Assessment of NFM measures and lessons learnt

Natural Flood Management Test and Trial

March 2021

Interreg 2 Seas Mers Zeeën
TRIPLE C
European Regional Development Fund

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SCAPE
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Document prepared by:	Mike Phillips	25th March 2021
Checked by:	Mary Tate	28th March 2021

This report has been prepared by Mike Phillips of White Horse Ecology on behalf of the Kent Downs AONB Unit and the Darent Valley Landscape Partnership.

The Natural Flood Management Test and Trial is being carried out by the National Association for the Areas of Outstanding Natural Beauty on behalf of Defra.

SCAPE (Shaping Climate Change Adaptive PlacEs) is a project that brings together partners from the UK, Netherlands and Belgium. It aims to develop 'Landscape-Led Design' (LLD) solutions for water management that make coastal landscapes in the 2 Seas area better adapted and more resilient to climate change.

Triple C (Climate resilient Community-based Catchment planning and management) is funded by the European Regional Development Fund and is a trans-national project looking to implement a set of cost-effective actions to reduce flooding and erosion. The project partners are based in Belgium, the Netherlands and the UK

Kent Downs Area of Outstanding Natural Beauty

DARENT VALLEY

White Horse Ecology

1 Introduction

Natural Flood Management (NFM) has attracted significant attention over the last decade or more and it is seen as an effective way to complement existing flood management engineering. However, NFM is still an emerging science and there is uncertainty surrounding the efficacy of different measures and whether they reduce the intensity of flood events. An evaluation of the overall impact of different measures is also made more complex by the range of additional public goods that NFM measures provide. In the context of NFM, these are often referred to as multiple benefits. Consequently, an assessment of the public goods that are derived from NFM measures can't be confined to simply how well they prevent flooding. It must also consider whether carbon is sequestered, whether water quality is improved as well as if biodiversity is enhanced.

Although, research has been done to estimate how much water specific features will slow down during a flood event, making assumptions about what a specific feature will achieve is problematic. Factors such as feature design, rate of water flow, topology, soil type and underlying geology will all impact the ultimate success of NFM measures. Equally, if water is slowed through the landscape, there is the chance that secondary flow peaks may be exacerbated.

Much work is currently being done to measure the effectiveness of NFM measures and this Test and trial is not the most appropriate place to discuss this further. However, it is worth summarising some of the current thinking about the impact of NFM and what lessons have been leant through recent Interreg funded NFM projects. This report will summarise just some of the work that has been done to assess the effectiveness of NFM as well as how these lessons can be applied to the current Test and Trial into NFM in schemes that reward farmers and land managers for producing public goods.

2 Evidence gathered from Interreg projects

The Interreg projects are yet to report fully on the effectiveness of the NFM measures that have been implemented. However, some useful information has been gathered about the likely impact of the NFM measures that have been installed. As well as this, the project has produced some excellent information about how to set up a catchment-based project and this will also be included.

The impact of Triple C work

Although, not yet completed, the Triple C project has carried out a large number of NFM, water level management and soil erosion alleviation projects in Devon, Somerset and Kent as well as partners in Belgium and The Netherlands. The 2020 annual project report (Somerset County Council, 2020) reviewed the features that had been implemented by the project and approximated the amount of water held back and soil erosion that had been prevented. A sediment model has also been developed to try and demonstrate the effects of implementing erosion control measures. Soil infiltration rates were measured with moisture probes and used to estimate the amount of water stored in the soil. Storage capacity of features was measured using simple volume measurements with data loggers monitoring water depth during flood events. The preliminary results are summarised below.

- 178 water retention features installed;
- 70 erosion control measures installed;
- 67,648m^3 of water retained through flow attenuation measures;
- 85,082m^3 of water stored through wet grassland creation;
- Weirs and level controlled drainage stored 52,520 m^3 of water;
- 369,000m^3 of water stored from half field trials;
- 680 homes have been given additional flood protection;
- The cost per m^3 of flow rate attenuation in Somerset is estimated at £3/m^3, just over half the price of traditional methods used in nearby traditional schemes.

These provisional results will be confirmed when the project is completed later in 2021. This will also be accompanied by a socio-economic and environmental assessment of the impact of the Triple C work.

The Effectiveness of Triple C work in Somerset

Evidence showing the potential for NFM measures to attenuate flow and store water during flood events is useful. However, the real test of NFM measures is what happens during a storm event. Do NFM measures actually limit the likelihood of flooding? This information is more difficult to assess as flood events only happen intermittently and the factors that result in flooding can be complex, making even seemingly similar storm events difficult to compare. Consequently, modelling is often relied upon to estimate the impact during flood events.

