together to implement the outstanding measures and to pursue opportunities to extend these and develop new measures to further reduce flood risk in Pickering and Sinnington.
2. The partnership continues to meet at regular intervals to oversee the implementation of the planned measures.
3. Monitoring is maintained to allow the longer-term effectiveness of the measures to be established.
4. The partnership continues to communicate and promote the benefits of a sustainable, whole-catchment approach to flood management, through the media, giving presentations, publishing results and by hosting site visits, including holding a follow-up dissemination event to demonstrate what has been achieved on the ground so far.
5. Work continues to extend and refine the ecosystem services assessment to provide a national case study of the multiple benefits that can be delivered by multi-objective flood management.

6. Partners apply the lessons learned in developing future flood risk and land use management policy and support mechanisms, including more targeted and integrated grant payments for service provision.
7. Partners support the development and trial of a payment system for ecosystem services aimed at securing wider implementation of targeted land management measures to reduce flood risk for affected communities across the UK.

10. Acknowledgements

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12. Appendices

12.1 Report on match funding

12.2 Assessment of the impact of upstream land management measures on flood flows in Pickering Beck using OVERFLOW

12.3 Report on evaluating potential sites for planting riparian and floodplain woodland

12.4 Assessing the impact of floodplain woodland planting in the River Seven catchment

12.5 Report on Ecosystem Services Evaluation

12.6 List of media interviews, press articles, publications in trade press and journals, presentations given and events attended

12.7 Community Engagement Plan