Forest Research

How trees, woodlands and forests can contribute to flood risk management - a review of the evidence

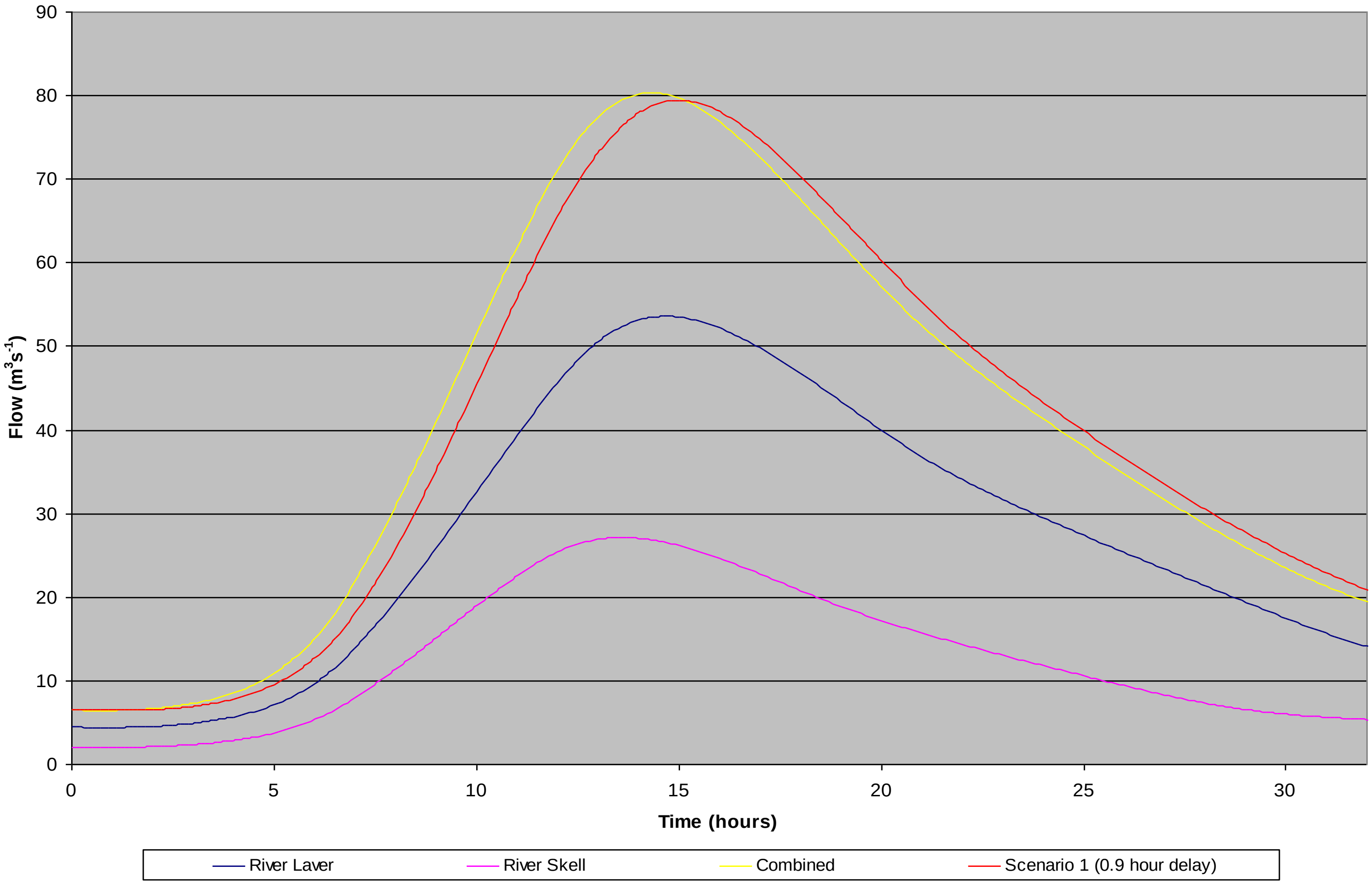
Dr T R Nisbet

Woodland can reduce flood risk by:

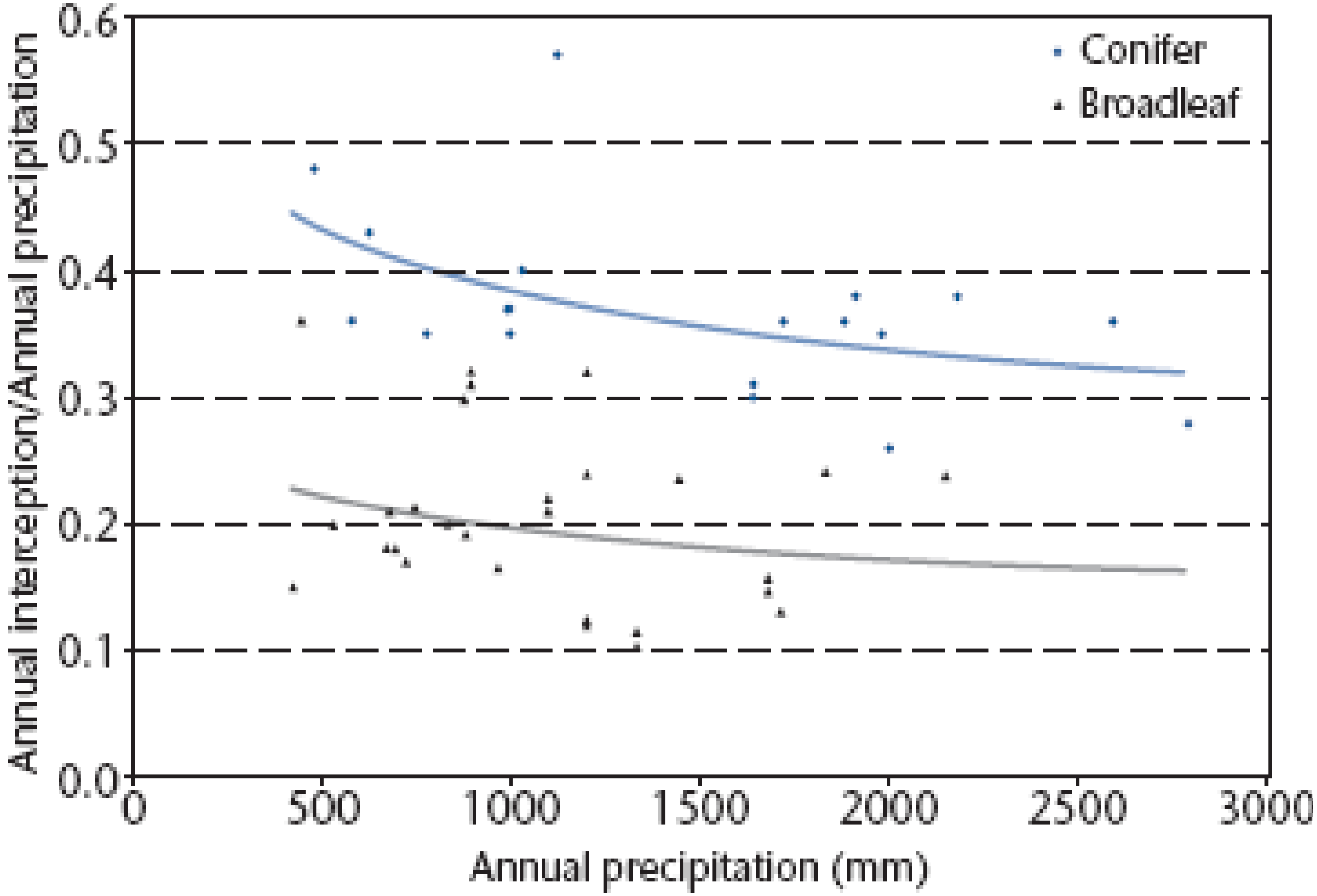
- Reducing the volume of flood water at source by **increasing evaporation**;
- Slowing the rate of runoff from the land by **increasing soil infiltration**;
- Enhancing floodplain storage and delaying the flood peak by **increasing hydraulic roughness**;
- **Reducing sediment delivery** and siltation, increasing conveyance.



