Rural runoff attenuation in the Belford catchment, UK

Year of issue

2025

Summary

Measures to attenuate runoff were installed in the small Belford catchment, in northeast England, in order to reduce the risk of flooding to the village downstream. The installations involved a network of small measures to capture and delay runoff from the rural catchment, including detention basins and overland flow features, as well as sediment capture measures to improve water quality.

However, since the implementation, the features were not maintained by the landowner, and have been then decommissioned. The measures that were implemented are no longer functional.

Photo Gallery



Location

55.5986067185, -1.83175794041

Project

NWRM

National ID

United Kingdom_01

Sector

Hydromorphology

Installation Date

2011

Implementation status

Completed

Contact

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Overview

Location of the project

Belford Burn catchment (~5.7–6 km²), Northumberland, UK, focused near Belford village.

Country

United Kingdom

NUTS2 Code

Northumberland and Tyne and Wear

Sponge measures implemented in the case study

Ponds and scrapes

Coarse woody debris

Peak flow control structures

Objectives

The main objective is to reduce flood risk to Belford village downstream. Some of the measures also contribute to sediment retention, which has the potential to contribute to the waterbody achieving good ecological status, and help towards maintaining the quality of the downstream SPA.

Involved partners

Authority type	Authority name	Authority role	Comments
National water authority	Environment Agency	Implementation	Implementation; co-ordination; financial
—	Newcastle University	Monitoring	Design and implementation of features; Monitoring; hydrological analyses and support tool generation
—	Northumbrian Regional Flood Defence Committee	Financing	Financial; co- ordination
Farmers	Famers and Residents of Belford	Other	Provision of land; support for scheme
—	Northumberland Rivers Trust	Other	Implimentation of more recent measures and maintenance

Site Information

Climate Zone

Cool temperate moist

Precipitation

750.00 mm

Temperature (°C)

9.00 °C

Runoff

400.00 mm

Runoff coefficient

0.40

Elevation range

55

Slope range

5-10%

Vegetation class

Rural with predominantly pasture and cultivated grasslands.

WFD Ecological status

Moderate

WFD Chemical status

Good

Water quality status

The waterbody is not at Good Ecological Status. There are high sediment and phosphorus levels from intensive agriculture.

Design and Implementation

Project scale

Meso

Project scale specifications

5.7–6 km² catchment. Multiple small-scale runoff attenuation features (bunds, leaky dams, ponds) distributed across the catchment.

Project area

570 ha

Basis of design

Relatively short, high-intensity rainfall events. 5-17 year return period.

Principles

Based on Catchment Systems Engineering (CSE): manipulating flow at source, using distributed RAFs, focusing on multiple benefits (flooding, water quality, biodiversity). Involves community engagement, adaptive management, cost-efficiency, and leveraging natural processes.

Constraints

These types of measures are most suited for rural headwater catchments. The benefits can most directly be seen in terms of flood protection for small settlements a short distance downstream, although will continue to have a cumulative benefit in the whole downstream catchment.

Modelling has indicated that the measures are most effective for short, high intensity rainfall events, which suggests that they could also be applicable in drier climates, where intense rainfall events are experienced. They are effective for managing overland flow runoff, so may be less suitable in groundwater-dominated areas (although even in those situations could still have benefit for high intensity events that generate overland flow).

Fish passage requirements can pose a constraint to the type of NWRM applied. Fish passage can be restricted by online structures (e.g. in stream dams) so they are more suited to small watercourses and ditches where fish passage is not important or the watercourse runs dry during the summer months.

Favourable preconditions

The upstream characteristics of the watercourse (small channels) are ideal for implementation to these types of NWRM features as the scale of flows to be retained is not large and the size of the feature can be kept small, resulting in little loss of agricultural land

Financing

Total cost

522270.00 €

Total cost information

Phase 1 : ~£350k Local Levy (North East RFCC). Of this, ~£250k was used by the Environment Agency (EA) to commission Newcastle University (monitoring, modelling, design, engagement, letting works); the ~£100k remainder went to village works (bridge wall repair, drainage upgrades).
Phase 2 (2013): ~£100k Local Levy for ~10 additional RAFs.

