Department for Environment Food & Rural Affairs
Llywodraeth Cymru Welsh Government
Cyfoeth Naturiol Cymru Natural Resources Wales
Environment Agency

delivering benefits through evidence

Cost estimation for land use and run-off – summary of evidence

Report –SC080039/R12

Flood and Coastal Erosion Risk Management Research and Development Programme

We are the Environment Agency. We protect and improve the environment and make it a better place for people and wildlife.

We operate at the place where environmental change has its greatest impact on people's lives. We reduce the risks to people and properties from flooding; make sure there is enough water for people and wildlife; protect and improve air, land and water quality and apply the environmental standards within which industry can operate.

Acting to reduce climate change and helping people and wildlife adapt to its consequences are at the heart of all that we do.

We cannot do this alone. We work closely with a wide range of partners including government, business, local authorities, other agencies, civil society groups and the communities we serve.

This report is the result of research commissioned by the Environment Agency's Evidence Directorate and funded by the joint Flood and Coastal Erosion Risk Management Research and Development Programme.

Published by:
Environment Agency, Horizon House, Deanery Road, Bristol, BS1 5AH

www.environment-agency.gov.uk

Email: fcerm.evidence@environment-agency.gov.uk.

Further copies of this report are available from our publications catalogue:
www.gov.uk/government/publications

or our National Customer Contact Centre:
T: 03708 506506

Email: enquiries@environment-agency.gov.uk

Author(s):
Kevin Keating, JBA Consulting
Angus Pettit, JBA Consulting
Steve Rose, JBA Consulting

Dissemination Status:
Publicily available

Keywords:
Whole life costing, cost estimation, land use, run-off management

Research Contractor:
JBA Consulting
South Barn, Broughton Hall, Skipton
North Yorkshire BD23 3AE
01756 799919

Environment Agency's Project Manager:
Adam Baylis, Evidence Directorate

Collaborator(s):
John Chatterton

Project Number:
SC080039/R12

Evidence at the Environment Agency

Evidence underpins the work of the Environment Agency. It provides an up-to-date understanding of the world about us, helps us to develop tools and techniques to monitor and manage our environment as efficiently and effectively as possible. It also helps us to understand how the environment is changing and to identify what the future pressures may be.

The work of the Environment Agency's Evidence Directorate is a key ingredient in the partnership between research, guidance and operations that enables the Environment Agency to protect and restore our environment.

This report was produced by the Scientific and Evidence Services team within Evidence. The team focuses on four main areas of activity:

- **Setting the agenda**, by providing the evidence for decisions;
- **Maintaining scientific credibility**, by ensuring that our programmes and projects are fit for purpose and executed according to international standards;
- **Carrying out research**, either by contracting it out to research organisations and consultancies or by doing it ourselves;
- **Delivering information, advice, tools and techniques**, by making appropriate products available.

Miranda Kavanagh

Director of Evidence

Executive summary

A number of case studies have been carried out in the UK at a variety of scales with the aim of reviewing various management methodologies and the costs of land use and run-off management. It is hoped these case studies can provide information and guidance for those commissioning or developing strategies and plans for similar projects and to help define indicative costs that can be used for broad scale cost estimation studies. There are no comments on the benefits of such flood risk management measures in this evidence summary as this is outside the scope of cost estimation.

Land use and run-off management		
Key cost components	Key cost components land use and run-off management measures will include: • initial design, management, and community/landowner liaison costs • capital costs • operation and maintenance (O&M) costs	
Key asset types	• Forestry and floodplain woodland and tree shelter belts • Ponds and wetlands • Field scrape/infiltration trench • In-channel barriers • Large woody debris • In-channel wetland • Peat drainage – grip/gully blocking • Floodplain reconnection/re-meandering • Soil management • Riparian buffer strip (and bund)	
Data reviewed in specific guidance	The availability of data and limited case studies/examples within the UK on these sorts of projects means that many of the techniques and costs associated with these aspects are based on actual case studies and research.	
Other relevant data	Local or proxy records such as data from Environment Agency SAMPs and local authority information Ongoing research projects *Manual of River Restoration Techniques*	
Relative cost importance	Enabling costs	Variable costs associated with project coordination, management and administration, site survey, investigation and assessment, design, and stakeholder consultation and liaison

	Capital costs	Variable costs depending on scale and type of measures
	Maintenance costs	Generally low costs associated with inspection and general maintenance
	Other cost considerations	May include management, publicity and public awareness campaigns. Loss of productive agricultural land (in some cases)
Cost estimation methodology	Initial concept/national appraisal	Some case studies and example projects provided to demonstrate cost elements required. Indicative costs provided for a range of applications. Insufficient information currently available to derive unit costs or cost curves for the purposes of cost estimation.
	Strategic, regional, or conceptual design	No specific cost information provided. Guidance on data availability and procedures provided. Site-specific assessment and specialist advice required.
	Preliminary feasibility/design	No specific cost information provided. Guidance on data availability and procedures provided. Site-specific assessment and specialist advice required.
Design life information	Design life for these measures is variable depending on the type of measure undertaken and indefinite in some cases once established and maintained.	
Quality of data	Case studies and examples are provided to support those undertaking similar schemes and to indicate the magnitude of the likely costs based on these previous studies. These case studies provide the necessary context and detail to support the cost information.	
Additional guidance	List of R&D and general design guidance Case studies of recent schemes	

Acknowledgements

The authors wish to thank the Project Board (Ian Meadowcroft, Linsay Hensman and Adam Baylis) and the Environment Agency, local authority and Internal Drainage Board representatives and operational staff who were consulted.

Contents

1 Flood mitigation measures – land use and run-off management

Much research has been carried out in recent years to determine the mechanisms and effects of rural land use and land management on flood risk at a range of scales (local to catchment wide).

The mechanisms by which precipitation reaching the land surface subsequently finds its way by various pathways into streams and rivers, and the intervention options that could affect these elements, can potentially impact upon the frequency and extent of flooding at the local to catchment scale.

There is strong scientific evidence that changes at the small catchment or sub-catchment scale could benefit flood risk management and that we could use rural land more effectively to store and attenuate floodwaters so as to reduce flood risk downstream. However, the scientific evidence to date has not established a clear link between land use management and a change in the flood risk posed by extreme events at the larger catchment scale. Furthermore, there are difficulties in the modelling and ability to predict accurately the impact of any proposed land use and land management changes. However, it should also be recognised that managing surface run-off can offer a range of other environmental enhancements in addition to reducing flood risk such as biodiversity, diffuse pollution management, resource protection, and social and economic benefits.

Despite this uncertainty, a number of case studies have been undertaken in the UK at a variety of scales with which to review a number of management methodologies and the costs of undertaking these tasks. It is hoped that these case studies can provide information and guidance for those commissioning or developing strategies and plans for similar projects, and to help define indicative costs that can be used for broad scale cost estimation studies.

It is anticipated that as evidence and guidance on the preferred options for land use and run-off management becomes more advanced, and any legislative or financial barriers to the incorporation of these practices are removed, that the body of evidence with which to inform future guidance on the costs of undertaking these options will increase in the future.

Due to the policy and legislative controls those projects that have been undertaken are often carried out to achieve multiple benefits and are rarely just for flood risk management purposes. Many case studies aim to provide evidence of how land use/management changes can help to achieve multiple objectives.

The guidance and costs provided in this evidence summary do not seek to recommend particular techniques for a specific site or scheme, but to inform those undertaking the process of project evaluation and appraisal to understand the process and costs required and the risks to be managed so as to ensure that projects represent good value for money and are an efficient use of resources.

1.1 Types of projects

The types of projects covered by this evidence summary include a number of different aspects broadly grouped into the following three categories as identified in the Pitt Review (Pitt 2008):

- water retention through management of infiltration such as by protecting or enhancing the condition of the soil and the inherent natural soil moisture storage potential
- provision of water storage such as on-farm reservoirs or enhanced wetlands and washlands
- slowing flows by managing hillslope and river conveyance such as planting cover crops, vegetated buffer strips, moorland grip blocking or restoring watercourses to more natural characteristics and function

Within these three broad categories there are a number of techniques that can help with the retention of floodwater and slow the conveyance of floodwaters. A good reference point for the identification of these techniques is the Environment Agency report on working with natural processes (Environment Agency 2010). This lists 25 techniques that can be used as part of a land use and run-off management strategy or integrated plan across the catchment landscape. The techniques appropriate to fluvial environments are shown in Table 1.1 (the other nine techniques are used in coastal and urban environments).

