Water Friendly Farming

Results update: autumn 2017

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Freshwater Habitats Trust, Environment Agency, Allerton Project: Game & Wildlife Conservation Trust and University of York

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Water Friendly Farming

Set up to fill one of the most important knowledge gaps in catchment management….

…the need for evidence of the effectiveness of land management measures in tackling catchment problems, especially reducing runoff, reducing diffuse pollution and improving freshwater biodiversity

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Of course….

Lots of evidence of measures working at plot and field scale….

Buffer strips

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Changing tillage practices

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Adding interception wetlands

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Creating new habitat

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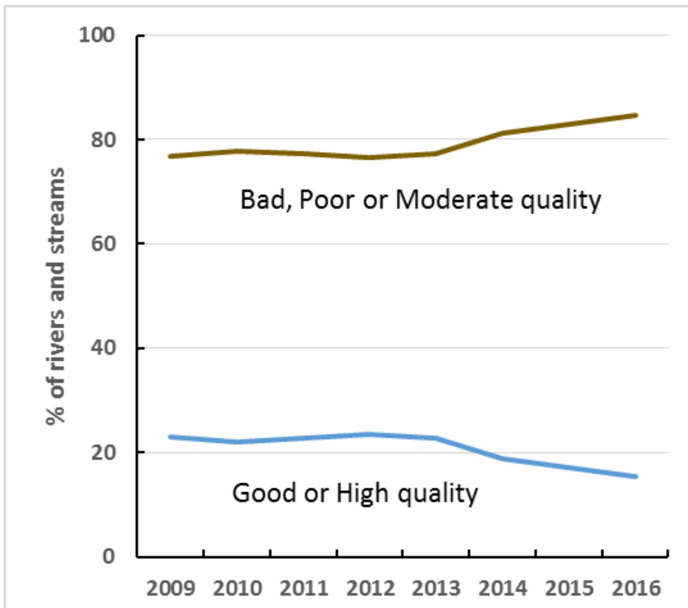
BUT….
We still don't have much evidence of how these practices translate into benefits at catchment scale….

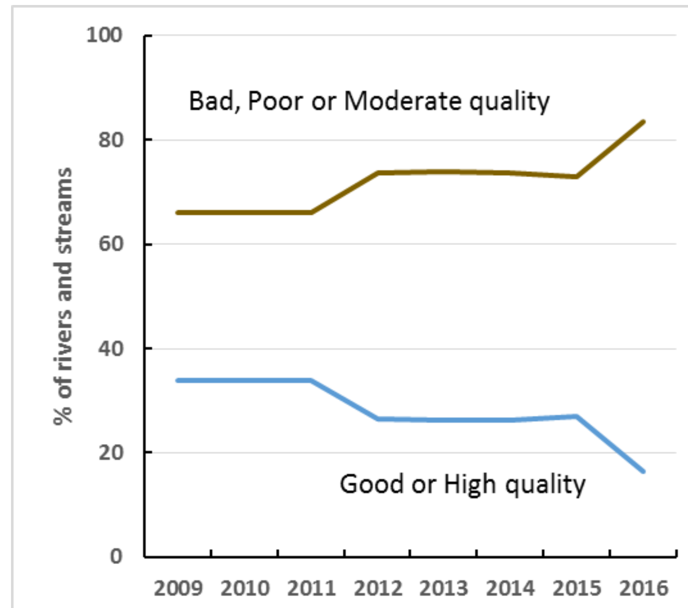
We do know….

What we are doing isn't yet working

River and stream ecological quality in England: 2009-16



Lake ecological quality in England: 2009-16



Source: Environment Agency statistics published in August 2017. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/635370/England_biodiversity_indicators_dataset_2017.ods

Water Friendly Farming's aim is….

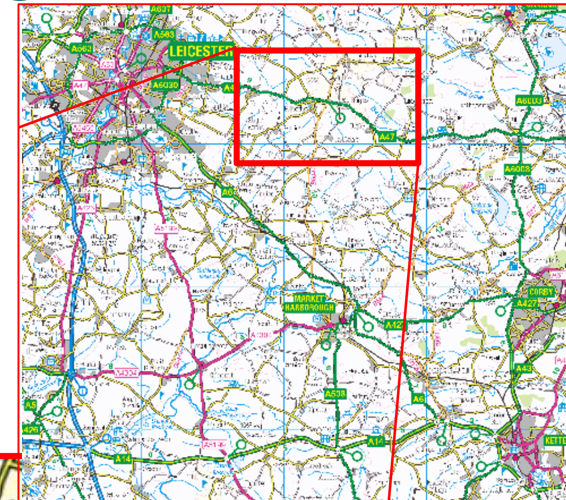
To apply all the measures we can in normal commercial farming landscape to assess catchment scale effects on:

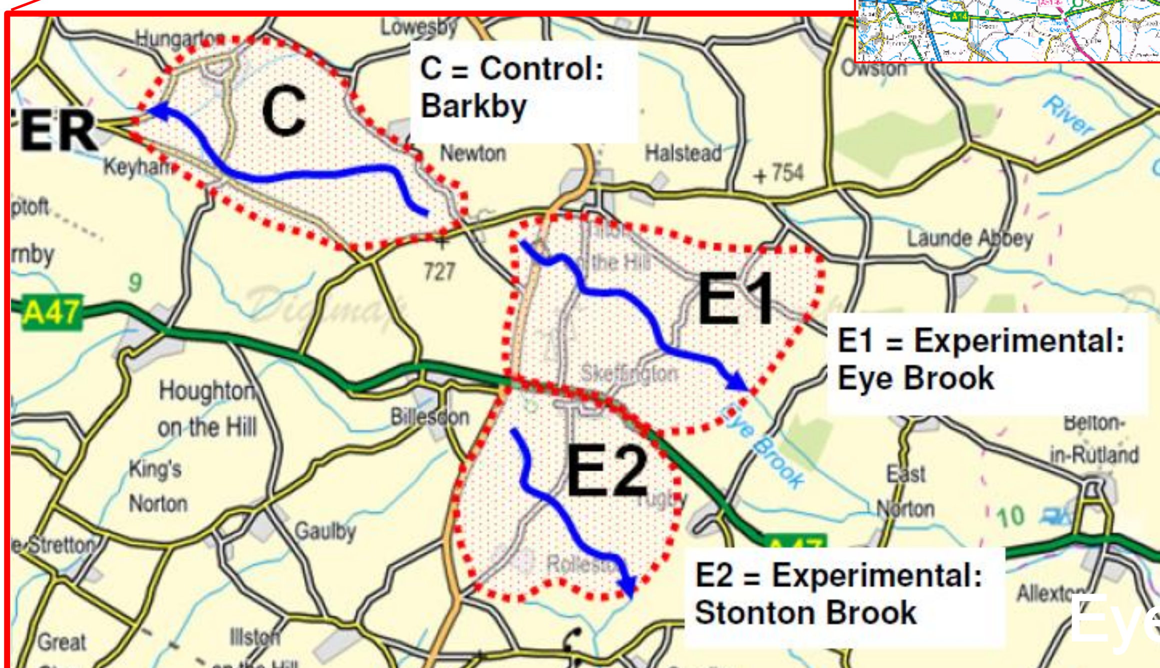
- **Flows/flooding**
- **Diffuse pollution**
- **Freshwater biodiversity**

Essentially…..a reality check

Water Friendly Farming

- **Experiment with BACI design**
- **Close to GWCT Allerton Project site at Loddington, Leicestershire**
- **Each catchment c.10 km^2**





Water Friendly Farming landscape…

- **80% farmland, clay under-drained**
- **Half arable, half grass (dairy, some sheep)**
- **Pretty typical landscape: like 1/3rd of lowland England**
- **Typical range of problems…..**

Eye Brook catchment

Typical problems…

Flow along tramlines: Stonton Brook catchment, February 2013 during the baseline phase

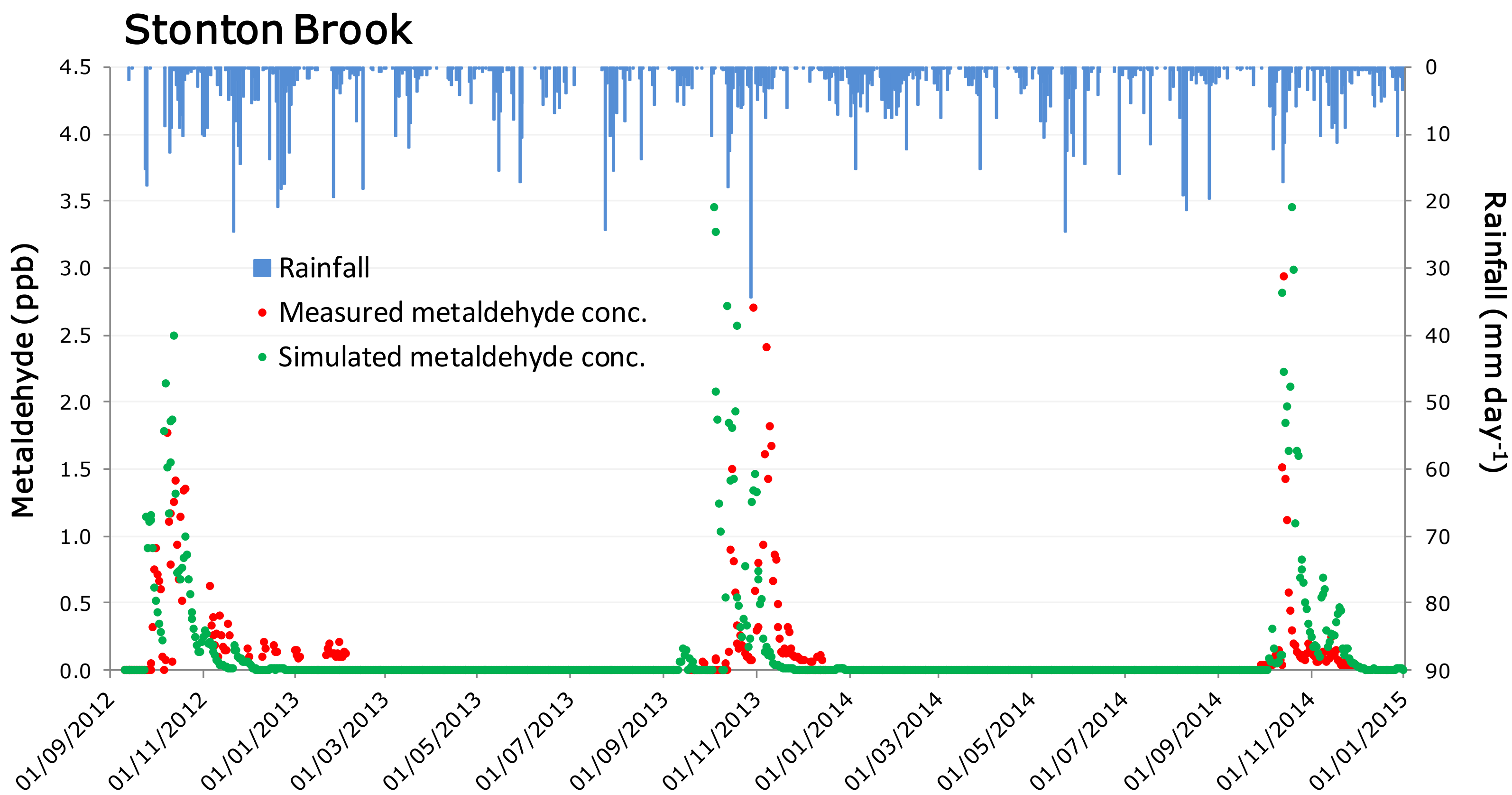
Typical problems…

Runoff from roads: Stonton Brook catchment, February 2013 during the baseline phase

Typical problems…

Surface erosion on slopes: Eye Brook catchment, October 2013 during the baseline phase

