

**Multiple benefits of river and wetland restoration –  
measured from projects implemented on the ground**

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**AS AT JUN 16 – WORK IN PROGRESS – FURTHER EXAMPLES NEEDED PLEASE!**

Environment Agency staff can find this document at: <O:\F&B - Bio\communications\Killer Facts>

**NB**

- Information gleaned from dozens of journals and reports
- Willingness to pay figs not included
- Actual observed, measured data, not modelled data
- Only UK examples used
- Only “transferable” project or site-based examples used ( ie no national summary stats)
- Blue shaded rows relate to Natural Flood Management
- **Red text – new or updated entries since previous version**

## KILLER FACT

## REFERENCE

### UPLAND RESTORATION

Re-wetting the Exmoor Mires by blocking drainage ditches has led to an average increase in the volume of water stored in peat of up to 0.004 cubic metres per square metre. This could equate to an increase in water storage of approximately 683 cubic metres across the 19.5ha Aclands sub-catchment area.	University of Exeter, Mires Monitoring Results- Phase 1 Report. March 2015
Re-wetting the Exmoor Mires by blocking drainage ditches has reduced peak storm flows by between 22% and 35% compared to pre-restoration discharge.	University of Exeter, Mires Monitoring Results- Phase 1 Report. March 2015
Blocking of 133 km of ditch has led to an average rise in water tables of up to 0.7cm across the monitored sub catchments.	University of Exeter, Mires Monitoring Results- Phase 1 Report. March 2015
Turbidity (ie suspended sediment) levels in Chew Clough declined from 27 NTU to 22 NTU between 2008 and 2012 as a result of peatland restoration upstream	United Utilities Sustainable Catchment Management Programme (SCaMP) – Water Quality Monitoring Results – July 2012. United Utilities/Penny Anderson Associates
Fully restored moorland gullies in the Bleaklow Plateau in the Peak District are sinks for CO <sub>2</sub> (-70 mg CO <sub>2</sub> m <sup>-2</sup> h <sup>-1</sup> ) whereas bare gullies are the largest sources of CO <sub>2</sub> (32 mg CO <sub>2</sub> m <sup>-2</sup> h <sup>-1</sup> )	Preliminary evidence of the impacts of blanket bog stabilisation on ecosystem services from projects Moors for the Future Partnership have delivered, collaborated or supported. Moors for the Future Partnership. December 2013
250 ha of peatland restoration in Pumlumon made a total contribution to the UK's carbon balance of 1347 tonnes of CO <sub>2</sub> stored each year	Invest in the Pumlumon Project – Wildlife Trusts Brochure for Green Investors. 2014.
The Pumlumon Project ditch blocking work affected the water-holding capability of a 1,013ha catchment area, raising the water table by an average five centimetres and retaining an extra 155 million litres of water.	Invest in the Pumlumon Project – Wildlife Trusts Brochure for Green Investors. 2014
During drought periods, drain blocking in the upland blanket bog of the Berwyn & South Clwyd Mountains SAC led to drain flows being more stable and up to 3x higher than those prior to blocking	The impact of drain blocking on an upland blanket bog during storm and drought events, and the importance of sampling-scale Wilson et al. Journal of Hydrology 404 (2011) 198–208
During storm events, drain blocking in the upland blanket bog of the Berwyn & South Clwyd Mountains SAC reduced average d/s stream flows by a third, from 7.5 cumecs prior to blocking, to 5 cumecs after blocking	The impact of drain blocking on an upland blanket bog during storm and drought events, and the importance of sampling-scale Wilson et al. Journal of Hydrology 404 (2011) 198–208
Despite involving large scale earth-moving in a high quality environment in good ecological condition (Horner Wood and	Glendell, M. and Brazier, R. 2014 Evaluating the benefits of catchment management for multiple ecosystem services. Environment Agency