Table 1.1 Land use and run-off management techniques

Ref No.	Technique name	Catchment location	Technique description
1	Land and soil management activities to retain/delay surface flows	Upper/ middle	Field scale activities including tree planting, reduced stocking densities, moving gates and water troughs, planting cover crops, contour ploughing, maintaining soil quality
2	Moorland grip blocking to slow run-off rate	Upper	Blocking previously dug drainage ditches (‘grips’) to allow peat bogs to re-wet
3	Woody debris dams on streams and tributaries	Upper/ middle	Naturally occurring or induced in-channel dams of woody debris and vegetation
4	Field drain blocking, ditch blocking	Middle/ lower	Deliberate blocking or impeding the flow of water along field drains and field ditches to raise water levels and increase field storage/detention potential (cf. moorland grip blocking)
5	Land use changes – arable reversion	Upper/ middle/ lower	Reversion of arable fields (or part fields (buffer strips)) to well managed pasture to improve soil infiltration rates and reduce surface run-off
6	Flood plain woodland, re-	Upper/ middle/	Creating or reinstating floodplain woodland to intercept out-of-channel flows and encourage

Ref No.	Technique name	Catchment location	Technique description
	forestation	lower	infiltration
7	Creation or reinstatement of a ditch network to promote infiltration	Middle/ lower	Maintained road and track-side ditches to intercept overland flow and detain field and road drainage (swales, interception ditches, and so on)
8	(Cessation of) in-channel vegetation management	Middle/ lower	Alteration of channel vegetation maintenance regime to selectively promote in-channel vegetation growth
9	Floodplain reconnection	Middle/ lower	Removed or lowered river embankments or new spillways to reconnect river channel to floodplain
10	Selective bed raising/riffle creation	Middle	Technique used to repair damage from over dredging. Mimics a natural process to the extent that it aligns with the river's natural sedimentation cycle.
11	Washlands	Middle/ lower	An area of floodplain that is allowed to flood or deliberately flooded for flood management purposes (cf. flood storage areas and wetlands)
12	Wetland creation	Middle/ lower	Permanently wet areas where water levels are managed to allow some additional flood storage and high flow detention.
13	On-line flood storage areas	Middle/ lower	Engineered flood storage typically involving use of a flood storage embankment and flow control structure to detain out-of-channel flows and control downstream flow volumes.
14	Off-line flood storage areas	Middle/ lower	Pond, backwater or off-line bypass channel providing a below surface level flood storage connected to the river by a low bund or overflow pipe allowing the storage to fill during times of high flow and empty through evaporation or seepage or designed drainage back to the main river. Design can allow for a minimum retained water level within the storage area.
15	Two-stage channels	Lower	Techniques to build additional high flow capacity into a river channel. May involve the creation of wet berms and measures to maintain a narrow low flow channel.
16	Re-meandering straightened rivers	Middle/ lower	Reintroduction or reconnection of river meanders to delay downstream time to peak

Some of these techniques are restricted to particular locations within the catchment and particular scales (small scale or farm scale to catchment scale or regional applications). Techniques for flood storage areas are covered in another evidence summary.

1.2 Cost requirements

Cost requirements for land use and run-off management practices for appraisal studies require:

- initial assessment, design, management, and community/landowner liaison costs
- capital costs
- operation and maintenance (O&M) costs

1.3 Enabling costs

As with any scheme there are initial procurement and capital costs that cover the initial stages of the project. These costs might include aspects such as:

- project coordination, management and administration
- site survey and assessment
- design
- initial gauging and investigations (assuming future verification is required)
- stakeholder consultation and liaison

The strategy shown in Figure 1.1 is typically followed for land-use and run-off techniques.

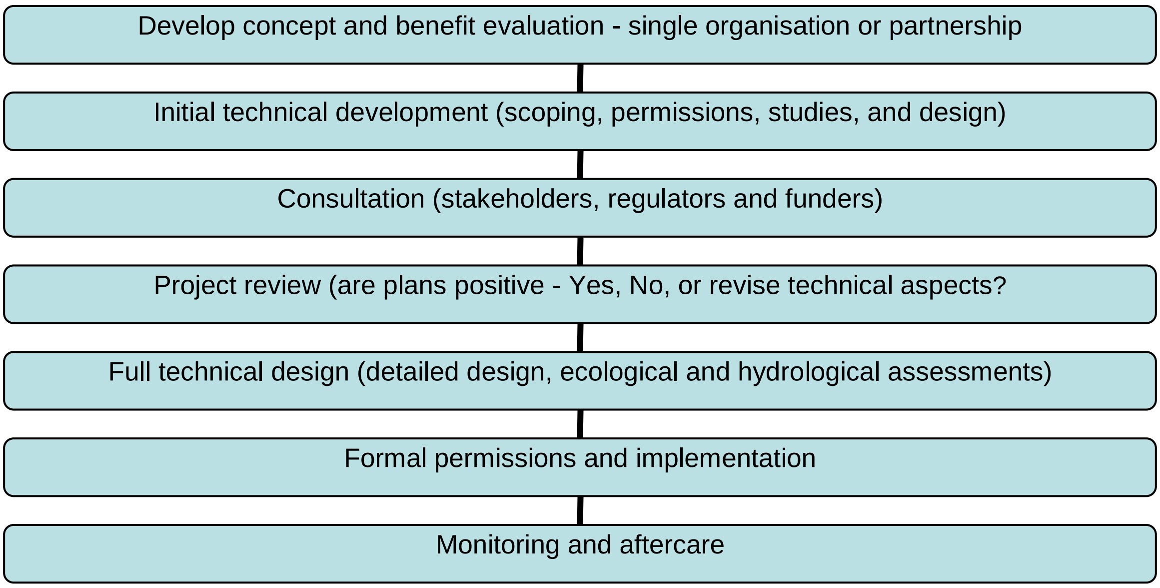

Figure 1.1 Strategy for determination of enabling costs for land use and run-off management

At present the initial assessment, design, management and administration costs tend to be high due to the research element that goes into the development of these projects. These costs are typically funded externally through research grants and levies. This is because many of these projects are carried out to inform and provide scientific evidence linking land use management practices to flood risk.

These costs may be substantially reduced in the future once practical guidance and best practice is established as ongoing research and evidence is gathered. Certainly small scale run-off management practices may not require substantial consents, licences or statutory procedures to be in place in order for the measures to be implemented. It may also be the case that the substantial costs for installing complex monitoring devices, piezometers and water level recorders (currently installed to sample and record detailed hydrometric information to determine the efficiency of practices) may be reduced significantly. However, as these measures are upscaled to a catchment scale, the costs associated with arranging and managing these aspects could increase substantially.

Costs for stakeholder consultation and liaison are necessary to:

- ensure landowners, farmers, land managers, local residents and associated organisations understand the strategy
- ensure adoption of measures
- inform landowners of relevant grants and funding
- increase the responsibility of landowners

In many cases practical demonstrations may be required to ensure acceptance to land managers (Posthumus et al. 2008).

Different techniques will require different pre-construction requirements. A useful list of these is available from Environment Agency (2008). Table 1.2 indicates the proportional impact of pre-construction requirements for various techniques.

Table 1.2 Proportional impact of pre-construction requirements

	Fencing	Large woody debris	Channel cross section modification	Structure modification and channel meandering
Strategic planning and feasibility (including assessment of geomorphological risk)	××	×	✓	✓✓
Planning permission	××	×	×	✓✓
Level survey	××	×	✓	✓✓
Detailed environmental surveys	×	✓	✓✓	✓✓
Environmental Impact Assessment (EIA) screening and scoping stages	✓	✓	✓✓	✓✓
Initial landowner approach	✓✓	✓✓	✓✓	✓✓

	Fencing	Large woody debris	Channel cross section modification	Structure modification and channel meandering
Detailed design including modelling	××	✓	✓✓	✓✓
Development control approval	××	✓	✓✓	✓✓
EIA (and Appropriate Assessment if necessary) reporting, environmental consenting	✓	✓	✓✓	✓✓
Landowner agreement	✓	✓	✓✓	✓✓
Tender and contract letting	✓	✓	✓✓	✓✓

Key:
×× – very unlikely to be necessary
× – likely to be unnecessary
✓ – likely to be necessary, limited input/relatively short duration
✓✓– likely to be necessary, significant input/long duration

1.3.1 Timing of works

Some aspects may require a long lead-in time before work begins due to the requirements for the above studies, feasibility/design, funding arrangements, stakeholder consultation and approvals. Simple measures may require limited lead-in times and can be completed immediately. More complicated works requiring additional works may take 3–5 years of works prior to full implementation.

1.4 Capital costs

Many of the techniques and costs associated with these aspects are based on available case studies and available research from the UK. Details of these case studies and research findings are given below to support those involved with similar schemes and to indicate the magnitude of the likely costs. Including these case studies provides the necessary context and detail to support the cost information. A summary cost table covering all the major techniques is provided in Table 1.16.

As these techniques are used more widely and the costs associated with particular schemes collected, it will be possible to provide a more thorough investigation of the costs and how costs vary.

For detailed cost estimates once designs, site conditions and methodologies are well understood, working up costs using standard rates and a bill of quantities will be appropriate. Guidance on detailed engineering costs is provided in standard price estimating books such as SPONS (Davis Langdon 2011) and CESMM (ICE 2012). A further key dataset includes the annual John Nix Farm Management Pocketbook (John Nix 2014) which includes typical rates for agricultural machinery and labour, conservation rates and land prices.

1.4.1 Forestry and floodplain woodland and tree shelter belts

Floodplain woodland

Most UK floodplains have been greatly modified with associated habitat loss, tree clearance and river confinement through the use of riparian embankments. There are increasing opportunities and endorsement for planting and extending relic areas of floodplain woodland for flood mitigation. Riparian and floodplain woodland planting provides the opportunity to hold back floodwater and restrict flood conveyance, through increased hydraulic roughness, on floodplains and encourage natural habitats. Indicative costs are given in Table 1.3.