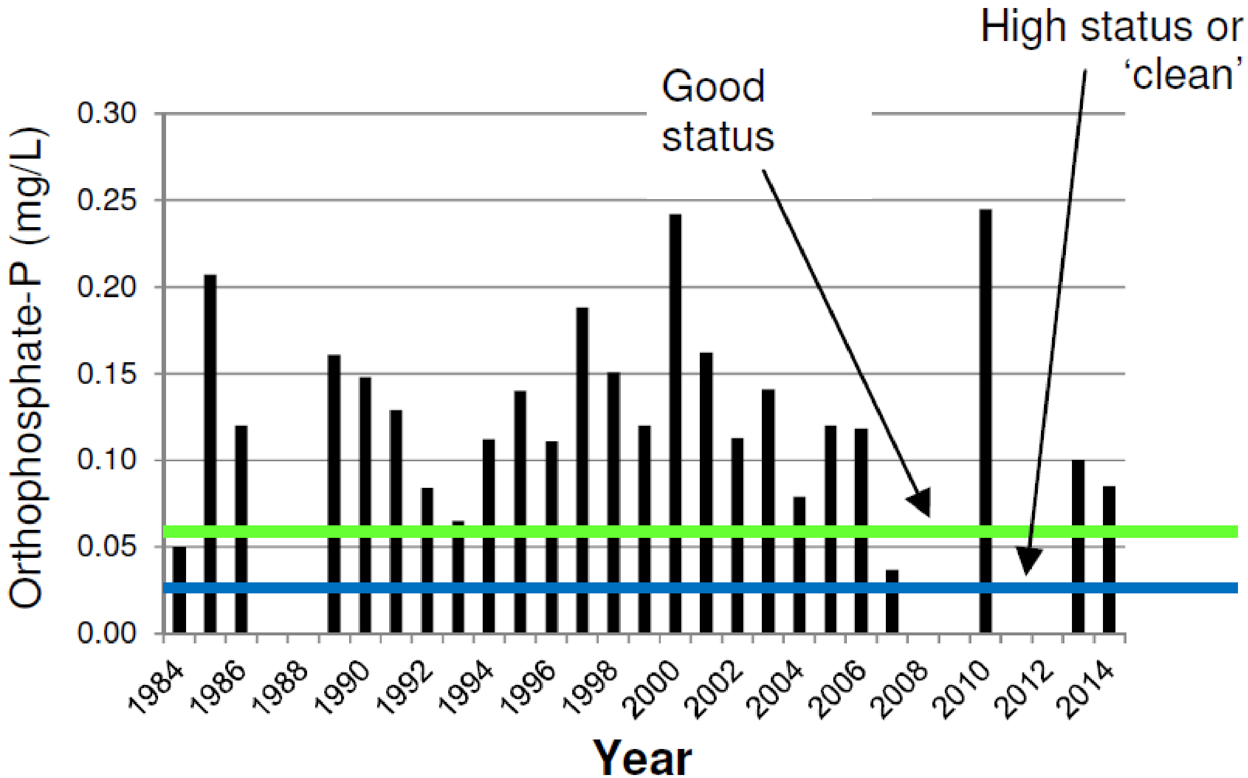
Typical problems…



Metaldehyde spikes in the Stonton Brook catchment are typical of lowland England

Typical problems…

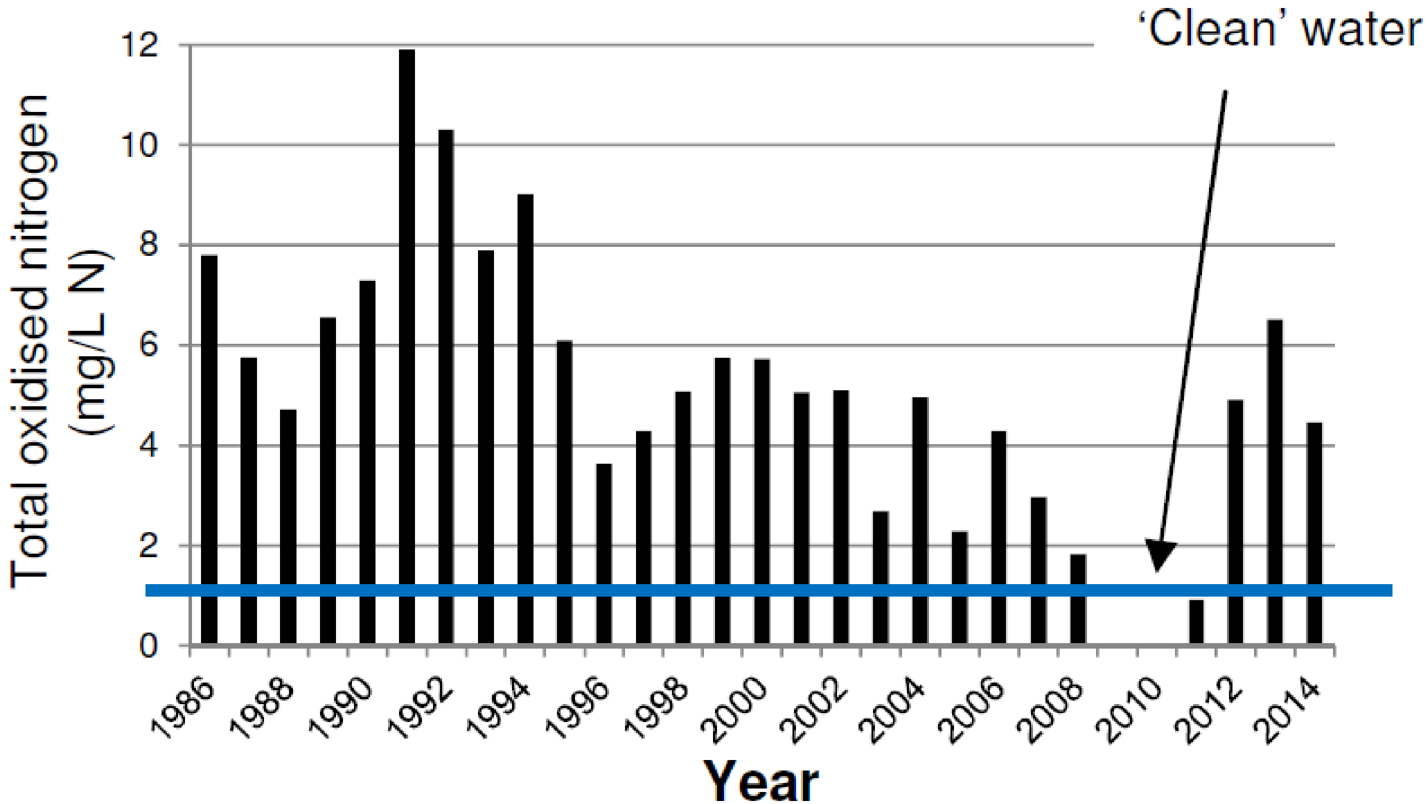
Elevated phosphorus levels



Long-term phosphorus concentrations in the Eye Brook are above Good and High status levels

Typical problems…

Nitrogen substantially above natural background levels



Long-term TON-N concentrations in the Stonton Brook

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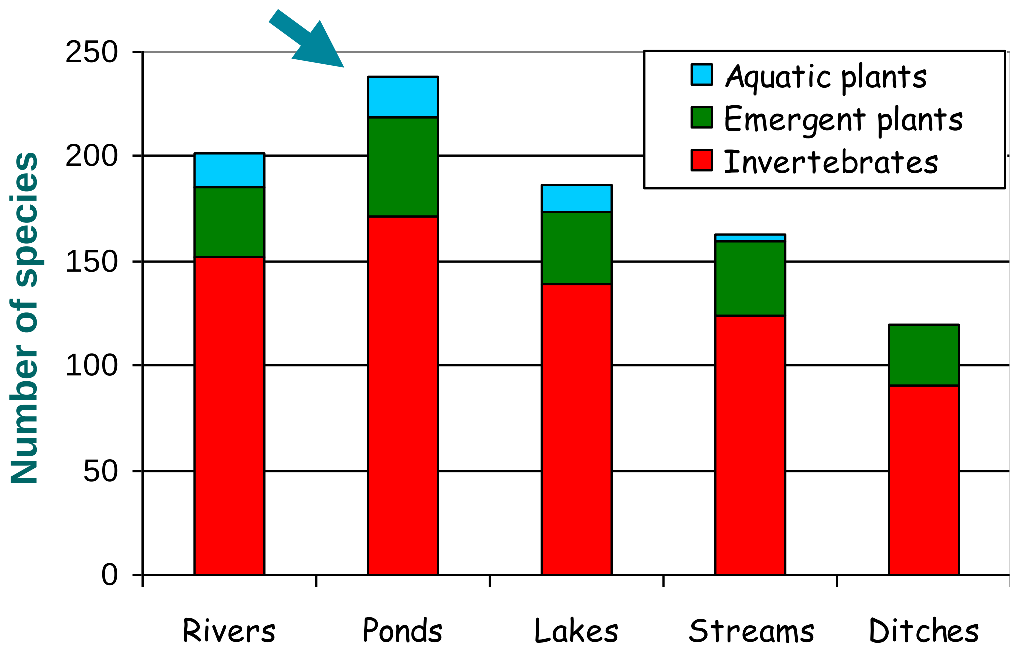
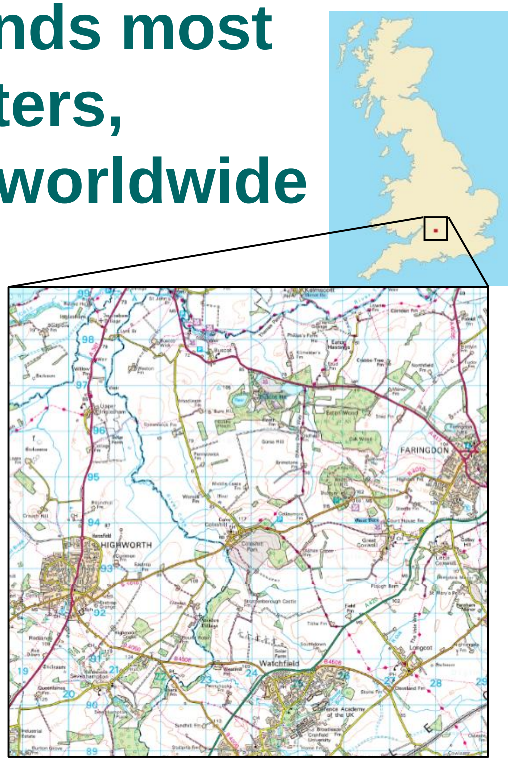
Important…

Project concerned with whole water environment

Previous work at landscape level finds most freshwater biodiversity in small waters, particularly ponds; finding echoed worldwide



Plant and animal species in freshwater habitats in the Coleshill landscape, Oxon/Wilts



The Coleshill landscape study area described in Williams P, Whitfield M, Biggs J, Bray S, Fox G, Nicolet P, and Sear D, 2004. Comparative biodiversity of rivers, streams, ditches and ponds in an agricultural landscape in Southern England. Biological Conservation 115: 329–341.

So taking account of <u>all</u> waterbody types

Rivers and streams...