Dunkery Beacon SSSI, NNR, SAC), upland ditch blocking activities did not have any discernible negative impact on downstream water quality (including NO <sub>3</sub> , PO <sub>4</sub> , dissolved organic carbon and suspended sediment) one year after restoration.	research Report – SC120042
Restoration by re-vegetation and gully blocking in the Moors for the Future project on Kinder Scout has reduced peak flows from the restored areas by up to 37% and increased storm flow lag times by up to 267%	Summary of the Final report of the Making Space for Water Project, 2015 <a href="http://www.moorsforthefuture.org.uk/making-space-water-2">http://www.moorsforthefuture.org.uk/making-space-water-2</a>
The weight of Particulate Organic Carbon trapped in water flowing down gullies of re-vegetated catchments in the Moors for the Future project on Kinder Scout was reduced by over 90% in comparison to those of untreated control (bare) catchments.	Summary of the Final report of the Making Space for Water Project, 2015 <a href="http://www.moorsforthefuture.org.uk/making-space-water-2">http://www.moorsforthefuture.org.uk/making-space-water-2</a>
On restored blanket peat bog catchments in the SCaMP Project, declining rates of raw water colour production are 0 and -1.45 Hazen per annum, compared with Upland Waters Monitoring Network Sites in unrestored catchments (eg R. Etherow) where the average annual rate of increase in raw water colour production is 3.28 Hazen per annum.	United Utilities SCaMP 1B Final Report, Dec 2015. Penny Anderson Associates Ltd for United Utilities.
All SCaMP monitoring catchments have seen statistically significant increases in Sphagnum moss cover after restoration. Some sites such as Brennand have seen average increases from 10% cover or less, to in excess of 40-50% cover. This is a key requirement for the restoration of hydrologically active blanket bog.	United Utilities SCaMP 1B Final Report, Dec 2015. Penny Anderson Associates Ltd for United Utilities.
After blanket bog restoration in 2008 as part of the SCaMP project, the median annual water table depth at the Whitendale Central Dipwell on the Bowland Estate reduced from 9cms below ground surface in 2008 to 5 cms below ground surface in 2015.	United Utilities SCaMP 1B Final Report, Dec 2015. Penny Anderson Associates Ltd for United Utilities.
<b>BEAVER INTRODUCTION</b>	
Since the introduction of Beavers into the 3 ha Boldventure site in Devon, they have constructed 13 dams holding up to 1M litres of additional water within ponds on the site. This equates to 33 litres of surface water storage per square metre of land.	Puttock et al., 2016 (University of Exeter). Quantifying the Multiple Benefit of Beaver Activity Across River to Catchment Scales. River Restoration Centre, Annual Conference.
During storm events, comparisons between flow entering the site (draining from agricultural land) and that leaving the site,	Puttock and Brazier 2016 (University of Exeter). From bogs to beavers; Multiple benefits of nature-based solutions to flood management. British