Table 1.3 Whole life costing for floodplain woodland

Measure	**Floodplain woodland**
Capital costs	In 2008 Forest Research undertook a study for Defra to evaluate and demonstrate the contribution of floodplain woodland to flood alleviation (Nisbet and Thomas 2008). This project built on the existing multi-objective, Defra/Environment Agency/English Nature/Forestry Commission pilot project (Ripon MOP) on the River Laver/Skell in North Yorkshire. The aim was to facilitate the establishment of a sizeable area of floodplain woodland (15 ha) to help reduce flood risk in the catchment. As part of this study researchers identified the costs and grants available to perform the proposed works. But while local landowners expressed an interest in planting woodland, the idea of the floodplain woodland was not progressed. The research suggested a standard cost for the establishment of native woodland was approximately £4,600–5,800/ha (2009 costs). A study into the Scottish forestry industry (Macaulay Land Use Research Institute 1999) provides some information on the average establishment costs for four different types of woodland (existing native woodlands, new-planted native woodlands, commercial conifer plantations, farm woodlands) ranging from £247, £1,042, £1,323 and £1,874 per hectare for each type respectively. The Bellfields Farm case study for Staffordshire Wildlife Trust (Jones 2010) provided a floodplain woodland in the form of strategic planting of bands of willow across the floodplain of the River Sow to slow flows during flood events (total area 0.87 ha). Planted at a 2 m spacing (2,500 trees/ha), each band consisted of five staggered rows of lower growing, shrubby varieties of willow. The majority of the site was planted with a mix of ash and alder (2.5 m spacing and 1,600 trees/ha). A further diversity was added along the floodplain boundary by planting a mix of broadleaved species at a 2.5 m spacing. Total costs were £3,370 (£3,900/ha). The Parrett Catchment Project (Somerset County Council, no date) involved a package of measures for tackling present and future flood events in accord with the holistic view of catchment systems. One element included woodland planting and a total area of 38.52 ha of demonstration woodland was planted across 14 strategically placed sites within the catchment. All woodlands were planted with a mix of native broadleaves typical of the area, (oak and ash), medium tree and shrub species to increase structural diversity and wet woodland

species (alder, willow and black poplar). Initial establishment costs for farm woodland varied from £2,300/ha to £3,805/ha, depending on the size of the planting, the location and the tree protection used. These costs and the breakdown of the activities are provided below.

Project activity	Description	Cost per hectare[1]		
		2,250 trees/ha[2]	1,600 trees/ha[3]	1,110 trees/ha[4]
Preparation of plan	Grant application and design	£300	£300	£300
Trees	£0.20–0.40 each	£382	£408	£374
Stakes and guards	£1.00 each	£1,912	£1,360	£944
Planting	£750 per ha	£638	£500	£400
Weeding	£0.10 per tree × 3	£573	£408	£282
Total cost		**£3,805**	**£2,976**	**£2,300**
Notes:	[1] The costs include cost of preparing the planting and management plan. Costs associated with additional 'beating up' to replace losses have not been included. The costs assume 15% of the area to be left as open ground. [2] Site area >3 ha [3] A 'new native woodland' [4] Site area <3 ha			

The River Wensum Restoration Strategy (Environment Agency 2009) estimated the costs of tree planting at a per tree level for riverside native trees (alder/willow). Estimated costs were in the order of £36 per tree (2009 costs). This was made up of £10 per tree, £2 for planting and supply and install of tubes/stakes and ties, and £24 for a deer-proof enclosure. Assuming a tree every 4 m, the cost per bank length was assumed to be £9/m.

UKBAP study reports (UKBAP 2006) provide the following costs for woodland establishment, restoration and management:

- Establishment: £1,500 per hectare followed by £200 per hectare annual payment for 10 years
- Restoration: £3,000 per hectare over 10 years
- Management: £75 per hectare per year

Maintenance costs

Maintenance may require stock-proof fencing and ongoing woodland management. Management requirements may change as the woodland matures.

Aftercare is usually required 2–3 years after planting. Willow coppicing may be required periodically (once every 10 years). Normal forestry practice for thinning would be required.

Factors

- Size of site

influencing costs	• Density of planting • Site accessibility. Getting materials and planting teams to the site can increase costs. Access may also affect maintenance costs. • Site conditions. If site preparation works (clearance) are required these will increase costs. • The presence of invasive species will also increase costs. • There may be negative costs associated with the loss of productive farm land.
Design life	Indefinite once established
Design guidelines	*Forests and Water: UK Forestry Standard Guidelines*, 5th edition, Forestry Commission, 2011 http://www.forestry.gov.uk/forestry/INFD-8BVGX9

Woodland shelter belts

Planting mixed woodland to produce a belt which primarily reduces wind speeds, but also encourages water infiltration and prevents soils erosion. Indicative costs are given in Table 1.4.

Table 1.4 Whole life costing for woodland shelter belts

Measure	**Woodland shelter belts**
Capital costs	Woodland shelter belts were used widely for the Pontbren study by the Flood Risk Management Research Consortium. Optimal shelterbelt design is achieved by an overall shelterbelt width of about 10 m and by planting a row of hedgerow shrubs along the sunny side of the shelterbelt to put additional dense vegetative coverage at the base. By including this hedgerow component, the overall tree density within the shelterbelt is increased to around 5,000 trees/ha. An example cost for establishing a shelterbelt of this type 100 m long × 10 m wide, occupying 0.1 ha, would be about £1,900 (personal communication from David Jenkins, Coed Cymru). Maintenance work would be needed in subsequent years. Hedgerow management and restoration costs are available from the UKBAP study reports (UKBAP 2006) and are provided below.

Location	**Management**	**Restoration**	**Expansion**
England	£4.50 per new planted tree + £0.20/m/year	£8 capital cost/m	£5.30 capital cost/m + £0.20/m/year annual cost
Northern Ireland	£3 per new planted tree + £0.21/m/year	£6 capital cost/m	£3.30 capital cost/m + £0.21/m/year annual cost
Scotland	£5 per new planted tree + £0.42/m/year	£6 capital cost/m	£5.50 capital cost/m + £0.42/m/year annual cost
Wales	£3.40 per new planted	£4.2 capital	£2.26 capital cost/m + £0.21/m/year annual

	<table><tr><td></td><td>tree + £0.21/m/year</td><td>cost/m</td><td>cost</td></tr><tr><td>Notes:</td><td colspan="3">Costs based on 2005-2006 prices</td></tr></table> Detailed costs for tree supply and planting in the 41st edition of the Nix Farm Management Pocket Book (2011) suggest that shelter belts tree supply costs range from £34 to £50 per 100 m, plus £265 for tree stakes, shelters and ties (site preparation, weed control, labour and fencing are in addition to these costs).
Maintenance costs	Maintenance may require stock-proof fencing and ongoing woodland management. Management requirements may change as the woodland matures.
Factors influencing costs	• Site, shape and number of shelter belts • Length and type of fencing/hedgerow needed • There may be negative costs associated with the loss of productive farm land.
Design life	Indefinite once established
Design guidelines	*Forests and Water: UK Forestry Standard Guidelines*, 5th edition, Forestry Commission, 2011 http://www.forestry.gov.uk/forestry/INFD-8BVGX9

1.4.2 Ponds and wetlands

These measures include dry basins designed to temporally store and slowly release run-off water (and often to also achieve water quality criteria). The use of restricted outflow controls allow a longer detention time.

Constructed wetlands are engineered systems designed to utilise natural processes in wetland plants and plant–substrate interactions for water quality improvements. Costs can be significantly higher for these especially if a basal lining is required.

In-line and off-line flood storage areas are excluded from this section as these are generally larger storage measures that are dealt with elsewhere in the guidance. Indicative costs are given in Table 1.5.

Table 1.5 Whole life costing for ponds and wetlands

Measure	**Pond**
Capital costs	Costs will be moderate as the construction and provision of outflow control is likely to require expert advice and specialist equipment. A number of reports provide case study examples and costs associated with pond creation. These reports and case studies are summarised below and include the following: • The *Farming Floodplains for the Future* report contains a number of unlined pond creation case studies (Jones 2010). • *Farm Integrated Run-off Management Plans* (Quinn et al. 2007) provides indicative costs based on work in Northumberland. These costs include built-in research costs that may not be fully representative.

- The Parrett Catchment Project constructed farm-scale flood storage reservoirs to intercept upland run-off for tackling present and future flood risks in accordance with the holistic view of catchment systems (information from Stephen Dury, Somerset County Council).

Example costs from these case studies are given below,

Scheme	**Costs**	**Storage (m^3)**	**£/m^3**	**Source/ year**	**Comment**
Bellfields Farm	£5,652	6,150	£0.9	FFF 2010	Construction of a 415 m long embankment, 0.6–1 m high with outflow controlled via two 150 mm diameter pipes. All material was sourced from site.
Bellfields Farm	£14,320	6,750	£2.1	FFF 2010	Construction of three bunds 0.6–1.2 m high. Material sourced onsite. Additional floodplain lowering was undertaken to create pools for wetland habitats.
Izaak Walton	£2,453	2,050	£1.2	FFF 2010	Improved storage by construction of shallow bunds, modified outflows and floodplain re-grading.
Little Horsley Farm	£8,403	275	£30.6	FFF 2010	Creation of two shallow ponds, associated wet grassland habitat and deepening of a historic channel. Costs include £2,250 for a new bridge, fencing, seed and remedial works.
Nafferton Farm	£2,000	100	£20	FIRM 2007	Estimated costs if research elements are ignored and if installed by local farmers and landowners
Creedy Bridge	£32,200	51,000	£0.6	Parrett 2005	Costs do not include consultant costs of £78,000 for all four reservoirs.
Bower Hinton	£42,550	5,000	£7.4	Parrett 2005	
Vokers	£40,250	5,600	£6.3	Parrett	

Bridge				2005	
Balham Hill	£6,000	1,200	£4.2	Parrett 2005	
Notes:	FFF = *Farming Floodplains for the Future*; FIRM = *Farm Integrated Run-off Management Plans.*				

In addition, Mitigation Options for Phosphorus and Sediment (MOPS) project constructed 10 storage areas for research into the cost-effectiveness of in-field storage to control diffuse pollution losses and surface run-off (personal communication Clare Deasy, Lancaster University). Dimensions varied from 20 m^2 to 320 m^2 and depths of 0.5–1.5 m (approximate storage volumes varied from 10 m^3 to 190 m^3). The costs for the simple smaller edge of field and in field systems ranged from £500 to 1,000 for excavation (1–3 days with digger). Costs for the larger more complex ones involving drainage diversion were around £3,000. They suggest that ongoing costs might be £500/year for dredging one year in five. Costs do not include time spent on getting permissions or compensation for land area taken out of production.

