BELFORD CATCHMENT PROACTIVE FLOOD SOLUTIONS: A TOOLKIT FOR MANAGING RUNOFF IN THE RURAL LANDSCAPE

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SUMMARY

Belford, Northumberland has suffered from an increased number of flood events over the past ten years. There is currently support within the Environment Agency for sustainable flood management solutions such as storage ponds, wetlands, beaver dams and willow riparian features (referred to here as Runoff Attenuation Features, or RAFs) which are being trialled at Belford. These also have benefits to water quality, reduce sediment and create new ecological zones. Although the process by which numerous RAFs were deployed in Belford proved initially difficult to achieve within the existing regulatory framework, an efficient uptake process is now supported by branches of the Environment Agency teams. This paper proposes a toolkit for implementing sustainable runoff management solutions. The Belford runoff management toolkit provides a step by step guide to implementing mitigation measures in the Belford burn catchment and could be easily applied to other catchments with a similar scale. The toolkit is based around implementing mitigation measures by engaging with catchment stakeholders and using solid field science and management protocols.

INTRODUCTION

Over the past ten years (1999-2009) there has been an increased number of severe flood events which have occurred in the UK. In addition, over the past fifty years, significant changes in UK land use and management practices have occurred, driven by UK and EU agricultural policies (O'Connell *et al.*, 2007). There is substantial evidence that modern land-use management practices have enhanced surface runoff generation at the local scale (O'Connell *et. al*, 2007). Surface runoff can mobilise vast amounts of sediment also leading to water quality issues within river channels. Increased runoff from agricultural land with increased rainfall totals could result in larger flood peaks.

There is a strong desire, based on field-scale science, to use land management to deliver flood and coastal erosion risk management (Parrott *et al.*, 2009). Making Space for Water (Defra, 2005), the Water Framework Directive (WFD, 2000/60/EC), Defra's Water Strategy (Defra, 2008) and climate change all drive us to deliver sustainable solutions for flood and coastal erosion risk management (Parrott *et al.*, 2009). There is also currently support within the Environment Agency for sustainable flood management solutions (see Environment Agency, 2008a,b). Properly designed sustainable solutions for flood management, such as the measures presented in this paper, also have benefits to water quality, in reducing sediment and the creation of new ecological zones.

The Belford Burn catchment is located the county of Northumberland in north-east England. There is a history of flooding in the town of Belford with records of flood events dating back to 1877. Traditional flood defences are not suitable for Belford because of the high cost, lack of space for flood walls and banks and the low number of properties at risk does not

meet the criteria for Grant-in Aid funding. There was a desire by the Local Environment Agency Flood Levy team to deliver an alternative catchment-based solution to the problem. With funding from the Northumbria Regional Flood Defence Committee, the Environment Agency North East Local Levy team and Newcastle University have created a partnership to address the flood problem using soft engineered runoff management features. The partnership project, *"Belford proactive flood solutions"* are testing novel techniques in reducing flood risk in small sub-catchments for the Environment Agency. The project provides the evidence which is needed to understand whether the mitigation measures are working at the sub-catchment scale. It also provides a demonstration site for interested stakeholders to come and look at and learn about this approach to flood risk management. As the project has progressed and lessons have been learnt, it has been possible to develop a toolkit for implementing these mitigation measures throughout the catchment and into new catchments. The Belford runoff management toolkit provides a step by step guide to implementing mitigation measures in the Belford burn catchment and could be easily applied to other catchments with a similar scale.

BELFORD RUNOFF MANAGEMENT TOOLKIT

Applying runoff management mitigation measures in Belford was a new approach to flood risk management for the Local Environment Agency Flood Levy team. The goal of the project is to: protect Belford from flooding; create a range of RAFs; gain permissions to build RAFs; gain evidences from the RAFs and catchment to investigate if the RAFs are working correctly; and create a maintenance system for the RAFs. In applying these measures a toolkit was developed (Figure 1). This toolkit provides the practical steps taken when applying mitigation measures within the catchment. The runoff management toolkit is a modification of the Hewett *et al.*, (2008) model for a multi-scale framework for strategic management of diffuse pollution . A step-by-step run through is now presented of the toolkit and how it was implemented in the Belford Burn catchment.