Costs investment

120000.00 €

Costs investment information

Construction costs only. 85,000 - 120,000 euros
Approximate costs per feature:
Barriers: €900-2,000 per m (dependent on material)
Woody debris: €120-1,200 per feature
Offline Ponds: €6,000 per feature (less if multiple ponds in close proximity)

Costs land acquisition information

No land aquisition was required as all measures were in-channel or on buffer strips, causing minimal disturbance to farmers' land.

Costs operation maintenance information

Due to the nature of the NWRM, operational costs will be minimal, but there are maintenance requirements. There is also some additional cost associated with optimisation following implementation, e.g. Raising the outflow from a pond to increase its capacity

Costs operational information

Small costs are envisaged, but no quantative indication available. Management of features is done by combination of Environment Agency, Northumberland Rivers Trust and Natural England.

Costs maintenance information

Sediment clearance is important e.g. At sediment traps. Maintenance is also required of log/debris dams, which may need repairing or replacing over time

Costs disposal decommissioning information

Minimal costs

Administrative annual cost information

Up to 2013 monitoring was funded by the Environment Agency. Now Newcastle University continue to provide skeletal monitoring at the site through student research projects.

Information on Economic costs - income loss

There is some minor land loss associated with the construction of ponds. However any costs associated with this could be offset in part by benefits of sediment recovery and re-use. No quantification is avaialble

Financing authorities

Authority name	Type of funding
Environment Agency	National funds
Northumbrian Regional Flood Defence Committee	Sub-national funds

Compensations

Yes

Compensations annual information

A one-off payment was made by the Environment Agency to famers for having access to the site for measure installation.

Policy and Governance

Policy description

Belford village has a long history of flooding, often causing damage to properties. An Environment Agency flood defence pre-feasibility study concluded that traditional flood defences were not suitable for Belford because of the high cost, lack of space for flood walls and banks, and the small number of properties at risk, resulting in an unfavourable cost-benefit assessment. There was a desire to deliver an alternative catchment based and more cost-effective solution to the problem. In addition to this, the waterbody is not at Good Ecological Status, and sediment retention and nutrient management as part of the NWRM programme help to address this.

Land ownership

Private farmland: the upstream catchment is privately owned by three main landowners; farmers provided land access

Policy targets

Runoff control

Peak-flow reduction

Increase Water Storage

Pollutants Removal

Policy pressure

Directive	Relevant pressure
WFD identified pressure	Pressure from poor water quality due to diffuse agricultural pollution.
Floods Directive identified pressure	Recurrent local flooding highlighted post-2007 floods.
Other non-EU	Defra 25-Year Plan: Emphasises nature-based flood solutions.
Other non-EU	Climate change policy (UKCCC): Rising peak flows demand NBS.

Pressure remarks

The Belford project directly responds to both water quality and flood control policy gaps. The Pitt Review, Environment Agency mandates, and UKCCC pressures pushed the shift to upstream natural flood management. The project acts as a response to local-scale issues under broader EU/UK frameworks.

Policy impact

Directive	Relevant impact
WFD identified pressure	Reduced sediment and phosphorus improves water body status.
Floods Directive identified pressure	Local flood risk reduction meets directive’s preventive aim.
Other non-EU	UK Defra Plan: Supports sustainable, nature-based mitigation.
Other non-EU	National Flood Strategy: Enhances resilience to climate-driven events.

Impact remarks

Belford’s success in reducing flood peaks and pollution aligns directly with WFD and Floods Directive goals. The evidence of cost-effectiveness and multifunctionality supports uptake under national planning and environment policy strategies.