Ponds…

Pond in Barkby Brook catchment

Ponds…

Pond in Stonton Brook

...springs and flushes

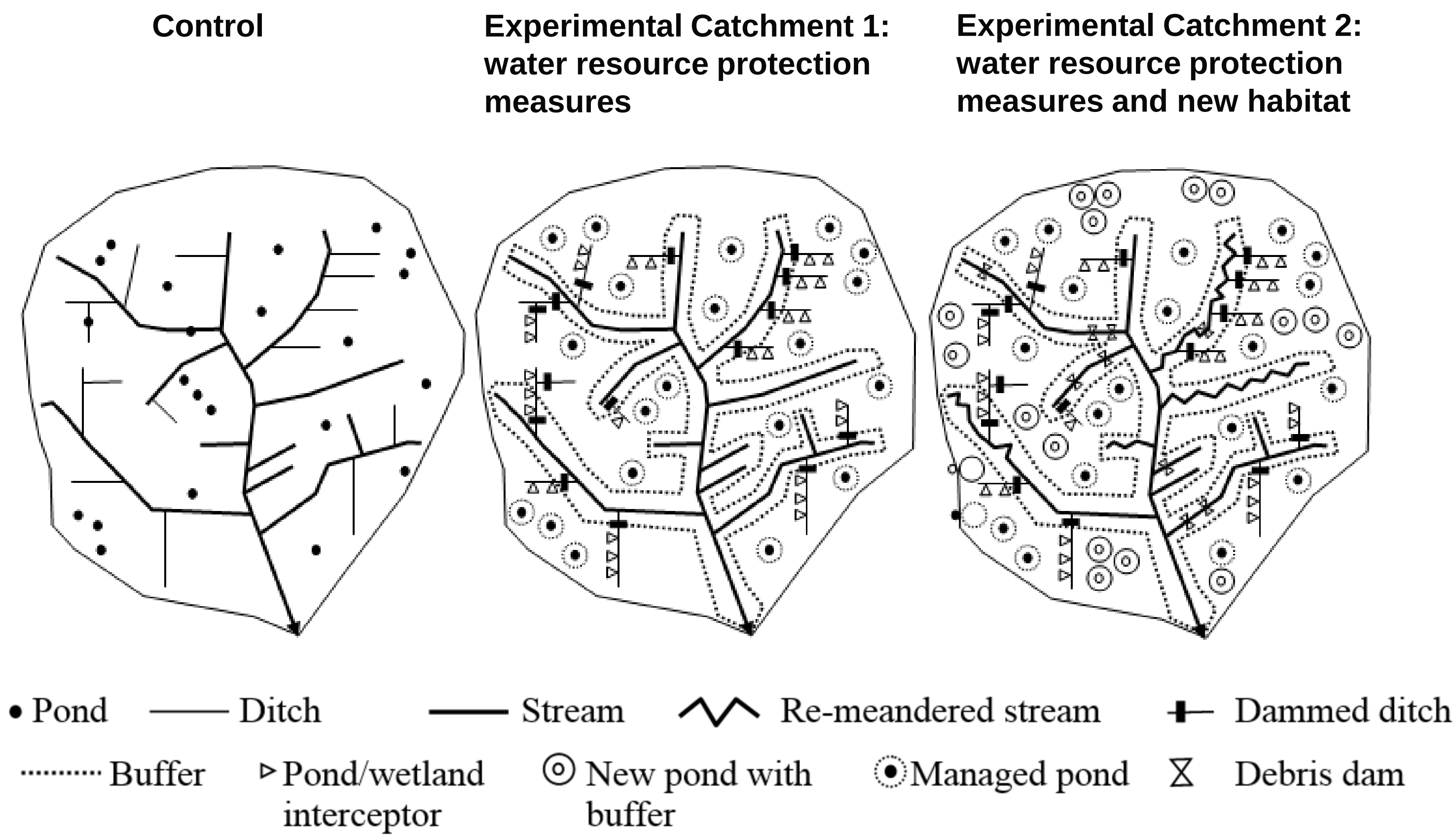
...small headwaters

........network of ditches

Project stages

- 2010-13 Describing baseline
- 2014 Main phase of introducing measures
- 2014 onwards: Monitoring and further measures implementation

Experimental design



Using as full a complement of measures as we can, assess overall effect in normal farming landscape

Water resource protection measures

Buffer strips

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Water resource protection measures

Bunded ditches

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Water resource protection measures

Installing larger field drain to prevent overland flow

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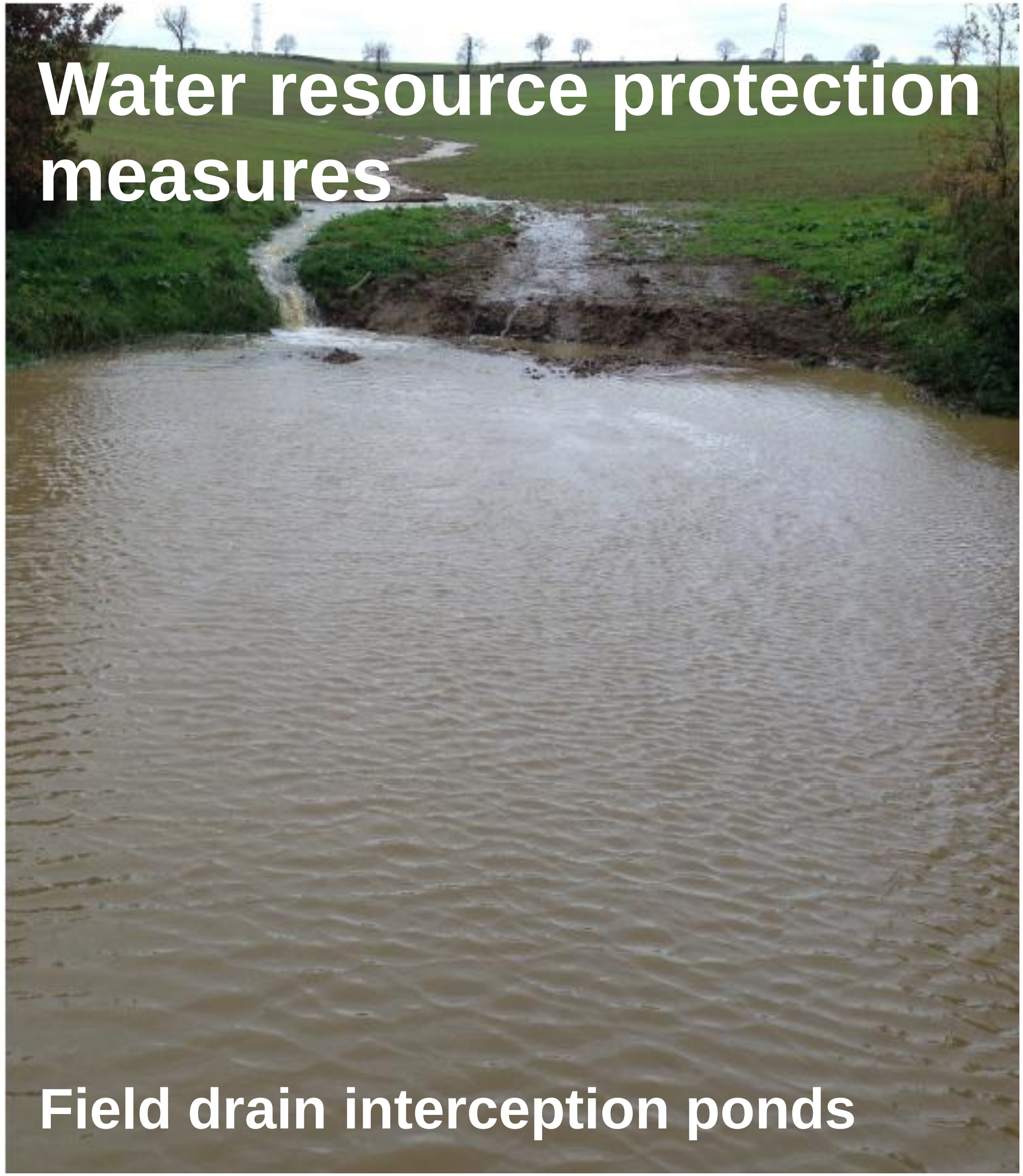
Water resource protection measures



Field drain interception ponds

Water resource protection measures

Offline flood storage basins

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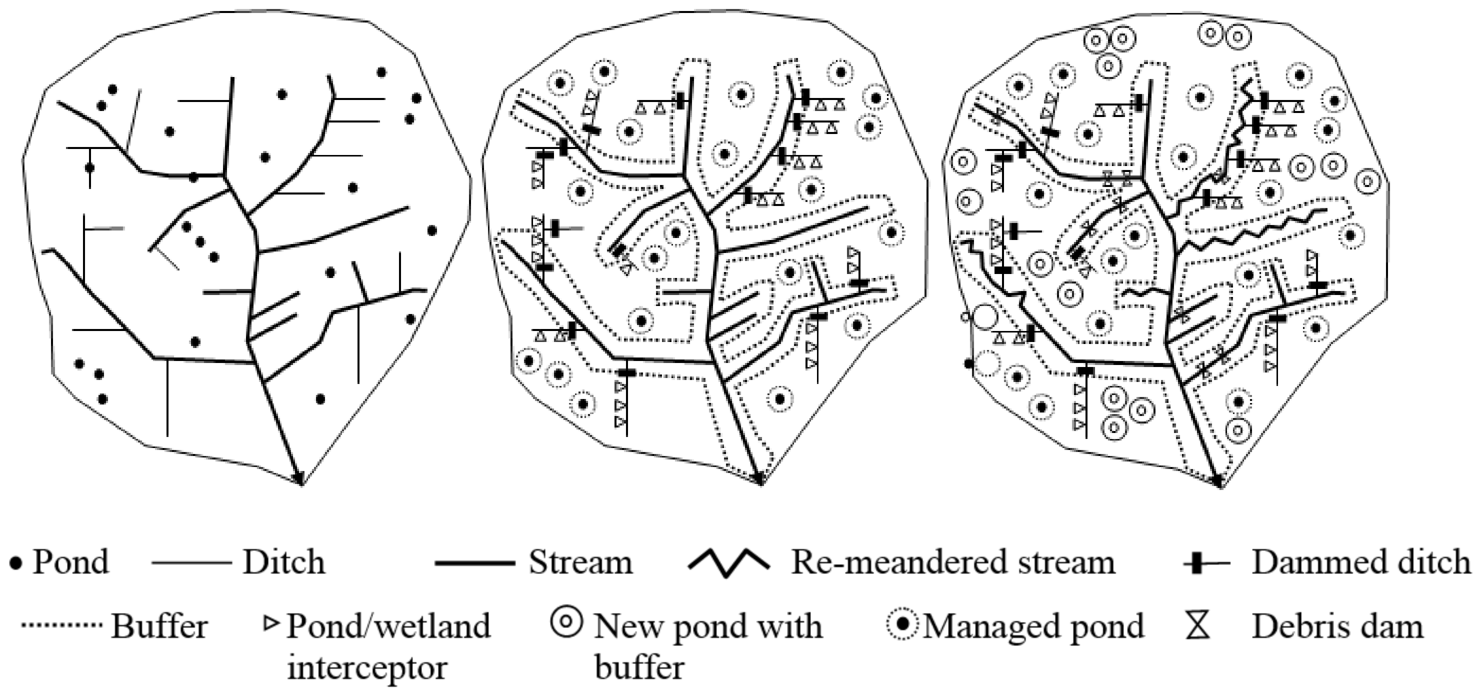
Experimental design

Control

Experimental Catchment 1: water resource protection measures

Experimental Catchment 2: water resource protection measures and new habitat



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Habitat creation measures

Adding woody debris dams

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Habitat creation measures

Managing existing ponds

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Habitat creation measures

Creating new clean water ponds

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Results

Natural flood management

Nutrient pollution

Freshwater biodiversity

Chemicals
Regulation
Directorate

Natural flood management

- **Flows and sediments both important to flood engineers**
- **Used SWAT to test alternative flow and sediment mitigation strategies**

- **Soil and Water Assessment Tool (Arnold *et al*., 1998)**
- **Physically based, time continuous simulation model at catchment-scale (Neitsch *et al*., 2002)**
- **Allows mitigation measures to be simulated**
- **GIS-integrated hydrological model**
- **Used around the world**