By reducing flood volume, extending response or desynchronising flows:

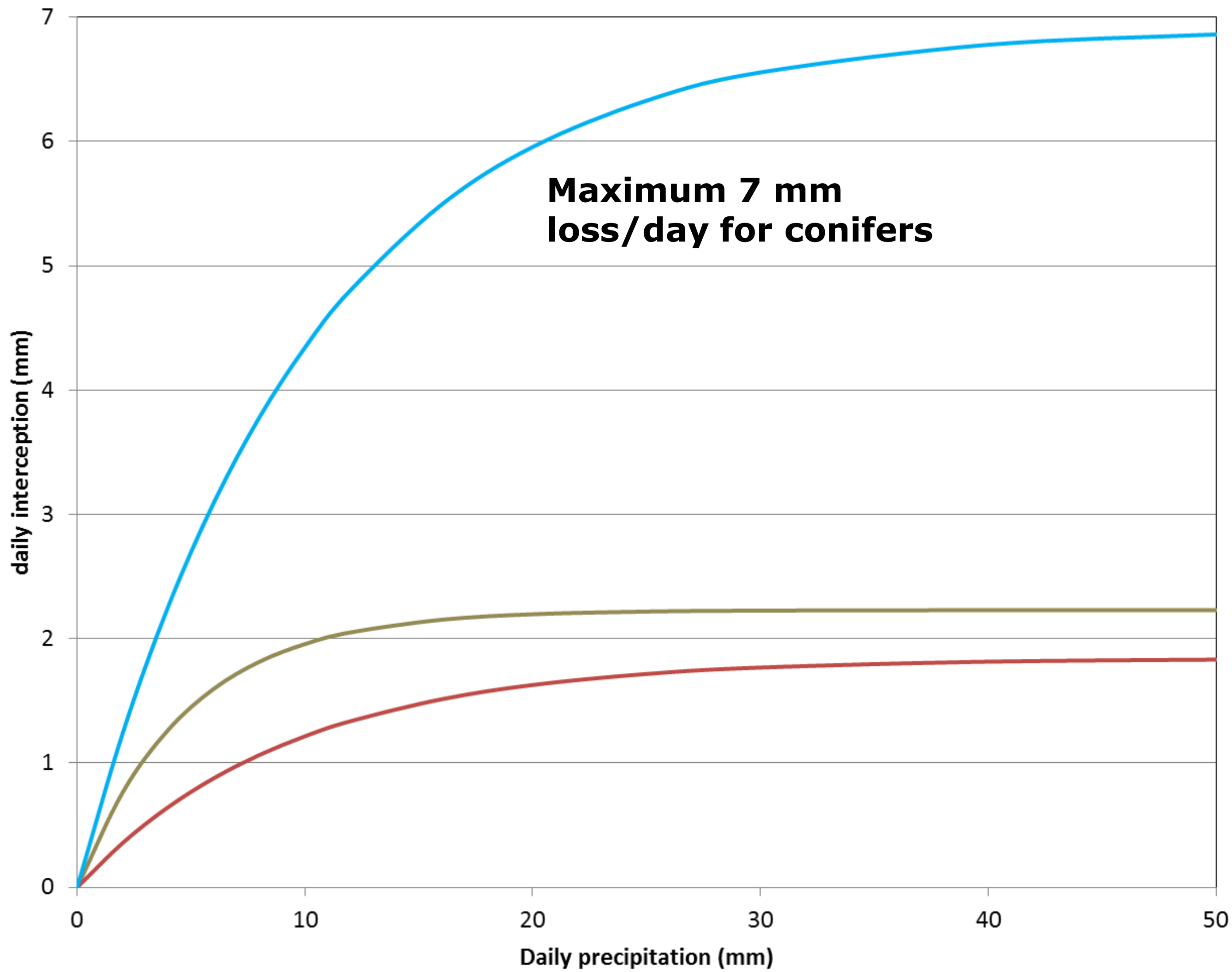


Flood mitigation by reduced run-off:



Annual interception loss: 32-45% for conifers, 17-23% for broadleaves

Limits on Daily Interception

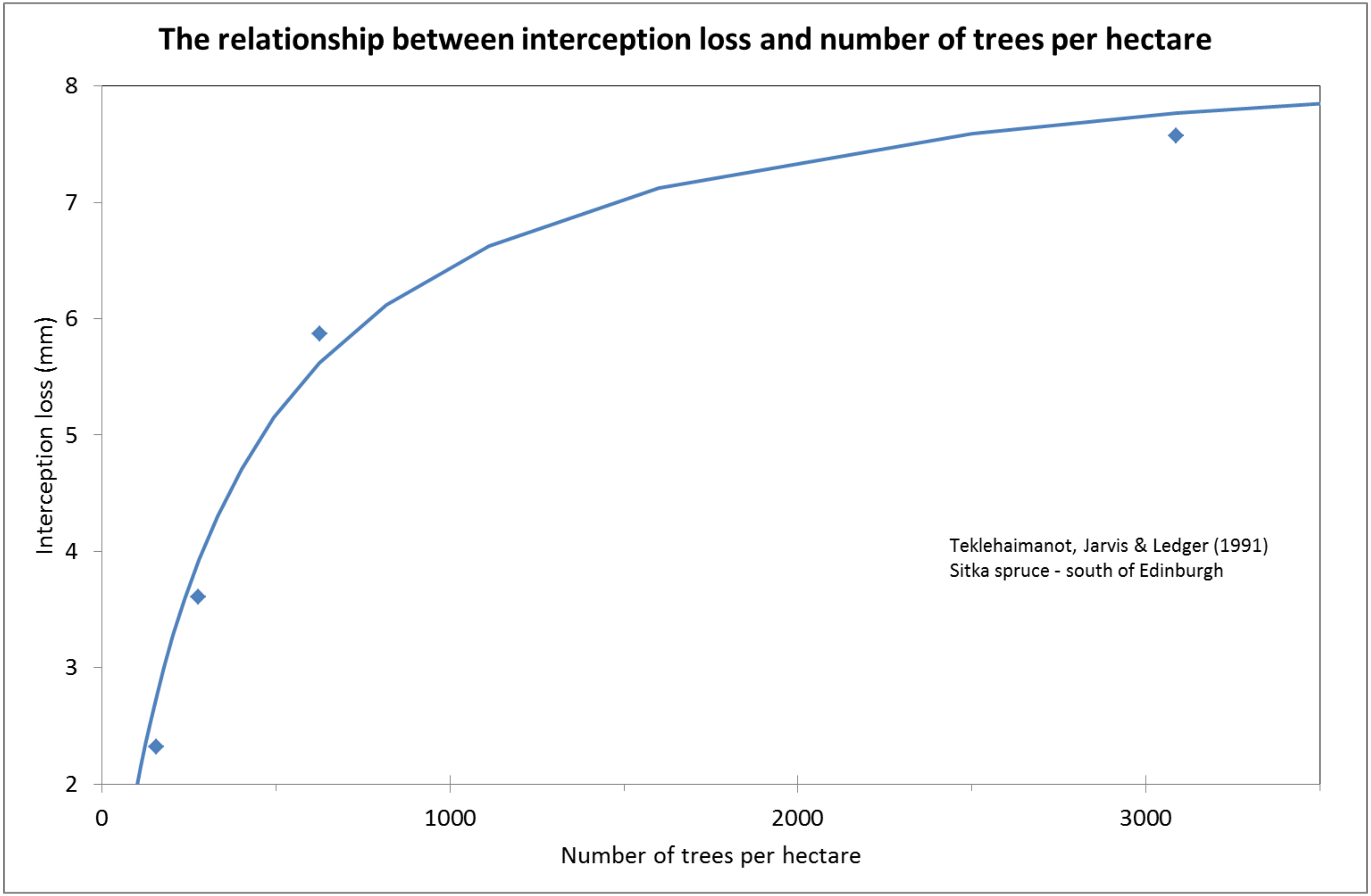


1 mm evaporation loss = 10 m³/ha

Maximum loss of 1 to 2 mm/day for broadleafs

Calder et al. (2007)