Maintenance costs

Maintenance costs may include the following:

- removal of leaves and debris
- mowing and vegetation management of side slopes
- periodic sediment removal from main pool
- visual check of outflows and removal of blockages as required
- occasional cleaning out of any sediment trap

While the construction costs of ponds and wetlands are relatively straightforward to calculate, the maintenance costs are more difficult to estimate. Key questions regarding maintenance concern:

- type and frequency of maintenance required (for example, sediment removal)
- inlet/outlet maintenance, landscaping, litter removal)
- costs of maintenance (for example, disposal route for excavated sediment)
- responsibility for maintenance (for example, local authority, highways agency, residents, developer)

Sustainable drainage systems (SuDS) cover both urban and non-urban measures. It is recommended that users check the maintenance costs associated with these measures for applicability to rural ponds.

Pond maintenance costs provided in 41st edition of the Nix Farm Management Pocket Book (2011) suggested that maintenance (pond sediment removal) would cost in the region of £25–40 per hour for plant hire and a maintenance rate of 100 m^2 per day, but will vary depending on ground conditions and species.

Factors

- Size of pond. Small informal farm level ponds can be relatively

influencing costs	cheap. Larger catchment scale ponds can be significantly more expensive due to legislative controls and standards/consents required for funding. • A consent for works affecting watercourse and/or flood defences may be required. • Associated wetland/meadow creation and planting/seeding can increase costs. • Fencing to control access can increase costs. • Associated water control structures or modifications will increase costs. • The degree of associated channel diversions if required will increase costs. • There may be negative costs associated with the loss of productive farm land.
Design life	Long design life if maintained
Design guidelines/ further information	*Sustainable Drainage Systems: Hydraulic, Structural and Water Quality Advice*, C609, CIRIA, 2004 Design Guides, Constructed Wetlands Association http://www.constructedwetland.co.uk/resources/design_guides/ *Constructed Farm Wetlands (CFW): Design Manual for Scotland and Northern Ireland*, 2008 http://www.dardni.gov.uk/index/farming/countryside-management/constructed-wetlands.htm

1.4.3 Field scrape/infiltration trench

Field scrapes and trenches are depressions designed to hold back and store run-off, and allow it to infiltrate into the ground during rainfall events. Depressions can be designed by excavating a depression into the ground or by constructing a low embankment at the bottom of a slope. Trenches may include the construction of shallow drains to direct flow from tracks/roads/hardstandings into the depression. Indicative costs are given in Table 1.6

Table 1.6 Whole life costing for field scrapes/infiltration trenches

Measure	Field scrape/infiltration trench
Capital costs	Costs can be low and often will involve only the costs associated with the hire of a digger and compaction of scrape/bund walls. Indicative costs from the Linking Environment And Farming project (LEAF and Environment Agency 2010) suggest that construction costs for a simple small field scrape could be between £200 and £500. The cost of moving material will depend on local contractor's costs and these vary between regions. Costs will also be very site-specific with site complexity, river type and site access all having a major impact on cost.

	It is suggested that the costs of field scrapes can be found by dividing the total volume of material to be moved by the quantity excavated per hour to determine the total time required. Multiplying this by the hourly cost of the machine (hire rate including operator) will determine the costs associated with the excavation works. Costs for seeding, outflow controls and fencing may also be required. This assumes that all material can be sourced onsite and that no disposal is required.
Maintenance costs	Cost to include monthly inspections, intermittent mowing, and occasional sediment removal.
Factors influencing costs	• There may be negative costs associated with the loss of productive farm land. • High siltation rates could reduce effectiveness and increase costs for removal of sediment. • Use of restricted outflow control or water filters may increase costs.
Design life	Up to 30 years if correctly designed and maintained
Design guidelines	*Sustainable Drainage Systems: Hydraulic, Structural and Water Quality Advice*, C609, CIRIA, 2004 *Infiltration Drainage – Manual of Good Practice*, R156, CIRIA, 1996

1.4.4 In-channel barriers

In-channel barriers are designed to slow and hold the flow of water so as to allow soil particles to settle out and hold back water within the drainage network to reduce peak flows in the main river. The concept could be scaled up at sub-catchment level and, with some spatial planning, could contribute to a reduction in flood risk. The barriers are designed with gaps to allow normal flows to pass through the barriers but to hold back flows during high flows. Indicative costs are given in Table 1.7

Table 1.7 Whole life costing for in-channel barriers

Measure	**In-channel barriers**
Capital costs	Costs should be low but will depend on the materials used and width of channel. Indicative costs from the Linking Environment And Farming project (LEAF and Environment Agency 2010) project suggest that construction costs for simple in-channel barriers are approximately £50–100, including costs for poles, posts, and construction and digger hire. Construction used a mixture of natural features and stumps of felled trees as an anchor for the wooden barrier. An alternative and cheaper version was constructed using locally sourced willow. Indicative costs from the Farm Integrated Run-off Management Plans case study at Nafferton Farm in Northumberland suggested that in-channel barriers cost £1,000 (Quinn et al. 2007). The main difference in the costs is the use of green oak from a sustainable source and the inclusion of built-in research costs. *Farming Floodplains for the Future* provides information on Internal Drainage Board (IDB) case studies (Jones 2010). These placed five

	water control structures on IDB drains in the Sow and Penk IDB area (Deepmore Drain and Millian Brook). Structures were constructed of plastic sheet-piling dams incorporating an adjustable section and two simple pipe dams to permanently raise water levels upstream. The total cost for the five structures was £3,940 (£800 per structure).
Maintenance costs	• Basic barriers will require periodic (every 1–5 years) removal of sediment and periodic structural inspection and repair. • Barriers may require re-construction after large floods if barriers fail. • Annual costs are expected to be minimal.
Factors influencing costs	• Barriers may be associated with water quality measures to encourage additional sedimentation and removal of sediment bound pollutants (for example, phosphorus and ochre traps). • The inclusion of works to add these additional benefits may increase costs substantially.
Design life	Highly variable depending on nature of flows, construction method and maintenance
Design guidelines	*Virginia's Forest Best Management Practice for Water Quality,* Technical Manual, 5th edition, Virginia Department of Forestry, 2011, Appendix A http://www.dof.virginia.gov/water/index-BMP-Guide.htm

1.4.5 Large woody debris

Large woody debris (LWD) or engineered log jam have historically been used to promote aquatic habitats through the creation of complex hydraulic and physical conditions. Although LWD has been seen in the past as a flood risk and historically removed, current research suggests that LWD can be used to increase flow resistance and may help to control run-off through flow attenuation on the local floodplain. Indicative costs are given in Table 1.8.

Table 1.8 Whole life costing for large woody debris

Measure	**Large woody debris**
Capital costs	Costs for LWD will vary from nothing at all (if using onsite material and volunteer resources), to significant costs if major, semi-permanent debris dams are required. Some examples are included below. The costs provided in the spreadsheet tool developed as part of the 'Estimating costs of delivering the river restoration element of the SSSI PSA target' project (Environment Agency 2008) give a cost for the construction of LWD deflectors of £821 per 100 m assuming four deflectors per 100 m reach, a 4 m long deflector, two days to build, and constructed by contractors and all posts/wire material. It also assumes that all logs are located onsite. Costs of a site agent, engineer, site setup and compound costs, together with a 25% allowance for feasibility, surveys, EIA, design and negotiation costs and compensation for fisheries interests may increase these costs substantially. LWD construction as part of the River Churnet national demonstration

	project indicated that the capital costs were £6,000 for construction of a large engineered log jam that involved the digging a shallow trench, placement of a 6 tonne oak tree trunk and oak posts for long term support, and a further placement of 22 tonnes of LWD (personal communication, Nick Mott, Staffordshire Wildlife Trust). At Tittesworth in the Peak District National Park, 700 m of stream course were re-profiled. Log weirs were installed at strategic locations and designed to create some ponded reaches upstream (but still allow fish passage). Raised water levels helped to re-wet approximately 10 ha of floodplain and a number of scrapes, ephemeral 'dragonfly' pools, 'ridge and furrow' reedbed shells and several more permanent ponds. The cost was approximately £25,000 for stream corridor work (Mott 2005).
Maintenance costs	Maintenance will be minimal other than periodic reconstruction and possible siltation removal upstream.
Factors influencing costs	• Costs will vary with the quantity of the LWD (number of barriers per reach) and size of watercourse. Costs will increase proportionally with stream size. • Costs will also depend on the size of material used. Larger materials are substantially more expensive to transport and place than smaller trees, stumps and so on that can be placed by hand. • Costs will also vary depending on the availability of material. Material sourced locally will reduce transportation costs. It is typically assumed that all material can be sourced locally. • The type of anchoring will influence costs. • Site location and accessibility will also affect the costs.
Design life	No reliable information on design life of large woody debris exists.
Design guidelines	*Large Woody Debris in British Headwater Rivers: Physical Habitat Role and Management Guidelines*, R&D Development Technical Report W181, Environment Agency, 1999 http://cdn.environment-agency.gov.uk/str-w185-e-e.pdf *The Robinwood Robinflood report: Evaluation of Large Woody Debris in Watercourses*, Forestry Research, 2008 http://www.robin-wood.eu/uploads/robinwood_flood.pdf *Engineering Log Jams: Conceptual Design Guidelines*, WAT-SG-37, SEPA, 2006 http://www.sepa.org.uk/water/water_regulation/guidance/engineering.aspx

1.4.6 In-channel wetland

Creation of a small linear wetland feature within a channel will slow and store water, and enhance sedimentation and the channel's ability to cleanse diffuse pollutants. Drainage control measures can aid the retention of water. Indicative costs are given in Table 1.9.