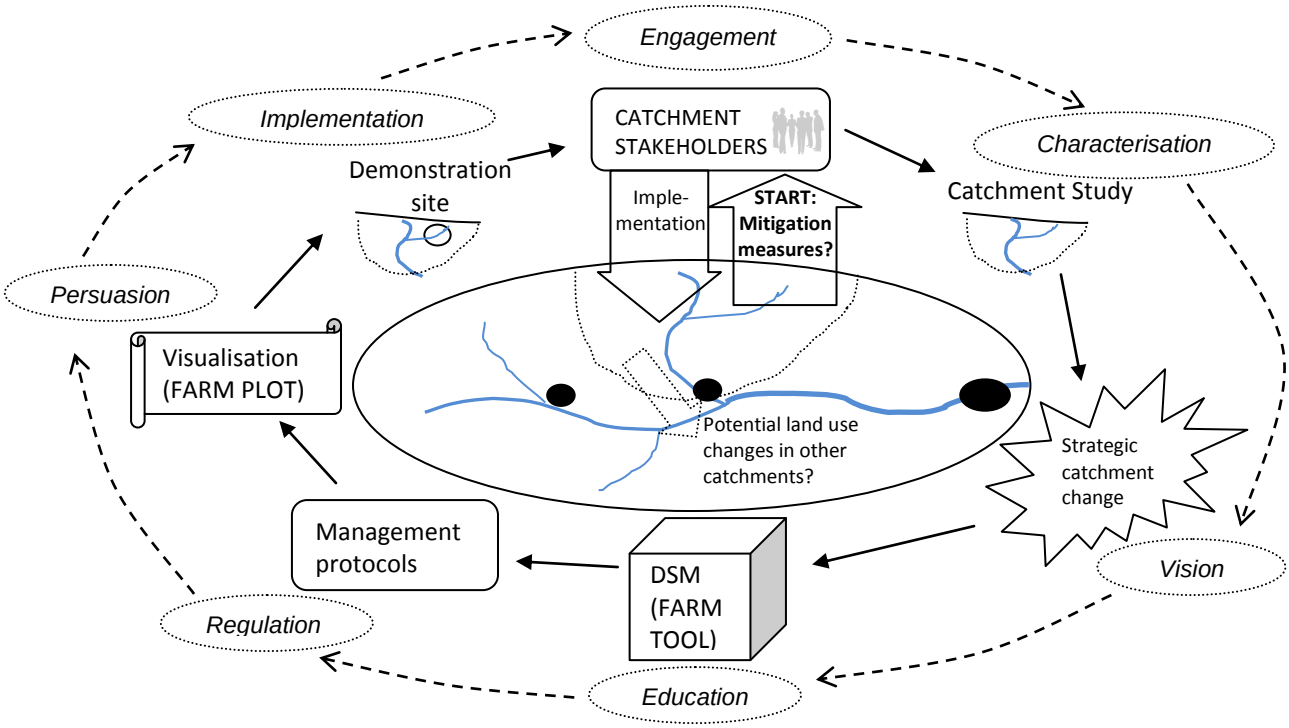

Figure 1: The Belford runoff management toolkit framework

Sub-catchment stakeholder - Engagement

Liaison with the catchment stakeholders is the most important step in the toolkit. This step must occur at the beginning and before implementation of a feature occurs. Stakeholders may be consulted at any other time throughout the process. A catchment stakeholder is anyone who has an interest in the management of the catchment. This would include farmers, residents in the catchment and visitors to the catchment. However, it also includes groups such as other offices in the Environment Agency, Natural England, Defra, RSPB, etc. who are involved in policy management in the catchment. Stakeholder meetings prior to catchment interventions allow the communities to highlight issues within the catchment and react to proposed interventions.

In Belford, the pre-intervention meetings highlighted that villagers were unhappy with the flooding problems in their village. . Some residents and businesses of Belford had been hit by five flooding incidents occurring over two years, including tides of foul-smelling sewage. Then in July 2007 a large flood occurred, and the resulting public reaction was captured by the local press headline *"Sick of sandbags and sympathy"* (12th July 2007, Northumbrian Gazette). The July 2007 event triggered the Environment Agency to take action. However, traditional flood defences were not feasible owing to the constricted channel. The community was enthusiastic but had little understanding of what was being proposed, hence the need for a pilot mitigation feature.

Catchment study - Characterisation

It is important to characterise the catchment pre, during and post-change. This allows the effectiveness of the catchment mitigation measures to be understood. In an ideal world it would be useful to have a long period of background data (pre-change) allowing the catchment to be understood before any mitigation strategies are put in place. However, in many cases this is not a feasible option owing to the time needed to do this and the need to respond to the pressures of stakeholders and policy. Nevertheless, even the shortest background dataset can be useful in understanding the catchment pre-change. This is why it was vital to implement a catchment study first, allowing for background data to be collected whilst the mitigation measures were being considered.