showed on average: 30 % lower event peak flows and 29 % longer peak rainfall to peak flow lag times for flow leaving the site.	Hydrological Society National meeting. Land Use and Hydrological Extremes.
During storm events, on average each litre of water draining from agricultural land and entering the 3 ha Boldventure Beaver site, contains 112 mg/l of sediment, but < 40 mg/l when it leaves the site.	Brazier et al., 2016 (University of Exeter). Quantifying the Multiple Environmental Benefits of Reintroducing the Eurasian Beaver. EGU General Assembly Conference Abstracts.
During storms events, on average each litre of water draining from agricultural land and entering the 3 ha Boldventure Beaver site, contains 3.35 mg/l of total oxidised nitrogen, but only 2.19 mg/l when it leaves the site.	Brazier et al., 2016 (University of Exeter). Quantifying the Multiple Environmental Benefits of Reintroducing the Eurasian Beaver. EGU General Assembly Conference Abstracts.
During storms events, on average each litre of water draining from agricultural land and entering the 3 ha Boldventure Beaver site, contains 0.10 mg/l of phosphate, but only 0.02 mg/l when it leaves the site.	Brazier et al., 2016 (University of Exeter). Quantifying the Multiple Environmental Benefits of Reintroducing the Eurasian Beaver. EGU General Assembly Conference Abstracts.
During storms events, on average each litre of surface water leaving the 3 ha Boldventure Beaver site has 3x less sediment, 0.7x less nitrogen and 5x less phosphate than the water entering the site from agricultural land upstream.	Brazier et al., 2016 (University of Exeter). Quantifying the Multiple Environmental Benefits of Reintroducing the Eurasian Beaver. EGU General Assembly Conference Abstracts.
Common Frog spawn clump counts increased from 10 clumps to 521 clumps in the first 4 years of the Boldventure Beaver project due to the creation of 13 ponds by the Beavers.	Pers comm.. Mark Elliott. Beaver Project Lead. Devon Wildlife Trust. Nov 2015.
Organic matter retention increased 7x and aquatic plant biomass increased 20x in Beaver-dammed agricultural streams at Blairgowrie in Eastern Scotland, compared with un-dammed channels.	Habitat engineering by beaver benefits aquatic biodiversity and ecosystem processes in agricultural streams. Law et al. Biological and Environmental Sciences, School of Natural Sciences, University of Stirling. Freshwater Biology. 2016.
On average, growing season concentrations of extractable Phosphorus were 49% lower and Nitrates were 43% lower below a series of Beaver dams in agricultural streams at Blairgowrie in Eastern Scotland than they were above the dams.	Habitat engineering by beaver benefits aquatic biodiversity and ecosystem processes in agricultural streams. Law et al. Biological and Environmental Sciences, School of Natural Sciences, University of Stirling. Freshwater Biology. 2016.
<b>LARGE WOODY DEBRIS INTRODUCTION</b>	
Installation of 6 large woody debris structures in a headstream near Belford, more than doubled the travel time for the peak of the flood 1km downstream.	Runoff management: Mitigation measures for disconnecting flow pathways in the Belford Burn catchment to reduce flood risk M.E. Wilkinson et al. School of Civil Engineering and Geosciences, Newcastle University
104 large woody debris dams u/s of Pickering gave storage volumes of between 0.1 m <sup>3</sup> and 108.9 m <sup>3</sup> for individual dams,	Slowing the Flow at Pickering: Final report to Defra on Project RMP5455. Defra, London. May 2015.

varying with channel width and gradient, floodplain area and dam spacing. Taken together, the 104 dams provided a total of ~1,020 m <sup>3</sup> of potential flood storage.	
2 timber bunds u/s of Pickering provided potential flood storage volumes of up to 1,260 m <sup>3</sup> for the smaller downstream bund (16.5 m wide, 1.5 m high) and 3,620 m <sup>3</sup> for the larger upstream one (57.5 m wide, 1.5 m high).	Slowing the Flow at Pickering: Final report to Defra on Project RMP5455. Defra, London. May 2015.
Woody debris installation increased habitat diversity by 46% in a 4 <sup>th</sup> order wooded stream in the New Forest.	Kitts, D.R., 2010. The Hydraulic and Hydrological Performance of Large Wood Accumulations in a Low-order Forest Stream. Ph.D dissertation, School of Geography, University of Southampton.
<b>WETLAND CREATION</b>	
The improvement of the Glasgow Green park landscape and amenities increased the attractiveness of the surrounding area, leading to additional council tax revenue of £800K – £2M.	Green Infrastructure's contribution to economic growth: a review. Final Report for Defra and Natural England. Eftec/Sheffield Hallam Univ/Centre for Regional Economic and Social Research. July 2013.
<b>GRASSLAND MANAGEMENT</b>	
Mean phosphorus concentrations in soil were significantly higher under intensively managed grassland (1.37 mg g <sup>-1</sup> ), than under Culm grassland (0.87 mg g <sup>-1</sup> ), scrub (0.73 mg g <sup>-1</sup> ) or woodland (0.72 mg g <sup>-1</sup> ).	Impact of Culm Grasslands upon water and soil quality. Univ of Exeter/Devon Wildlife Trust research project fact sheet.
In the Culm grassland dominated headwater catchment, the median levels for sediment were 24mg/l compared with a distinctly turbid 78mg/l in the agriculture-dominated Aller catchment.	The Culm Grasslands Proof of Concept Study – Developing an understanding of the hydrology, water quality and soil resources of unimproved grasslands. Alan Puttock and Richard Brazier, 2014.
Across all Culm grassland sites studied, the mean carbon concentrations were 133mg/g whereas in the adjacent intensively managed grasslands they were only 88mg/g	The Culm Grasslands Proof of Concept Study – Developing an understanding of the hydrology, water quality and soil resources of unimproved grasslands. Alan Puttock and Richard Brazier, 2014.
Culm grasslands store 1.8g/cm <sup>2</sup> of carbon in soils with a given surface area, compared with 1.5g/cm <sup>2</sup> in agriculturally improved fields – ie they provide an extra 20% carbon storage.	The Culm Grasslands Proof of Concept Study – Developing an understanding of the hydrology, water quality and soil resources of unimproved grasslands. Alan Puttock and Richard Brazier, 2014.
Soil moisture content (70 %) and soil depth (47 cm) in Culm grasslands are significantly higher than in intensively managed grasslands.	Understanding the hydrology of Culm grasslands. Univ of Exeter/Devon Wildlife Trust research project fact sheet.
Culm grasslands have 4.5x the water storage capacity (av 277 litres/m <sup>2</sup> ) of intensively managed grasslands (av. 61litres/m <sup>2</sup> ).	The Culm Grasslands Proof of Concept Study – Developing an understanding of the hydrology, water quality and soil resources of unimproved grasslands. Alan Puttock and Richard Brazier, 2014.
<b>POND CREATION AND RESTORATION</b>	