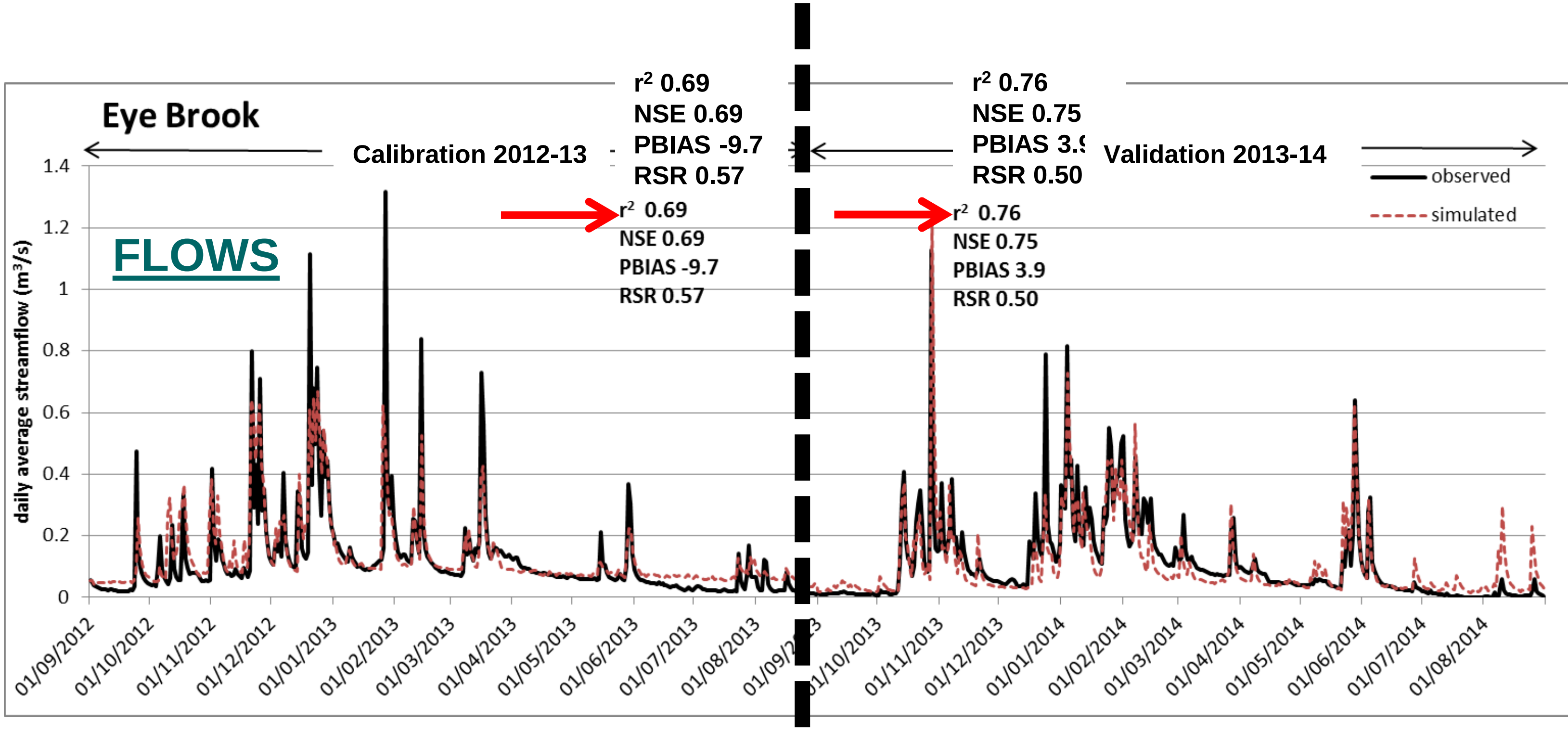
Arnold, J.G., Srinivasan, R.,Muttiah, R.S. and Williams, J.R. . (1998). Large area hydrologic modelling and assessment part I: Model development. *J. Am. Water Resour. Assoc*. 34(1):73–89.

Neitsch S.L., Arnold J.G., Kiniry J.R., Williams J.R., King K.W. (2002). Soil and Water Assessment Tool Theoretical Documentation. Texas: Water Resources Institute, College Station, Texas.

Step 1: SWAT model construction

We have continuous monitoring of flows and sediments at catchment outfalls from 2012 onwards

These data used to create and validate SWAT model



Model gives pretty good simulation of the observed flows; r^2 ("r-squared"; range is 0 to 1; values over 0.5 regarded as acceptable)

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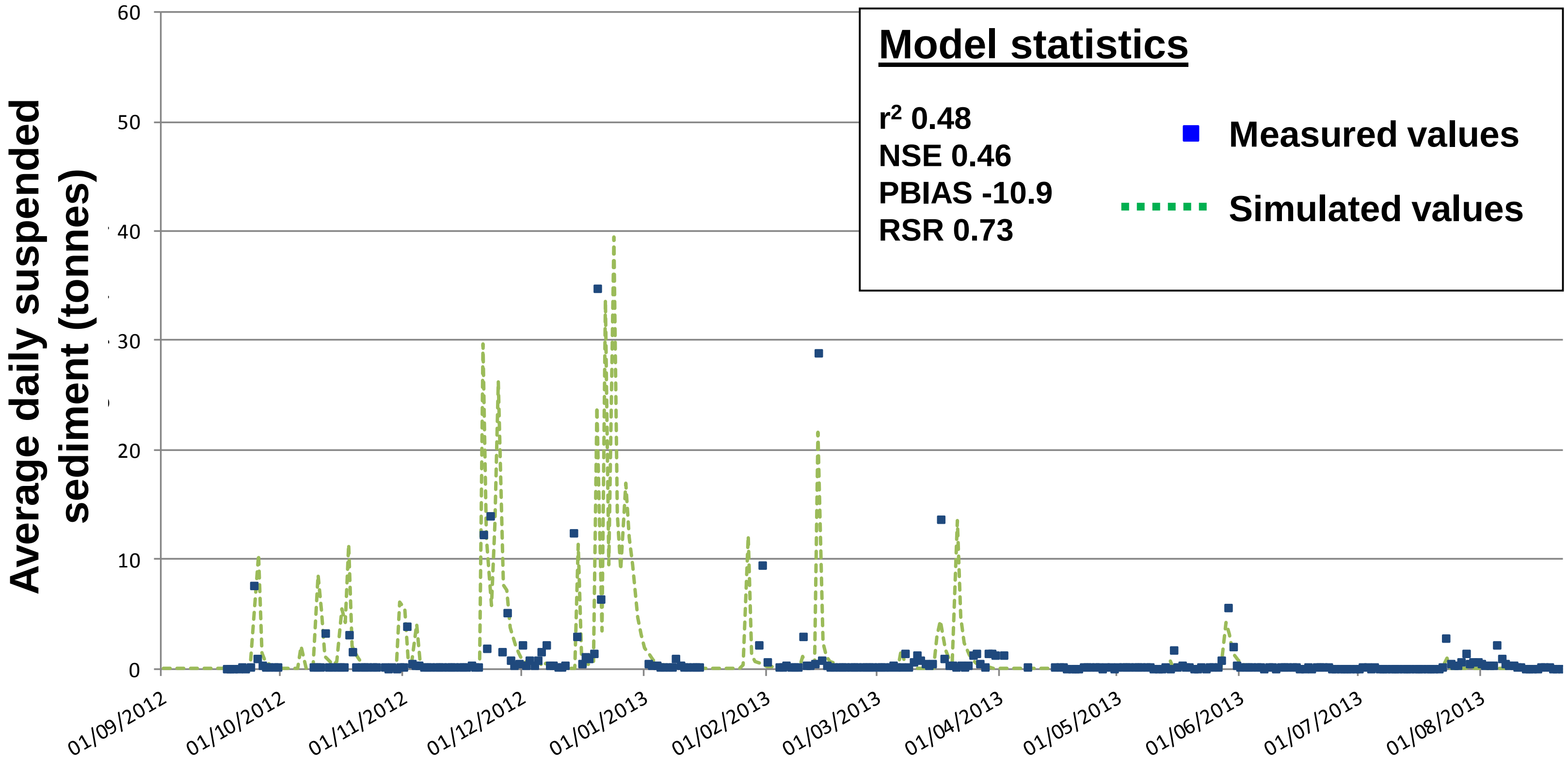
SWAT model simulates sediment loss (c.f. monitoring data)

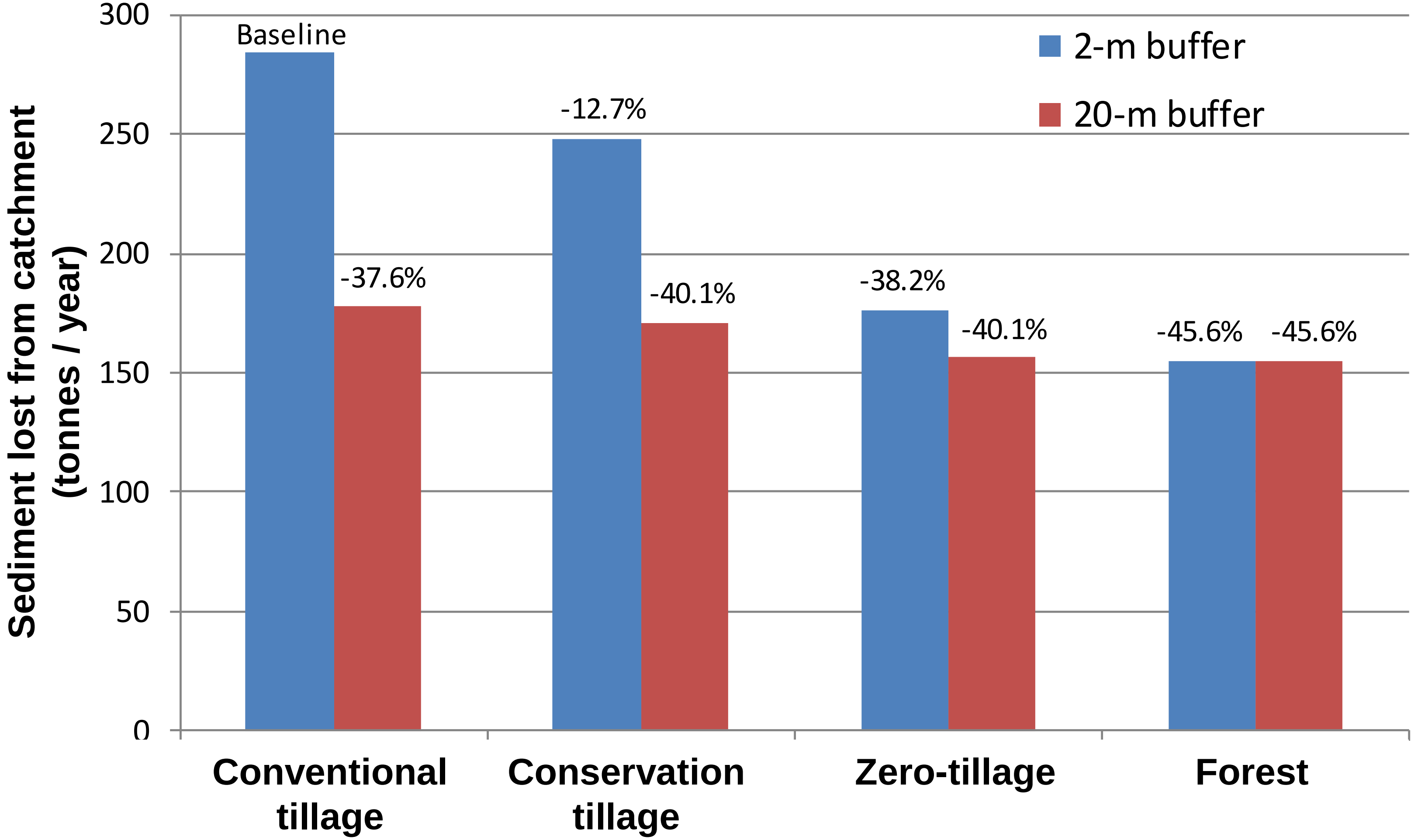


Sediment loss: modelling results

Now we have a field-validated model it's possible to assess effects of adding different measures:

- **Buffer strips**:
  - Statutory minimum buffer strips (2 m for cross compliance)
  - The buffers that exist now (typically 6-10+ m)
  - Adding larger buffers
- **Cultivation changes**:
  - Conventional (i.e. ploughing)
  - Conservation tillage
  - Zero tillage
- **Hypothetical afforestation of whole catchment (=natural baseline)**

e.g. Modelled sediment loss of buffer strips under different cultivation scenarios – in 'ordinary' storms