Table 1.9 Whole life costing for in-channel wetland

Measure	In channel wetlands
Capital costs	Costs can be high depending on the scale or works and the need for specialist advice to widen ditches and install barriers and plants to maximise efficiency. Indicative costs from the Linking Environment And Farming project (LEAF and Environment Agency 2010) suggest that construction costs to include re-profiling, reed planting, and alterations to surface water and flood defence consent applications cost a total of £895 for a small (approximately 100 m) reach. Indicative costs from the Farm Integrated Run-off Management Plans project at Nafferton Farm in Northumberland are provided for two case studies that included channel widening and re-profiling, and either sedge or willow planting (Quinn et al. 2007). The costs for a 30 m reach were £5,000 and £6,000 for the sedge and willow reaches respectively.
Maintenance costs	Maintenance costs are low but may require periodic debris/rubbish clearance at the upstream end of willow barriers.
Factors influencing costs	There are very few examples of these sorts of measures for flood run-off reduction measures. It is anticipated that as these measures become more widely used, the costs and factors influencing the costs will become better understood.
Design life	Assumed the same as constructed wetland, therefore 50–100years if maintained
Design guidelines	No specific guidelines available – see general constructed wetland guidance.

1.4.7 Peat drainage – grip/gully blocking

This section includes blocking off of old moorland grips (shallow surface drainage channels) and gullies in upland peatlands. Grip/gulley blocking operations in the last 10–20 years have been carried out for a variety of purposes, many of which were interlinked. Grip/gulley blocking can serve to re-wet upland peatlands for restoration purposes and help to reduce the erosion of valuable peat resources. In places grip/gulley blocking has also been driven by the need to reduce water colour problems that existed in some upland reservoir and potable water supply sources. Water colour is caused by the presence of dissolved organic compounds – predominantly humic and fulvic acids, which are the products of decomposition from all organic soils. Any impoundment in the drainage network can also function to attenuate flood flows from the uplands.

Grips can be blocked by several methods including:

- excavation of an adjacent portion of peat and placement in the grip channel
- piling material (corrugated plastic, wood, metal) or bales of heather or rushes that can be placed across the grip to impede water movement

The costs of enhancing easily restorable bog (for example by reducing grazing or varying management practices) are low and comparable to annual management costs. However, the costs of restoration of heavily degraded sites, involving tree removal, large scale grip blocking or rehabilitation of heavily burnt or eroded sites incur much larger capital costs. Indicative costs are given in Table 1.10.

Table 1.10 Whole life costing for peat drainage – grip blocking

Measure	**Peat drainage – grip blocking**
Generic capital costs	While costs for individual grips are small, the extensive nature of the grip system and their density means that the costs of implementing these schemes can be very high. Defra undertook a review of all current UK peat restoration and management projects as part of a compendium of UK peat restoration and management projects (Defra 2007). The costs ranged from £1,000 per km to £6,500 per km depending on location and the techniques used. Costs for gully blocking (gullies are erosion channels that form in degraded peatlands) are typically £2,500 per km of gully based on a typical dam spacing of 15 m, although this depends on the gully slope. Costs based on the UKBAP study (UKBAP 2006) include the following costs based on an area basis: • Management costs: £8–40/ha/year • Enhancement of readily restored bog: £8–40/ha/year • Restoration of degraded bog: £500/ha

Detailed capital costs	Detailed costs for peat management collated as part of the peat compendium include the following examples of specific restoration actions undertaken as part of grip blocking measures:
	• Peat stabilisation. On the heavily eroded Peak District slopes, brash was spread at a rate of 18 tonnes per hectare at a cost of £1,700 per hectare.
	• Peat re-profiling. £600 per ha (£5 per m) but can be much greater if a large amount of re-profiling is required.
	• Reseeding: £900 per ha to £95 per ha (Moors for the Future report gives £215–300/ha for seed and application; Evans et al. 2005)
	• Planting: £2,700 per ha (Moors for the Future gives £1,500–£3,000/ha)
	• Scrub clearance: £400–3,000 per ha but is mainly done by in-house staff or volunteers
	• Information provided by the Moors for the Future Partnership (personal communication, Matt Buckler, Conservation Works Manager) and quoted in the Moors for the Future report (Evans et al. 2005) provides detailed cost estimation for individual grips.
	• Material:
	  ◦ Plastic piling (£6/m) (£50–80 per dam)
	  ◦ Wood (£2/m) (£8–20 per dam)
	  ◦ Stone (£60/tonne) (£40 per dam)
	  ◦ Wooden slats or wool bag or coir log, stakes (£10/m) (£20–60 per grip)

	• Heather bales (£2–6 per bale) (£6–30 per dam)
	• Heather brash (£70/tonne) (£20 per dam)
	
	• Transport:
	  • Helicopter drops have been calculated at £450/h or £5 per dam.
	
	• Labour:
	  • £13 per dam; 6–8 dams can be completed within a day by two people (£15/hour or £105/day per person). Assuming that 100 m would require 10–20 dams, the cost for a 100 m reach would be £260–1,960.

Maintenance costs	Maintenance costs are minimal as grips tend to trap sediment once the initial dam construction is undertaken. Maintenance may be required after large storm events. It is essential to budget for ongoing maintenance and monitoring after block installation.
Factors influencing costs	• Ditch morphology (size and slope) and interval of grips required. Steeper gullies require a greater density of dams (that is, short distance between dams) and will therefore be more expensive to block. • Use of plastic or wooden piling is more expensive than use of peat turves. • Maintenance of erosion around grips may also increase costs. • Travel time to site may be substantial and should be allowed for in costs. • Archaeological survey costs can be expensive in some cases (£10,000 and £80,000 for two projects collated as part of the Defra peat compendium).
Design life	Little reliable information on design life is currently available.
Design guidelines	Understanding Gully Blocking in Deep Peat, Moors for the Future Report No 4. 2005 http://www.moorsforthefuture.org.uk/research-publications

1.4.8 Floodplain reconnection/re-meandering

The aim of these restoration measures is to manage flood risk by protecting, restoring and emulating the natural regulating function of catchments, rivers and floodplains. This can be achieved by the removal or lowering of river embankments, the creation of new spillways to reconnect rivers with floodplains and the lengthening of watercourses to a more natural alignment (with additional meanders). Indicative costs are given in Table 1.11.

Table 1.11 Whole life costing for floodplain reconnection/re-meandering

<table>
<tr><th>Measure</th><th>Floodplain reconnection/re-meandering</th></tr>
<tr><td>Generic capital costs</td><td>Despite a wide cost range for these types of projects, a number of studies have attempted to estimate generic floodplain re-connection/ re-meandering costs. This includes the studies summarised in below.
<table>
<tr><th>Project/study</th><th>Description</th><th>Cost per m</th></tr>
<tr><td rowspan="4">River Wensum Restoration Strategy (Environment Agency 2009)</td><td>Back-channel re-connection</td><td>£60</td></tr>
<tr><td>New back-channel</td><td>£230</td></tr>
<tr><td>Channel re-sectioning</td><td>£60</td></tr>
<tr><td>Channel realignment</td><td>£150</td></tr>
<tr><td rowspan="2">SNIFFER Water Framework Directive (SNIFFER 2005)</td><td>Re-connection of existing meanders to main channel</td><td>£10–40</td></tr>
<tr><td>Initiation or construction of new meanders</td><td>£25–80</td></tr>
<tr><td rowspan="3">Collaborative Research Programme on River Basin Management Planning (Entec 2008)</td><td>Partial restoration (initiation of existing meanders)</td><td>£25–80</td></tr>
<tr><td>Construction of new of meanders</td><td>£50–240</td></tr>
<tr><td>Re-profiling of banks</td><td>£14–40</td></tr>
</table></td></tr>
<tr><td>Detailed capital costs</td><td>Floodplain restoration costs are among the most variable and difficult to predict due to site-specific aspects and design requirements/ constraints. Expert opinion varies on which factors are most responsible for differences in project costs. More systematic record-keeping with consistent parameters would encourage greater predictability for these projects.

The costs provided in the spreadsheet tool developed as part of an Environment Agency project (Environment Agency 2008) give a cost for re-meandering a channel of the order of £1,603 per m. This value is based on a channel width of 11 m, a depth to be excavated of 2.6 m and a new channel length of 150 m. Excavation of material is assumed to be at a rate of 10 m^3 per hour with 33% of the total material to be disposed of offsite. Costs also include channel section modifications and bed raising, all preliminaries and site costs, and a 50% allowance for design, EIA, feasibility and negotiation costs.