Organic carbon stored in pond sediments is highest in uncompacted sediments in permanent ponds with extensive natural vegetation (app. 10% OC), and lowest in sediments in ponds in arable or pasture fields (app 3 % OC) and in adjacent soil controls (app 3% OC).	Variations in sediment organic carbon among different types of small natural ponds along Druridge Bay, Northumberland, UK Gilbert et al. Journal of the International Society of Limnology. Vol 4 No 1. 2014
A “leaky pond” aka Run-off Attenuation Feature (RAF) in the Belford Burn catchment, holding 800 m3 of water, takes roughly 8 to 12 hours to drain from full to empty and delays the peak flow 1 km downstream by app. 15 mins.	Belford catchment proactive flood solutions: a toolkit for managing runoff in the rural landscape. ME Wilkinson and PF Quinn. <i>School of Civil Engineering and Geosciences, Newcastle University.</i>
“Leaky ponds” aka Run-off Attenuation Features (RAFs) in the Belford Burn catchment, led to the following average reductions in pollutant concentrations downstream during storms: suspended solids 40%, total phosphorus 25% and nitrate 15%	A framework for managing runoff and pollution in the rural landscape using a Catchment Systems Engineering approach. M.E.Wilkinson et al. Science of the Total Environment 468–469 (2014) 1245–1254
In pond-rich agricultural regions typically dominated by overgrown, highly terrestrialised ponds, restoration of some ponds by scrub and sediment removal to create open-canopy, macrophyte-dominated ponds, dramatically enhances landscape-scale aquatic diversity, whilst also benefitting populations of farmland birds.	Sayer, C.D., Andrews, K., Shilland, E., Edmonds, N., Edmonds-Brown, R., Patmore, I.R., Emson, D. & Axmacher, J.A. (2012). The role of pond management for biodiversity conservation in an agricultural landscape. <i>Aquatic Conservation: Marine and Freshwater Ecosystems</i> , 22, 626-638.  Davies, S.R., Sayer, C.D., Greaves, H., Siriwardena, G.M. & Axmacher, J.C. (submitted Dec. 2015) A new role for pond management in farmland bird conservation. <i>Biological Conservation</i>
<b>SOIL MANAGEMENT</b>	
Sediment traps constructed upstream of a flood storage pond on the Netherton Burn over a period of one year, reduced the sediment load reaching the pond by 57%, the total phosphorus by 45% and nitrate by 27%.	Cheviot Futures Case Study report: Netherton Burn Runoff Management Works Elilaw Farm, Netherton, Northumberland – from PhD research undertaken by Nicholas Barber, University of Newcastle Upon Tyne.
The total volume of sediment captured by sediment traps upstream of a flood storage pond on the Netherton Burn over a period of one year, was 22 m <sup>3</sup> (wet), which equates to approximately 22 tonnes (dry). This is a trapping rate of 0.3 tonnes per hectare of sheep-grazed catchment.	Cheviot Futures Case Study report: Netherton Burn Runoff Management Works Elilaw Farm, Netherton, Northumberland – from PhD research undertaken by Nicholas Barber, University of Newcastle Upon Tyne.
A subsoiler was purchased by the EA and made available to farmers in 3 catchments in East Devon to remediate soil compaction causing runoff. Soils surveys showed a significant improvement on 30% of fields. Partial improvements had occurred on remaining fields but with more treatment needed.	Assessment of effectiveness of attempts to improve soil structure in three East Devon catchments in 2009-11. EA Report. RC Palmer, 2011.
An extensive field investigation discovered that 38% of soils in southwest England show signs of enhanced surface water	R. C. Palmer and R. P. Smith. Soil structural degradation in SW England and its impact on surface-water runoff generation. Published online: 8 AUG



