

From source to sea

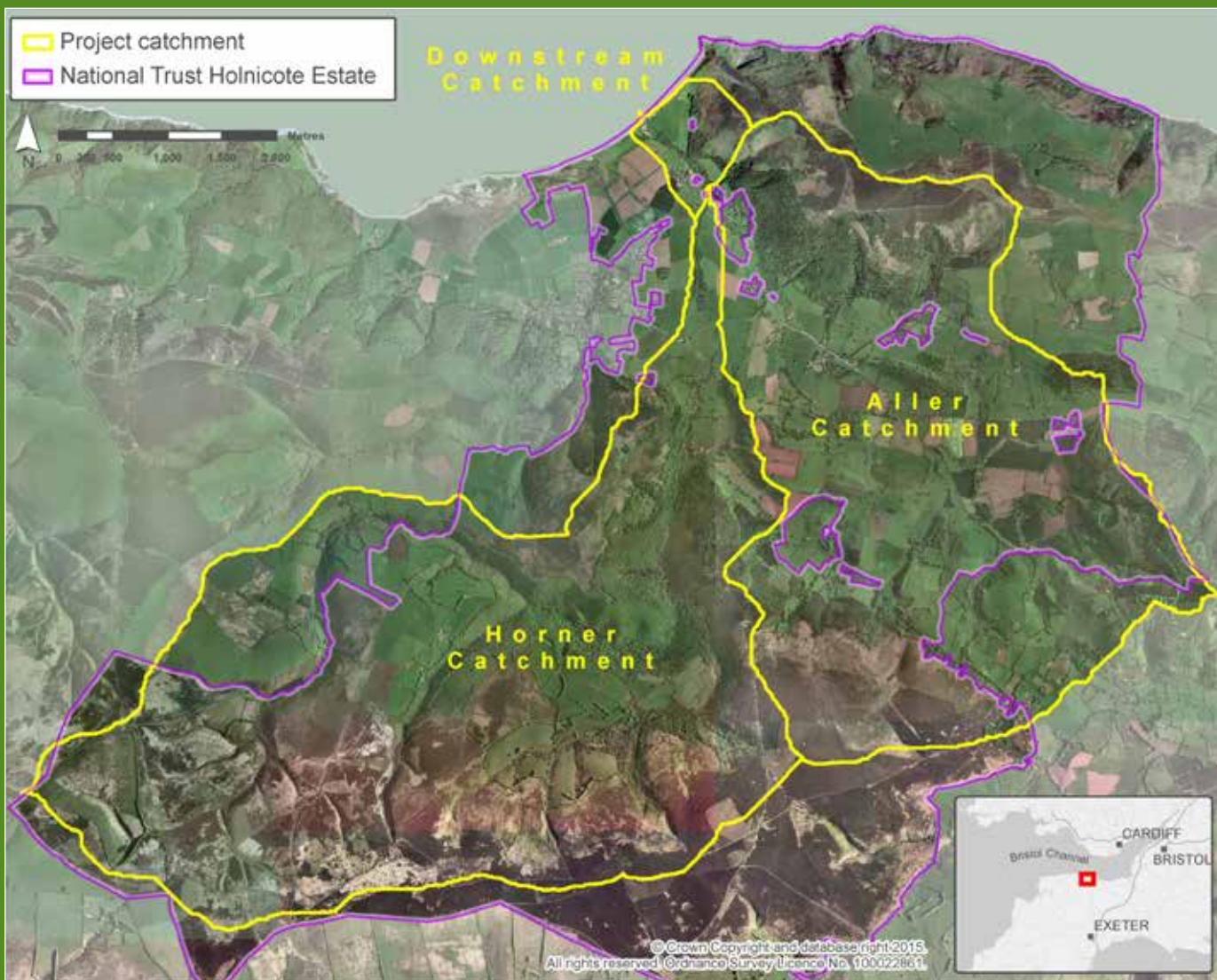
NATURAL FLOOD MANAGEMENT | THE HOLNICOTE EXPERIENCE

CONTENTS

- I. Background 1
- II. Catchment characterisation and interventions..... 2
- III. Assessment of effects..... 5
- IV. Multiple benefits 14
- V. Outcomes and lessons learnt17
- VI. Future work 21
- VII. Project Database..... 24

ACKNOWLEDGEMENTS

Project code RMP 5508 – Multi-Objective Flood Management Demonstration Project – The National Trust Holnicote. The project delivery team consisted of: National Trust (NT), Environment Agency (EA), Penny Anderson Associates (PAA) and JBA Consulting (JBA). The funding for the project was primarily obtained from Defra (£473,000 for phase 1 (2009-2011) and £248,760 for phase 2 (2011-2015)); together with generous contributions from the Environment Agency and National Trust. The project delivery team would like to acknowledge the support and contributions from all the project funders, project associates (Exeter University and Cranfield University), key stakeholders (including Wessex Water, Natural England, Exmoor National Park Authority), NT staff, tenants and the local community.



All project reports referred to in the text can be accessed via the Project Database (see Section VII).

OUTCOMES AND LEGACIES

- ▶ The targeted implementation of a range of natural flood management (NFM) measures across the Holnicote catchments has been shown to reduce downstream flood risk and generate a wide range of other benefits.
- ▶ A sophisticated rainfall and flow monitoring network was deployed across the two study catchments. This monitoring network is currently being upgraded and expanded to serve the project going forward and to provide additional, high resolution data for suspended sediment and flow measurement.
- ▶ The project has generated a substantial 'resource' of information and data which can be used as a description of baseline conditions. Crucially, the database also represents an invaluable resource for other organisations and groups involved in NFM scheme delivery elsewhere.
- ▶ The flow variability and hydrograph analysis methods adapted and refined for use in this project provide a standardised, transferable toolkit for analysing catchment scale impacts of NFM interventions on flow response and flood risk. Importantly, the method employs statistical analysis of real data, rather than modelled outcomes.
- ▶ In terms of catchment scale interventions, the withdrawal of coarse woody debris removal and management in woodlands is a highly cost effective and simple way of achieving NFM and mitigating flood risk in the medium and long term, as well as providing considerable biodiversity benefits.
- ▶ During the extremely wet winter 2013/14 in Somerset, there was no flooding in the vulnerable villages that have experienced regular flooding in the past, containing 98 properties (55 NT and 43 private) at risk with an insurance value of £30M.
- ▶ A set of newly constructed offline banded flood storage areas helped to deliver a 10% reduction in flood peak during a severe storm in late December 2013 on an already saturated catchment.
- ▶ Altered hydrological and biogeochemical processes within the agricultural catchment, including accelerated soil erosion and soil organic matter turnover, contributed to an enhanced fluvial suspended sediment and carbon export.
- ▶ Greatest water quality impairment was observed in the most intensively farmed central part of the Aller catchment associated with arable land use, so wherever possible arable reversion to grassland especially on steeper slopes should be encouraged, together with riparian woodland.
- ▶ An ecosystem services approach has been at the heart of the Holnicote Project which has delivered multiple ecosystem benefits for biodiversity, soil management and water quality. A Payment for Ecosystem Services pilot has explored novel markets for the supply of ecosystem services at a catchment scale.
- ▶ Careful management of soils and the continuance of agri-environment support mechanisms hold the key to creating sustainable and resilient rural landscapes.
- ▶ Engagement of the local community and with other stakeholders has been a critical project activity from the outset of the scheme. Such processes take time and require a variety of tools and approaches.
- ▶ Regular and sensitive engagement has created an environment within the local community that makes all those involved with the catchments more amenable to suggestions for land management changes that have multi-beneficial outcomes.
- ▶ A local project manager involved in all elements of NFM identification, approval and implementation, together with the stakeholder engagement activities, greatly contributed to the success of the project.
- ▶ The processes adopted and the outcomes from Holnicote are influencing NFM initiatives elsewhere in Somerset and the UK. Individuals, community groups, statutory and non-statutory organisations are using the Holnicote scheme to give support to the momentum for change in the use of NFM.

I. Background

Determining and predicting the influence and contribution that rural land management practices have on catchment scale flood risk management is a topic of national importance. Extreme weather events that have occurred over the last 15 years in the UK have highlighted the significant economic and social costs associated with major flooding incidents. These recent flood events have prompted a greater interest in the role of surface runoff generation from the rural environment and the inter-relationships between river channels and floodplains in catchments. The notion that by changing the way our rural catchments are managed could positively contribute to reducing flood risk, through the processes of flow attenuation and flood storage is very attractive.

In 2009, in response to one of the recommendations of the Pitt Review of the Summer 2007 Floods, Defra commissioned three new Multi-Objective Flood Management Demonstration Projects, including the Holnicote Project on the National Trust Holnicote Estate in West Somerset. The projects were all tasked with generating hard evidence to demonstrate how working with natural processes, implementing a range of natural flood management (NFM) measures, and utilising a partnership approach, can contribute to reducing local flood risk while producing a wide range of other benefits for the environment and communities. Working with natural processes represents a range of techniques that

aim to reduce flooding by working with natural features and characteristics to store or slow down flood waters.

The project has been completed through the delivery of the following elements:

1. Catchment characterisation and implementation of an extensive hydrometric monitoring network
2. Exploration of potential NFM opportunities, including modelling and multiple benefits
3. Engagement with catchment stakeholders on NFM and wider benefits
4. Selection of NFM measures for implementation
5. Acquisition of the necessary consents/approvals for implementing NFM measures
6. Implementation of NFM measures
7. Quantification of NFM benefits
8. Identification of future NFM initiatives

The range of NFM measures that have been successfully implemented at Holnicote since 2011 include: moorland drainage impedance, woody debris dams and accumulation, woodland creation, leaky weirs and offline flood storage areas. Advice has also been provided to the land managers on soil management practices in arable and grassland systems.