Examples from the literature are given below to provide a number of case studies and an appreciation of the range of costs applicable to this restoration strategy. Case studies have been provided by the following projects/reports:

• River Restoration Centre manual (2002) (RRC)
• Forestry Commission New Forest Wetland Management Plan (2006) (FC)
• Environment Agency report, Working with Natural Processes, (2010) (EA)
• Staffordshire Wildlife Trust (Jones 2010) (SWT)</td></tr>
</table>

Measure	Floodplain reconnection/re-meandering					
	Site	**Length (m)**	**Cost**	**Cost per m**	**Ref**	**Comments**
	Markway stream restoration	1,300	£18,238	£14	FC	Excavation and reinstatement of former meandering channel, and short section of new channel
	River Erewash	700	£35,000	£50	EA	Connection (via sloping riffle weir) of two meanders to the existing straightened channel
	Church House Farm	350	£10,893	£31	SWT	Reconnected and re-profiled 350 m of floodplain.
	River Trent at Wolseley Bridge	340	£10,000	£29	SWT	Re-profile 340 m along the inside of a large meander to help kick start natural geomorphologic al processes.
	Croxall Lakes	540	£159,000	£294	SWT	River rehabilitation and river widening and braiding scheme including reedbed creation. Significant sediment movement required to widen river and create shallows, islands and braided sections.
	Sinderland Brook	1,800	£3.9 million	£2,1 70	EA	Re-meandering the brook and creation of a new valley form at a lower elevation that ranges from 30–60 m wide to encourage more frequent

Measure	Floodplain reconnection/re-meandering

					inundation of the floodplain.
River Cole – new channel through open fields	500	£9,000	£18	RRC	New river course was created to introduce a reach of free-flowing water to a floodplain.
River Cole – new channel meandering either side of existing	700	£25,000	£36	RRC	New channel was created to restore meanders.
River Cole – new meander in an impounded river channel	300	£9,000	£30	RRC	By-passes the mill (and the leat) in a new meandering channel.
River Skerne – new meanders to one side of existing channel	500	£40,000	£80	RRC	A new meandering river that partially incorporated into the existing channel.
River Ravensbourne – opening up a culverted stream	300	£127,000	£423	RRC	Restoration of a more 'natural' stream with diverse in-channel. Culvert plugged and 300 mm diameter culvert inserted for land drainage connections.
Little Ouse – reconnecting remnant meanders	900	£15,000	£17	RRC	New canalised course was straight, trapezoidal, 6 m wide and 1–2 m deep, with 3 m dry, steep banks.

Notes:
[1] Costs include all equipment hire, materials and labour costs.
[2] Costs associated with meander construction cost only.
[3] Consultants' supervision and surveys costs were an additional £4,500.
[4] Project management, supervision and planning costs were an additional £17,000.

Maintenance costs	Long-term annual maintenance costs will be similar to standard channel maintenance costs.

Measure	Floodplain reconnection/re-meandering
	Initial inspection and maintenance for a period after construction may be higher due to need for a higher frequency of inspection to ensure channels are stable and vegetation establishment is achieved.
Factors influencing costs	• The degree of earth moving will be a key aspect with regard to costs. Some cases may only require minimal earthmoving where the connections to the floodplain require little work. Conversely, substantial earthmoving will be required where levees need to be removed or lowered, or entire channel segments require excavation or reconfiguration. • High energy rivers with high velocities and discharge will increase costs as these will require more robust materials, more complicated design and engineering, and costlier construction techniques. • The size of the channel and proposed works will affect the planning and licence/consent applications. In-river works and more extensive projects will incur significantly greater costs associated with these aspects. • Environmental constraints such as presence of protected species and habitats, invasive species, fish spawning, and bird/mammal breeding
Design life	Little reliable information on design life is currently available.
Design guidelines	*Manual of River Restoration Techniques*, 3rd edition, The River Restoration Centre, 2013 http://www.therrc.co.uk/rrc_manual.php

1.4.9 Soil management

Soil management includes farm-based, agricultural options that are typically used to control diffuse pollution. While the drivers for these options are typically to mitigate diffuse pollution, they may also improve soil infiltration rates and reduce surface run-off. Options may include a range of options such as:

- contour ploughing
- tramline management
- minimum tillage
- cultivation direction
- in-field barriers

The success and uptake of these mitigation options therefore depends on the farmer's attitude and willingness to implement options. There are therefore likely to be additional costs for the management and liaison with farmers to inform aspects such as:

- adoption costs (for example, equipment, training)
- potential risks (for example, disease, pests, yield)
- how mitigation management practices can be practically and cost-effectively integrated into conventional farming operations

Generic costs for these types of measures have been estimated as part of projects contributing to the Water Framework Directive including the Collaborative Research Programme on River Basin Management Planning Economics (Entec 2008) and the Defra Diffuse Water Pollution from Agriculture (DPWA) study (Cuttle et al. 2006). Cost estimates from these studies are summarised in Table 1.12.

Table 1.12 Cost estimates for farm-based agricultural soil management options

Measure	Cost	Comment/assumption
Soil management	£123/ha/year	Based on an arable farm system.
	£36/ha/year	Based on a dairy farm system.
Conversion of arable to extensive grazing	Capital: £800–1,000/ha O&M: £80–100/ha/year	Taking a farm or a proportion out of production may have a negative cost.
Tramline management	£4.5/ha/year	
In-field barriers/buffer strips	£32/ha	Establishment costs using natural regeneration and a light cultivation. The buffer strip will be topped once in five years to control woody growth.

The Defra Mitigation Options for Phosphorus and Sediment (MOPS) project (Deasy et al. 2009) project investigated the efficacy and cost-effectiveness of different in-field mitigation options to control diffuse pollution losses in surface run-off from arable fields. As part of this study field monitoring over three years on three different soil types was performed, together with the development of simple spreadsheet models to test the cost-effectiveness of different mitigation treatments. While the driver for this study was the reduction in phosphorus and sediment, the options trialled are similar to those undertaken for catchment sensitive farming. Cost estimates estimated as part of this project are summarised in Table 1.13.

Table 1.13 Cost estimates from the MOPS project

Measure	Costs of undertaking mitigation measures
Contour ploughing	Costs of £3–5 per ha suggested due to slower work rate in operations on the contour.
Tramline management	Although expensive when considered at the experimental field scale (£18–£38/ha), tramline disruption at the farm scale represents a small cost of £2–4/ha, assuming a typical field rotation, 24 m tramline spacing and a work rate of 5–10 ha/hour.
Minimum tillage	Minimum tillage should not increase costs.
Crop residue incorporation	Crop residue incorporation rather than baling and removal of straw reduced run-off. Incorporation of crop residues may incur costs through lost revenues from straw sales, and additional costs of £25 ha where straw chopping is not part of the harvest operation.

Measure	Costs of undertaking mitigation measures
In-field barriers	The costs of including a 2 m wide vegetative barrier on the contour include a one-off capital cost for establishment of £3–5 per 100 m of 2 m width barrier, and an ongoing annual maintenance cost for topping the vegetation £0.5–0.6 per 100 m of 2 m width barrier. In-field vegetative barriers on the contour may promote contour cultivation and may also have further biodiversity benefits. There may also be a further cost associated with reduced field size and increasing operational complexity.

The 41st edition of the Nix Farm Management Pocket Book (2011) provided the costs given in Table 1.14 associated with the establishment and maintenance of permanent field margins.

Table 1.14 Costs associated with establishment and maintenance of permanent field margins

Margin type/width	Establishment costs	Maintenance costs
2 m	£5–6 per 100 m	£0.6–0.7 per 100 m
6 m	£15–20 per 100 m	£1.8–2.1 per 100 m
Beetle bank (6 m wide)	£4.5–6 per 100 m	–

Source: Nix Pocket Farm Management Pocket Book, 41st edition, 2011

1.4.10 Riparian buffer strip (and bund)

This includes the provision of bands (typically 5–15 m wide) of established rough vegetation situated alongside water bodies. They are primarily used to reduce the risk of pollution and encourage sedimentation, but may reduce flow into channels where overland flow dominates. They may also be combined with low ridges or bunds to divert run-off away from water bodies (possibly into ponds, wetlands or swales). Indicative costs are given in Table 1.15.

Table 1.15 Whole life costing for riparian buffer strip (and bund)

<table>
<tr><th>Measure</th><th>Buffer strips and bunds</th></tr>
<tr><td>Generic capital costs</td><td>Generic costs for the establishment and maintenance of buffer strips have been estimated as part of projects contributing to the Water Framework Directive (Scottish Government 2008) and the Collaborative Research Programme on River Basin Management Planning Economics (Entec 2008). Cost estimates from these two studies are summarised below.
<table>
<tr><th>Measure</th><th>Cost</th><th>Comment/assumptions</th></tr>
<tr><td rowspan="2">Boundary management</td><td>£58/ha setup
£6/ha/year maintenance</td><td>Based on an arable farm system.</td></tr>
<tr><td>£93/ha setup
£38/ha/year maintenance</td><td>Based on a dairy farm system.</td></tr>
</table>
</td></tr>
</table>

	Establish riparian buffer strips	£16/ha/year	Based on an arable farm system.
		£20/ha/year	Based on a pastoral farm system.