runoff due to soil degradation. Cultivated sites posed a large problem, with 55% having high or severe damage. 75% of land under late-harvest crops showed signs of degradation. 60% of winter cereal crops displayed high or severe degradation.	2013
Soil compaction studies using a Van Walt penetrometer in Bishopdale in the Upper Ure catchment, showed that grassland areas where sheep had been excluded for 5 years, had significantly lower soil compaction (40 N m <sup>2</sup> soil resistance) than areas from which sheep had been excluded for 3 years or less (44-46 N m <sup>2</sup> soil resistance).	Gao et al (2015) <i>Flood modelling and compaction studies for the Upper Ure</i> . Final report to Yorkshire Dales National Park Authority, Project UUCP1/2015, University of Leeds, Leeds.
<b>TREE PLANTING</b>	
The mean constant infiltration rate at a distance of 5m into tree plantations was approximately 100 cm/hr in the Pontbren catchment, compared to being negligible, at a distance of 5m into grazed pastures	Pontbren: Effects of tree planting on agricultural soils and their functions. Final Report. March 2003. Bird et al.
Shade provided by trees in the New Forest reduces water temperature by up to 5.5°C on hot summer days compared to open grassland sections, preventing it from rising above the lethal limit for brown trout.	The influence of riparian shade on lowland stream temperatures in southern England and their viability for Brown Trout. Broadmeadow et al. River Research and Applications DOI: 10.1002/rra.1354
Woodland contributes less than 5% of the fine sediments to the R.Frome in SW England compared with pasture (app 25%) and arable (app 65%)	Sources of fine sediment recovered from the channel bed of lowland groundwater-fed catchments in the UK. Collins and Walling. 2007. <i>Geomorphology</i> , 88. 120-138
The key ecosystem services (carbon capture, rainwater interception, reduction of air pollution, building energy savings and building energy carbon avoided) provided by London's 8.4 million urban trees were valued at £132.7M per annum in 2014.	Valuing London's Urban Forest. Results of the London i-Tree Eco Project. Online report. 2014.
The key ecosystem services (carbon capture, rainwater interception, and the reduction of air pollution) provided by the Tawe catchment's 530,000+ trees were valued at £1.72M per annum in 2014.	Valuing ecosystem services provided by the urban trees of the Tawe catchment. Forest Research. Research Summary. 2014.
Infiltration rates at Pont Bren are up to 60 times higher under young native woodland shelterbelts compared to adjacent heavily grazed pasture, with 90% of the improvement occurring within two years of stock removal and tree planting	Carroll, Z.L., Bird, S.B., Emmett, B.A., Reynolds, B. and Sinclair, F.L. (2004). Investigating the impact of tree shelterbelts on agricultural soils. In: <i>Landscape ecology of trees and forests</i> . Edited by R. Smithers. International Association for Landscape Ecology (UK).
The interception loss as a proportion of daily rainfall is up to 7 mm/day for conifers and 1-2 mm/day for broadleaves, depending on season. These values equate to a potential	Calder, I. R. (2003) Assessing the water use of short vegetation and forests: Development of the Hydrological Land Use Change model. <i>Water Resources Research</i> , 39, 1319-1328.