II. Catchment characterisation and interventions

SETTING

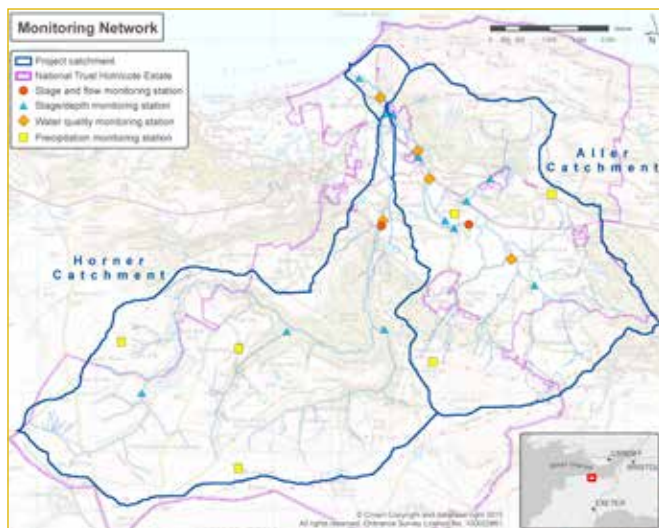
The Holnicote Estate covers the majority of two study catchments, Horner Water and the Aller. The catchments are located on the north-east edge of Exmoor National Park and flow down to the sea in Porlock Bay. The Horner Water catchment has an area of about 22km². The Horner Water, is about 15km long and drains the hills of Exmoor to the confluence with the River Aller, from where the combined river flows into Porlock Bay by seeping through a large shingle ridge. The topography of the catchment is characterised by extensive high upland moors at the headwaters (Exmoor) at about 500mAOD; with rapid response steep wooded gullies and combes further downstream at about 300mAOD with very confined floodplains, sloping down through woodland, grassland and arable land uses towards the low lying areas (around 20mAOD) at the confluence with the River Aller. The uppermost 20% of the Horner catchment flows through a small water supply reservoir (currently not operational), Nutscale Reservoir, managed by Wessex Water, which does exert a control on stream flows in this area, before it passes through a nationally important area of ancient oak woodland called Horner Wood. Most of the Horner catchment is SSSI, SAC and NNR and includes a high concentration of nationally important archaeological features.

The Aller catchment has an area of about 18km² and the river is about 7km long. The topography of the catchment is generally lower than that of the Horner catchment, ranging from about 400mAOD in the moorland headwaters to around 40-50mAOD in the middle reach of the Aller encompassing a range of woodland, grassland and arable land uses, together with the villages of Allerford and West Lynch. The middle and lower Aller catchment contains a wider floodplain than the Horner does and in parts this floodplain has been actively managed as flood meadows in the past. The catchment area downstream of the confluence of the Aller and the Horner drops down from about 20mAOD in the river valley to sea level, containing mostly grassland and arable land uses with woodland on the eastern valley side and the village of Bossington.

The flood risk receptors are the villages of Allerford, West Lynch and Bossington. Properties in these villages are at risk of flooding from local watercourses, which are also influenced by a legacy of flow constrictions within the drainage networks, such as narrow historic stone bridges, and the lack of undeveloped channel and floodplain capacity through the built-up areas.

MONITORING

The development of the hydrological monitoring network, as illustrated in the map below, was informed by the investigations reported in the Inception Process Report (2010), which covered the project objectives, catchment scoping, proposed NFM interventions and logistical considerations.



Hydrological Monitoring Equipment Network

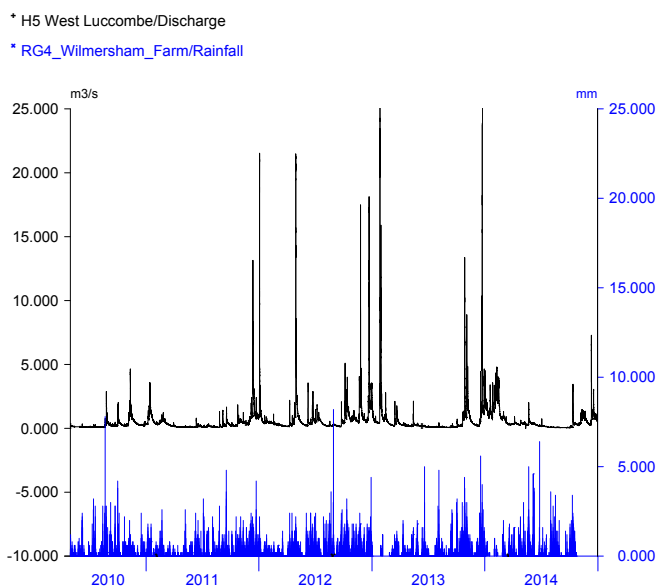
The monitoring network was designed to provide high-quality, high resolution rainfall, stage and flow data for assessing the impacts of NFM measures on flood risk in Bossington, Allerford and the Piles Mill area through hydrological data analysis and modelling approaches. Suspended sediment data were also collected for key sites in the Aller catchment, as part of a PhD research project, which formed part of the overall project output. A standard measurement interval of 15 minutes was chosen for the study in order to achieve a high resolution dataset suitable for computer modelling requirements; 15 minute resolution data offering a practical trade-off between resolution and data volume.

The instrumentation network was installed and commissioned in spring of 2010. The siting of each monitoring station was carefully chosen through a rigorous, multi-criteria evaluation of project requirements in order to locate the best locations for monitoring at sites likely to be most sensitive to NFM-related interventions. The instrumentation network

has provided high-quality data over the lifespan of the project and has largely proved to be highly reliable.

At the project implementation stage, the instrumentation network was considered 'optimal' for the purposes of the study. Over the course of the project however, it became clear that several instruments were located at sub-optimal locations and, as a result, the monitoring network has gone through some minor changes and updates. The issue of data telemetry (via UHF radio and cellular mobile GSM) has also proved problematic in several locations due to the challenging topography of the Horner and Aller catchments and these issues are also currently being addressed. Other challenges have included equipment reliability, power issues and even the logistical difficulties associated with regular visits to remote sites for equipment maintenance and data download. In addition, as the project developed, it became clear that there were data and instrumentation 'gaps', which have since been filled with the installation of additional monitoring equipment. Many lessons have been learnt concerning the siting, deployment and ongoing maintenance of hydrological monitoring instruments in this type of environment.

The graph below illustrates some typical hydrometric data output, expressed in terms of near real-time flow, (calculated from measurements of stage and a stage-discharge rating formula) and rainfall totals.



Typical recorded rainfall and flow data series, for station H5, Horner Water at West Luccombe and EA Raingauge at Wilmersham Farm (RG4): Spring 2010 - Winter 2014

2009 Project commences

2010 Installation of main hydrological monitoring network

2011-2015 Implementation monitoring period

2012 Horner moorland drainage management works

2009-2010 Catchment characterisation period

2010-2011 Baseline monitoring period

2011 Horner moorland drainage demonstration works

INTERVENTIONS

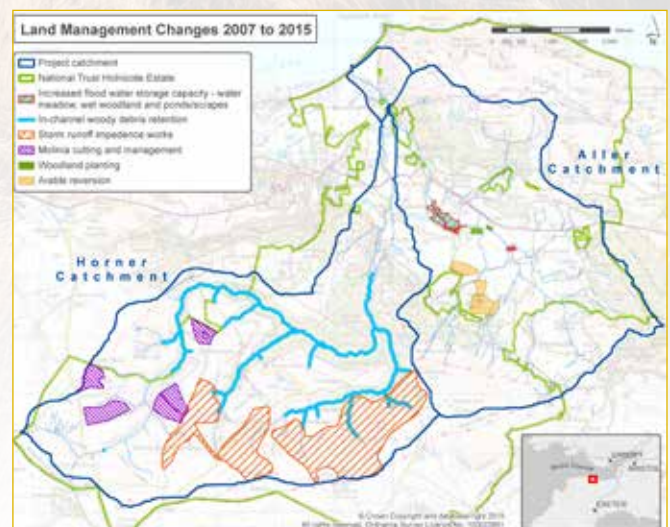
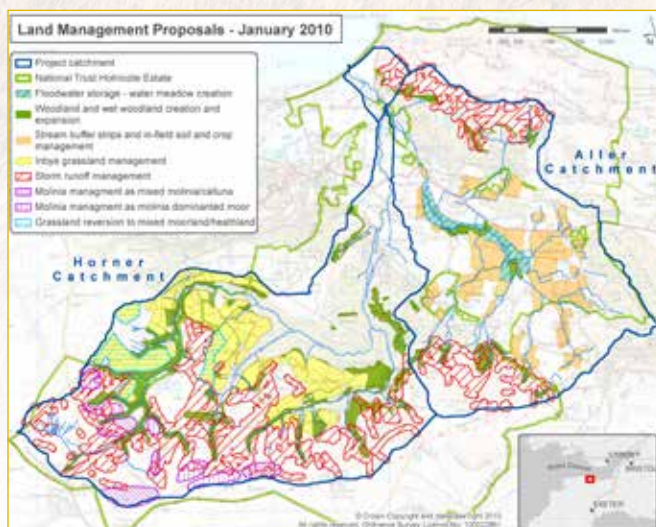
The project was initiated in July 2009 and by January 2010 an Inception Phase Process Report was published which established the environmental and hydrological characterisation of the two catchments, together with details of the scale of required land management changes thought necessary to achieve the project objectives. In addition, this report also specified the hydrometric and water quality monitoring required for the project. It became apparent at this stage that the initial presumption that agri-environment payments would be the key funding source for catchment change was overly optimistic. Change at a scale and a type of that being recommended would be unlikely to qualify for funding under the existing farm payment schemes so alternative and supportive funding approaches had to be adopted.

Between January 2010 and the publication of the first Progress Report in April 2011 an array of river level/flow, rainfall and water quality systems had been established in the two catchments. Proposals for land management change were being refined and the process of consultation and engagement were well underway. Ecosystem services analysis was initiated through the involvement of Cranfield University. At this time the notion that catchment scale changes could be made to deliver flood risk and other benefits within the project's three year time frame were questioned and Defra, the National Trust and the Environment Agency agreed to extend the project period to six years. Given delays in the

commencement of monitoring the catchments this led to an agreed finish date of March 2015.

Although the project timeline below indicates several key dates when land management works sponsored by the project were being implemented, numerous activities were continuing throughout the project period. In particular, the process of community involvement, consultation, communication and project promotion was continuous. As the project area lies within a national park and much of the land is designated SAC, NNR and SSSI, great care was taken to consult and engage with statutory organisations, local authorities, interest groups, other landowners and tenants to ensure that any proposed land management changes enhanced the landscape and habitats without damage or detriment to any conservation or archaeological features. It was also important to promote the project as a demonstration model to the widest audience ranging from local residents, farmers, land managers and communities throughout Somerset to academic institutions, other project managers, interested organisations and the press at a local and national scale.

Additionally, ecosystem services evaluation and later the drive to explore the potential for a Payments for Ecosystem Services (PES) scheme was an ongoing programme. Likewise, the development and refinement of the hydrometric and water quality monitoring systems and the tools used for the analysis of the results have been continuous work streams.



2012 Horner Wood artificial woody debris dam construction

2013 Aller Flood storage area construction

2013 Horner purple moor grass (Molinia) reversion works

2012 Aller Paddock Wood pond restoration works

2012/14 Aller Woodland creation and arable reversion

2012/13/14 Major flood events

III. Assessment of effects

MONITORING THE EFFECTS

Hydrology

The Holnicote Project required rainfall, river stage and flow (calculated by rating) data in order to characterise each catchment's hydrological behaviour and determine areas at risk from flooding, for the purposes of assessing the impacts of catchment NFM interventions.