A multi-scale nested hydrometric experiment was deployed in the Belford burn catchment in November 2007. This consisted of a raingauge, three gauging stations within the channel, four level recorders in four features and a water level recorder in a dipwell (measuring the water table height in the soil). The Environment Agency had recently installed a flood warning stage recorder (defined as the catchment outlet) and a raingauge. At gauging stations stage height is recorded at five-minute intervals. Data from these sub-catchments will help to understand the impact that the features are having on the flood peak hydrograph. The Bowden Crags (R1), pheasant wood (R2) and wood outlet (R3) catchments are 0.5 km^2, 1.46 km^2 and 2.58 km^2 respectively in area (Figure 2). The catchment area discharging in Belford village (EA flood level recorder) is 5.7km^2.

Land use within the Bowden Crags catchment was pasture with a small area of ungrazed moorland. The pheasant wood catchment had similar land use. The wood outlet catchment was also pasture, but included a large area of woodland. The area downstream of this station to Belford was predominantly hay meadows and intense arable cropping. Three farmers manage most of the agricultural land within the upper Belford Burn catchment. The yearly average rainfall for Belford is 695 mm.

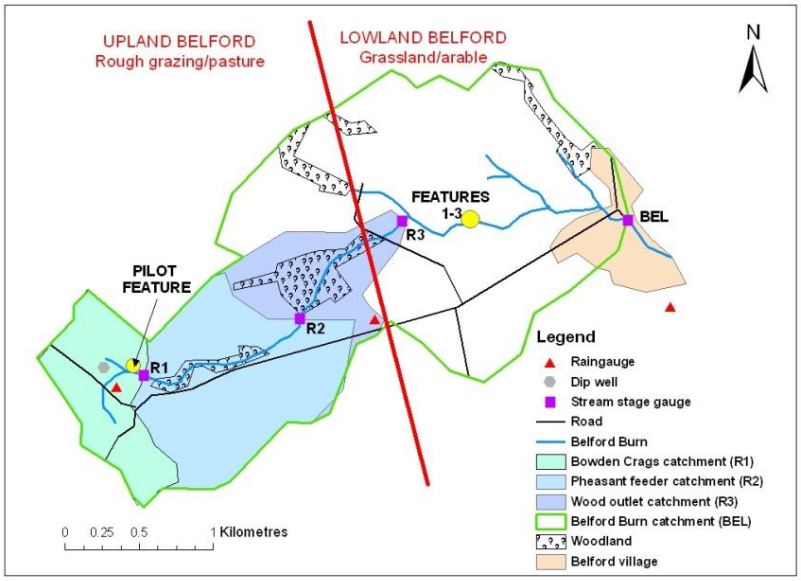

Figure 2: The Belford Burn catchment (OS grid reference: NU107338)

Potential catchment change – Vision

Farm Integrated Runoff Management (FIRM) plans are the backbone to Belford Proactive Flood solutions. Farm Integrated Runoff Management (FIRM) plans (Quinn *et al.*, 2009; Quinn *et al.*, 2007a; Quinn *et al.*, 2007b) are based on the concept of the storage, slowing, filtering and infiltration of runoff on farms at source. These are believed to be practical and achievable strategic investments of agri-environment and flood mitigation funding. There are great advantages in controlling runoff at source and within hours of the runoff generation. These spatial and temporal windows of opportunity are not being fully exploited in environmental management. The most common way to control runoff within FIRM plans is to construct Runoff Attenuation Features (RAFs). Within the FIRM plans the Runoff Attenuation Features (RAFs) include bunds, drain barriers, runoff storage features (both online and offline), woody debris dams, buffer strip management and willow barriers. If a typical farm or small catchment can sacrifice 2-10% of the landscape to runoff storage and mitigation features, which would only flood in the largest events, then the properties of the runoff regime can be radically altered. The size, location, materials and vegetation used in the features are the key to the practical and economical implementation and maintenance of FIRM plans.