Detailed capital costs	Establishment costs will include planting on vulnerable soils to help reduce erosion/improve soil structure. Costs may also include a number of other aspects such as: • fencing of ditches, streams and boggy areas to exclude animals from waterways • works to provide alternative drinking spots • new stream crossings to protect river banks and prevent erosion Examples of these costs from the Environment Agency (2002) report on agriculture and natural resources are provided below.

Measure	Cost
Arable field margins (seed cost only)	Annual cost: £7.50 per 100 m
Buffer strip vegetation planting	Capital cost: £0.3 per m for 2 m wide field margin Annual cost: £0.5 per 100 m for 2 m wide strip grass maintenance
Planting hedges and fencing	£11 per m planting hedges and fencing
Fencing	£0.9–1.10 per m electric fence
Provide alternative drinking spots	Capital cost: £400 per stabilised drinking area
Stream crossings and access, fencing & bridge	Capital cost: £200 to stabilise banks. Capital cost: £400–500 for simple bridge

Maintenance costs	See above
Factors influencing costs	• Width, vegetation variety and density • Slope • Contributing catchment area • Loss of land may result in dis-benefits to land owners.
Design life	Indefinite if maintained
Design guidelines	*Strategic Placement and Design of Buffering Features for Sediment and P in the Landscape*, PE0205, Defra, 2006 http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=11028 *Good Practice Management of Riparian Vegetation*, Environment Agency [online] http://evidence.environment-agency.gov.uk/FCERM/en/SC060065/MeasuresList/M2/M2T2.aspx?p

	agenum=2 *Good Practice Guide – Riparian Vegetation Management,* SEPA, 2009 http://www.sepa.org.uk/water/water_publications.aspx

1.5 Summary of costs

A summary of the costs associated with each of the key land use and run-off management options is provided in Table 1.16.

Table 1.16 Summary of land use and run-off management costs

Measure	Unit	Cost
Floodplain woodland establishment	Per hectare	£2,000–6,000
Floodplain woodland management	Per hectare per year	£75
Hedgerow establishment	Per m length	£4–8
Hedgerow management	Per m per year	£0.2–0.4
Ponds and wetland establishment	Too site-specific to provide unit costs. Costs range from £1 to 30/m^3 storage.	
Field scrap/infiltration trench	Per small scrape	£200–500
In-channel barriers	Per barrier	£100–800
Large woody debris	Highly variable depending on size of barrier/deflector	
In-channel wetland	Insufficient case studies to provide meaningful costs	
Grip blocking – restoration	Per hectare	£500
Grip blocking – restoration	Per 100 m	£250–2,000
Floodplain reconnection/re-meandering (of existing)	Per m	£10–80
Construction of new meanders	Per m	£50–250

1.6 Cost estimation methodology

The flow diagram in Figure 1.2 summarises the key aspects required to generate a whole life cost for land use and run-off management options to include all relevant capital costs and O&M costs.

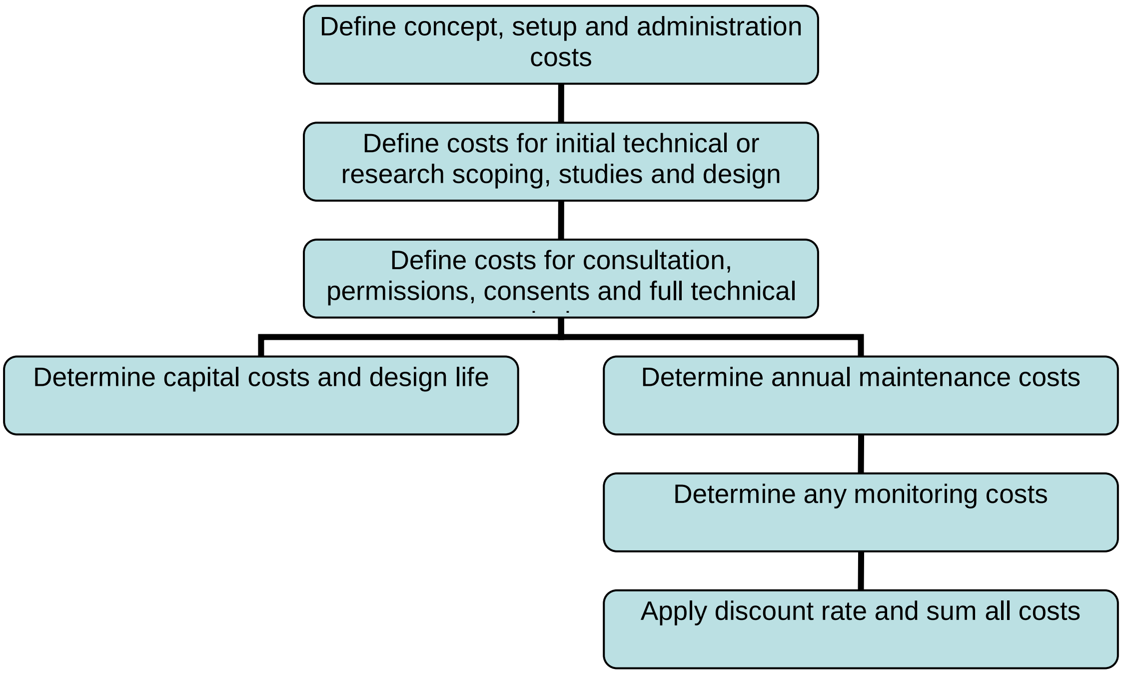

Figure 1.2 Flow diagram for land use and run-off management whole life costs

1.7 Risks/data confidence and uncertainties

There are a number of considerations and risks that need to be considered for the estimation of costs for land use management and run-off practices.

General risks include:

- confidence in understanding the issues and scale of works required to achieve the required outcome
- landowner and stakeholder constraints such as willingness of private landowners and acceptance by associated interest groups
- physical and technical constraints such as access, environmental constraints, cultural and heritage constraints and geomorphological risks
- permissions and consent requirements

The costs provided will be lower if installed by local farmers, landowners and local agricultural engineers. Features carried out within the case studies are often over-designed and have additional costs associated with research-related aspects, demonstration purposes and practical lessons learnt during implementation/construction.

Most of the case studies, examples and studies where cost estimates or recorded out-turn costs are available are site-specific and often relate to single location studies/trials. For these mechanisms to be used more widely and integrated into catchment and strategic plans, economies of scale will need to be applied to ensure a holistic approach to flood storage within a catchment. The costs and methodology of achieving this will inevitably require a significant cost in terms of initial setting up and management/liaison and advice, consultation, monitoring and support through a project lifetime.

There are uncertainties with regard to design standards of run-off management practices. Currently the more rural, farm-based practices assume that techniques can be carried out locally by landowners, farmers and local agricultural engineers; the costs of implementing these aspects are significantly lower than alternative techniques. Conversely, some examples that have used flood storage have done so at a larger scale and require additional regulatory requirements under the Reservoirs Act 1975[1] and the subsequent Flood and Water Management Act 2010 are therefore significantly more costly to construct and maintain.

There are uncertainties in the design life of some of the systems as many of these techniques have only been trialled relatively recently and information on the maintenance and reinstatement of some elements is unknown and untested.

Options that involve the creation and management of habitats or the amending of agricultural practices can often result in a loss of agricultural production. Conversely, these options may also provide environmental benefits through an increase in biodiversity. These associated costs would need to be considered in an appraisal if significant.

1.8 R&D and general design guidance

- Environment Agency, 2010. *Working with Natural Processes to Manage Flood and Coastal Erosion Risk: A Guidance Document*. Describes a broad range of techniques for working with natural processes in all areas of a catchment. Case studies illustrate where these techniques have already been used. http://publications.environment-agency.gov.uk/pdf/GEHO0310BSFI-e-e.pdf [Accessed 28 January 2014]
- Environment Agency, 2008. *Delivery of Making Space for Water: HA6 Catchment Scale Land-use Management and HA7 Land Management Practices*. *Review of existing land management delivery mechanisms.* http://webarchive.nationalarchives.gov.uk/20130123162956/http:/www.defra.gov.uk/environment/flooding/documents/manage/deliverymech.pdf [Accessed 28 January 2014]
- Environment Agency, 2008. Delivery of Making Space for Water: HA6 Catchment Scale Land-use Management and HA7 Land Management Practices. The role of land use and land management in delivering flood risk management. http://archive.defra.gov.uk/environment/flooding/documents/manage/landuserole.pdf [Accessed 28 January 2014]
- Environment Agency (2008) *R&D Update Review of the Impact of Land Use and Management on Flooding.* Updates Defra and Environment Agency 2004 report detailed below. Reviews current research relevant to the role of land management and land use in flood risk management. Identification of future research and development needs. http://webarchive.nationalarchives.gov.uk/20130123162956/http:/www.defra.gov.uk/environment/flooding/documents/manage/updatereview.pdf [Accessed 28 January 2014]
- Environment Agency, 2008. *Best Farming Practices.* Introduces ideas to reduce and control run-off. Identifies grants for agri-environment measures and catchment sensitive farming that could help to reduce run-off and adapt

[1] The Flood and Water Management Act 2010 updated the Reservoirs Act 1975 and reflects a more risk-based approach to reservoir regulation through reducing the capacity at which a reservoir will be regulated from 25,000 m^3 to 10,000 m^3 and ensuring that only those reservoirs assessed as a higher risk are subject to regulation.

to flood risk. http://www.wensumalliance.org.uk/publications/EA_Best_farming_practices.pdf [Accessed 28 January 2014]