For the purposes of hydrological modelling for flood risk and statistical analysis of flow variability and hydrograph response, it was critical to collect a representative baseline of flow data for each station on the network, in order to be able to characterise hydrological characteristics and response of both the Horner and Aller catchments before any NFM interventions were applied.

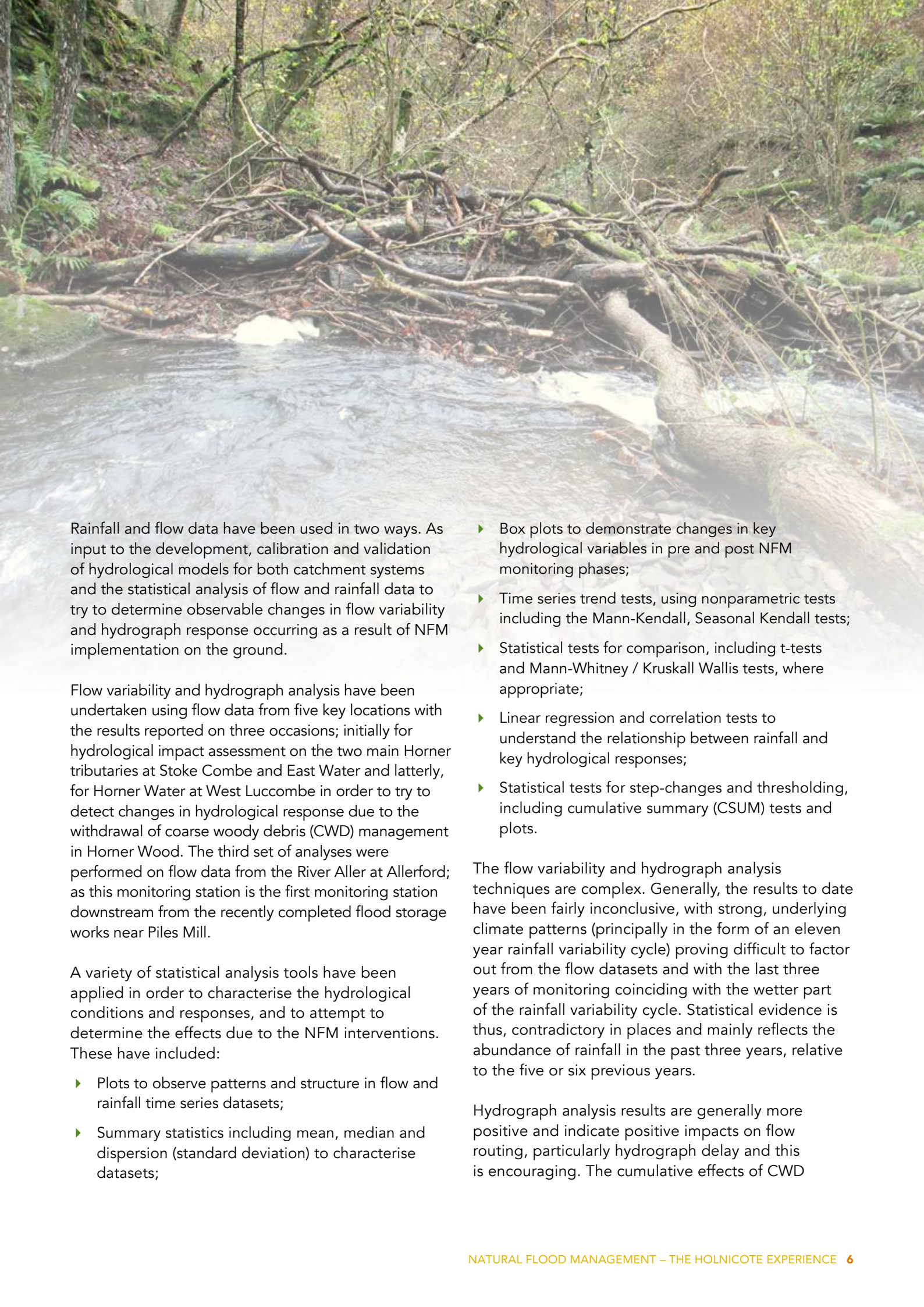
As the Holnicote Project has a finite lifespan, the size of the baseline dataset was restricted to two years of data (and in some cases, slightly less) before the initial catchment NFM works proceeded. For example, the moorland drainage impedance work on the Horner headwaters catchment was undertaken at a fairly early stage in the project cycle and so baseline datasets are somewhat limited.

However, it has been possible to characterise the 'signature' annual flow pattern for key tributaries on both catchments. In general, flow can be described as higher on the Horner, due to the higher catchment elevation and stream gradient; when compared to the lower and flatter Aller catchment. Catchment flow response on both catchments is dominated by generally dry summers and much wetter winters; where winter flow is controlled by successive 'swarms' of rainfall-runoff events, generated by series of frontal systems crossing the UK from the Atlantic and continental Europe. Generally, both catchments remain very dry during the summer months, though at times, flow is influenced by summer frontal rainfall and thunderstorm-based rainfall events, which can be very intense in this part of the UK.

Rainfall, stage and flow monitoring has continued during and after the implementation of catchment NFM interventions, including moorland drainage impedance work on the Horner, purple moor grass (*Molinia*) reversion (Upper Horner), the removal of coarse woody debris management in Horner Wood SSSI (mid Horner), wet woodland creation (mid Aller) and the completion of the flood storage scheme on the mid-Aller floodplain between Piles Mill and Paddock Wood.



Left to right: Shallow earthen flood storage bunds on Aller floodplain; Aller leaky sluice; Aller river level gauge; and Raingauge station.



Rainfall and flow data have been used in two ways. As input to the development, calibration and validation of hydrological models for both catchment systems and the statistical analysis of flow and rainfall data to try to determine observable changes in flow variability and hydrograph response occurring as a result of NFM implementation on the ground.

Flow variability and hydrograph analysis have been undertaken using flow data from five key locations with the results reported on three occasions; initially for hydrological impact assessment on the two main Horner tributaries at Stoke Combe and East Water and latterly, for Horner Water at West Luccombe in order to try to detect changes in hydrological response due to the withdrawal of coarse woody debris (CWD) management in Horner Wood. The third set of analyses were performed on flow data from the River Aller at Allerford; as this monitoring station is the first monitoring station downstream from the recently completed flood storage works near Piles Mill.

A variety of statistical analysis tools have been applied in order to characterise the hydrological conditions and responses, and to attempt to determine the effects due to the NFM interventions. These have included:

- ▶ Plots to observe patterns and structure in flow and rainfall time series datasets;
- ▶ Summary statistics including mean, median and dispersion (standard deviation) to characterise datasets;

- ▶ Box plots to demonstrate changes in key hydrological variables in pre and post NFM monitoring phases;
- ▶ Time series trend tests, using nonparametric tests including the Mann-Kendall, Seasonal Kendall tests;
- ▶ Statistical tests for comparison, including t-tests and Mann-Whitney / Kruskal Wallis tests, where appropriate;
- ▶ Linear regression and correlation tests to understand the relationship between rainfall and key hydrological responses;
- ▶ Statistical tests for step-changes and thresholding, including cumulative summary (CSUM) tests and plots.

The flow variability and hydrograph analysis techniques are complex. Generally, the results to date have been fairly inconclusive, with strong, underlying climate patterns (principally in the form of an eleven year rainfall variability cycle) proving difficult to factor out from the flow datasets and with the last three years of monitoring coinciding with the wetter part of the rainfall variability cycle. Statistical evidence is thus, contradictory in places and mainly reflects the abundance of rainfall in the past three years, relative to the five or six previous years.

Hydrograph analysis results are generally more positive and indicate positive impacts on flow routing, particularly hydrograph delay and this is encouraging. The cumulative effects of CWD



Clockwise from top left: Erosion rill generation in Aller arable field; Runoff delivering sediment from fields into Aller river; Flooding through riparian woodland; and runoff and erosion from Horner in-bye grass field.

accumulation in the stream and river channels of Horner Wood, coupled with the earlier moorland drainage impedance works are having a positive effect on slowing flow and reducing potential flood risk. At this stage, it is important to note that changes appear slight.

Similarly, hydrograph response and flow variability results for the Aller downstream of the large scale flood meadows scheme at Holnicote demonstrate little change, except during very high flow conditions, when flow overtops bank level and the system of flood storage bunds become active. Statistical evidence is supported by the results of the hydrological flood modelling, which are reported elsewhere in this report.

The statistical analysis of flow requires long-term datasets, demonstrating a range of hydrological activity over many years to be useful. The relatively short period of monitoring at Holnicote has so far produced relatively modest datasets and this has

hindered statistical testing and made interpretation of results more difficult. With time, flow datasets will become larger and more representative of real conditions and responses on catchment and as the size of these datasets increases, there will be increasing certainty in statistical results. For this reason, coupled with the ongoing planned programme of NFM interventions on catchment (particularly on the Aller), it is critical that the hydrological monitoring programme is continued in its current form.

Water quality

A PhD thesis undertaken during the course of the Holnicote Project by Miriam Glendell, Exeter University, evaluated the effects of upland ditch blocking on physico-chemical and biological parameters of water quality in the upland Horner catchment one year after some targeted restoration works, and established a solid baseline for the

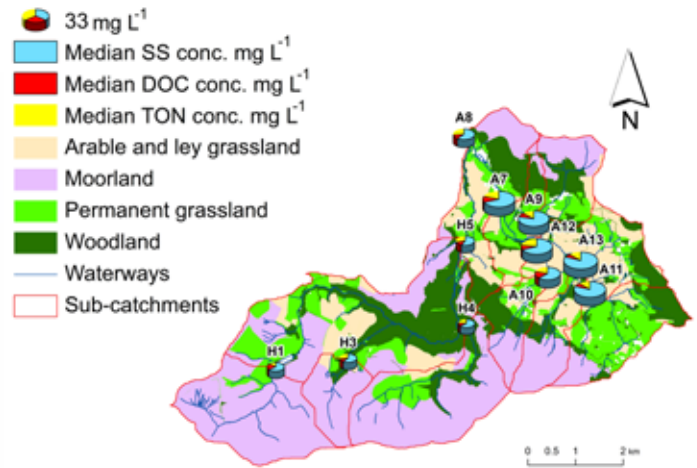
monitoring of the effects of current and future land management changes in the more intensively managed, agricultural Aller catchment.