Effect of Tree Spacing on Water Use



Role of Soil Moisture Deficit

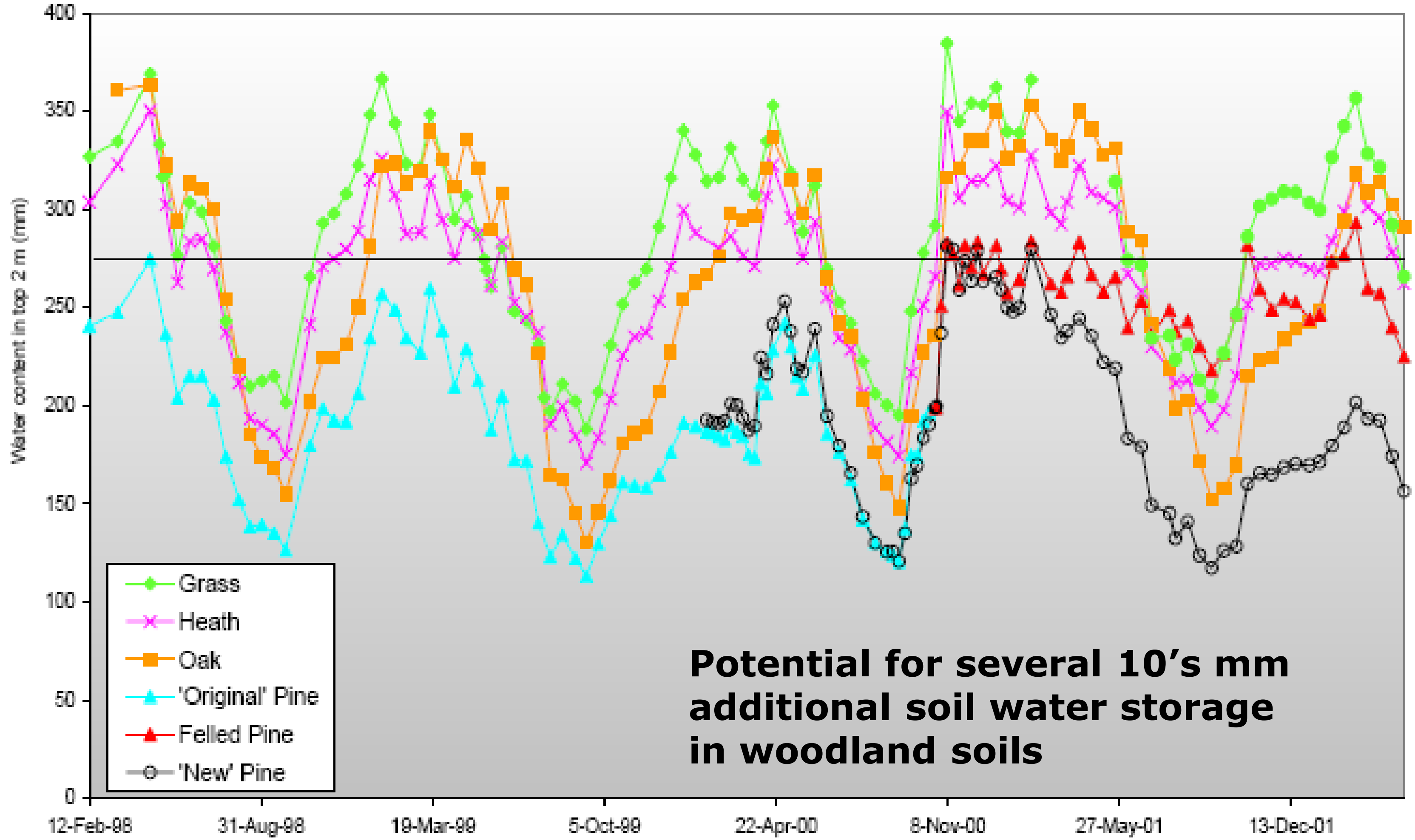
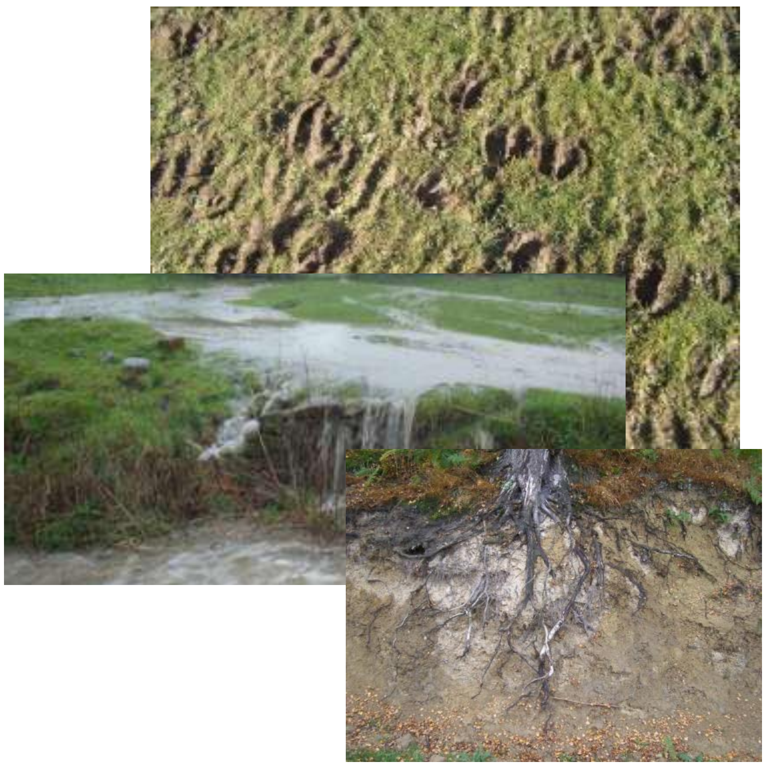


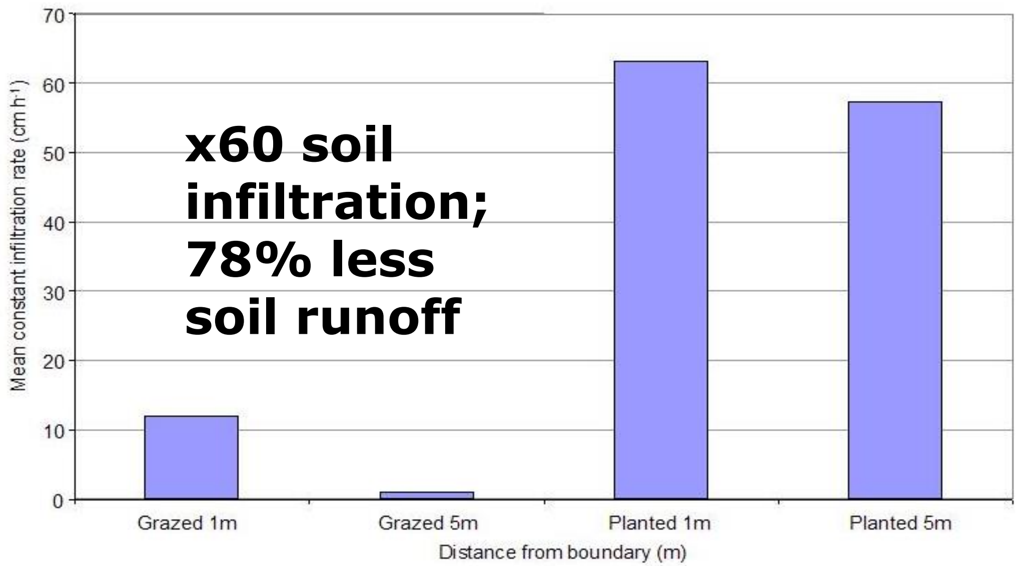
Figure 42. Water content in the uppermost 2 m under each land cover (12th February 1998 to 23rd April 2002) as measured by the neutron probe.