So when is a pond a pond? The concept of a pond for the storage of excess runoff is widely used. However, there is an issue when using this term. A pond can be defined as a standing area of water, smaller than a lake, which has no flow and is usually permanently filled with water. The latter point raises concerns when flood risk management is an issue: a full pond has no new runoff storage potential. In fact, it can speed up runoff processes. However, ponds have positive benefits to the ecological environment, holding water creates new habitats and can create wetlands which can help with denitrification and water quality issues. But creating ponds on productive agricultural land is something many farmers do not agree with.
What was needed in Belford was a detention pond that holds a tiny amount of water for ecological purposes but has the capacity to store vast amounts of runoff in times of flood. This would be more like an attenuation feature, only working in the larger storm events. Therefore the term Runoff Attenuation Feature (RAF) is used instead of pond to demonstrate that these 'nearly dry' ponds have greater runoff storage and attenuating potential. RAFs also include a

package of different measures other than flood storage ponds. These include beaver dams, woody debris and riparian willow zones.

The Farm and Agricultural Risk Matrix (FARM) tool - Education

The Floods and Agriculture Risk Matrix (FARM) is a set of tools designed to help assess the risk of flooding from farm land and to explore options for reducing flood risk. The FARM tool was used in the Belford Burn catchment to demonstrate to farmers, various members of the Environment Agency and Natural England the risk associated with runoff in storms on agricultural fields. More information on the FARM tool can be found on *www.ceg.ncl.ac.uk/thefarm* and also within these conference proceedings (poster presentation).

Management protocols - Regulation

The concept of storing runoff in small attenuation features on agricultural land was a new concept for the Local Environment Agency Flood Levy team. Care was needed to make sure that this new approach was not damaging to the environment, ecology or public safety. Many departments in the Environment Agency have therefore been consulted in the construction process of RAFs. For the pilot RAF site, this was a long process with many departments raising different issues about the construction of the RAF. If this happened at every site the construction process would be greatly extended. At first, it was difficult to cope with the plethora of EA advice, regulation and administration. In time, by engagement with all the EA parties, a new mode of RAF implementation has arisen and the pro-forma system was developed. The pro-forma system summarises each RAF in a two page summary. This summary contains all basic information needed on the site to enable the functioning department to decide whether construction can go ahead or not and if conditions need to be met. If the RAF is offline (not in or interfering with a watercourse), there are usually no problems for construction. However, if the RAF is online or has issues the relevant Environment Agency departments may require further information. So far many Environment Agency departments have been involved in the Belford project, these include: Development Control, Fisheries, Bio-diversity, Catchment sensitive farming and Archaeology.

Farm PLOT - Persuasion

Disconnecting obvious flow pathways at opportune sites is the most effective way to manage surface runoff. As discussed in the previous sections, these sites are often at bottom of fields where many flow pathways come together. At the hillslope scale (~1 km^2) it is simple to identify these sites with a field visit and using the farmer's knowledge. When a site is identified, a simple survey can quantify the storage potential and identify the materials that will be needed to construct a RAF. An example would be several fields draining into a hollow in the landscape. This hollow drains out through one point. Therefore, constructing a bund across this hollow disconnects the flow pathway and stores and attenuates the surface runoff. But, as catchment size increases, so too does the time and effort needed to identify and survey new sites. If the farmer is involved in this process he may not have time to visit all sites. Therefore a tool was required to identify sites in the Belford Burn catchment before consolidation with the farmer and other interested bodies.

The Farm Pond LOcation Tool (PLOT) was developed to aid the process of locating ideal sites in larger catchments. Farm PLOT interpolates LIDAR (LIght Detection And Ranging) data in ArcGIS to show opportune sites and cost effective locations for disconnecting

and storing runoff (Figure 3). Farm PLOT can calculate a rough bund length needed based on a 0.5m or 1m high bund and the associated storage values of that feature. Flow pathways can be identified using the flow accumulation tool within Arcview's hydrological tools. Knowing the flow pathway can also allow the user to calculate the runoff contributing area a pond may capture and disconnect. It works on a field by field basis. However, if a feature in one field collects runoff from other fields it can receive a higher ranking. It also receives a higher ranking if the feature can remove peak flow runoff from a field. Information from Farm PLOT is then exported to Google Earth allowing it to be easily distributed to stakeholders for consultation and feedback (Figure 3).