The spatial variability of soil physical and chemical properties was characterised in the two study catchments with contrasting land use to identify the likely critical source areas of diffuse water pollution. The research found that agricultural land use resulted in extensive alteration of soil physical and chemical properties, which is likely to have long-term implications for the restoration of ecosystem functioning and water quality management.

The intensive land use seems to have resulted in an altered 'catchment metabolism', manifested in a proportionally greater total fluvial carbon (dissolved and particulate) export from the Aller than from the Horner catchment. During an eight month period for which a comparable continuous turbidity record was available, the estimated suspended sediment (SS) yields from the agricultural catchment (26-116 t/km²) were higher than from the semi-natural catchment (22-58 t/km²), which corresponded well with visual evidence of erosion episodes particularly in the Aller catchment.

Upland drainage management has not had any discernible effect on water quality in the Horner headwaters one year after restoration, which may be due to the short-term post-restoration monitoring period but may also reflect benign effects of the targeted restoration works that were undertaken in this high quality environment.

Prior to the implementation of land management changes, the greatest concentrations of Suspended Solids (SS), Dissolved Reactive Phosphorus (DRP) and Total Oxides of Nitrogen (TON) were recorded in the middle reaches of the Aller catchment, reflecting the enhanced input of sediment and nutrients from the intensively farmed arable and grassland land uses. Field observations identified a number of direct preferential overland delivery pathways of sediment from arable fields along paved roads. The conversion of arable land on steep slopes within the Aller catchment is likely to reduce this source of enhanced



flux of sediment into the watercourse, as are the proposed floodplain bunds.

Whilst the observed median TON concentrations in the Aller catchment between 6.5 – 10.4 mg TON L⁻¹ are low, compared to the current freshwater drinking standard of 50 mg TON L⁻¹, they are above the perceived eutrophication level of 2.2 – 4.4 mg TON L⁻¹ for running waters. The extended period of soil saturation in the floodplain and the introduction of wooded riparian areas is likely to lead to enhanced denitrification and thus help to reduce TON concentrations in the middle reaches of the Aller catchment.

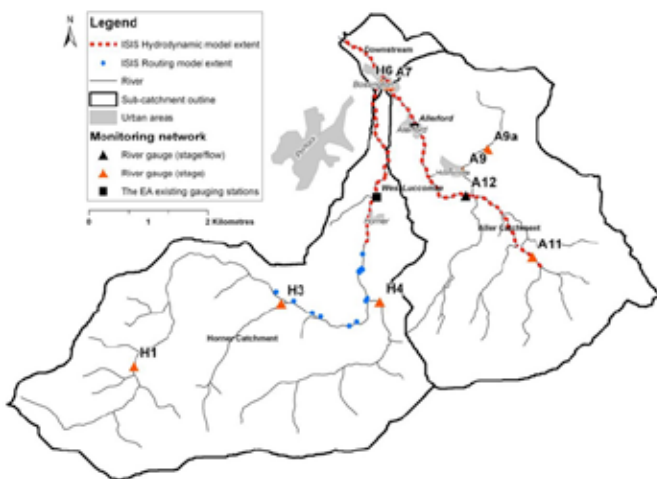
This element of the Holnicote Project has highlighted the profound influence that agricultural land use and land management has on soil properties and the enhanced export of sediment and carbon from the terrestrial to the aquatic ecosystem. These extensive alterations to ecosystem processes may have important implications for the timescales over which improvements in water quality can be achieved at a catchment scale. However, the study also found that a relatively simple approach such as the new invertebrate index PSI has the potential to be developed into a sensitive tool for setting and measuring of ecologically meaningful water quality targets in relation to sedimentation impacts.

MODELLING THE EFFECTS

Catchment modelling

A linked 1D-2D full hydrodynamic river channel and floodplain model was built to represent the lower and middle reaches of the rivers Aller and Horner Water. The model was produced using a specifically commissioned river channel and floodplain topographic survey, the ISIS software for the river channel and the TUFLOW software for the floodplain. The two models were linked in order to adequately represent the river-floodplain flow interactions.

The upper reaches of the River Horner were represented using a routing model, before the 1D-2D linked model begins just upstream of the village of Horner. The 1D-2D model on the Aller begins close to the A11 gauge, upstream of Blackford.



Floodplain storage opportunity mapping

At the start of the project, no previous detailed hydraulic modelling had been undertaken in this catchment, despite the known flood risk to a number of communities. There was also considerable uncertainty about the key flood mechanisms present within the catchment and the overall risk. During the initial stages of the project, the model was used to improve the understanding of the behaviour of the system in extreme floods, and to better understand the communities at risk.

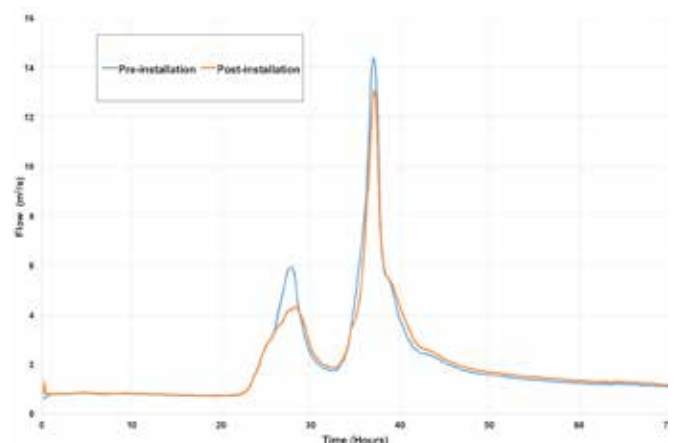
The model was also used, (in conjunction with local knowledge) to map key areas where NFM interventions may contribute to a reduction in flood risk to communities downstream. One such location was the Aller floodplain upstream of Allerford, between Piles Mill and Paddock Wood.

Flood storage bunds near Holnicote House

Once the floodplain between Piles Mill and Paddock Wood was identified, the 1D-2D model was firstly used to refine the design of the bund and associated leaky sluice system, maximising the effectiveness of the proposed design. The detailed modelling work was integral to overcoming various regulatory hurdles, including Flood Risk Assessment, Land Drainage Consent and compliance with the Reservoirs Act, and gaining permission for the construction to take place. The bunds were constructed in the summer of 2013, and an as-built survey was commissioned, which allowed the exact dimensions of the bunds, together with the in-stream structures and floodplain lowering, to be included in the model. The model was then used to investigate the impact of the as-built bunds on downstream flood risk.

The winter of 2013/14 was very wet and there was a significant flood on 23-24 December 2013, following 50mm of rainfall over a 24 hour period falling on an already saturated catchment. Comparison of the recorded discharge at Allerford during the flood event suggested that this event had a return period of 75-100 years. However, it must be noted that events of a similar size were recorded in October 2000 and November 2012 respectively, which would suggest that three events of greater than 75-year return period in 14-years. This is unlikely because two of these events have occurred after the original flood estimation work was undertaken for this catchment. The intention is to revisit the flood frequency analysis when more flood event data have been collected.

During this flood event there is a decrease in peak flow just upstream of Allerford from 14.4m³/s to 13.1m³/s (a



Flows just upstream of Allerford during the 23-24 December 2013 event

a 10% reduction), as consequence of the operation of the floodplain storage systems, combined with a small delay in the timing of the flood peak.

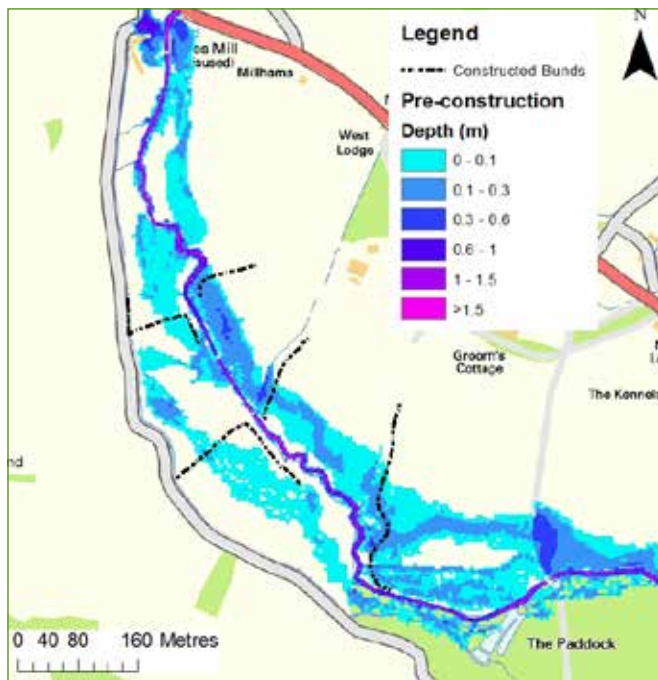
The figures below show that the introduction of the bunds leads to a very different pattern of inundation in and around the bunds. In Allerford, the modelled flood outline produced by the post-installation scenario is smaller than that produced by the pre-installation scenario. In particular, flooding of the right hand floodplain downstream of the bunds, close to Brandish Street Farm, which had occurred in the pre-installation scenario, did not occur in the post-installation scenario. The table below includes model runs that explored different flood magnitudes and the resulting benefits of the flood storage bunds.

Runoff attenuation opportunity mapping

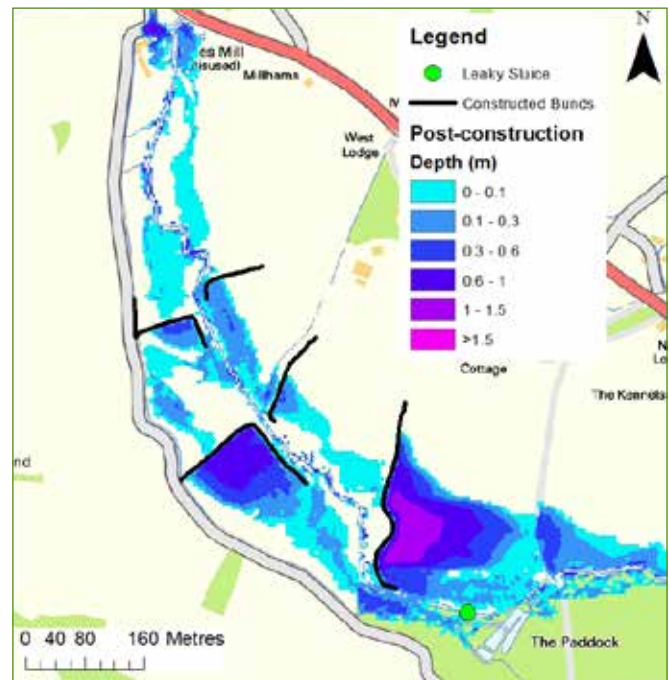
A key element of the Holnicote Project has been to use modelling approaches and spatial analysis tools to assist in the identification of possible locations across

parts of the catchments where particular NFM measures could be implemented. A methodology was developed, using JBA's JFLOW 2D raster-based inundation model, to identify areas where surface runoff would naturally pond due to depressions in the topography, and also to identify flow pathways connecting such areas with the main arterial drainage network. Excess incident rainfall from a particular design rainfall event is routed across the surface of a detailed digital terrain model (DTM) taking in account the surface characteristics of the ground. Once identified and screened, taking into account constraints such as archaeology, heritage, ecology, environmental designations, land ownership, etc., these flow pathways and depressions could be modified by introducing combinations of surface runoff control and temporary flood storage measures.