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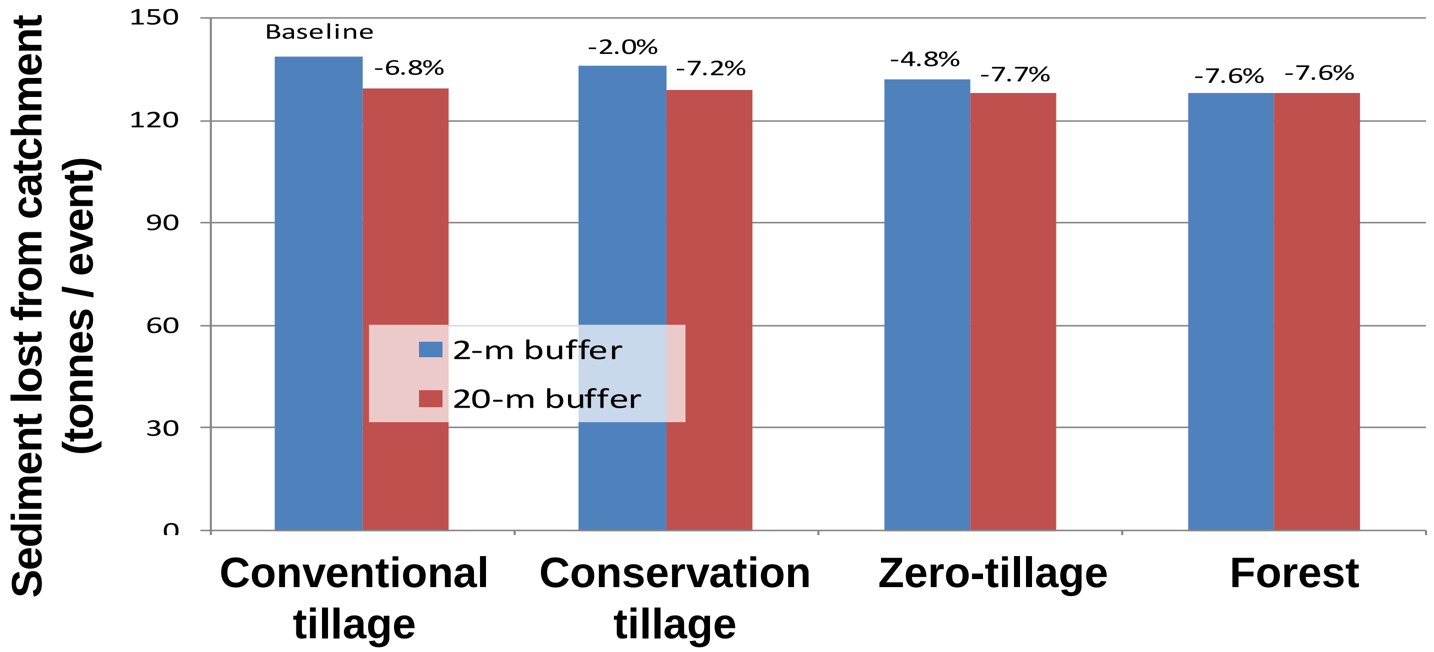
Sedimentloss during *extreme* rainfall events (1:100)

- Flooding overwhelms buffer strips <u>and</u> forest in our clay-based catchment
- Almost as much sediment lost in one storm as whole normal year

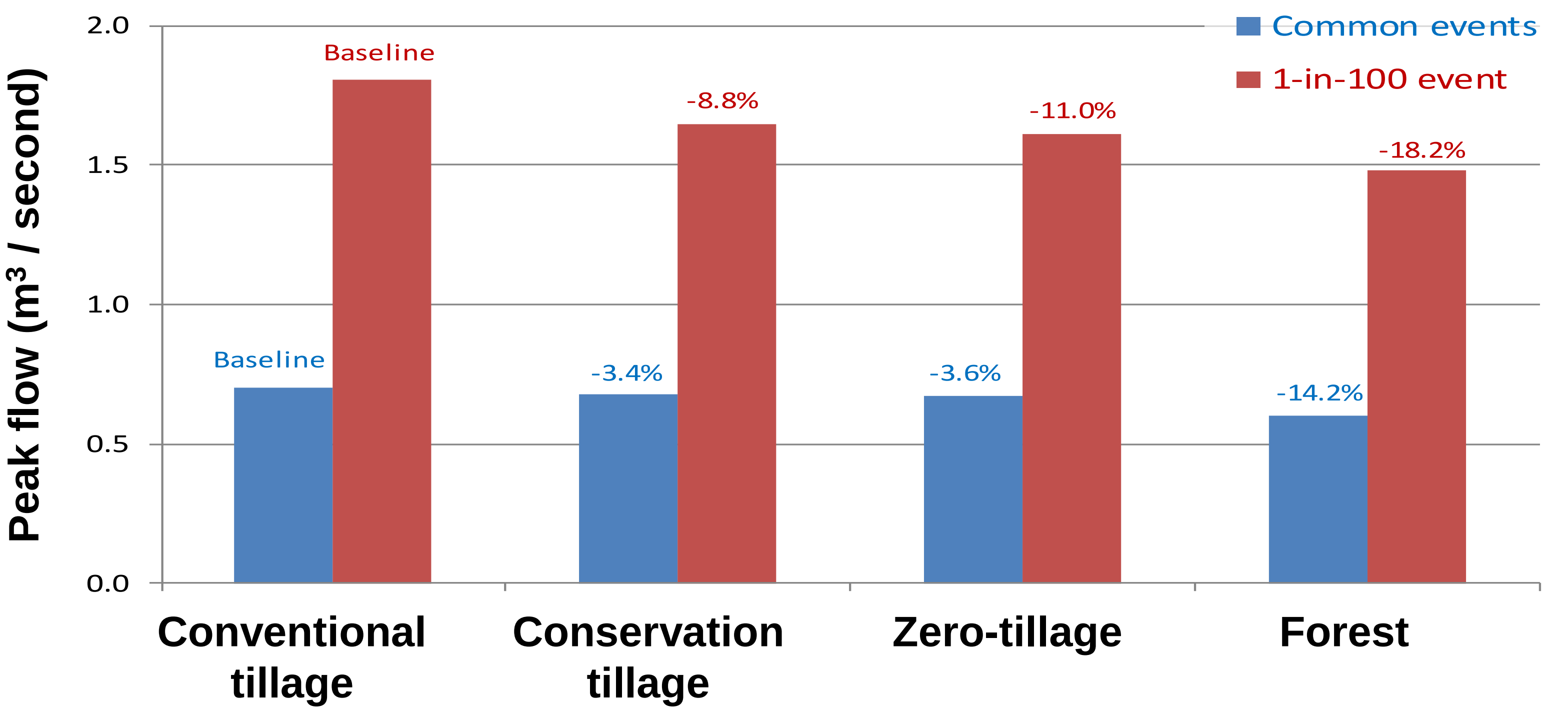
So interestingly….in Loddington's lowland clay-based catchment, wide buffers are an advantage in normal storms, but all protection measures fail under serious flooding events



Flows: effects of landuse change

Here we're looking at the effect of different land uses on peak flows under ordinary and unusual storms

- **Common flood events (blue): changing tillage has little effect (clay catchments) e.g. converting to forest reduces peak flows by only 14%**
- **1:100 floods (red): changing tillage practice = little effect. Full afforestation: 18% reduction in flood peak = significant – but no agriculture!**



Storage is the most viable technique for holding back water, reducing peak flows

First round storage: bunded ditches, interception ponds - created 3000 m^3 before ran out of space

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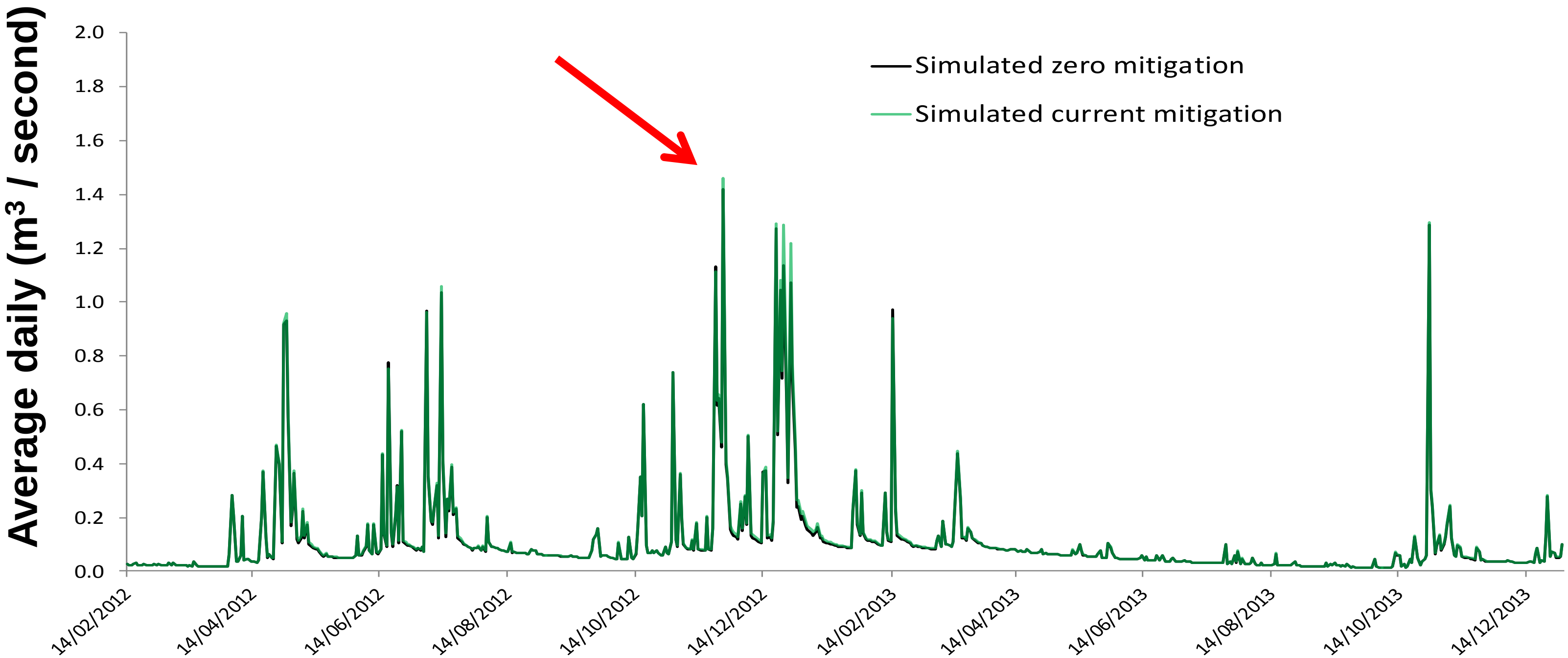
Modelled effect of initial water storage measures on flows

- **Very small reduction on peak flows**

  e.g. largest event on 25/11/2012 reduced from average daily flow of 1.46 m^3/s to 1.42 m^3/s.