FWAG SW, with partners at the Environment Agency, the University of Exeter and the University of Bristol looked in detail at some of the leaky wooden dams and leaky ponds to make a more detailed evaluation of their effectiveness.

Phillips et al (2020) studied a series of 20 leaky woody dams in the Merriott Stream in Somerset. Not only did this study look at flow attenuation, but it also looked at whether the dams had an impact on habitats and whether they required maintenance. Results were variable and the work found that there were a number of factors that affected how dams held back water and impacted on habitat including:

- Shape of the valley and the extent of the floodplain available to hold water;
- The materials used to construct the dam and the design itself;
- The surface soils and underlying geology;
- How silted up the area behind the dam is;
- The coarseness of substrate.

Work monitoring the depth of water held by dams during storm events showed that the dams did hold water and both reduced as well as delayed peak flow. However, these results were variable and decreased over time without maintenance that cleared silt.

The study also showed that bank erosion was caused in some cases and that aggradation also occurred downstream of the leaky dam. More positively, outwash gravel bars were also created in some of the dams that provide excellent habitat for fish and invertebrates. It was estimated that the 20 structures in place would store approximately 2% of the water during a one in ten year flood event.

Lockwood et al (2020) looked at the amount of water that leaky ponds stored and whether they slowed down flow during storm events. The preliminary results from this work show that the offline ponds are filling during the largest winter rainfall events and are producing significant lag times when water flow rates are recorded both upstream and downstream of the leaky ponds.

How to set up a successful catchment-based project

The Triple C (2019) project also produced an action plan entitled, “How to set up a successful catchment-scale project.” This document provides especially useful lessons learnt whilst engaging with farmers and land managers. It has the potential to be used as a blueprint for future engagement work with farmers. These recommendations lend themselves to the deployment of catchment or sub-catchment advisers that will be discussed later in this report.

In summary, the document makes the following recommendations:

Measures to engage and mobilise stakeholders

- Identify all stakeholders (not just landholders but local people and people in flooded properties).
- Set out key messages and inform all stakeholders.
- Hold stakeholder events and form groups.
- Hold demonstrations of measures and thank those who get involved.

Identifying issues

- Map target catchments to help understand geology, river networks, land use and designations.
- Walkovers to help ground truth maps and identify issues.
- Model hydrology and flow pathways.
- Gather local knowledge (people know which areas get waterlogged and flood).

Identifying solutions

- Target areas for actions (though don’t ignore opportunistic delivery when it presents itself).
- Identify which measures are appropriate and can be funded.

- Identify where measures can be sited.

Deliver measures

- Land owner consent, funding, statutory consents, quotes, managing contractors

Monitoring

- Monitor individual measures
- Half field trials and demonstrations (to monitor and encourage further implementation
- Catchment scale monitoring
- Communicating monitoring results

Table 1: Methods of monitoring NFM measures: Source - Triple C

Intended effect	Natural Flood Management measure	Monitoring technique
Infiltration of rainwater into the soil, soil water storage capacity	Soil structural assessment, Mechanical soil damage alleviation (subsoiling, aeration), Choosing a tillage system suitable to soils, Strategic woodland and hedge planting, Arable Reversion, Wet grassland restoration, Drainage modification	Infiltration tests before and after in treated and untreated half of a field, compaction survey before and after intervention Calculation of increase soil water storage based on infiltration results Soil moisture probes Photos of before and after surface wetness, photos of soil profile before and after, video of infiltration cylinder before and after next to each other
Reduced runoff generation	Soil structural assessment, Mechanical soil damage alleviation (subsoiling, aeration), Choosing a tillage system suitable to soils, Strategic woodland and hedge planting, Arable Reversion, Wet grassland restoration, Drainage modification	Rainfall simulation and measurement Depth measurement with dive loggers in little runoff trenches downslope
Temporary storage of runoff	Buffer strip, creation of wetland, filter soxx and fences, silt trap, leaky pond, scrape, bund, cross drains, connecting floodplains	Dive loggers measuring water level, Time lapse photography showing the water levels going up and down Calculate storage volume with design and water depth measurements
Trapping silt	Buffer strip, filter soxx and fences, silt trap, leaky ponds, scrapes, bunds, in-ditch features	Measure depth of silt accumulation by placing astroturf on the ground and simply measuring down to it, comparing cross sections over time
Slowing the flow in-stream	In-ditch features, leaky woody dams, river restoration, re-meandering,	Depth measurements with dive loggers, cross channel measurements over time Channel cross sections over time Calculate storage volume based on depth measurements and cross sections

3 Other evidence

The body of work that is being built up supporting the efficacy of NFM measures is growing all the time. In this section we will look at one of the main sources of information that have been gathered to date as well as some research that is currently taking place that will inform the use of NFM within schemes that reward farmers and land managers for producing public goods.