This modelling approach, combined with spatial analysis of the DTM, was initially used in the headwaters of the Horner catchment, on Exmoor, to target the primary surface runoff pathways that were delivering water to the arterial drainage network, which in this



Flood depths – pre installation, 23-24 December 2013 event.



Flood depths – post installation, 23-24 December 2013 event.

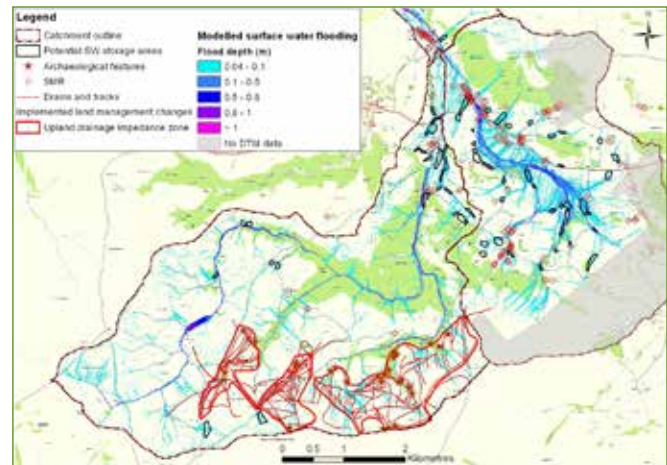
Flood return period (years)	Peak flow (m ³ /s)	Peak flow (m ³ /s)	% reduction in peak flow	Delay in time of peak flow (mins)	Volume stored on floodplain (m ³)	Volume stored on floodplain (m ³)	Increase in volume stored on floodplain (m ³)
	without bunds	with bunds			without bunds	with bunds	
2	3.6	3.3	9	1	12	1,840	1,828
5	5.5	4.1	25	35	33	10,652	10,619
20	7.7	7.4	5	13	2,278	17,808	15,530
100	17.5	17.5	0	13	12,366	35,464	23,098
Event 24/12/2013	14.4	13.1	10	3	7,956	25,772	17,816

The effect of the floodplain bunds between Piles Mill and Paddock Wood on the flood hydrograph and volume stored.

case was the large network of interconnecting pathways and tracks that criss-cross the landscape here. Outputs from the modelling work, verified by a detailed site walkover, led to the development of the proposals to install over 800 shallow earthen bunds across selected pathways and tracks to route surface runoff back onto the much rougher moor surface, where the runoff could be slowed and/or temporarily stored. The modelling was also able to identify small depressions in the topography where it could be possible to excavate small ponds where some of this excess surface runoff could be re-directed for temporary storage. These features were constructed across three target areas in the Horner headwaters during 2012.

The same modelling approach was subsequently applied across the rest of the Horner and the Aller catchments to map strategic opportunities for NFM interventions of this type. One of the findings from this work in association with local observations, particularly for the more intensively farmed parts of the Aller catchment, identified that access routes into fields (e.g. gateways) are often key preferential pathways through which a considerable amount of runoff and soil loss can occur onto roads during intense heavy rainstorms. Wherever possible these critical flow routes should be managed in order to reduce the surface runoff and soil loss from the fields; for example, by moving the gateway and infilling the opening with a hedge or wall, or by diverting the runoff away from the gateway area and into an appropriate small temporary flood storage pond or soak-away located in the same field.

The outputs from this opportunity mapping are intended to be used to target the implementation of additional NFM interventions in the future as/when the appropriate funding and permissions can be put in place.

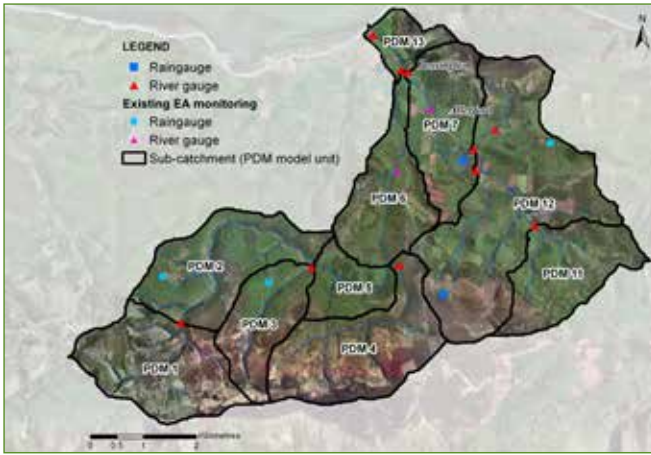


Runoff attenuation opportunity map.

Modelling the effect of soil condition on runoff generation

A desk based investigation was undertaken to explore how soils, soil condition and soil management in agricultural fields across parts of the Holnicote Estate affect the potential generation of rapid surface runoff across field surfaces. The generation of this surface runoff, together with its subsequent conveyance into the arterial drainage network, greatly affects flood flows in the river Aller and Horner Water which can produce potentially damaging consequences to the properties at risk of flooding in the villages.

The characteristics of the soils across the Aller and Horner catchments contain a legacy of both recent and historical land management practices. Intensive livestock production in the improved grassland areas and/or livestock grazing on potentially vulnerable soils during wet winter months can cause vulnerable soils to compact and/or cap thereby losing some or all of their



PDM units in the Aller and Horner catchments, together with the hydrological monitoring network.

inherent infiltration capacity. Certain arable cultivation and/or harvesting techniques may have generated plough pans or other compaction/capping problems that reduce infiltration of incident rainfall into the soils. However, these degraded conditions, generally producing more and faster runoff, will not necessarily be present across the entire catchment or at the same time. Some areas of the catchment will have maintained naturally good soil structural conditions allowing water to rapidly infiltrate the soil surface and not run off across the soil surface, such as wooded areas, more extensively managed older grasslands or semi-natural surfaces. In addition, well managed arable cultivation techniques on certain soil types can actively improve the infiltration of incident rainfall into the soil profile where temporary storage and slower drainage will take place.

The wide variety of land management and soil management practices employed across the Aller and Horner catchments will have produced a mosaic

of good to poor soil structural conditions and their associated hydrological characteristics. The soil assessment commissioned by the NT with EA funding in 2011 across the Holnicote Estate reported that more than 50 per cent of all sites under the range of arable crops grown (i.e. maize, cereals, roots) required urgent remediation of the soil structural condition (due to high or severe levels of soil structural degradation) in order to reduce their high risk of runoff generation.

The PDM rainfall-runoff modelling approach can be used to simulate flow outputs from catchment areas by determining the movement of rainfall inputs through three linked stores, namely the (i) soil moisture storage, (ii) surface storage and (iii) groundwater storage. The Aller and Horner catchments were split into 10 sub-catchment areas (or PDM units) and a PDM model was constructed for each.

A detailed knowledge of the characteristics of each of the modelled sub-catchments, together with the hydrological properties that determine the likely response to rainfall, were crucial to the setting up of the initial PDM model configurations. This ensured that the physical processes in each sub-catchment area were adequately represented before the calibration of the model took place using measured flow datasets.

The premise of the methodology applied at Holnicote is that particular parameters in the PDM model can be altered to reflect certain types of land management change in a catchment or sub-catchment, especially with respect to soil management practices affecting the soil condition and its physical characteristics. By altering these PDM parameters in specific ways, based on previous academic research, either positive or negative impacts of particular soil management change can be investigated in a comparative way.



CASE STUDIES



Sediment laden floodwaters in Allerford.

Upper Aller catchment (PDM11)

This PDM unit is diverse with just over 50% of the catchment being actively managed for arable production or improved grassland, often on relatively steep slopes where rapid surface runoff and erosion episodes have been observed. Some of the underlying soil types here are quite sensitive to land and soil management practices which could affect their condition. The modelling of various flood magnitudes (2 year to 100 year return periods) have indicated that the consequence for altering the soil structural condition from good condition to severely degraded condition, as result of inappropriate and/or untimely soil/land management practices could lead to an increase in the peak flow leaving the outlet to this PDM unit by 7%-9%.

Upper Horner catchments (PDM2/PDM3/PDM4/PDM5)

These PDM units contain various amount of in-bye (improved) grassland ranging from 7% to 35% of the PDM catchment area, some of which is also on quite steeply sloping ground between the moorland edge and Horner Wood. Episodes of rapid runoff and erosion have been observed from some of in-bye fields, especially during wet winter periods. Modelling the effects of changing the soil structural condition from good to severely degraded for a range of flood magnitudes, in the same way as PDM11, could lead to an increase in the peak flow leaving the outlet to each PDM unit by up to 6%, with the higher values derived from those units containing a larger proportion of improved grassland.

The results from these case studies indicate how sensitive parts of the catchment can be to land/soil management decisions. A better understanding of the complex interactions between the soils, land use, land/soil management, all set within the physical, environmental, climatic and socio-economic characteristics of the Holnicote catchments, by using this type of modelling approach, is helping to inform the debate about the future management of the Holnicote Estate and assist in the targeting the implementation of appropriate NFM measures across different parts of the catchment landscape.



Left to right: Sediment transport from Aller arable fields; In-bye grass fields above Nutscale Reservoir; Horner moorland drainage impedance bunds; and Sediment deposition following erosion from Aller arable field.

IV. Multiple benefits

An Ecosystem Services approach has been central to the evolution of the Holnicote Project. An initial ecosystem services assessment was produced as a thesis by Christopher Taylor as part of his MSc at Cranfield University. In this document the evaluation of potential environmental benefits (services) associated with land management change was based on an idealised array of land management change within the two Holnicote catchments. These proposals recommended landscape-scale changes that the Project consultancy team believed to be of an appropriate nature and scale to affect positive benefits to flood risk within the two catchments.

As the Project progressed it became apparent that for a variety of economic, social and environmental reasons many of the proposed land management changes could not be delivered either within the timeframe of the project or because of conflicting land use aspirations and services currently held within the catchments. As deliverable land management changes evolved within the Project a second round of ecosystem services assessments was undertaken by the consultancy team in 2011.