Requirement directive

Requirement directive	Specification
WFD-mitigation of significant pressure	Diffuse pollution
WFD-achievement of good ecological status	—

Requirement directive	Specification
Floods Directive-mitigating Flood Risk	—
Floods Directive-establishing adequate PoM	—

Requirement directive remarks

RAFs in Belford serve multiple WFD aims, especially reducing sediment/nutrient loading and enhancing ecological integrity. They contribute to Floods Directive goals by mitigating peak flow.

Part of a wider plan

Yes

Wider plan

Wider plan type	Wider plan focus	Name	Comments
Local	Water	Defence strengthening in Belford Village	This strategy was 1 of 3 strategies (including the natural water retention measures implementation) where the Environment Agency funded investigation and strengthening wirk to be undertaken at the existing "structural" flood defences within Belford Village.
Local	Urban	Sewer upgrade	This strategy was 1 of the 3 strategies (including the NWRM implementation) where Northumbrian Water upgraded sewers to improve the resiliance and prevent surface water flooding.

Public consultation

Yes

Consultation activities

Activity stage	Activity type	Key issues
Design phase	meetings	Decision support tools were made availalble to the famers to understand the underlying issues and provide them with adequate knowledge to participate in formulating a solution
Other	Effectiveness understanding	Famers were taking photographs and videos during flood events of the NWRM during flood conditions.
Implementation phase	Field trips	Field trips were organised for villagers to see the wrok being undertaken

Has contractual arrangements

No

Impacts and Monitoring

Monitoring System

Monitoring parameters

At the start of the project there was no hydrometry present within the catchment. The Environment Agency has installed a telemetered gauging station within Belford village for Flood warning purposes. In addition they have installed a tipping bucket rain gauge at a farm to help with flood warning predictions. Alongside this Newcastle university installed a raingauge and three flow gauging stations, which will help understand the impact of the features on the flood peak hydrograph as a flood moves through the catchment.
A grab sampling campaign began in 2009 to characterize the sediment and nutrient regime and identify locations contributing to elevated levels of agricultural diffuse pollution.
Four auto samplers were deployed at two online pond features, one upstream and one downstream of each feature. This was to understand if they were retaining sediments and nutrients during storm events.

Upstream station

Monitoring was undertaken at locations directly upstream and downstream of some natural water retention features.

Downstream station

Monitoring was undertaken at locations directly pstream and downstream of some natural water retention features. There is a WFD monitoring location on the Belford Burn.

Maintenance

Maintenance requirements

Includes sediment removal, vegetation clearing, ensuring flow through pipes and leaky barriers.

Impact Assessment Methodology

Performance impact assessment method

Laboratory

Performance impact estimation information

For some water retention features direct comparisons were made pre and post implementation, and also upstream and downstream of individual measures. Impact assessments were undertaken at a number of the indivdiual measures using available observed data. Model interpolation was used to understand the effects of multiple measures using hydraulic modelling.

Biophysical impact assessment method

Monitoring, modelling (CityCAT)

Cost assessment method

Compared Natural Flood Management cost with conventional scheme.

Socio-economic Impacts

Direct benefits information

There is no quantified information on the socio-economic benefits.
The use of a network of NWRMs in a rural landscape has provided a cost effective means to reduce flood risk downstream. Additional benefits include:
- Storing water in ponds on the fields removes sediment picked up by overland flow which can be returned to the farmer's field.
- Creating wetlands on some of the ponds provides new habitat for wildlife.
- The increased habitat and improved water quality is leading to an increase in the biodiversity in the catchment.

Biophysical impacts: Hydrology

Hydrological effects

Rural attenuation features reduced peak discharge, increased flow lag time, altered surface/subsurface pathways, and encouraged floodplain connectivity, enhancing natural storage.

Information on retained water

The estimated total for the suite of NWRMs is around 10,000 cubic metres in total.

Information on increased water storage

There was no storage previously.The estimated total for the suite of NWRMs is around 10,000 cubic metres in total.