- **Implication: needed substantially more storage to have effect**



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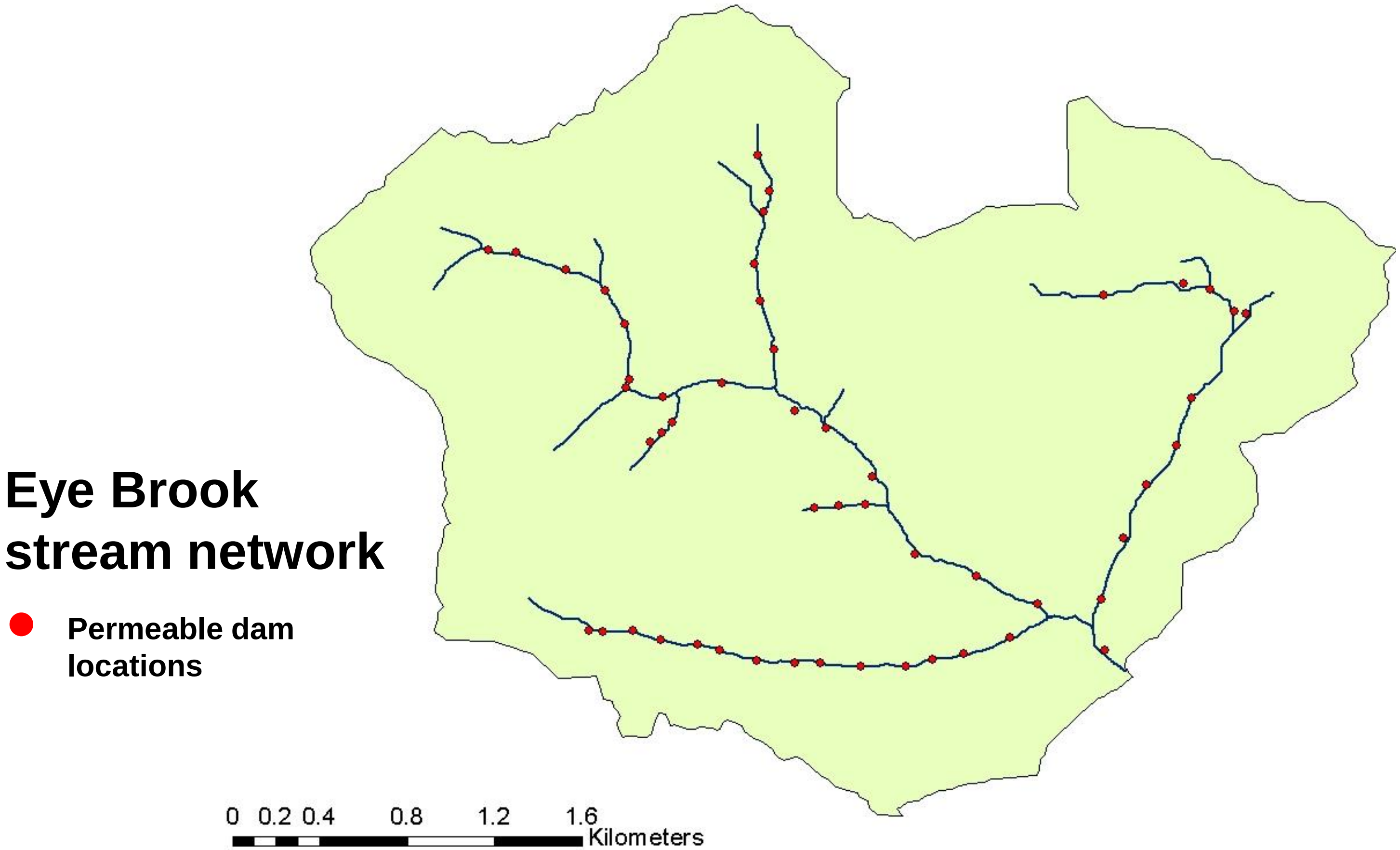
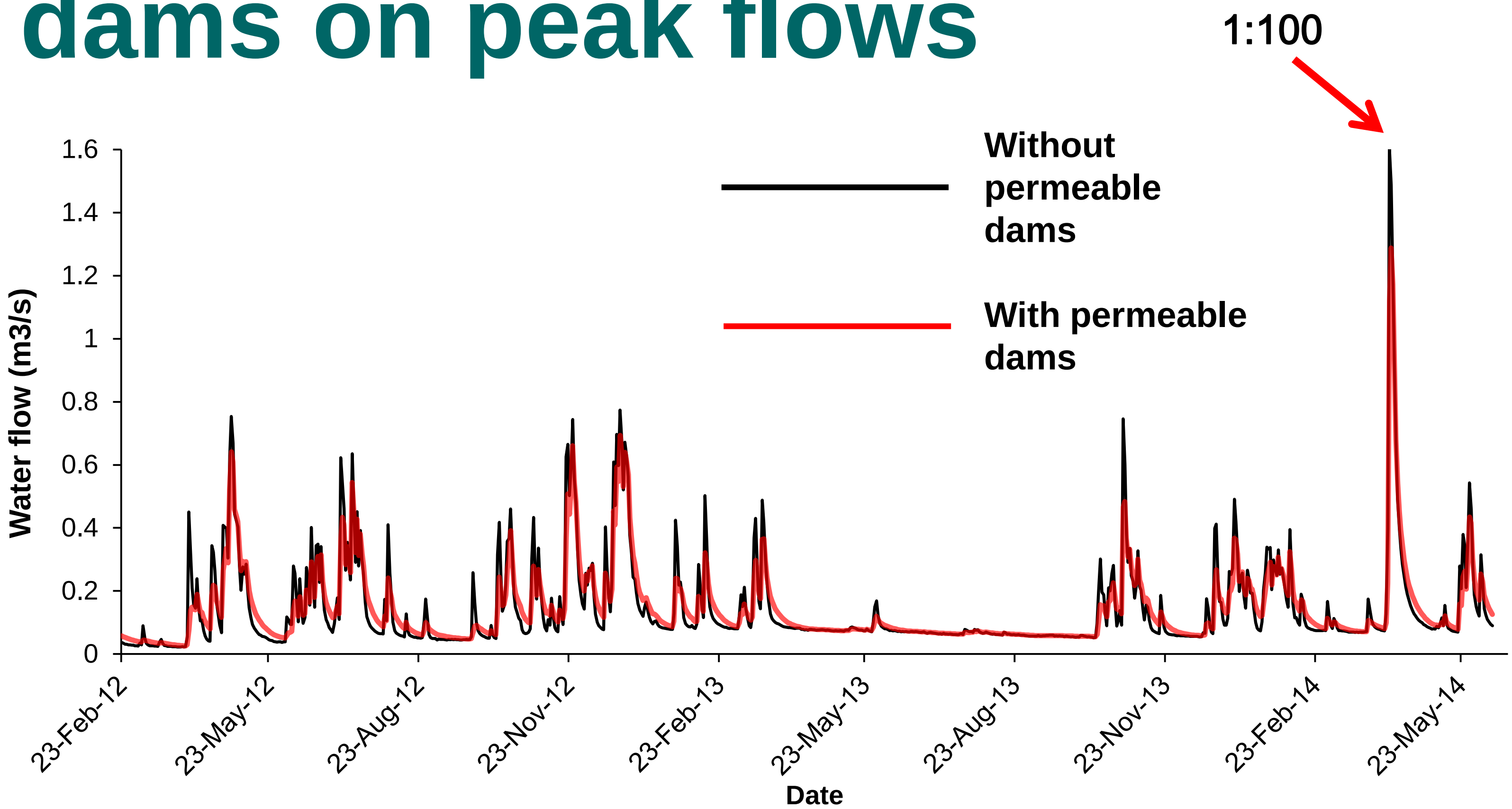
A more interventionist approach

- **We estimate that to make a significant impact on flood flows we need c30,000 m3 (10x more) temporary storage**
- **Modelled effect of permeable (leaky) dams to force water into riparian zone / floodplain, and retain temporarily**

Eye Brook stream network



Modelled effect of permeable dams on peak flows

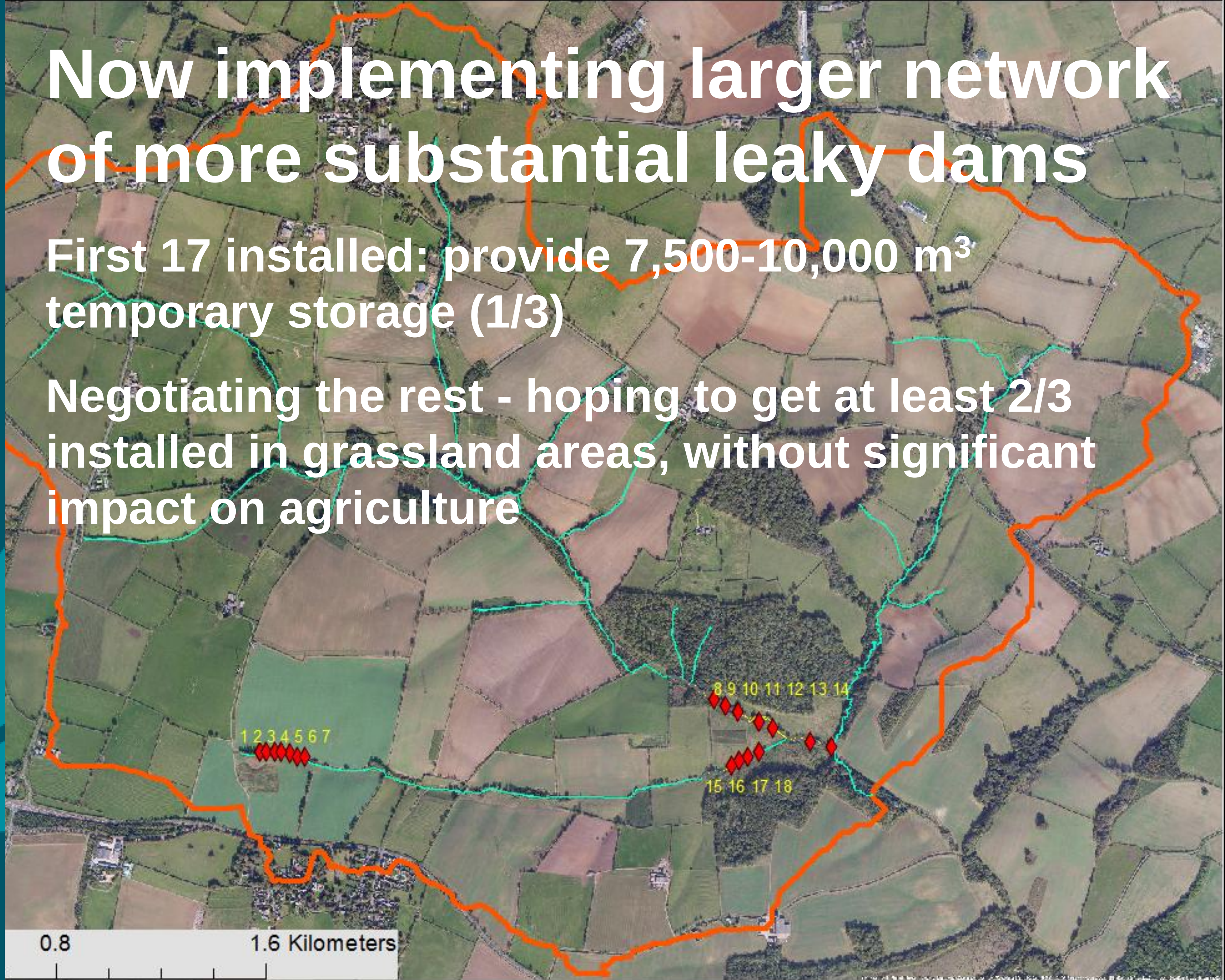


- **The peak daily flow is reduced from 1.61 m^3/s to 1.29 m^3/s (20% reduction); other events reduced by 27% average**
- **Peak delayed by 24 hrs; suggests significant benefits**

Now implementing larger network of more substantial leaky dams

First 17 installed: provide 7,500-10,000 m^3 temporary storage (1/3)

Negotiating the rest - hoping to get at least 2/3 installed in grassland areas, without significant impact on agriculture



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We’re now monitoring the results….and hoping for some decent storms to see how these new features: (a) perform hydrologically (b) stand up to wear and tear

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Results

Natural flood management

Nutrient pollution

Freshwater biodiversity

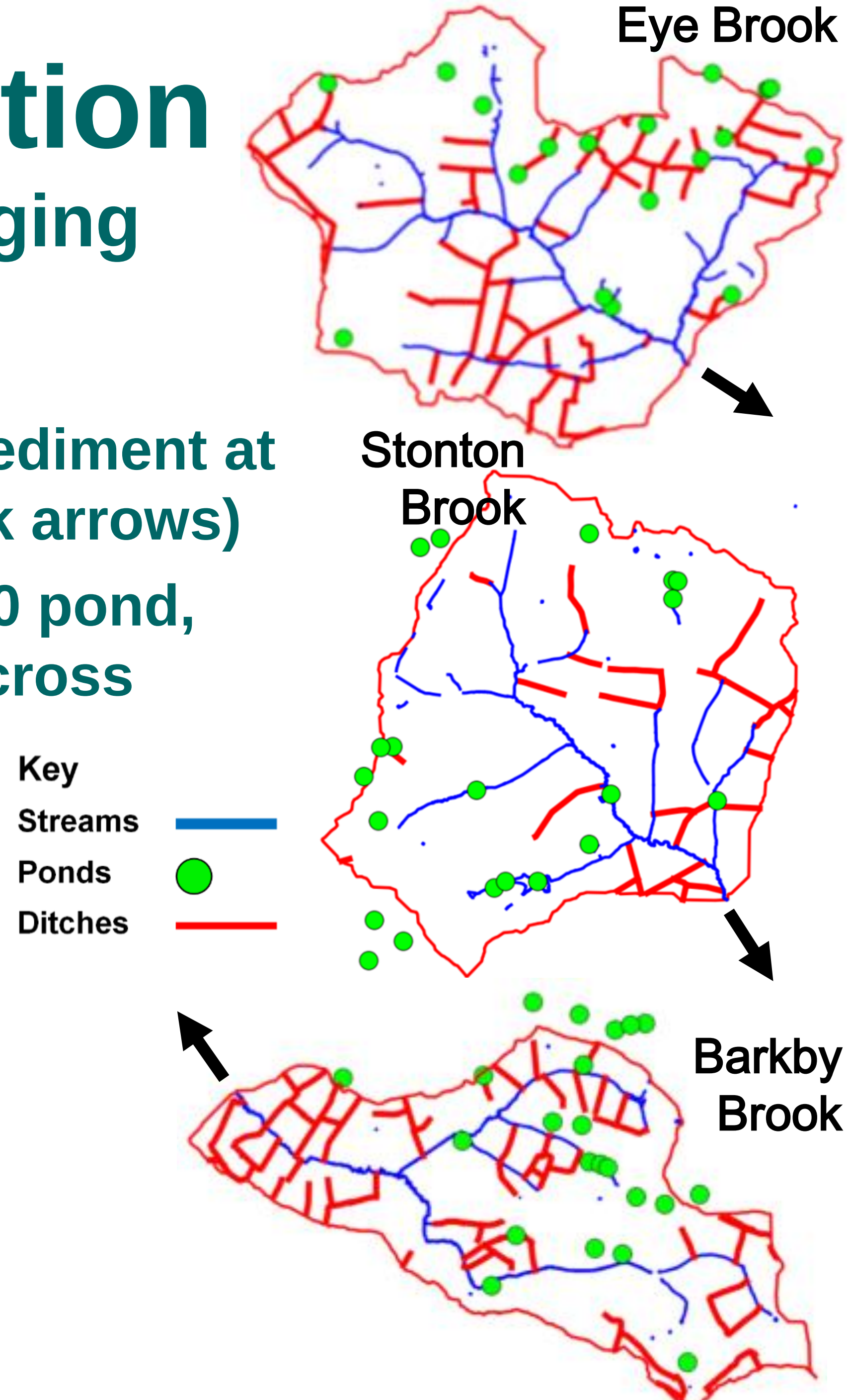
Nutrient pollution

Results less encouraging

Monitoring:

- Continuously N, P and sediment at catchment outfalls (black arrows)
- Annual snapshot of c.250 pond, stream and ditch sites across landscape

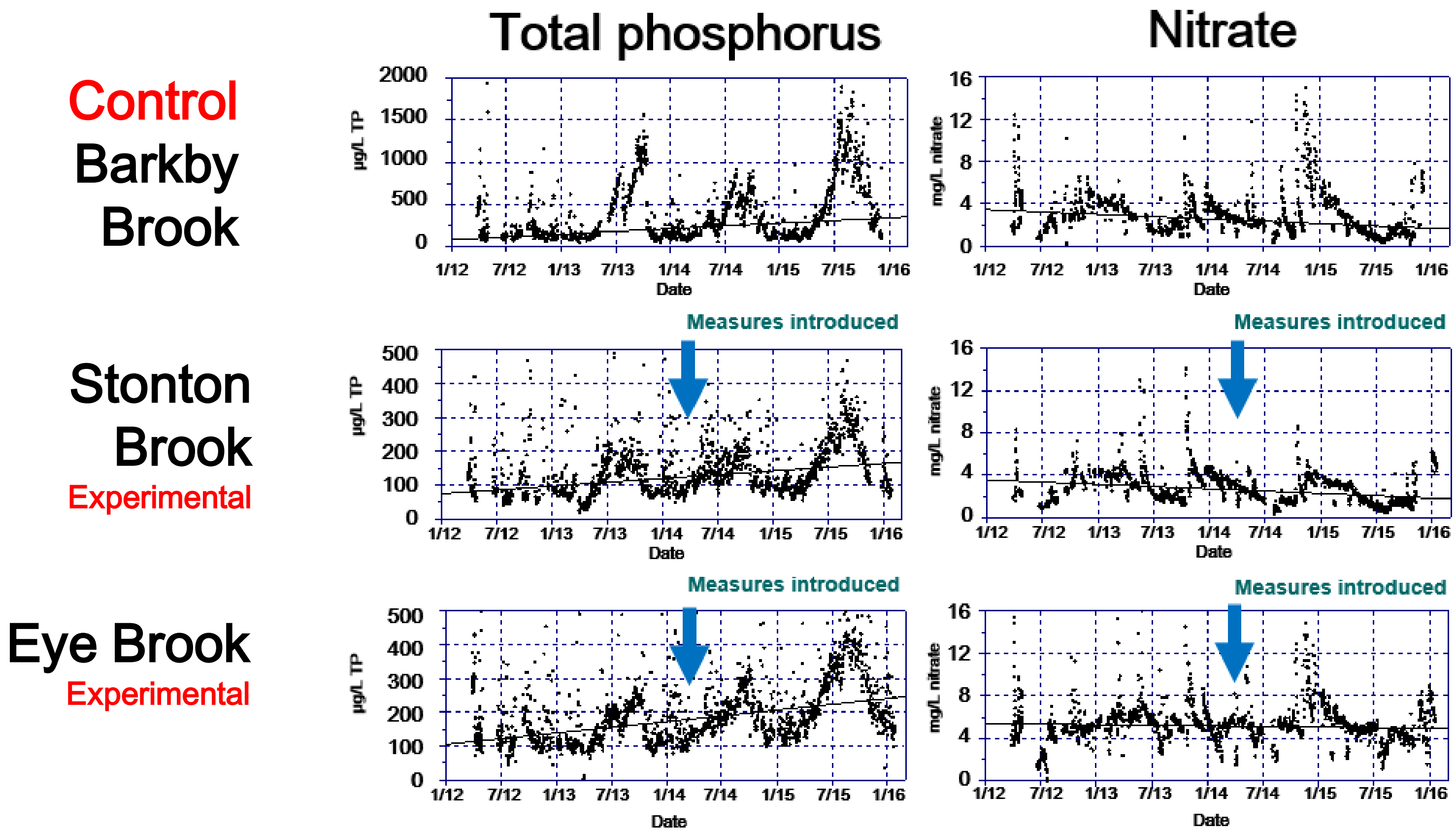

Auto-sampler at outfall of Eye Brook catchment



Effect of measures on nutrient pollution

- No signal from measures at catchment scale
- Changes probably reflect climatic drivers with lower runoff in more recent period of project
- Effectively – measures overwhelmed by weather

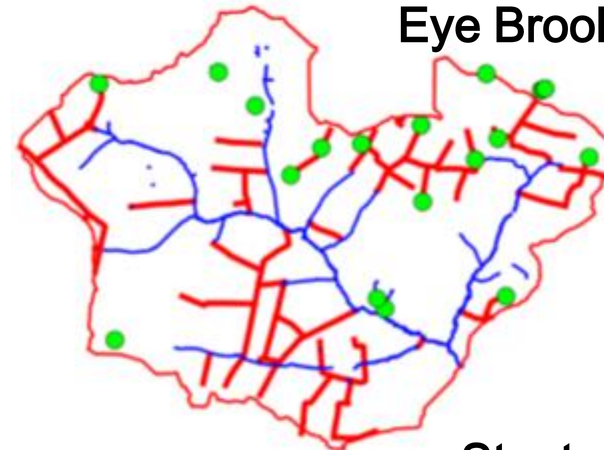
Recent report (Ockendon et al. 2017): suggests likely to be an increasing issue winter P loads predicted to increase up to 30% by 2050s; limited only by large-scale ag changes (e.g. 20–80% reduction in P inputs)



That's streams…..

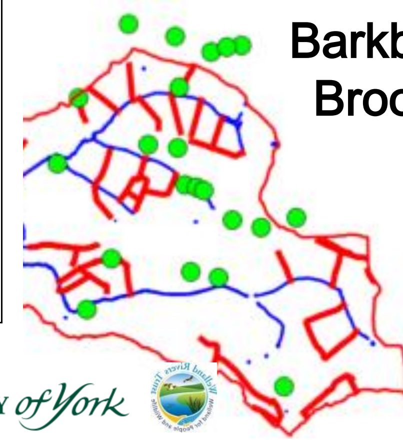
On positive side, looking across whole landscape, some clean water (= natural background) and has increased following our interventions - through pond creation

Eye Brook

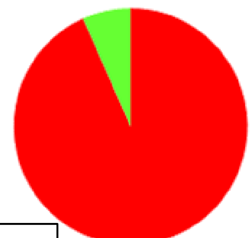
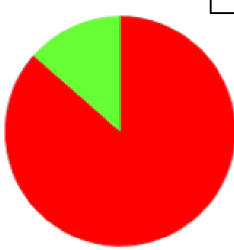


Stonton Brook

Barkby Brook



Pre- and post works water quality: proportion of 'clean water' sites

	Stonton Brook (clean water ponds added)	Eye Brook	Barkby Brook (control)
2013	5% 	7% 	16% 
2017	14% 	5% 	14% 

Clean
Polluted

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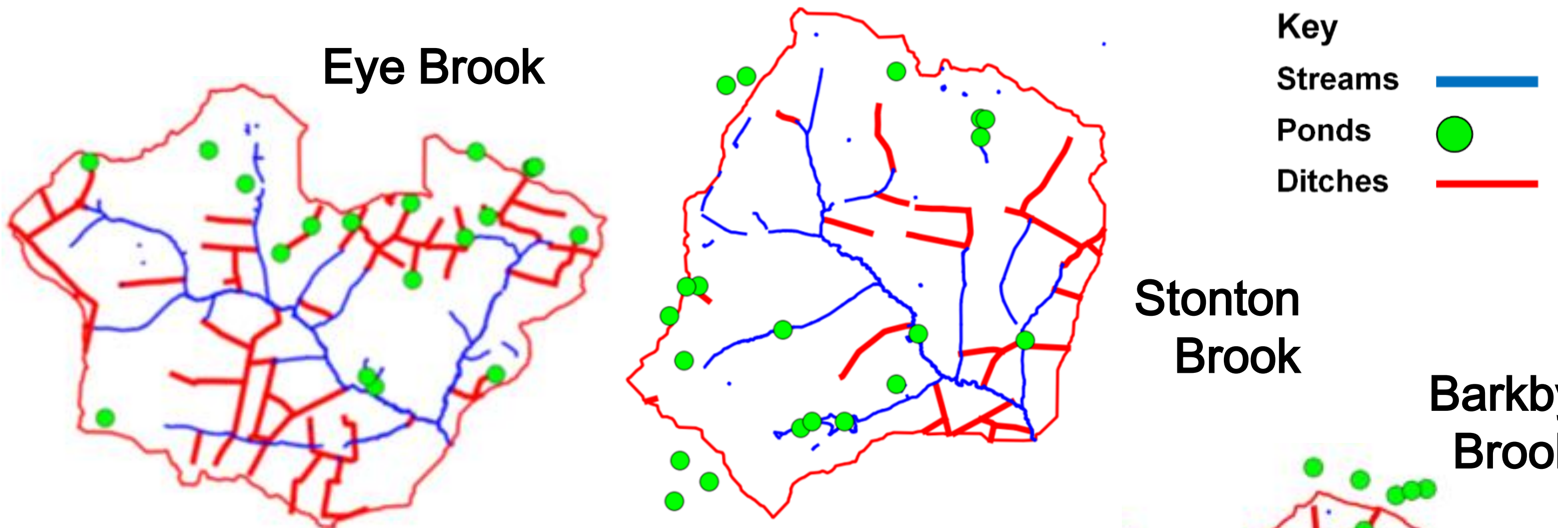
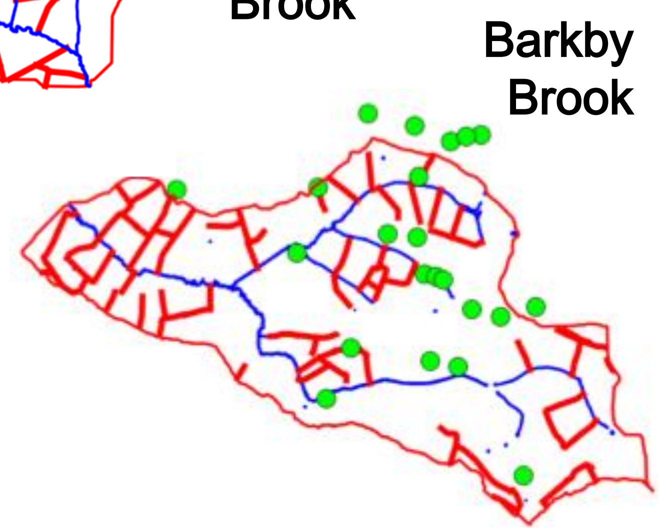
Freshwater biodiversity

- **Biota gives most positive story so far – though perhaps in unexpected way**
- **Monitoring is stratified random survey of wetland plants and macroinvertebrates across 3 catchments looking at c.300 sites - streams, ponds, ditches, flushes, including new ponds, bunded ditches, interception basins, debris dams etc**