Calder et al. (2002)

Flood mitigation by 'sponge effect':

The open structure and high organic content of woodland soil aids water infiltration and storage, reducing the risk of rapid surface runoff.





(From Caroll *et al*, 2004)

Soils can store 20% of volume as water between Field Capacity and Saturation; 30 cm depth = 60 mm

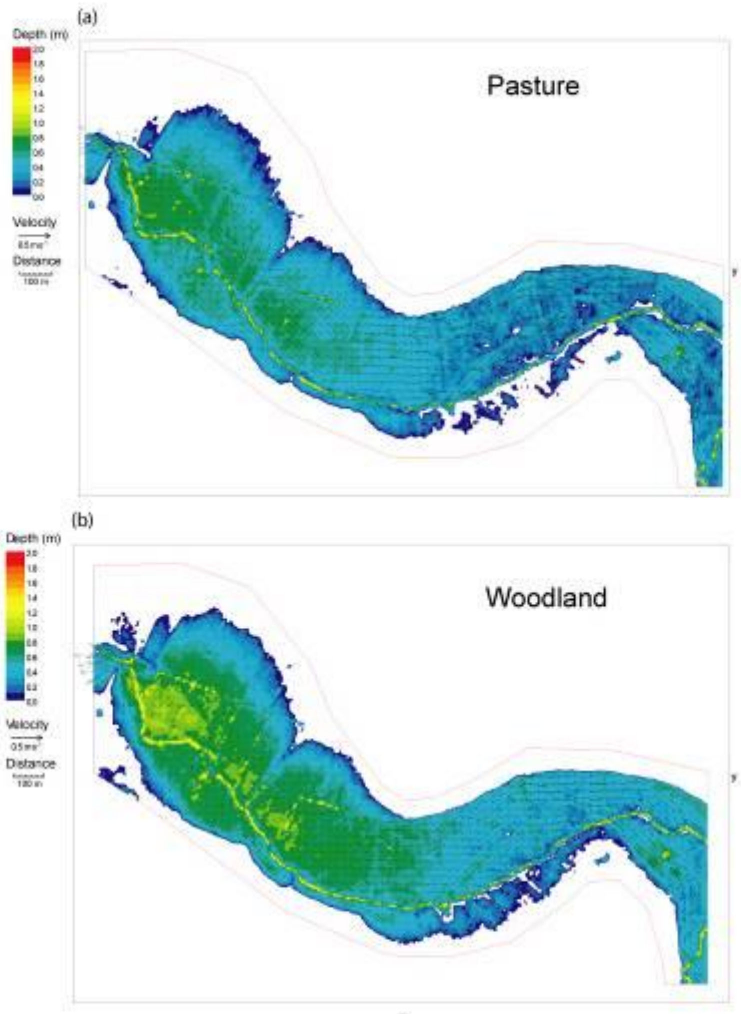
Flood mitigation by physical barrier:

Floodplains	Min	Normal	Max
a. Pasture no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Trees			
1. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
2. Same as above but heavy sprouts	0.050	0.060	0.080
3. Heavy stand of timber, few downed trees, little undergrowth, flow below branches	0.080	0.100	0.120
4. Same as above but with flow into branches	0.100	0.150	0.200
5. Dense willows, summer, straight	0.110	0.150	0.300

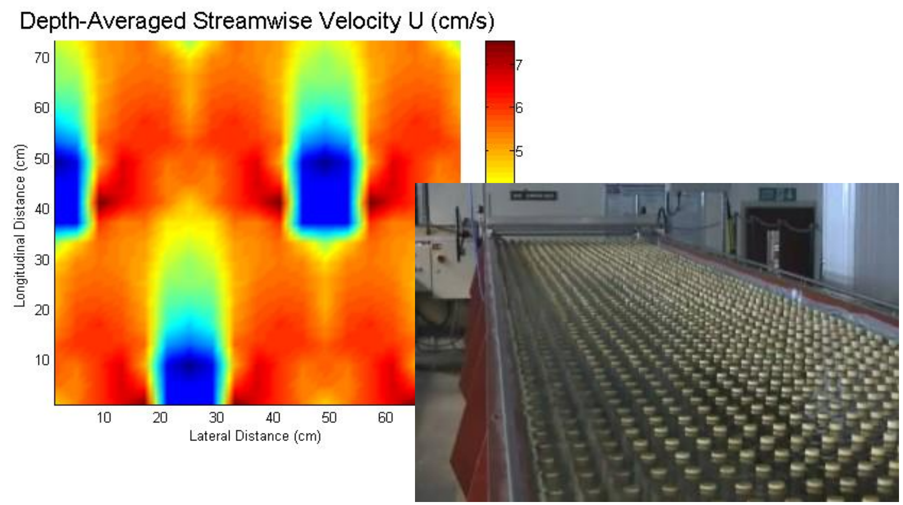
Table 1 Typical Manning's n values for floodplains, after Chow (1959)

Hydraulic roughness (x5) creates a barrier effect, slowing river flows, pushing water onto floodplains and temporarily increasing flood storage (100 m^3 to 100,000+ m^3).

Delaying the passage of flood flows:

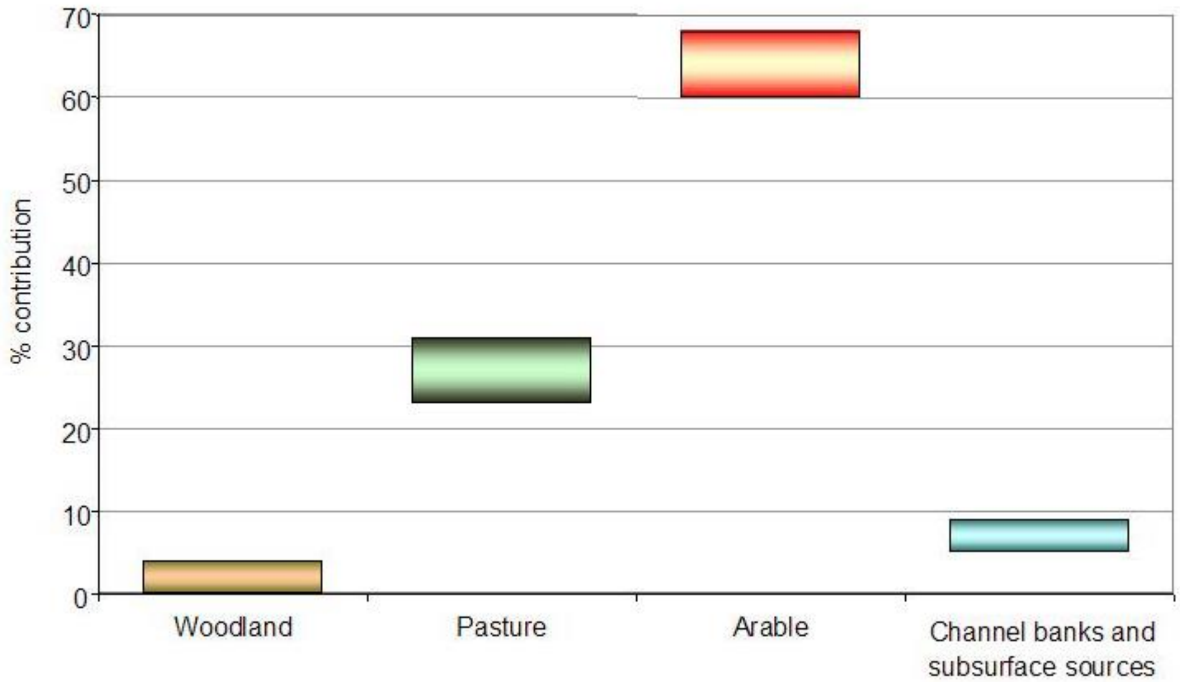


Establishing 130 ha of floodplain woodland along a 2.2 km reach of the River Cary in Somerset increased the flood level for a 1-in-100 year event by 50-270 mm (~120,000 m^3) and delayed the flood peak by 140 min in an 80 km^2 catchment (Thomas & Nisbet, 2006).