Information on runoff reduction

Little net change in total runoff

Peak flow reduction

35.00

Peak flow reduction unit

% Percent

Information on peak flow reduction

An individual NWRM may only provide a very small reduction in the peak flow, but in combination larger peak flow reductions can be observed. This value is for a MODELLED system representative of Belford with total storage of 19,250 cubic metres, for the reduction of peak flow at the downstream end of the network of measures: 15-30% peak flow reduction.

Information on increased infiltration

Possible increases in infiltration due to water being retained within the upper catchment for longer before flowing downstream.

Information on reducing flood risks quantity

No major flooding in Belford village despite several 1:100-year events. Runoff attenuation features are effective for flash floods in small catchments.

Information on peak delay effects

Per NWRM the influence is small, but in combination the effects are significant

Biophysical impacts: Biodiversity

Improved biodiversity

Yes

Information on improved biodiversity

Overall there is increased habitat for wildlife (water features), however the overall ecological performance is difficult to quantify and required further evidence. Habitats improved include ditches, riparian zones, and wetlands. Runoff attenuation features led to increased biodiversity and ecological resilience. Stream/riparian fauna benefited, though no formal index change is reported. Soil structure and aquatic habitat quality improved

Biophysical impacts: Water & Soil Quality

Water quality overall improvements

Positive impact-WQ improvement

Information on water quality overall

An investigation was begun in 2009 to assess effectiveness of features to reduce losses of sediment and nutrients. Parts of the catchment already had high concentrations of SS, P and NO3. The overall, cumulative impact of all the NWRMs has been found to be difficult to prove, and to require extensive monitoring. However some findings included:
- It was identified that online ponds were not retaining pollutants during the rising limb and peak of flood events.
- Overall conclusion was that online features are functioning to reduce chronic losses of Suspended solids but are less effective in storm events.
- Different features operate to retain pollutants under contrasting flow conditions.
The study area covers the upper 50% (approximate) of the associated WFD waterbody. Therefore it is likely that the improvements identified in water quality (e.g. phosphate) due the NWRMs will contribute to overall improvements in the Ecological status of the waterbody.
- A multi stage NWRM (constructed following findings of initial NWRMs) that included a sediment trap and willow barriers works effectively to reduce sediment and nutrient losses from the catchment during storms

Water quality improvements - Phosphorus (P)

26.00

Water quality improvements - Phosphorus (P) - Unit

% reduction pf pollutant

Information on water quality improvements (P)

Multi stage NWRM measured over a 24hour storm event. 26% TP reduction, 25% soluble RP reduction

Water quality improvements - Nitrogen (N)

15.00

Water quality improvements - Nitrogen (N) - Unit

% reduction pf pollutant

Information on water quality Improvements (N)

Multi stage NWRM measured over a 24hour storm event. 15% NO3 reduction

Water quality improvements - Total Suspended Solid (TSS)

40.00

Water quality improvements - Total Suspended Solid (TSS) - Unit

% reduction pf pollutant

Information on water quality improvements (TSS)

After a large runoff event a retention bund. Estimated 0.99 tonnes of sediment captured (retention bund)
Multi stage NWRM over a 24hour storm event. 40% SS reduction (multi stage NWRM)

Soil quality overall improvements

N/A info

Information on soil quality overall improvements

No information available. Unlikely to be significant changes

Ecosystem erosion control

No

Biophysical impacts: Others

Ecosystem impact climate regulation

Not relevant for the specific application

Increased evapotranspiration information

There is an increased extent of open water, but effects on evapotranspiration are likely to be insignificant since the retention times are low.

Lessons Learned

Key lessons

The implementation has shown how a catchment plan was effective at providing multi purpose benefits.
- A number of natural water retention measures can be used together, with the materials, location and choice of feature being dependant on local factors including land owner/farmer preferences and local terrain.
- One single natural water retention feature only has a small benefit and it is likely that a number may be required together, but this should not ignore the fact that other structural measures may also be beneficial.
- Online features are best suited to smaller channels. Scaling remains difficult beyond 10–20 km².
- The effectiveness of networks of natural water retention measures to attenuate flood depends upon the shape of the hydrograph, often being more effective for flashy short duration flood events.
- It is essential to engage stakeholders, as this will encourage uptake by farmers.
- It is crucial to build up the trust of farmers and residents from the earliest opportunity and maintain it throughout.
- Motivation of the land owner is quintessential for the longevity of measures, especially when they rely on maintenance.
- Lack of maintenance leads to the end of the measures' effectiveness.