This second ecosystem assessment attempted to make the best use of the data available to address the relative value of ecosystem goods and services resulting from the now altered range of proposed landscape-scale habitat modifications. It was recognised that these changes, although aimed at flood risk management for those local to the Holnicote Estate, would engender a range of associated benefits including enhanced biodiversity, aesthetic improvements, and timber production. Following on from this second, habitat based ecosystem services assessment, a workshop was convened with the Ecosystems Knowledge Network and Valuing Nature Network in 2012 to form the basis of future ecosystems work for the Project.

The next round of ecosystem services work for the Project was to focus on developing a further round of land management change proposals for both catchments which would take account of the current prospects and deliverability of change by the National Trust. These proposals would act as the future scenario against which services and benefits may be evaluated and a new evaluation would be made focussing on social and cultural services.





Flood storage and biodiversity benefits following Paddock Wood pond restoration.

During 2013 there was, however, a growing interest in the concept of Payments for Ecosystem Services (PES) being driven by a series of Defra funded pilot projects. These pilots demonstrated a range of novel approaches to securing funding from beneficiaries of ecosystem services which delivered tangible outcomes for the environment.

The PES concept chimed with the aspirations of the Holnicote Project to secure continued funding for a suite of land management measures which would allow for:

- ▶ the Project to become self-financing;
- ▶ environmental and other benefits such as positive engagement with local and national stakeholders accrued through the Flood Demonstration Project to be optimised and extended to deliver additional wider and multiple benefits;
- ▶ potential for additional land management changes to be implemented over a wider geographic scale within the project area; and
- ▶ the continued generation of long-term monitoring datasets to provide the evidence base for the demonstration of multiple benefits derived from catchment scale land management change.

In early 2014 the Project team successfully secured Defra funding to develop the PES concept at Holnicote as one of five Round 3 PES Pilot Projects. The aim of these pilots was to take the PES concept forward to the development of novel markets for ecosystem services. At Holnicote the PES approach focused on identifying and engaging with beneficiaries of a catchment wide approach to flood risk management to promote and generate support for continuation of the project by demonstrating tangible benefits in reduced flood risk, as well as wider benefits for ecology, water quality, soil management and carbon sequestration.

CASE STUDY

In 2011, with the support of the Environment Agency (South West Region) Habitat Creation and Restoration initiative the National Trust commissioned a feasibility study into the possibility of permitting some of the flood water from Horner Water, at a point downstream of Bossington, to overflow via a control structure into an open overflow/diversion channel. This channel would then convey flood flows south westwards before ultimately discharging onto a field surface within the Porlock Ridge & Saltmarsh SSSI. The flood water would then eventually find its way into an existing inter-tidal lagoon near Porlock Weir that has a permanently open exit route out into Porlock Bay.

The primary driver for this overflow/diversion channel scheme was the potential enhancement of existing inter-tidal habitats (including saltmarsh) behind the shingle bank in the area between an old disused landfill site and the existing inter-tidal lagoon near Porlock Weir. A secondary benefit was the possibility of some reduction in the flood risk for the residents of Bossington.

The feasibility of the proposed scheme was explored within the context of all the environmental considerations and constraints of the locality, and the requirements of the statutory planning and consenting procedures. The exercise included hydraulic modelling of the existing fluvial-tidal flood dynamics in the area and the exploration of the possible effects of the scheme on flood risk in Bossington.

A workshop and site walkover with all the key statutory and non-statutory stakeholders was convened to openly discuss the outcomes of the feasibility study. The model results indicated that the properties within Bossington are on higher ground well above the extreme tide levels being modelled. Model test runs were carried out both with and without the shingle ridge present to assess the sensitivity of the Horner Water channel to the backing up of fluvial flows during periods of high tidal levels. With or without the shingle ridge the tides did not affect the flooding within Bossington. Even when there are high fluvial flows within the Horner Water, the flow would be able to overtop the former landfill site and enter the saltwater lagoon or drain away into the sea as soon as the tidal cycle allows. Model results with the diversion channel in place indicated that flood levels would only be reduced locally and downstream of the diversion channel, but not upstream into Bossington.

Given the extremely limited benefits in terms of flood risk, the considerable visual impact that the constructed scheme would bring, together with the provision of only a limited amount of habitat improvement, the stakeholders took a collective decision that the scheme would not be taken forward. This decision, taken following a full and open discussion with stakeholders and the local community, provided an extremely positive example of the value of public engagement in the local development planning process.

By retaining storm water runoff within the upper catchment of the Horner, and storing flood waters on the floodplain of the River Aller subtle shifts in the ecological and wildlife potential of these catchments has been initiated. On the Aller the number of wintering waders and wildfowl, such as snipe and teal have increased significantly since 2013. Above Horner Wood the creation of ephemeral pools associated with storm water runoff management has already seen benefits to invertebrate diversity on the moorlands. Similarly, management of woody debris within the river channel has increased opportunities for aquatic invertebrates and enhanced the foraging habitat for the dipper population. Additionally, the ecological functions of newly planted woodland blocks in the Aller are being enhanced by the reversion of adjacent arable fields to pasture, and the exclusion of winter livestock on parts of the Aller floodplain is creating opportunities for improved sward diversity in riverside grasslands.

The additive environmental and ecological impacts of these changes in land management will take time to be fully realised but the direction and momentum is positive, and is supporting the realisation of the multiple benefits of catchment scale changes originally focussed on flood risk management.

The PES pilot has laid the foundations for the National Trust to place an ecosystem approach at the heart of catchment wide land management. It has explored the potential mechanisms for generating income at Holnicote and other properties which can be taken forward as part of the Land Choices programme and, in partnership with the Environment Agency, the Catchments in Trust initiative.



Creation of habitat scrapes on Aller floodplain at Blackford.

V. Outcomes and lessons learnt

Monitoring and modelling

By far the most important outcome from the Holnicote Project is that the project has demonstrated that real, tangible benefits in terms of the reduction of flood risk can be achieved by implementing a portfolio of well thought out, targeted NFM measures and interventions on the ground. Furthermore, results suggest that these benefits are having positive impacts on hydrology and the reduction of flood risk on a catchment scale larger than many seen previously, and will help to provide some resilience to projected future climate change effects.

Modelling results are strong and statistical evidence, although somewhat cautious, all indicate positive impacts on flow peak flow attenuation and delay and this is backed up by anecdotal and visual evidence on the ground.

The Holnicote Project has proved invaluable in terms of lessons learnt. This is especially true in terms of flow monitoring, hydrometric data management, analysis and modelling. In this respect, the project has certainly fulfilled one of the initial objectives, in that it has acted as a demonstration project of best practice in many different ways. Key lessons learnt include:

- ▶ Adopting a formal experimental design makes for more rigorous statistical comparisons and analysis and more certainty in statistical outcomes. Experimental design has to feed into the design of the monitoring network and the data collected have to be able to answer the questions asked of them.
 - ▶ Monitoring equipment reliability is critical and needs to be given careful consideration and planning at the pre-implementation stage of
- ▶ the project. Key instruments have proved to be unreliable and this has led to compromises in data quality and coverage. In this respect, it is essential to review and trial equipment and to obtain testimonials before committing to purchase.
 - ▶ Unreliable equipment leads to data gaps and inaccurate measurements, both of which degrade the quality of statistical outputs and introduce additional uncertainty in analysis and modelling results. It is essential to plan for regular equipment maintenance, data download and technical troubleshooting.
 - ▶ The most efficient instrumentation must be used for the task in hand. The adoption of new technologies and methods should be encouraged, rather than resorting to older, less efficient instruments and methods. The value of data telemetry cannot be stressed enough. The Holnicote Project showed that a monitoring network with a mixture of telemetered and non-telemetered instruments is problematic, time-consuming to manage and is less cost-effective in the long run.
 - ▶ It is essential to plan for and schedule time for thorough statistical analysis, investigations and interpretations at the pre-reporting stage.
 - ▶ Measurement interval is a critical consideration in order to accurately represent individual rainfall-runoff event response as well as long-term flow variability response. Data resolution is always a compromise: a trade-off between resolution and data handling.
 - ▶ In statistical analysis for flow, it is essential to try to account for the role of climate variability - this is notoriously difficult to do though and strong climate



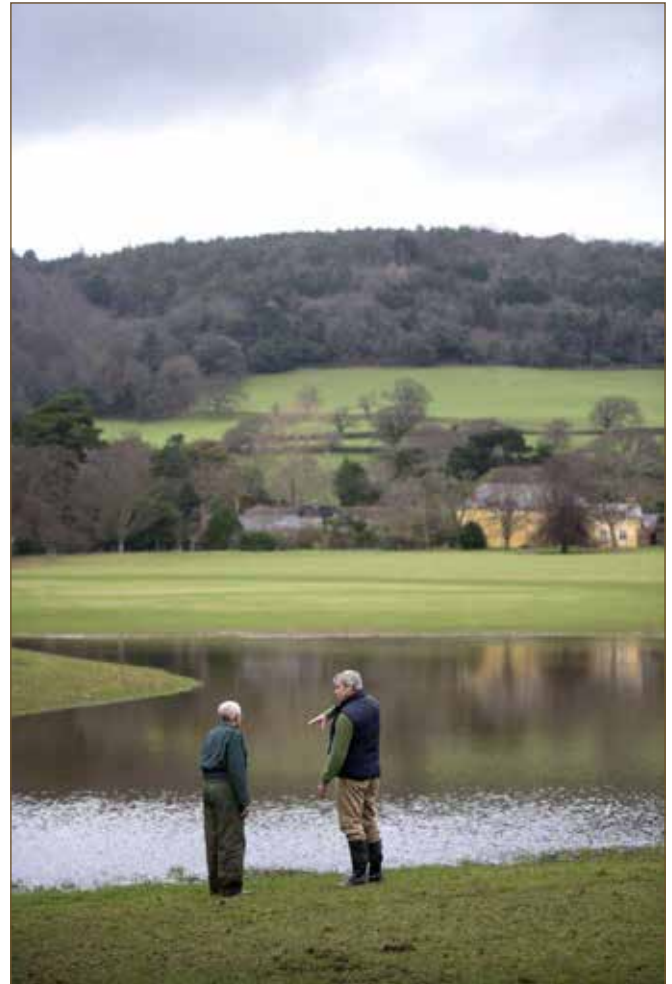
variability, both annually and over the observed year cycle, serve to complicate the analysis and interpretation of flow response and variability.