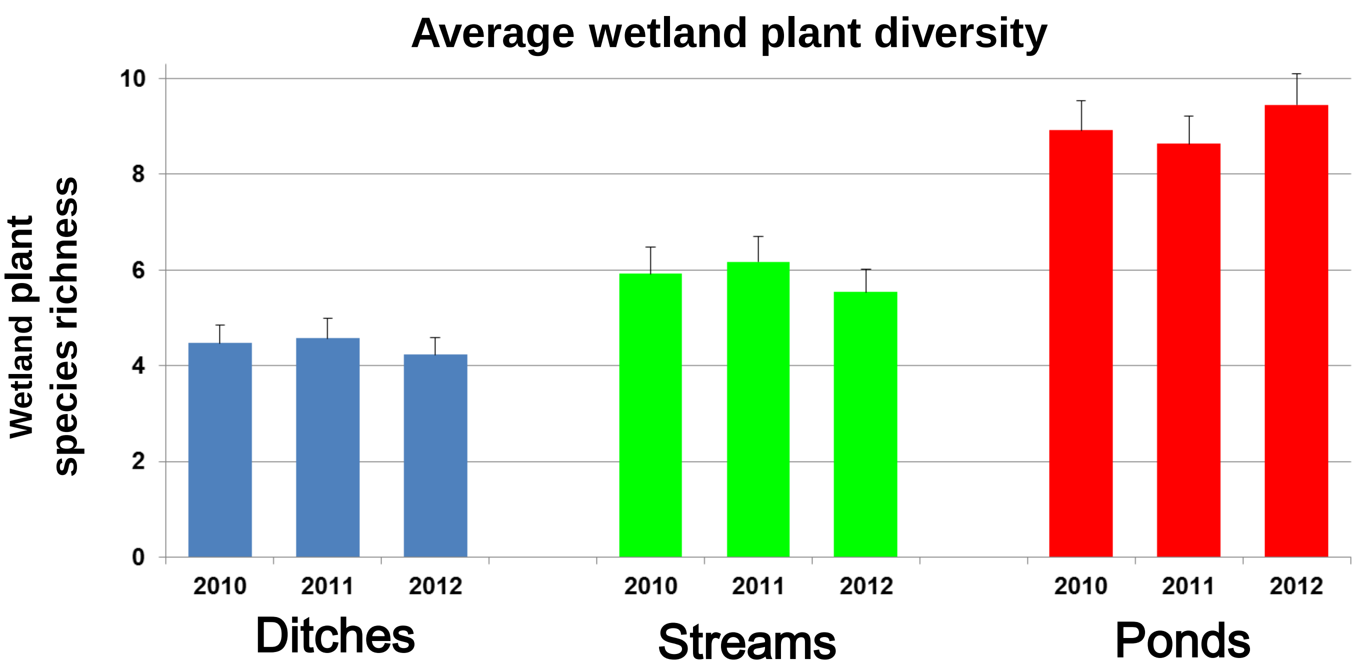


- **Also, more limited fish and diatom data from streams only**

Freshwater biodiversity

- Focus on wetland plants today; invert samples mostly awaiting analysis (funding!)
- BUT: in previous landscape studies inverts have broadly reflected plant results

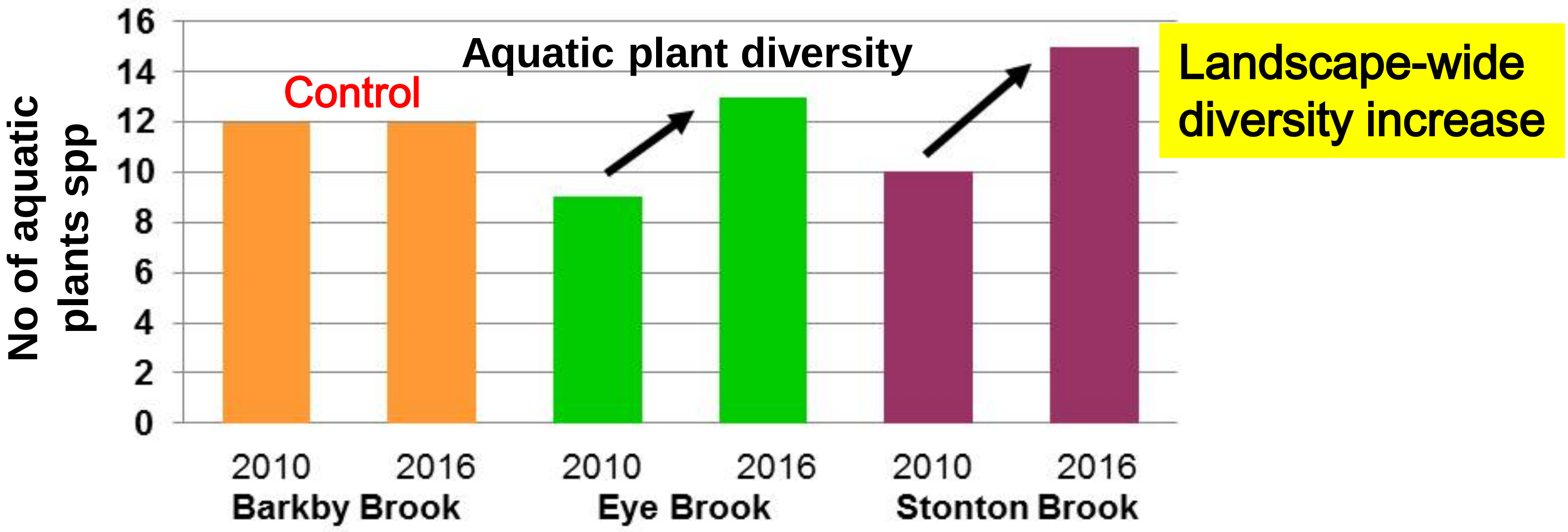
First…Baseline conditions across all 3 catchments: not a surprise, but good confirmation of pattern



Results: Biodiversity of whole water environment (i.e. ponds, streams and ditches)

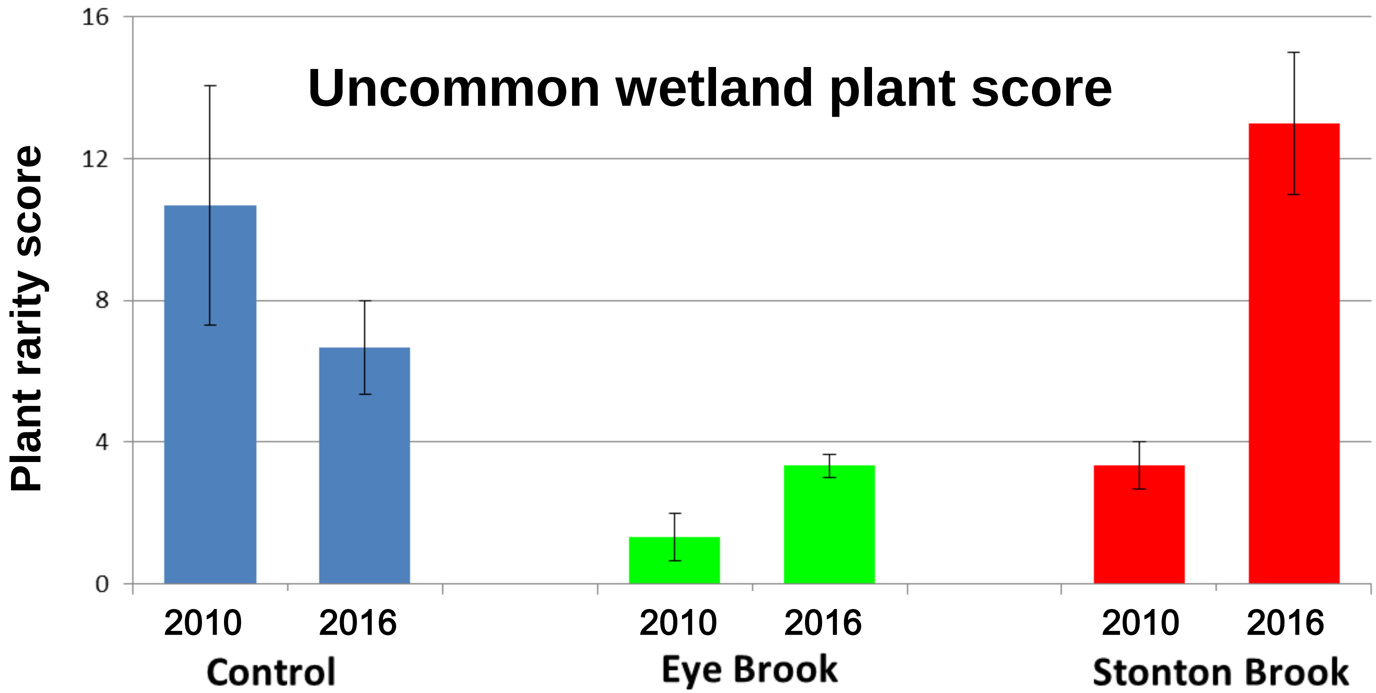
<u>Result</u>: looking at the total number of species of aquatic plants (most sensitive) over last 6 years in each catchment:

- ***Control*: number of species is static**
- ***Eye Brook*: increase in number of aquatics = due to addition of interception ponds**
- ***Stonton Brook*: c.50% increase = due to adding interception ponds *<u>plus</u>* clean water ponds, not connected to drainage network (no change in running network)**



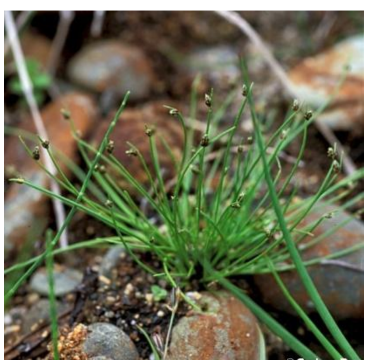
Freshwater biodiversity: rare species

- Looking at presence of uncommon plants = good measure of quality of communities
- Number of uncommon plants dropped in the Control landscape; slight increase in Eye Brook; strong increase in Stonton Brook where clean water ponds created



New ponds have brought back uncommon plants to the catchment

Marsh Arrowgrass



Bristle Clubrush

e.g. Red Data Book Marsh Arrowgrass (probably came up from seed bank), marestail, bristle clubrush, mixed beds of stoneworts, pondweeds and water-buttercups

Unlikely most *interception* ponds will <u>stay</u> in good condition…this site 3 years old

Although interception basins are often hyped as good for biodiversity, because they clean up contaminated water, most start good then decline - and we're already seeing this.

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But for clean water ponds like this…. expecting to retain high richness and species rarity value

Not connected to polluted drains, ditches or streams

Elsewhere we’ve shown that such sites can stay in good condition for at least 30 years

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Conclusions (1/3)

1. <u>Freshwater biodiversity:</u>

In decline across UK, widespread loss of sensitive species (we know loss will continue because of extinction debt effects)

- **WFF provides first evidence it <u>is</u> possible to *significantly* turn around biodiversity loss at catchment level including return of uncommon species to ordinary countryside; <u>some benefits almost immediate</u>**
- **Achieved by focusing on clean-water ponds, because they are lynch-pin habitat**

  (as long as you know what you're doing, and put them in the right place!)

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Conclusions (2/3)

2. Sediments and nutrients:

Our field-validated modelling work suggests zero tillage could theoretically substantially reduce sediment loss…under typical storms – but in clay catchments hard for any landuse to mitigate sediment loss in extreme events.

Our nutrient results haven't yet shown a catchment-scale chemical benefit from measures we've put in place.

- **Perhaps not surprising given extent of nutrient loading and legacy**
- **As other published studies suggest - nutrient loading in waterbodies is a pretty intractable problem without wider landuse change combined with STW clean-up**

Conclusions (3/3)

3. Flood alleviation

We've learnt that, in our pretty typical, clay upper catchment:

- **Storage, rather than change in land-use, is key – if we want to keep farming**
- **There's good opportunities for temporary flood storage**
- **Tried a variety of techniques for storing water; to date, leaky dams look most cost-effective in terms of volumes stored**

Next steps

- **Waiting for floods! – so new leaky dam network performance can be evaluated**

- **Linking our flood and sediment models to downstream Mike 11 models used to design flood schemes; evaluate cost:benefit contribution of NFM schemes**

  (Initial rough costs: our NFM storage is £1 / cumec c.f. £2.5/cumec in conventional scheme)

- **Creating SWAT models of N and P to test different land management scenarios and see if possible to better optimise our nutrient interception.**

- **Biodiversity: exciting to see if biodiversity in measures catchments continues to grow; look at invertebrate changes in streams, ponds and diches. *Plus*: performance of clean ponds vs interception ponds, effect of managing vs creating ponds, performance of woody debris, biological effects of leaky dams.**

Chemicals Regulation Directorate

anglianwater
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Environment Agency
Freshwater Habitats Trust
Game & Wildlife Conservation Trust
syngenta
The University Of Sheffield.
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