- Environment Agency, 2002. *Agriculture and Natural Resources: Benefits, Costs and Potential Solutions.* Provides an economic overview of the relationship between agriculture and the environment. It looks in detail at natural resource issues, society benefits, damage costs, the effectiveness of technical solutions, solution costs, and the strengths and weaknesses of current and potential Government policies. http://www.environment-agency.gov.uk/research/policy/33061.aspx

- Defra and Environment Agency, 2004. *Review of the Impacts of Rural Land Use and Management on Flood Generation* (FD2114). Examines the factors contributing to run-off and flooding in the rural environment and suggests research needed to improve the identification of the management policies and interventions to reduce the impact of flooding. http://sciencesearch.defra.gov.uk/Document.aspx?Document=FD2114_2197_TRP.pdf [Accessed 28 January 2014]

- WWF, 2008. *Flood Planner: A Manual for the Natural Management of River Floods*. Outlines the background to natural flood management, provides evidence of the effect of natural flood management on run-off rates and storage, and describes the techniques required to successfully lower flood risk to communities within catchments. http://assets.wwf.org.uk/downloads/floodplanner_web.pdf [Accessed 28 January 2014]

- Forest Research. Various reports on the impact of floodplain woodland on flood risk. http://www.forestresearch.gov.uk/fr/INFD-7ZUCQY [Accessed 28 January 2014]

- Cuttle et al., 2006. *An Inventory of Methods to Control Diffuse Water Pollution from Agriculture (DWPA). User Manual.* Provides estimates of the cost and effectiveness of the various pollution control methods at the farm scale. http://randd.defra.gov.uk/Document.aspx?Document=es0203_4145_FRA.pdf [Accessed 28 January 2014]

- Scottish Government, 2008. *Impact Assessment of the River Basin Management Plan for Scottish River Basin District: Technical Report*. Considers policy issues and the costs and benefits of proposed measures for implementation of the RBMP. http://www.scotland.gov.uk/Publications/2009/01/08093641/0 [Accessed 28 January 2014]

- Entec, 2008. *Collaborative Research Programme on River Basin Management Planning Economics. Update of benchmark cost database with pCEA results*. Project 2c under the Collaborative Research Programme (CRP) has developed a cost database containing unit costs for a number of WFD relevant measures. http://www.ukbap.org.uk/librarysearchresults.aspx?ID=528 [Accessed 28 January 2014]

- UK Biodiversity Action Plan, 2006. *Preparing Costings for Species and Habitat Action Plans. Revising the Costs of Delivering Habitat Action Plans. Revised Report to Defra and Partners, with Provisional Cost Estimates Based on March 2006 Targets*. GHK Consulting Ltd and RPS Ecology Ltd

were commissioned in 2005 by Defra, English Nature, the Welsh Assembly, the Scottish Executive and the Department of the Environment in Northern Ireland to review and update estimates of the costs of delivering the UK BAP. http://archive.defra.gov.uk/evidence/economics/foodfarm/reports/documents/Biodiversity.pdf [Accessed 28 January 2014]

- SNIFFER, 2005. *Development of Hydro-morphological Improvement Targets for Surface Water Bodies.* Final Report. Project WFD56. Provides an assessment of the likely costs of implementing measures that may be carried out to mitigate or remove hydro-morphological pressures on watercourses. http://www.sniffer.org.uk/files/7113/4183/8031/WFD56.pdf [Accessed 28 January 2014]

1.9 References

CUTTLE, S.P., MACLEOD, C.J.A., CHADWICK, D.R., SCHOLEFIELD D., HAYGARTH P. M., NEWELL-PRICE, P., HARRIS, D. SHEPHERD, M.A., CHAMBERS, B.J. and HUMPHREY, R., 2006. *An Inventory of Methods to Control Diffuse Water Pollution from Agriculture (DWPA). User Manual.* Prepared as part of Defra Project ES0203. London: Department for Environment, Food and Rural Affairs.

DAVIS LANGDON, 2011. *Spon's Civil Engineering and Highway Works Price Book*, 25th edition. London: Spon Press.

DEASY, C., QUINTON, J., SILGRAM, M., JACKSON, B. and BAILEY, A., 2009. *Final Report: Defra PE0206 Field Testing of Mitigation Options*. London: Department for Environment, Food and Rural Affairs.

DEFRA, 2007. *A Compendium of UK Peat Restoration and Management Projects.* Project SP0556. London: Department for Environment, Food and Rural Affairs.

ENTEC, 2008. *Update of Benchmark Cost Database with pCEA Results.* Project 2c update. Collaborative Research Programme on River Basin Management Planning Economics.

ENVIRONMENT AGENCY, 2002. *Agriculture and Natural Resources: Benefits, Costs and Potential Solutions.* Bristol: Environment Agency.

ENVIRONMENT AGENCY, 2008. *Estimating Costs of Delivering the River Restoration Element of the SSSI PSA Target*. Final Report. Bristol: Environment Agency.

ENVIRONMENT AGENCY, 2009. *River Wensum Restoration Strategy: Implementation River Unit 50 Bintree Mill to North Elmham Mill. Feasibility and environmental scoping assessment*. Bristol: Environment Agency.

ENVIRONMENT AGENCY, 2010. *Working with Natural Processes to Manage Flood and Coastal Erosion Risk: A Guidance Document*. Bristol: Environment Agency.

EVANS, M.G., ALLLOTT, T.E.H., HOLDEN, J. FLITCROFT, C. and BONN, A., 2005. *Understanding Gully Blocking in Deep Peat*. Moors for the Future Report No 4. Castleton: Moors for the Future Partnership. Available from: http://www.moorsforthefuture.org.uk/research-publications [Accessed 28 January 2014].

FORESTRY COMMISSION, 2006. *New Forest Wetland Management Plan 2006–2016.* Sustainable Wetland Restoration in the New Forest – A LIFE-Nature European Union funded project. LIFE02/NAT/UK8544. Farnham: Forestry Commission.

ICE, 2012. *Civil Engineering Standard Method of Measurement (CESMM)*, 4th edition]. London: ICE Publishing.

JONES, M., 2010. *Farming Floodplains for the Future*. Final Report. Stafford: Staffordshire Wildlife Trust. Available from: http://www.staffs-wildlife.org.uk/what-we-do/protecting-wildlife-and-wild-places/publications [Accessed 28 January 2014].

JOHN NIX, 2014. *John Nix Farm Management Pocketbook*, 44th edition. Melton Mowbray: John Nix.

LEAF and ENVIRONMENT AGENCY, 2010. *SUDS – Sustainable Drainage Systems.* Interim report – August 2010 [provided by Jamie Letts].

MACAULAY LAND USE RESEARCH INSTITUTE, 1999. *Scottish Forestry: An Input–Output Analysis.* Aberdeen: Macaulay Land Use Research Institute.

MOTT, N., 2005. *Managing Woody Debris in Rivers, Streams and Floodplains.* Stafford: Staffordshire Wildlife Trust. Available from: http://www.staffs-wildlife.org.uk/what-we-do/protecting-wildlife-and-wild-places/publications [Accessed 28 January 2014].

NISBET, T.R. and THOMAS, H., 2008. *Restoring Floodplain Woodland for Flood Alleviation*. Final Report. Defra FCERM Innovation Fund Project SLD2316. London: Department for Environment, Food and Rural Affairs.

PITT, M., 2008. *Lessons Learnt from the 2007 Floods*. London: HMSO.

POSTHUMUS, H., HEWETT, C.J.M. MORRIS, J. and QUINN, P.F., 2008. Agricultural land use and flood risk management: engaging with stakeholders in North Yorkshire. *Agricultural Water Management*, 95 (7), 787-798.

QUINN, P.F., HEWETT, C.J.M, JONCZYK, J. and GLENIS, V., 2007. *The PROACTIVE Approach to Farm Integrated Run-off Management Plans: Flood Storage on Farms*. Newcastle: Newcastle University.

RRC, 2002. *Manual of River Restoration Techniques*, 2nd edition. Cranfield, Bedfordshire: River Restoration Centre.

SCOTTISH GOVERNMENT, 2008. *Impact Assessment of the River Basin Management Plan for Scotland River Basin District.* Edinburgh: Scottish Government.

SOMERSET COUNTY COUNCIL, no date. *Final Report. Woodland and Flood Management* [provided by Stephen Dury].

SNIFFER, 2005. *Development of Hydro-morphological Improvement Targets for Surface Water Bodies*. Final Report, Project WFD56. Edinburgh: Scotland and Northern Ireland Forum for Environmental Research.

UKBAP, 2006. *UK Biodiversity Action Plan Preparing Costings for Species and Habitat Action Plans. Revising the Costs of Delivering Habitat Action Plans*. *Revised Report to Defra and partners, with provisional cost estimates based on March 2006 targets.* Plymouth: GHK Consulting Ltd. Available from: http://archive.defra.gov.uk/evidence/economics/foodfarm/reports/documents/Biodiversity.pdf [Accessed 24 January 2014].

Would you like to find out more about us or about your environment?

Then call us on
03708 506 506 (Monday to Friday, 8am to 6pm)

email
enquiries@environment-agency.gov.uk

or visit our website
www.gov.uk/environment-agency

incident hotline **0800 807060** (24 hours)
floodline **0345 988 1188 / 0845 988 1188** (24 hours)

Find out about call charges (www.gov.uk/call-charges)

Environment first: Are you viewing this on screen? Please consider the environment and only print if absolutely recessary. If you are reading a paper copy, please don't forget to reuse and recycle if possible.