- ▶ NFM demonstration projects such as this rely on hydrological and hydraulic modelling and data analysis to assess impacts and project success. Large volumes of reliable, accurate and high quality datasets are required and in this respect, the more data collected, the better the outcome in the study.
- ▶ A range of modelling approaches can be applied to investigate opportunities for NFM implementation and the targeting of construction to maximise the flood attenuation function. Scenario modelling also helps to quantify the flood risk benefits of particular NFM measures, as installed or theoretically, for both design and recorded flood events.
- ▶ The scale of NFM interventions and management changes is a critical consideration. Positive effects on flow and the reduction of flood risk can only be achieved by bold, medium to large-scale NFM measures or else well-targeted soft engineering schemes, such as the flood storage scheme between Piles Mill and Paddock Wood and the proposed flood storage scheme at Blackford. However, widespread implementation of NFM measures can be costly and no overall guideline exists as to the reduction of flood risk in relation to the scale (and cost) of interventions.

Timescale of NFM change identification & implementation

Much of the area where land management change was initially proposed is either tenanted farmland or open moorland where farm tenants hold grazing rights. Thus, gaining support and co-operation from these farm tenants was critical to achieving sufficient landscape scale change that might affect flood risk and other potential benefits. At the project outset in 2009, it was envisaged that management changes and interventions could largely be implemented and funded through existing agri-environment schemes administered by Natural England and the Forestry Commission. However, it soon became apparent that the only opportunity to pursue this route would be at the onset of new schemes as the existing ESA had no suitable options, particularly for the upper catchment changes required.

In 2012, applications were made by the Trust and its tenants to join the existing ELS/HLS scheme with agreements in place by mid-2013. The available options under this scheme would help with some aspects of land management change, such as purple moor grass (*Molinia*) management in the upper catchment, but water management on the floodplain was not sufficiently



NT Project Manager discussing Aller flood storage area with tenant farmer.

supported. However, the scheme was used indirectly to good effect in that NE consented to some lowland farms qualifying for HLS because they formed part of the landscape scale project. Thus, on one farm, under an agreement between NE and the tenant, five fields were reverted to permanent grass from arable production. Some riverside woodland was planted under this scheme, also benefitting the project objectives.

The forthcoming new Countryside Stewardship scheme will include a number of options based on water and soil management that would benefit the Holnicote project in terms of in-field management and interventions but, as the existing HLS agreements will be in place for 10 years with a possible 5 year break clause, farm tenants and the Trust cannot benefit from this more flexible scheme for some considerable time.

In an ideal scenario, funding for catchment-based projects such as Holnicote should be available from agri-environment schemes but, due to the rigid timescale for application and lack of available options, this has proven very difficult at Holnicote and alternative funding sources have had to be secured in order to undertake the land management changes required within the project timeframe.



Horner moorland drainage impedance demonstration in 2011.

FLAG Somerset

@dredgetherivers

Thank you @holnicoteNT for helping FLAG galvanise/mobilise community support for #slowtheflow Somerset @GeorgeMonbiot pic.twitter.com/NfekarXCNjE

09:16 PM - 25 Feb 15

Bryony Sadler

@pinktrackies

@holnicoteNT @dredgetherivers @NTSouthWest @FWAGSouthWest what you have achieved is great and with heaps of communicating! Working together

12:33 PM - 25 Feb 15

Samples of community engagement through social media.

The value of engagement and demonstration activities

From the project outset, the involvement of people in both a formal and informal context was seen as fundamental to the multi-objective approach. Due to the extent of NT ownership at Holnicote, it was vital to keep the 170 cottage and 14 farm tenants informed of the project progress right from inception through to implementation in order to gain their confidence, support and cooperation in undertaking land management change. The outcomes of the project could also affect the lives and livelihoods of the local community by shifting attitudes to flood risk management within their own neighbourhood.

Engaging local communities, other stakeholders, as well as statutory and non-statutory organisations in catchment change, is by its very nature a lengthy process. It has to be approached consistently with clear understandable messages and information, and there has to be a persistent drive to ensure that the message is 'getting across' to a range of different audiences. Successful community engagement and involvement can be determined by the individual or group handling the process; they have to be believable and above all trusted.

Mechanisms for stakeholder involvement relied initially on public meetings, site visits and presentations but, over the project lifetime, opportunities for wider engagement were explored through the use of social media, particularly Twitter. Since 2011, this has been increasingly used to make contact with other water and land management projects throughout the UK to exchange information, to share ideas and to disseminate project progress and outcomes.

As Holnicote is situated in Somerset, it is not surprising that the project received heightened interest during the extreme rainfall events that took place in the very wet winter 2013/14. Following a presentation to the Somerset Water Management Partnership in November 2014, a site visit to Holnicote was arranged for this group, including members of the Flooding on the Levels Action Group (FLAG). The visit generated much discussion about catchment management using NFM and the advantages of 'slowing the flow', particular in the upper catchment. FLAG members embraced this view, recognising that dredging alone was not the single solution to flooding in their communities and that some of the land management techniques implemented at Holnicote might be relevant to farmland in the upper catchments of the Rivers Tone and Parrett. This exchange of ideas and information between the communities on the Somerset Levels and the Holnicote project has been enabled through social media as a viable and instant tool for stakeholder engagement. A key outcome of the Holnicote project has therefore been its impact in changing people's perceptions of an NFM approach to flood risk, even in a community where people's lives have been so severely affected by extreme flooding.

However, projects that have a limited timeframe have to accept that no matter how 'good' their engagement and communication processes are they can still fall foul of significant delay when statutory permissions and consents are being sought. This makes planning for works on site and the appointment of contractors in periods where weather and/or wildlife conditions are appropriate, problematic. There is no suggestion that projects such as Holnicote should avoid statutory due process but sometimes these processes are in themselves flawed. In the

case of the consents to construct flood storage bund features on the Aller floodplain, lengthy consultation and direct involvement of the Environment Agency in the planning of the scheme still did not avoid unacceptable delays in consenting. Consent applications made in August 2011 did not receive agreement until late December of that year. This had significant consequences for the momentum of these proposals not least because after the consents were issued a requirement was made by the Agency to address the Reservoirs Act (1975), which with the delays caused by wet weather meant that works on the Aller floodplain storage scheme did not start in earnest until mid-May 2013.

Why this was the case is difficult to pinpoint but a major contributory factor is the way projects such as this are dealt with administratively within the Environmental Agency. Understandably, and quite correctly, all relevant parties in the Agency had to be consulted over the proposals to construct leaky sluices across the River Aller and flood storage bunds on the adjacent floodplain. Although the Agency was contributing to the funding of the scheme, and there

had been several consultation meetings prior to the consent application, there was still nevertheless a lack of internal communication between key Agency interest groups which inevitably led to delay for the scheme. Furthermore, there were two instances (2011 and 2014) when river maintenance work was carried out which directly challenged the project's key objective of 'slowing the flow' and which potentially jeopardised the project outcomes. In the latter case, external contractors were brought in by the Agency to clear overhanging riverside vegetation and to remove woody debris, thereby increasing flow rates. As a result, this lack of communication between Agency departments has led to an internal review of procedures, especially in catchment-based project areas where the Agency is a partner and, in this case, a co-funder.

The key lesson to be learnt from this experience is that project managers involved in land management change or NFM schemes need to allocate significant resources to this aspect of the programme, as it is far too risky for the scheme to rely on a presumption that consenting will be a matter of course – even if it is believed that all the appropriate steps have been taken.



VI. Future work

Long term monitoring

The question “at what scale does land management leave a detectable and quantifiable change on flow?” is certainly applicable to this study and others like it. It is very clear from the Holnicote Project and other comparable studies, (e.g. Moors for the Future, Kinder Scout bare peat restoration and hydrological monitoring, Newcastle University Belford Catchment, the Slowing the Flow Project at Pickering), that the scale of intervention is a critical consideration when aiming for real and positive impacts on reducing flood risk by implementing NFM measures.

The Moors for the Future studies, together with those such as the United Utilities SCaMP Project have provided considerable evidence of hydrological impacts and changes over small-scale study areas and sub-catchments. It is therefore relatively easy to identify and quantify hydrological impact and change on small micro-catchments, as the spatial scale of intervention may be very high relative to the size of the catchment.

Similarly, this is also reflected in earlier hydrological studies such as those conducted on the Institute of Hydrology (and later the Macaulay Land Research Institute's) Balquhiddar catchments in Scotland, where the catchments are larger, but the scale of intervention, in this case deforestation, had very pronounced, negative effects on hydrological response.

Elsewhere however, in larger catchments with multiple land owners, agricultural practices and land use, it is rarely the case that the scale of intervention is significant enough to produce a marked change in hydrology and so it becomes more difficult to find change and responses from marginal interventions and noisy, complex datasets. Predictability of the scale of change in these case studies is complicated due to the interactions between the large catchments, complex shapes, topography, soils, hydrology, vegetation and land use, together with prevailing climate conditions.

As a result of this, statistical analysis and interpretation of flow data relative to land management interventions becomes challenging. One of the best ways to overcome these challenges is to obtain the best data possible, from which to make assessments. In this

respect, the continued collection of high resolution, hydrometric data are thus critical in order to make this possible. The long term datasets also permit the existing hydrological and hydraulic models for the catchments to be improved in order to enhance the value of the model outputs to inform all the stakeholders and local communities of the continuing success of the project.

The 2014 woody debris re-survey of Horner Wood has demonstrated a significant increase in the presence and frequency of major coarse woody debris (CWD) structures in the wooded sections of the Horner Water catchment (as seen in maps opposite). This was mainly due to the change in NT policy to retain woody debris within the channel rather than remove it, but also because of the significant weather events that occurred in the intervening years. A further re-survey in about 5 years time would determine whether the amount of woody debris in Horner Wood increases further, or whether the system has already reached equilibrium under the current “leave alone” woodland management regime. Additional survey and monitoring might also inform future management of coarse woody debris which migrates downstream from Horner Wood and how best to tackle this issue long term.

In terms of vegetation response to NFM interventions, a vegetation survey was undertaken on the Aller floodplain at Holnicote in 2011, with the purpose of establishing a baseline to which future vegetation surveys of the same area could be compared. The area is of particular interest as it has undergone considerable changes in hydrological regime, due to the construction of the earth flood bunds and the subsequent presence (and residence) of standing water for extended periods of the year, usually in the winter months. Only continued vegetation monitoring will determine the ecological effects of NFM implementation across the catchments.

Statistical analysis of an additional 5 years worth of flow data collected at West Luccombe might also provide stronger evidence of the positive impacts of fluvial CWD on reducing flood risk downstream.