Flood mitigation by reduced siltation:

- By providing physical shelter
- By reducing water runoff
- By improving soil strength/stability
- By protecting river banks



Well managed woodland is usually associated with low sediment losses, helping to maintain slope stability and channel conveyance (Collins and Walling, 2006)

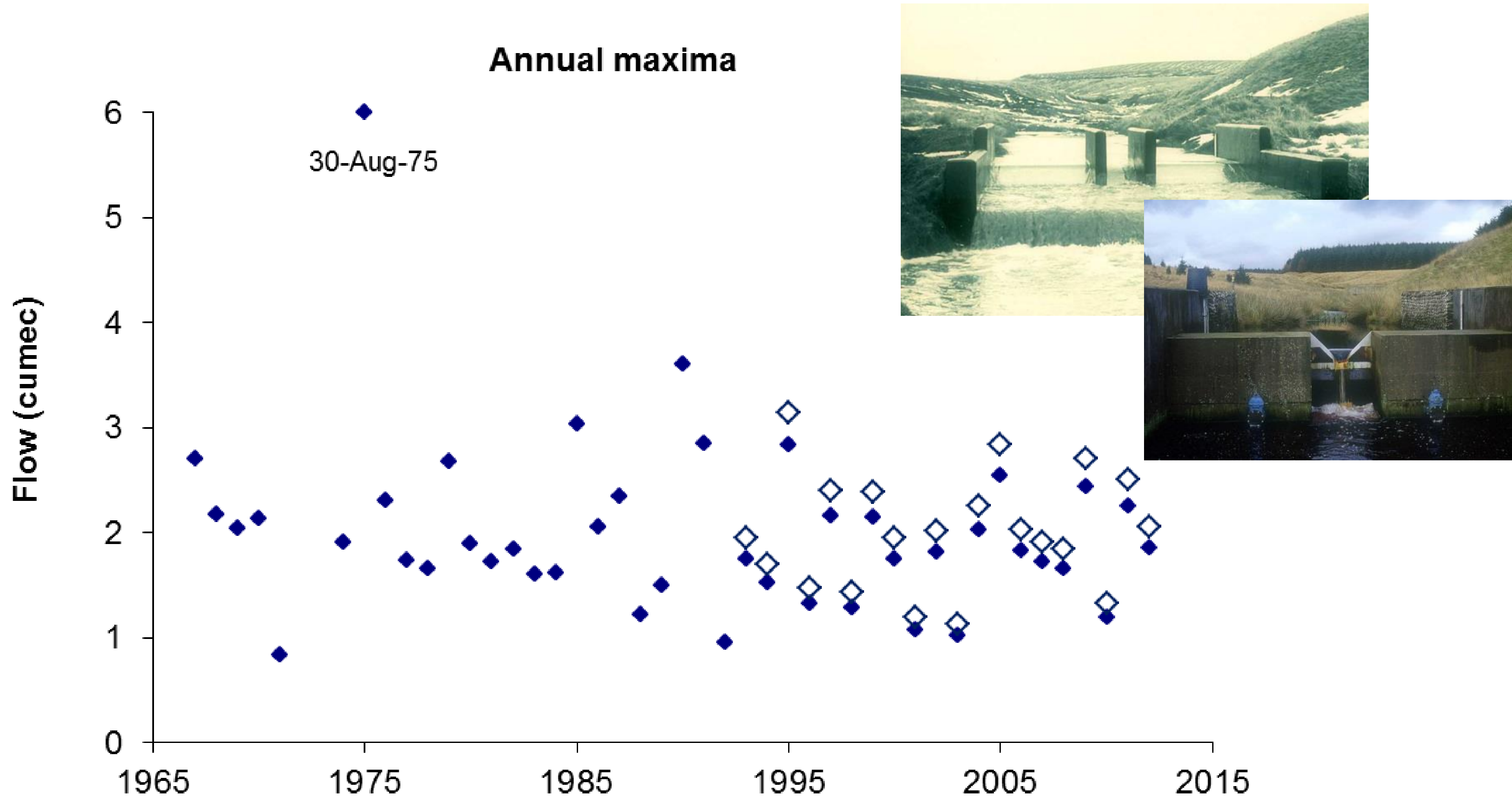
However, woodland can increase flood risk by:

- The backing-up of flood water upstream of floodplain and riparian woodland;
- The washout of large woody debris blocking downstream structures;
- The synchronisation of flood flows within catchments.

Factors influencing effectiveness:

- Scale and location of woodland within catchment in relation to assets at risk;
- Nature of existing land use and management practices;
- Woodland design, e.g. in terms of type, age, shape and structure;
- Woodland management, including scale and timing of practices such as felling;
- Site vulnerability to potential dis-benefits.

Long-term study at Coalburn, N England



(From Robinson, 2015)

Longer-term changes in annual rainfall:

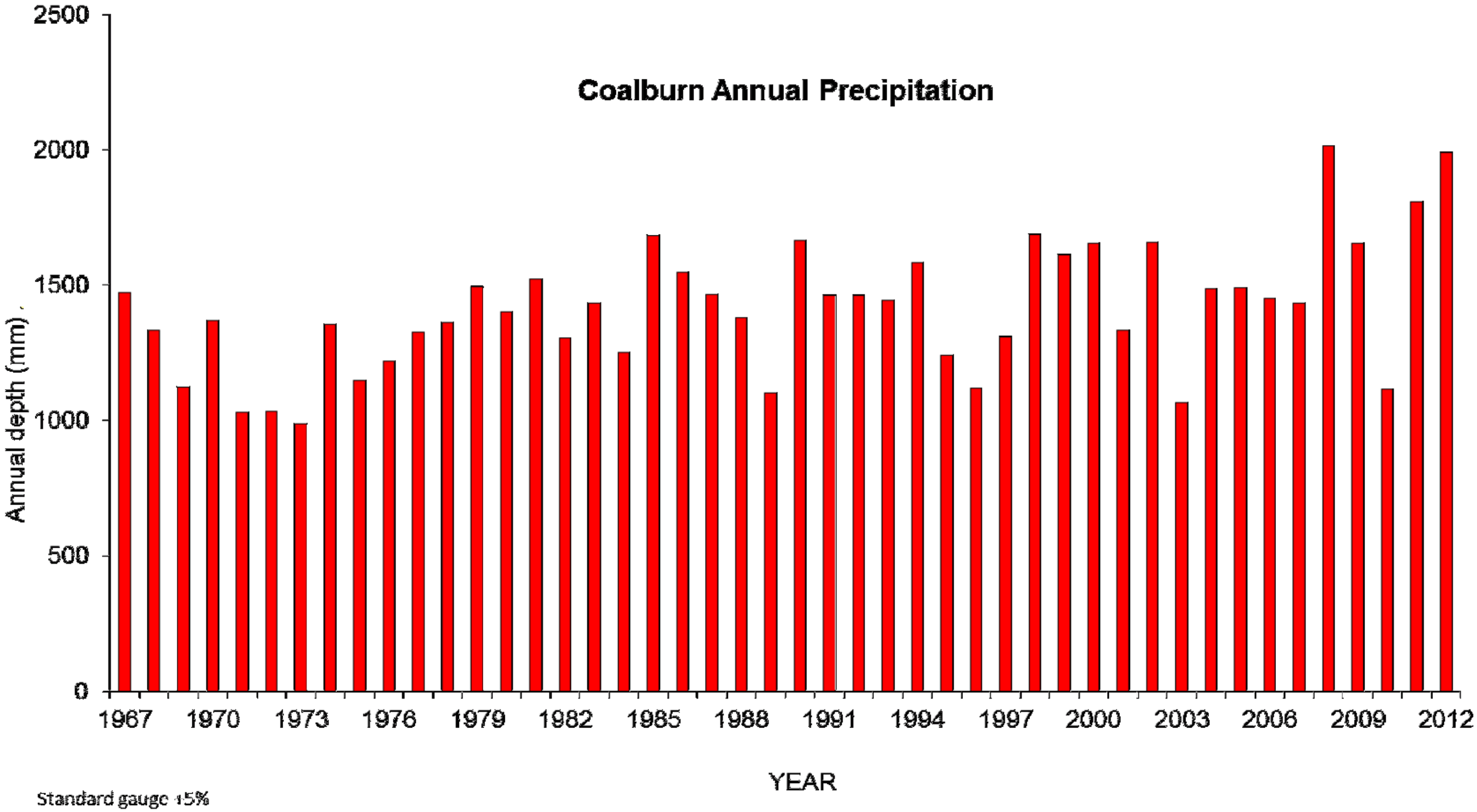
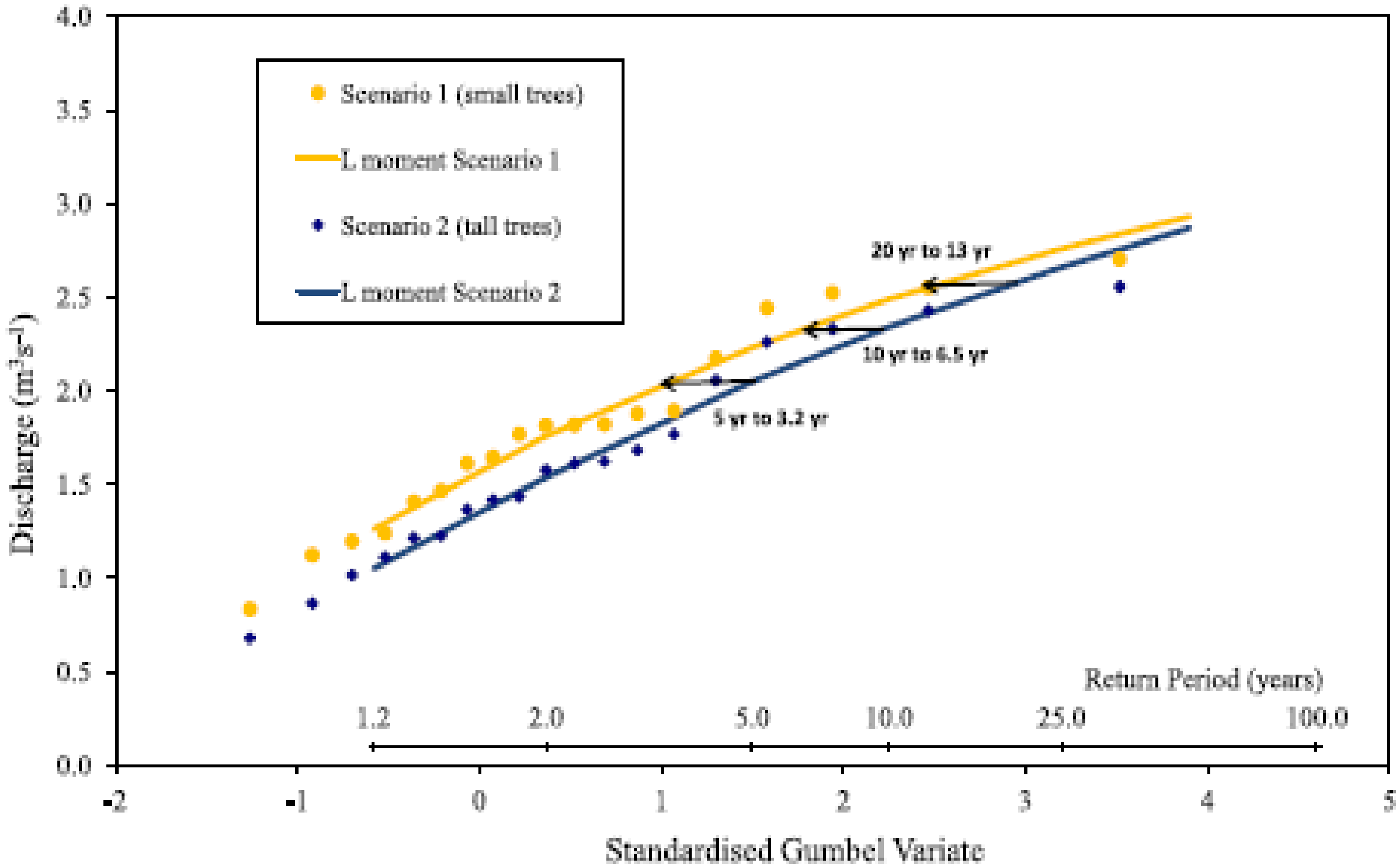


Figure 3 *Quality controlled time series of the annual precipitation at Coalburn.*

(From Robinson, 2015)

Correcting for changes in rainfall: effect of forest growth on peak flows at Coalburn



S.J. Birkinshaw et al. / Journal of Hydrology 519 (2014) 559–573

Changes in peak flows due to forest felling:

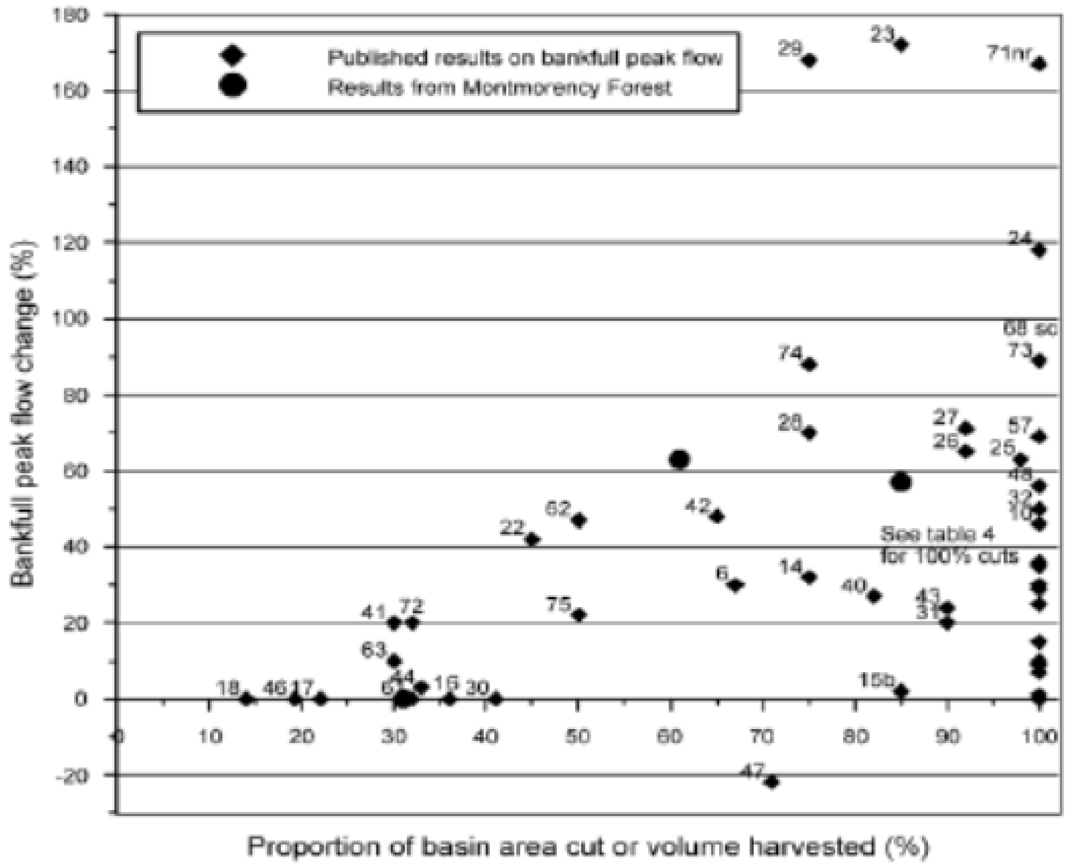


Fig. 20 A review of changes in river peak-flow following forest cutting in boreal and temperate regions by Guillemette et al. (2005 J. Hydrol. 302: 137-153).