reduction of 10-20 m <sup>3</sup> /ha of flood runoff for planting broadleaved woodland on grassland and up to 70 m <sup>3</sup> /ha for conifers.	
The generally greater water use by woodland compared to shorter vegetation generates greater soil moisture deficits in summer periods. This can amount to several 10s of mm of additional potential soil water storage available under trees, which could help to significantly reduce flood runoff during summer storms (1 mm = 10 m <sup>3</sup> /ha of water).	Calder I.R. et al. (2003) Impact of lowland forests in England on water resources: Application of the Hydrological Land Use Change (HYLUC) model. <i>Water Resources Research</i> , 39, 1319-1328. Green, J. C. et al (2006) Four-year comparison of water contents beneath a grass ley and a deciduous oak wood overlying Triassic sandstone in lowland England. <i>Journal of Hydrology</i> , 329, 16-25. Nisbet, T. (2005) Water use by trees. <i>Forestry Commission Inform. Note 65</i> , Edinburgh, UK.
Field studies demonstrate that the hydraulic roughness associated with a dense stand of willow coppice on the floodplain are more than 5x times that of grass. The willow coppice thus acts as a drag on flood waters, slowing down flood flows and enhancing flood storage.	Chow V.T. (1959) <i>Open channel hydraulics</i> . New York: Mc-Graw Hill.

**CHARISMATIC MEGAFUNA !**

Bird watchers contribute on average £7 per person per visit per site (at 2006 prices) for watching spectacular species eg osprey, rare migrants, etc.	Dickie et al, 2006 – Watched like never before – the local economic benefits of spectacular bird species. Sandy: RSPB.
One pair of Ospreys breeding at the Montgomery Wildlife Trust Cors Dyfi reserve in Wales, have attracted 35,000 extra visits to the area bringing in an estimated £350,000 a year locally	Invest in the Pumlumon Project – Wildlife Trusts Brochure for Green Investors

**RIVER RESTORATION**

A 21% increase in channel length combined with a 142% increase in the frequency of large woody debris accumulations across a range of river restoration projects, resulted in a 21% reduction in flood peak magnitude on average	Dixon et al, in press (via David Sear, Univ of Southampton)
Visitors to Ladywell Fields urban greenspace increased by > 250% after restoration of the R. Ravensbourne	Visitors to Ladywell Fields urban greenspace increased by > 250% after restoration of the R. Ravensbourne
78% of visitors to Ladywell Fields felt “safe” or “very safe” after restoration of the R. Ravensbourne through the park compared with 44% before restoration	78% of visitors to Ladywell Fields felt “safe” or “very safe” after restoration of the R. Ravensbourne through the park compared with 44% before restoration
89% of visitors to Chinbrook Meadows urban greenspace thought that the restoration of the R. Quaggy had improved the	89% of visitors to Chinbrook Meadows urban greenspace thought that the restoration of the R. Quaggy had improved the park



park	
The average amount of time spent per person in Sutcliffe Park increased from 8 hrs per month before “daylighting” of the R. Quaggy to 11.5 hrs after restoration – an increase of 44%.	Reference needed
The restoration of 500 metres of the Mayes Brook at Mayesbrook Park, in North London, along with associated landscaping work, resulted in the creation of 15,800 cubic metres of extra floodplain storage	Mayesbrook Park - a park adapted to climate change. London Borough of Barking and Dagenham. Publication MC6826. July 2012
The award-winning restoration of the R. Quaggy and creation of associated wetlands through Sutcliffe Park in South London created 85,000 cubic metres of flood storage and significantly reduced the flood risk to 600 properties	Reference needed
90% of the visitors to the River Skerne in Darlington were quite or very satisfied with the restoration of the river, 15 years on from the completion of the work.	Revisiting the River Skerne: The long-term social benefits of river rehabilitation. Åberga and Tapsell. Landscape and Urban Planning 113 (2013) 94– 103
<b>Semi-natural reaches of New Forest streams have at least 30% lower gravel mobility and less than a quarter of the distance of gravel transport of channelized reaches.</b>	<b>Sear et al. 2006. The geomorphic and hydrological response of New Forest streams to river restoration, Hampshire County Council.</b>

## URBAN SuDS

Overall the maintenance costs associated with the Lamb Drive SuDS at Cambourne in Cambs are 4% lower than costs associated with equivalent conventional pipe drainage systems.	Monitoring the Lamb Drove SuDS in Cambourne, Cambridgeshire Presentation - 6 September 2013 - R. Stevens and F. Ogunyoye – Royal Haskonin DHV – proper reference to be obtained
The capital costs of the Lamb Drive SuDS at Cambourne in Cambs scheme were found to be £314 per property cheaper than the equivalent alternative pipe drainage system needed for such a site.	Monitoring the Lamb Drove SuDS in Cambourne, Cambridgeshire Presentation - 6 September 2013 - R. Stevens and F. Ogunyoye – Royal Haskonin DHV – proper reference to be obtained