In summary, the value of long term monitoring is critical to the overall success of the project and the ongoing need to provide further evidence about the multiple

benefits that this type of NFM initiative can bring. Monitoring can be justified due to the timescales of adjustment to NFM implementations, many of which take several years to become fully effective, together with the increased certainty in statistical testing and modelling results, obtained by using larger, more comprehensive and more accurate datasets.

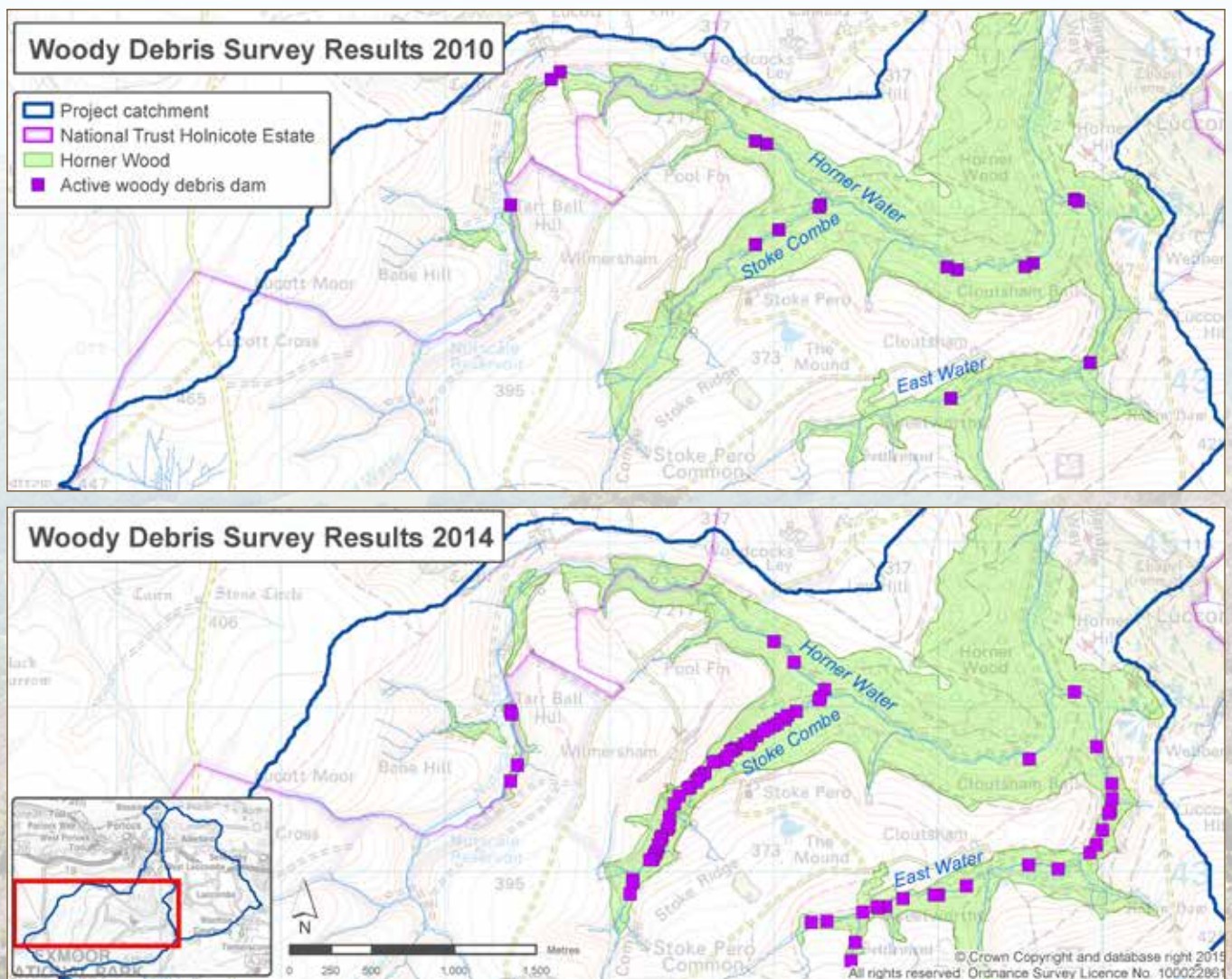
Transferability and upscaling

The range of NFM measures explored and implemented at Holnicote, together with a number of the data analysis and modelling approaches applied, could easily be transferred to other catchments. The lessons learnt from the process of applying and obtaining the relevant consents and approvals from regulatory bodies in order for certain NFM measures to be constructed are equally applicable wherever any NFM initiative is located. The results from the work at

Holnicote suggests that further upscaling of the size and distribution of the range of NFM measures present, together with the potential inclusion of some additional new NFM measures not previously considered, would create even greater flood resilience to the vulnerable village communities in a cost effective way.

Good practice demonstration catchment

The true value of any demonstration project, such as Holnicote lies not so much in providing evidence that all the various activities and changes in the landscape 'worked' in their objective of achieving flood risk and other benefits but in influencing others outside of the project to take on the challenges of natural flood management. From the tweets presented in the previous section of this report it can be seen that the influence of what has been done, how it has been



done and the sense of things moving in the right direction have enabled other groups, organisations and individuals outside Holnicote to embark on similar processes of change.

In order to achieve a viable and lasting demonstration of effective practice in NFM the National Trust are investing in a further year of work within the catchments (up to March 2016). This involves the refinement and extension of the hydrometric monitoring system, thereby addressing many of the lessons learnt, and providing a reliable and focussed acquisition of data to show the effectiveness of changes on numerous aspects of NFM. Equally importantly, enormous efforts over the past six years have been invested in the engagement, involvement and exposure of ideas related to land management change and their potential benefits. Such a platform for change always takes time to develop, especially when obvious funding mechanisms are thin on the ground. The fact that communities within Holnicote are now familiar with the ideas and mechanisms of change will make the implementation of NFM which work with natural processes a smoother and more easily accepted concept and reality. This additional year of effort will provide a legacy of two catchments from source to sea that offer an ongoing insight into how to affect land management change and demonstrate the associated benefits.

NT Holnicote Estate – long term plan/vision

As a charity, the National Trust has a statutory obligation to conserve its land, wildlife, buildings, collections and archaeological sites in perpetuity for everyone to enjoy. However, the Holnicote Project has provided a unique opportunity for the NT to focus on one of its largest countryside estates in the context of improving water and soil management to reduce flood risk and to provide a range of other environmental gains, in addition to its existing conservation work programme.

This shift in approach to land management is based on recognising the pivotal role that water plays in linking components of the catchment at a landscape scale. Farmland in the floodplain is no longer seen as a separate entity to the high moorland or to the ancient sessile oakwoods; the 'golden thread' of water has freed up our thinking to explore future management options at a much broader scale and with greater ambition.

This approach fits neatly with new strategic thinking within the NT, the "Land Choices" process, which seeks to understand the current functions of all its land and how they might be better balanced to achieve



Flood storage and biodiversity benefits on Aller floodplain near Paddock Wood.

its aspirations in the future. Traditionally, NT tenanted farmland has been viewed as primarily productive land which, through rental income, provides money to support its conservation work in the wider countryside. However, Land Choices demands a rethink so that water, soils, carbon, wildlife, landscape, cultural significance and public enjoyment are as valid functions of farmland as productivity. Currently, the wider functions of the land at Holnicote are being assessed and the flood project has been and continues to be a major driver for this holistic approach to land management.

In early 2015, a new strategic partnership has been developed between the NT and the EA at a national level, "Catchments in Trust". This aims to enable a 6 year programme of 10 catchment scale projects which delivers within the NT land, outdoors and nature strategy and intends to deliver more strategically for biodiversity, flood risk, land and water quality targets throughout England. The Holnicote Project is regarded as a key catalyst in securing this partnership, demonstrating collaborative working at a catchment scale to deliver multiple and quantifiable outputs. It provides further clear evidence that the catchment scale NFM approach demonstrated at Holnicote, the lessons learnt and the key outputs of the project, are all helping to shape NT land management policy in England, Wales and Northern Ireland.

VII. Project Database

What is it?

The Holnicote Source to Sea Project has generated a large resource of information and data relating to the project and to the wider issues of natural flood management in general. As a national flood management demonstration project, it was considered crucial to make as much information developed from the various project activities available as possible within copyright and confidentiality limitations.

As a key project output, this data resource has been assembled and integrated for wider dissemination to key stakeholders, academic institutions and other interested organisations across the public and private sectors, who are currently involved in implementing NFM projects.

The data resource has been collated and organised in order to be easily distributed and installed on any Windows PC based computer. The data resource is organised into themed folders and sub-folders of information and data, structured in such a way as to enable easy access and drill-down to relevant information.

An index document is provided in Adobe PDF format and this is designed to provide a simple, easy to use index into the various elements of the data resource. Here, the user reads the index and clicks on the relevant link. A system of bookmarks and hyperlinks navigates the user to the appropriate data resource.

The Project Database contains published project reports, technical and interim reports, other technical notes, hydrometric data, statistical and modelling results and outputs. Additional relevant information and datasets are also included, which have been collected or generated from the many tasks and objectives that the project has involved.

Two versions of the data resource have been prepared for the project. An abridged version has been prepared for distribution in the public domain.

This version contains key reports, data and project outputs, but does not contain any published papers or digital mapping products and so avoids copyright infringement. The second version contains all relevant material and is subject to the usual copyright laws and data licence restrictions.

Installation

The data resource is supplied on a DVD and will execute automatically. Alternately, the user may choose to copy the entire contents of the DVD disk to a local hard disk or server for ease of use.

Using the database

The index is supplied as an Adobe PDF document. Once opened, a description of the database and its contents and structure is provided. The database folder structure and contents can then be accessed using the bookmarked hyperlinks contained within the text. Alternatively, the user can navigate the folder and file structure of the database to find the information they require. The data can be browsed and accessed using the standard Windows folder tools and software such as Word processing, spreadsheet, database and statistical analysis software as well as Adobe Reader.

The key resources are the project reports, including the inception report (2010), the annual progress reports, 2011-2014 and the final 2015 report. The hydrometric data are also of value as are the themed reports covering modelling outcomes, catchment hydrological monitoring and ecosystem services.

Further Information

The data resource is designed to be simple to use and easy to understand and, as such, does not come with technical support. For information on obtaining a copy of the data resource DVD, contact Nigel Hester, the Project Manager, or the National Trust Holnicote Estate Office, Holnicote, Minehead, Somerset, TA24 8TJ.



Department
for Environment
Food & Rural Affairs

 National Trust

 Environment
Agency

Penny Anderson
Associates Ltd
CONSULTANT ECOLOGISTS 

 JBA
consulting

UNIVERSITY OF
EXETER 