Predicting the impact of soil infiltration and water use effects at Pontbren, Wales

Table 2.7 *Summary of changes in peak streamflow for three land use change scenarios during a synthetic extreme rain storm event at gauge 6 in the Pontbren catchment. 95 per cent confidence intervals are in parenthesis*

Land use change	Area affected (%)	Mean change in peak flow (%)	Normalised change in peak flow[1] (-)
Remove trees	7	+5 (3 to 7)	+73 (42 to 100)
Add tree strips	7	-5 (-2 to -11)	-71(-29 to -157)
Full afforestation	93	-36 (-10 to -54)	-39 (-11 to -58)

Note

1 This is the mean change in peak flow divided by the area affected expressed as a percentage.

(From McIntyre & Thorne, 2013)

Impact of tree planting in 25 km² Hodder sub-catchment (using physics-based, Runoff Generating Model):

Table 2.8 *Examples of scenario effects for a 25 km² Hodder sub-catchment. 95 per cent confidence intervals are in parenthesis*

Scenario (% of catchment)	Area affected 10 largest peak flows (%)	Increase in mean of increase (Δflow/area)	Normalised
Full coniferous planting of mineral soils	29	-7 (-3 to -13)	-24 (-46 to -10)
Full deciduous planting of mineral soils	29	-4 (0 to -9)	-15 (-2 to -32)
Deciduous riparian planting	9	-2 (0 to -3)	-17 (-1 to -36)

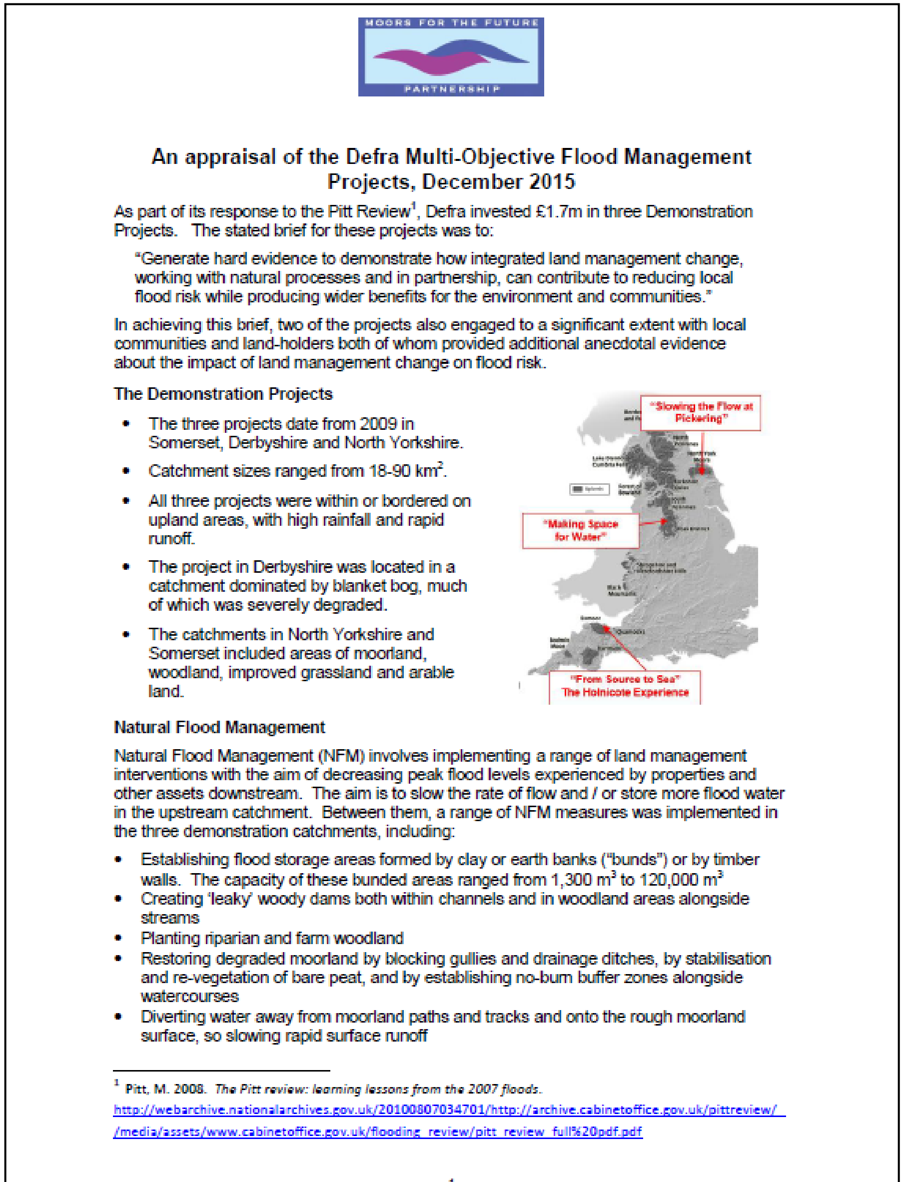
(From McIntyre & Thorne, 2013)

Modelling: Summary

Modelling studies demonstrate:

- Adjusting model parameters in line with process understanding shows woodland can reduce downstream flood levels and delay peak flows;
- Woodland creation predicted to reduce catchment flood peaks by **4-8%** (Pickering, 68 km^2), **0-13%** (Hodder, 25 km^2) **-3 to 27%** (River Tone) **2-54%** (Pont Bren, 6 km^2) and **6-19%** (New Forest);
- Ability of woodland to reduce flood flows declines with flood size, although modelling suggests can influence 1 in 100 year or larger events;
- Scope to alleviate flooding decreases with increasing catchment size (greatest for <100 km^2).

Overview of Defra Projects



MOORS FOR THE FUTURE PARTNERSHIP

An appraisal of the Defra Multi-Objective Flood Management Projects, December 2015

As part of its response to the Pitt Review[1], Defra invested £1.7m in three Demonstration Projects. The stated brief for these projects was to:

"Generate hard evidence to demonstrate how integrated land management change, working with natural processes and in partnership, can contribute to reducing local flood risk while producing wider benefits for the environment and communities."

In achieving this brief, two of the projects also engaged to a significant extent with local communities and land-holders both of whom provided additional anecdotal evidence about the impact of land management change on flood risk.

The Demonstration Projects

- The three projects date from 2009 in Somerset, Derbyshire and North Yorkshire.
- Catchment sizes ranged from 18-90 km^2.
- All three projects were within or bordered on upland areas, with high rainfall and rapid runoff.
- The project in Derbyshire was located in a catchment dominated by blanket bog, much of which was severely degraded.
- The catchments in North Yorkshire and Somerset included areas of moorland, woodland, improved grassland and arable land.