3.1 Working with Natural Processes

This work was commissioned by the Environment Agency and published in 2017. It is a meta study of all of the research and evidence gathered into one place and published on the government website[1]. Although it is now four years old and the pace of NFM research continues unabated, this is still a very comprehensive set of resources.

The Evidence Directory (Burgess-Gamble, 2017) sets out the evidence for a range of different NFM and coastal erosion measures and identifies the level of confidence that specific measures work and where additional research is required. These are also condensed into accessible one-page summaries. This work is summarised in the following table.

Table 2: Summary of confidence in measures and multiple benefits: Source - https://assets.publishing.service.gov.uk/media/6036c730d3bf7f0aac939a47/Working_with_natural_processes_one_page_summaries.pdf

Measure	Flood reduction confidence	Multiple benefits
River restoration (reintroducing meanders and restoring natural processes)	Medium Confidence limited as most of evidence comes from modelling	aesthetic qualities habitat enhancement reduced fluvial flooding climate regulation
Floodplain restoration (reconnecting floodplains)	Medium to low Most evidence is modelled and uncertainty over how it works at different scales	aesthetic qualities habitat enhancement reduced fluvial flooding climate regulation
Leaky barriers (slowing flows using barriers such as leaky woody dams)	Medium confidence for reducing flood risk for small scale events. Low confidence for large events	water quality reduced fluvial flooding habitat enhancement climate regulation
Offline storage areas (leaky bunds, offline ponds etc)	Medium confidence of positive impact of offline storage. More evidence needed about multiple small-scale storage areas	reduced fluvial flooding reduced surface and ground water flooding reducing low flows
Catchment woodland (woodland in catchment slowing flow of water)	High to medium confidence due to a good understanding of the processes. More evidence needed about placement of woodland	habitat enhancement climate regulation water quality flooding aesthetic quality
Cross-slope woodland (planting trees across slopes to intercept water as it flows)	Medium to low confidence as more field trials are needed	water quality reduced surface and ground water flooding habitat enhancement

[1] https://www.gov.uk/government/publications/working-with-natural-processes-to-reduce-flood-risk

Floodplain woodland (planting trees in the floodplain)	Medium to low confidence as most evidence from models and more understanding needed over a range of scales	habitat enhancement climate regulation water quality reduced fluvial flooding
Riparian woodland (planted either side of watercourse)	Medium to low confidence as most evidence from models and more understanding needed over a range of scales	habitat enhancement climate regulation water quality reduced fluvial flooding aesthetic quality
Soil and land management (land management that slows the flow through the landscape)	Low confidence in flood risk benefits at a catchment scale but impact seen at local scale	water quality climate regulation reduced surface and ground water flooding
Headwater management (blocking flow of water and holding in land)	Medium to low confidence for agricultural headwaters and medium confidence for peat restoration measures	habitat enhancement reduced surface and ground water flooding climate regulation water quality
Runoff management (ponds, swales and sediment traps)	Medium confidence in flood risk benefits though mainly modelled	water quality reduced surface and ground water flooding reduced fluvial flooding habitat enhancement

Sadly, the latest revision of the government website has removed some of the documentation around this research.

3.2 NERC funded research

The Natural Environment Research Council is funding a Natural Flood Management research programme.[2] This work is being conducted by Reading University, Lancaster University, University of Manchester, University of Leeds, Newcastle University, The Rivers Trust, JBA Consulting, British Geological Survey, Centre for Ecology and Hydrology and Forest Research.

This work is primarily about understanding the effectiveness of NFM and aims to 'improve understanding of the suitability and effectiveness of different NFM measures for a range of flood risk scenarios.' It goes on to state that outputs from the programme will improve the NFM evidence base, and help policy makers, businesses and local communities make best use of NFM measures. Stakeholder engagement is an important element of the work.

Clearly, the results of this research will have an important bearing on how NFM is promoted and applied through schemes that reward environmental benefits. The projects will run until 2022 but are already beginning to release research papers.