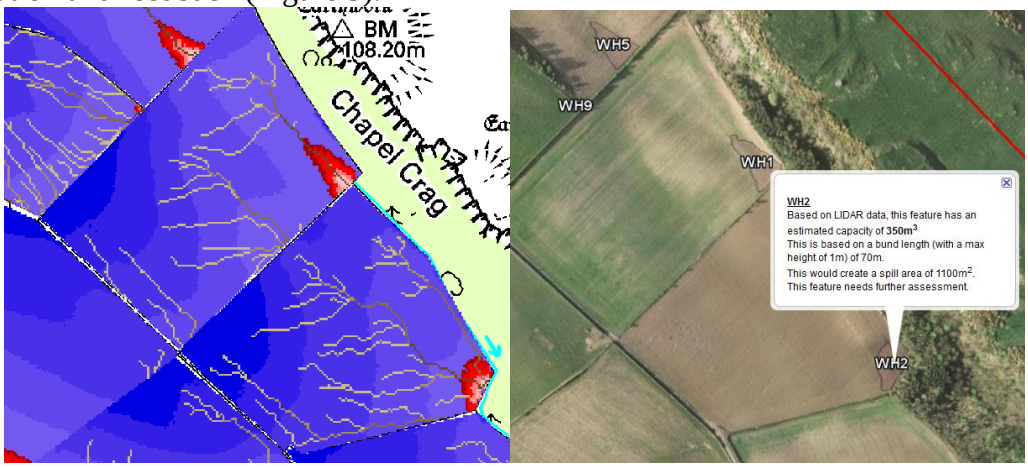

Figure 3: Farm PLOT tool with (left) red areas identifying ideal storage sites and (right) showing this information on Google Earth with pop out information boxes.

Demonstrating the concept - Implementation

It was necessary to demonstrate the concept of FIRM plans and what a RAF would look like in the Belford Burn catchment. This was needed to demonstrate to the farmer the low impact to the landscape of constructing a RAF on a field. It also re-assured the farmer that he would not be losing vast amounts of land. However, it was not just the farmer who needed to understand the concept: the pilot feature became a local landmark to the local villagers in Belford. The villagers could use the pilot RAF to understand how the project would work. It was given the nickname by the villagers of the 'whiskey barrel' as the bund was a slotted wooden wall.

The pilot RAF was constructed May 2009. It not only disconnects and stores runoff from a major pathway but also holds water from the stream when it is in flood. High flows from the stream are diverted into the pilot RAF by a small weir in the channel. Diverting the peak from the stream on a long route through the pond adds to the attenuation process in the channel. Important information has been gathered from the pilot RAF as it functions during a storm event. The pilot RAF holds ~800 m^3 of water and takes roughly 8 to 12 hours to drain from full to empty. The impact of the attenuation process of the feature can be seen in the stream flow characteristics. Pre-construction, the delay between peak flow at the diversion weir (R1) and a point1 km downstream (R2) (Figure 2) was an average (based on 8 peaks) of 20 minutes. Post-construction, the average delay, based on four peaks, is 35 minutes, an increase of 15 minutes. Clearly the impact of this feature could not only be seen visibly but also in the data. The demonstration site showed stakeholders the concept and how well it was working in a small part of the catchment. The site also raised some important issues about problems that may be encountered when constructing RAFs. For example, these features will fill with sediment over time and this will reduce storage capacity. Therefore a maintenance system is now being drawn up. There are currently 12 RAFs implemented and it is envisaged that there

will be 20-30 RAFs in the catchment by the end of the project.

CONCLUSIONS - EVALUATION

Current and proposed mitigation measures have been welcomed by most stakeholders involved in the catchment. One of the most important stakeholder groups in a rural catchment are the farmers. We are currently working with two farmers in the catchment. We meet with them regularly to keep them up to date with progress and hear their views so we can take into account what they think. There has been a positive response from the farmers. One farmer has watched the construction of some of the features and is now constructing features himself (with guidance from the project team). Villagers are also happy with the project. Since mid-2008 there have been three large flood events to pass through the village. Only one of these floods caused flooding (two houses) but this was mainly owing to drainage problems. Villagers have noted that the stream takes longer to peak. The response from the village during the September 2008 flood (which devastated the north east of England) was very positive. The headline in the local newspaper stated: *"Pioneering ponds save Belford from flooding"* (Berwick Advertiser, 17th September 2008). This headline was a stark contrast to the sandbags and sympathy mentioned a year previously. The catchment has received many visitors from within the Environment Agency and Natural England looking to see what is happening and learn from the project. Newcastle University and the local Environment Agency have recently held a workshop on runoff management which is disseminating the theory into further catchments, working with flood risk managers and catchment sensitive farming officers. However, maintenance issues of the RAFs are currently being considered. This included such activities as sediment removal from a RAF and keeping pipes and drains clear.

Recently the local flood levy has indicated a similar approach to Belford will be carried out in the nearby catchments of Powburn and Hepscott.

ACKNOWLEDGEMENTS

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