Natural Flood Management

Natural Flood Management (NFM) involves implementing a range of land management interventions with the aim of decreasing peak flood levels experienced by properties and other assets downstream. The aim is to slow the rate of flow and / or store more flood water in the upstream catchment. Between them, a range of NFM measures was implemented in the three demonstration catchments, including:

- Establishing flood storage areas formed by clay or earth banks ("bunds") or by timber walls. The capacity of these bunded areas ranged from 1,300 m^3 to 120,000 m^3
- Creating 'leaky' woody dams both within channels and in woodland areas alongside streams
- Planting riparian and farm woodland
- Restoring degraded moorland by blocking gullies and drainage ditches, by stabilisation and re-vegetation of bare peat, and by establishing no-burn buffer zones alongside watercourses
- Diverting water away from moorland paths and tracks and onto the rough moorland surface, so slowing rapid surface runoff

[1] Pitt, M. 2008. *The Pitt review: learning lessons from the 2007 floods.* http://webarchive.nationalarchives.gov.uk/20100807034701/http://archive.cabinetoffice.gov.uk/pittreview/_/media/assets/www.cabinetoffice.gov.uk/flooding_review/pitt_review_full%20pdf.pdf

1

Headline findings:

NFM techniques can reduce flood risk

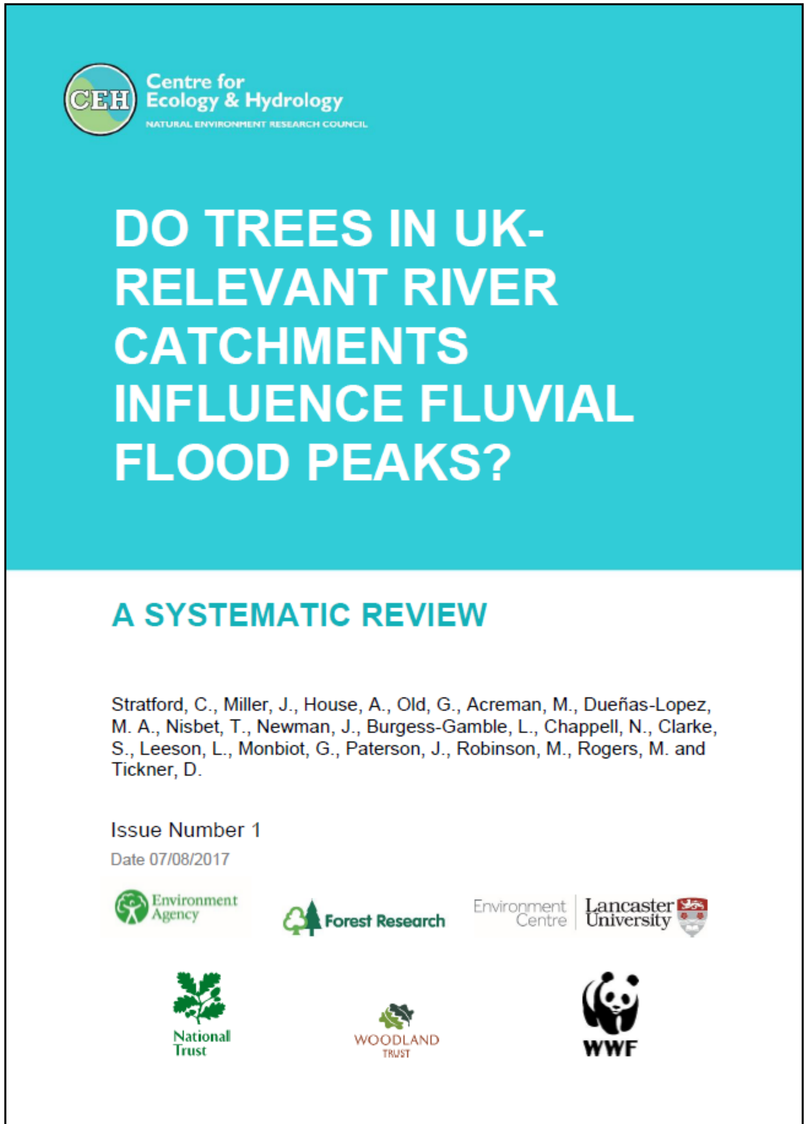
NFM techniques provide a wide range of additional benefits

NFM techniques can be effective in catchments up to 100 km^2

Local communities can become powerful advocates of NFM techniques

NFM requires careful planning and would benefit from 'priority mapping'

CEH Systematic Review


Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

DO TREES IN UK-RELEVANT RIVER CATCHMENTS INFLUENCE FLUVIAL FLOOD PEAKS?

A SYSTEMATIC REVIEW

Stratford, C., Miller, J., House, A., Old, G., Acreman, M., Dueñas-Lopez, M. A., Nisbet, T., Newman, J., Burgess-Gamble, L., Chappell, N., Clarke, S., Leeson, L., Monbiot, G., Paterson, J., Robinson, M., Rogers, M. and Tickner, D.

Issue Number 1

Date 07/08/2017

Environment Agency
Forest Research
Environment Centre
Lancaster University
National Trust
WOODLAND TRUST
WWF

<u>Headline findings</u>:

There is broad support for the conclusion that increased tree cover in catchments results in decreasing flood peaks, while decreased tree cover results in increasing flood peaks.

While there is strong evidence of an influence during small floods, only a few observational studies have assessed large floods and the majority of these found no influence on flood peak.

EA Review of WWNP

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CIWEM Events

Network – Learn - Debate

Working with Natural Processes:

The Evidence Behind Natural Flood Management

31 October 2017 | CIWEM One-Day Conference

Coin Street Conference Centre, London, SE1 9NH

#ciwemevents @CIWEM

Working with Natural Processes: The Evidence Behind Natural Flood Management — CIWEM Events

Speaker Agenda

	09.00 – 09.30	Registration and Refreshments
	09.30 – 09.40	Welcome
Session 1: The Evidence Base	09.40 – 09.55	Keynote Address: **John Curtin,** Executive Director of Flood and Coastal Risk Management, **Environment Agency**
	09.55 – 10.00	High Water Common Ground Trailer
	10.00 – 10.15	Introduction/Overview/setting the scene of the Evidence base **Lydia Burgess-Gamble,** Principal Scientist Flood & Coastal Risk Management Research, **Environment Agency**
	10.15 – 10.25	Short Break
	10.25 – 10.45	Introducing the Evidence Directory *Speaker tbc,* **JBA**
	10.45 – 11.00	Natural England **Tim Collins,** Principal Specialist - Coasts & Flood Management, **Natural England**
	11.00 – 11.10	Case study 1: Haswater and Yorkshire Washlands **Simon Wightman, RSPB**
	11.10 – 11.20	Cast study 2: *(invited)*
	11.20 – 11.30	Case study 3: Stroud **Chris Uttley, Stroud District Council**
	11.30 – 12.00	Discussion and Q&A
	12.00 – 13.00	Lunch Break and Networking
Session 2: Making the case for NFM	13.00 – 13.15	Introducing the NFM maps & modelling guide **Barry Hankin,** Head of Environmental Modelling, **JBA**
	13.15 – 13.30	NFM on the coast **Nigel Pontee, CH2M**
	13.30 – 13.40	Case study 1. North Norfolk **Oli Burns, Environment Agency** and **Sue Rees, Natural England**
	13.40 – 13.50	Case study 2. Sussex Flow Initiative **Fran Southgate, Sussex Wildlife Trust**
	13.50 – 14.00	Case study 3: Clywd/Barrog **Jacques Sisson, Natural Resources Wales**
	14.00 – 14.30	Discussion and Q&A
	14.30 – 15.00	Refreshments and Networking
Session 3: Filling gaps & monitoring	15.00 – 15.15	Introducing the R&D gaps that we still need to fill and introducing the monitoring guide **Tom Nisbet,** Head Physical Environment Research, **Forest Research**
	15.15 – 15.25	Case study 1: Mires **Tom Dauben, Environment Agency** and **Morag Angus, South West Water**
	15.25 – 15.35	Case study 2: Evenlode **Joanne Old, Environment Agency**
	15.35 – 15.45	Case study 3: Bowmont **Mark Wilkinson, The James Hutton Institute**
	15.45 – 16.15	Discussion and Q&A
	16.15 – 16.30	Wrap up

CIWEM Events

Conclusions

- There is strong understanding of the different processes by which trees, woodlands and forests can affect flood flows.
- An increasing number of modelling studies suggest that woodland creation has the potential to reduce flood flows, typically in the range of 5-20%.
- 'Hard' evidence of forestry reducing flood flows in larger catchments remains 'light' and difficult to prove.
- The amount, location, type and way forests are managed all influence the ability to affect flood flows.
- Risk factors such as the backing-up of floodwaters and the wash-out of woody debris can be controlled by site selection and woodland design.