## COASTAL REALIGNMENT

Four managed realignment sites in the Blackwater Estuary, totalling app. 220 ha in area, are sequestering and storing 15 tonnes of phosphorus per year and 690 tonnes of CO2 equivalent per year	Carbon Burial and Greenhouse Gas Fluxes of New Intertidal and Saltmarsh Sediments. C. Adams. PhD thesis. October 2008. University of East Anglia School of Environmental Sciences
The 400 ha Alkborough Flats managed realignment scheme in the Humber estuary cost app. £10M to build and provided £12M of storm protection benefits to land and property. Other ecosystems services benefits linked to the scheme were app. £1M per annum.	Ecosystems Services Case Studies. M. Everard. Environment Agency Science Report. ISBN: 978-1-84911-042-6

Saltmarsh created through managed realignment such as that at Abbott's Hall in Essex, provide important nursery areas for a range of commercially important fish species including mullet, flounder, herring and bass.	Fish utilisation of managed realignments. Colclough et al. Fisheries Management and Ecology, 2005, 12, 1–10
Neap tide samples from permanent water bodies in the Freiston realignment showed that the site provides important nursery habitat for juvenile fishes (< 1yr old) throughout the entire tidal cycle, including important commercial species (sprat, herring and bass).	Brown et al. (2008) Future monitoring at coastal realignment sites: lessons learnt from the Frieston flood defence scheme, Defra paper, 12pp.
Over a distance of 40 metres, salt marsh reduced the height of large waves in deep water by 18%, making them an effective tool for reducing the risk of coastal erosion and flooding. 60% of this reduction is due to the presence of marsh plants alone.	Wave attenuation over coastal salt marshes under storm conditions. Moller et al. Nature Geoscience 7, 727-731. (2014)
Fisheries surveys carried out at the Medmerry managed realignment site in Sussex, one year after breaching, revealed that it was already providing valuable important nursery areas for 21 fish species, including commercially important Bass, Gilthead Bream, Herring and Grey Mullet.	EA/IFCA Medmerry small fish survey report. June/July 2015. Kathryn Nelson, Senior Research Officer, Sussex IFCA.

## MULTIPLE INTERVENTIONS

£160K of NFM work in the Holnicote Estate catchment area reduced the flood peak by 10% and helped to prevent £30M of assets (98 properties) from flooding during a greater than 1 in 50 year event on Christmas Eve 2013.	From Source to Sea: Natural Flood Management – The Holnicote Experience. Final Report on the Defra Multi-Objective Flood Management Demonstration Project. National Trust/Penny Anderson Associates/JBA Consulting.
Comparison of the very similar pre-NFM scheme rainfall events of Sept 2008 and Nov 2009 and the post-NFM scheme rainfall event of Dec 2015 in the Pickering Beck catchment (all app 50 mm rain in 24-36 hrs), revealed that the catchment restoration measures (land management, multiple woody debris dams and a flood storage area) reduced peak flows by 15-20%, despite the fact that in Dec 2015 the antecedent conditions were far wetter. Initial results suggest that half of the reduction was due to the upstream land management measures and half due to the flood storage area. It can be concluded with a relatively high degree of certainty that these “Slowing the Flow” project measures prevented flooding that would otherwise have occurred to a small number of residential properties and the museum in the Beck Isle area of Pickering.	Slowing the Flow Partnership Briefing: Boxing Day 2015 Flood Event

Following installation of 40 woody debris structures on the Slad Brook as part of the Stroud rural SuDS project, the flood hydrograph at the Slad gauging station peaked at 0.4 m in March 2016 compared with 1.8 m in Nov 2012 (before woody debris installation), during very similar rainfall events. Antecedent ground saturation levels were higher in 2012, but all involved with the project are certain that the upstream interventions reduced the flood peak in 2016 sufficiently to prevent the flooding which affected a small number of properties in 2012.

Stroud Rural SuDS project – Site Visit Report. A Driver. May 2016