Barriers

Barrier type	Barrier role	Comments
Attitude of the public	Secondary barrier	In the early stages the new concept meant that time was required to build the trust with Farmers and the community, to confirm benefits and effectiveness of the approach. This became less of a problem as more measures were implemented.
Attitude of relevant stakeholders	Secondary barrier	Being a new concept there were delays in early measure implementation due to the need to consult everyone on the appropriate approach to use. All departments within the Environment Agency were consulted from Fisheries through to the Archaeology department. (For example placing barriers in channels required consultation with Fisheries experts to ensure adequate fish passage.)
Legal obligations / restrictions	Secondary barrier	On all watercourses, in stream channel structures (e.g. Online flow storage) that interrupt normal flow will require a consent from the Environment Agency for works in a watercourse.

Drivers

Driver type	Driver role	Comments
Past flooding events	Main driver	Severe flood events in small settlements downstream caused this to be considered. The Environment Agency were the main driver behind this measure being implemented, looking for lower-cost solutions to enable protection of small communities where high capital expenditure could not be justified. Other 'normal'flood defence approaches failed cost benefit criteria for support, and would not be suitable within Belford due to shortage of space between the channel and nearby houses. The 'natural' approaches were financially viable for the site, and enabled storing and attenuating flows in the upstream area.
Other	Secondary driver	Unsuitability of 'structural' measures in the area.

Success factors

Success factor type	Success factor role	Comments

Attitude of relevant stakeholders	Main factor	Identification of a combined approach that was flexible and adapted to the local factors, and the willingness of the regulator to explore new approaches.
Available support tools	Main factor	Availability of the tools for non-expert stakeholders to appreciate and inform solutions
Communication activities	Secondary factor	Crucial in getting "buy -in" from land owners and famers to allow these features on the land
Conducted assessments (incl. economic)	Secondary factor	Interest in a catchment based approach and the requirement for monitoring and modeling investigations did not prevent the work going ahead, but ensured confidence in the outcomes of the work and further understanding of effectiveness of the NWRM approach.
Attitude of the public	Secondary factor	It helps greatly when there is good relationship between the community and farmers.

Cost effectiveness

Very high cost effectiveness : £200k for runoff attenuation features vs £2.5M traditional defence. Achieved ~35% local peak flow reduction.

Flexibility / Adaptability

Designs adapted to terrain and local flow paths. Modular rural attenuation features allowed changes based on observation. No single blueprint - emphasis on experimental, site-specific solutions with local input and ability to evolve over time.

Transferability

Highly transferable to small, flashy rural catchments. Easy replication if landowners collaborate. Requires flexibility, site-specific design, and upfront engagement. Difficult in urban or large-scale catchments due to complexity and policy/land issues.

Basin characteristics influence

Flashy, small catchment enhances runoff attenuation features impact. Short storm response time allows effective flood peak reduction.

Sources

Sources

Potential Use of Runoff Attenuation Features in small Rural Catchments for Flood Mitigation

A framework for managing runoff and pollution in the rural landscape using a Catchment Systems Engineering approach

Belford catchment proactive flood soutions: storing and attenuating runoff on farms

Runoff management: Mitigation measures for disconnecting flow pathways in the Belford Burn catchmen to reduce flood Risk

Runoff Attenuation Features - A guide for all those working in catchment Management

A catchment systems engineering approach to managing runoff in rural catchments

The Role of Runoff Attenuation Features (RAFs) in Natural Flood Management

Runoff attenuation features: a sustainable flood mitigation strategy in the Belford catchment, UK