The work consists of three projects. The following text is taken from the research project website:

[2] https://research.reading.ac.uk/nerc-nfm/

Landwise NFM: (with a focus on land use and management, including soil management, crops and woodlands)

LANDWISE will evaluate the effectiveness of realistic and scalable land-based NFM measures to reduce the risk from flooding from surface runoff, rivers and groundwater in groundwater-fed lowland catchments. We will study measures like crop choice, tillage practices and tree planting, that have been identified by people who own and manage land to have the greatest realisable potential. NFM measures will be evaluated for their ability to increase infiltration, evaporative losses and/or below-ground water storage, thereby helping to store precipitation to reduce surface runoff and slow down the movement of water to reduce peak levels in groundwater and rivers.

Currently, there are many unanswered gaps in knowledge that make it hard to include land-based NFM measures in flood risk mitigation schemes. Yet, land-based NFM measures have potential to do more than just reduce flood risk, including improving water quality, biodiversity and sustainable food and fibre production. We will carry out research to help to fill the evidence gaps.

There is a view that as the catchment size and flood events increase, the effectiveness of land-based NFM measures in reducing flood risk decrease significantly; land-based NFM measures only provide effective protection against small flood events in small catchments. We will test this.

Protect NFM: (with a focus on moorland restoration, including gully blocking, *Sphagnum* reintroduction and upland woodland planting)

The project aims to demonstrate that upland moorland restoration offers a low-cost way to reduce the risk of flooding in vulnerable rural communities, and to optimise multi-benefit restoration work for NFM.

Headwaters comprise 60-80% of the length of most river systems, and their steep slopes and high rainfall volumes mean that they are important areas of hillslope runoff production. The Environment Agency has identified 22 communities at risk of flooding along the western fringe of the Pennines. These communities are relatively small, which can make it difficult to secure resources for conventional engineering approaches to flood risk management.

The Protect-NFM team is working closely with project partners Moors for the Future Partnership and the Environment Agency to assess the impact of various forms of moorland restoration (gully blocking, Sphagnum reintroduction, and establishment of upland woodlands) on hillslope runoff production and channel flow. They are also investigating the longer term evolution of restoration measures to better understand the longevity of NFM benefits.

To facilitate planning and prediction of potential impacts, Protect-NFM is developing conceptually sophisticated but user-friendly, open-source models to optimise combinations of interventions. Later in the project, they will work with project partners (Environment Agency, Natural Resources Wales, Scottish Environmental Protection Agency, International Union the Conservation for Nature) to investigate how the project's findings can be applied to elsewhere in the UK.

Q-NFM: (with a focus on agricultural interventions such as sward lifting and leaky bunds, hedgerow and wall restoration, leaky dams in peatland gullies and headwater channels, tree planting and floodplain reconnection)

Our focus is on the quantification of the likely effectiveness of NFM measures for mitigating flood risk at small to large catchment scales. We are addressing gaps in the evidence on how individual NFM measures work and the reductions in peakflow for communities at risk of flooding.

We will also consider the non-optimal performance and failure of NFM measures.

We are developing our computer modelling approaches to constrain the uncertainties in streamflow predictions arising from model structure uncertainty, uncertainty in rainfall and streamflow observations and in the magnitude of change in component catchment characteristics delivered by NFM interventions.

Throughout the project we will work closely with our 17 partner organisations that are delivering NFM interventions, drawing on their expertise and experience.

4 Spatial prioritisation and multiple benefits

In this section we will consider where NFM measures will have the greatest positive impact and how these are identified. We will also discuss the other benefits and public goods that can be derived from NFM measures.

4.1 Where should water be held back?

The evidence in this report has shown that one of the most effective ways of establishing the merits of NFM actions is to measure the amount of water that they hold back. However, in order for the water held back to have an impact on flood events it needs to in the correct places. NFM actions that hold back water during flood events are not needed everywhere. This may be because there is little or no risk of flooding, flooding is unlikely to cause significant damage to property or the measures installed do not have any impact where they are located. Good decision making is an essential part of spatial prioritisation for NFM measures and this needs to be assessed at different scales.

Catchment or sub-catchment spatial prioritisation

Payments should only be made to farmers and land managers solely to help alleviate flood risk when those measures are likely to protect property from flooding. Clearly this means that some areas are a much higher priority than others for NFM. The Environment Agency has prioritised (Chris Uttley, 2020) catchments and sub-catchments for NFM based upon:

- Properties being identified that would have a reduced flood risk if NFM measures were installed upstream.
- NFM measures can provide flood alleviation where engineered flood solutions are either not appropriate or not cost effective.

It is intended that these catchments and sub-catchments would be proposed as areas where NFM would be promoted as part of the Local nature Recovery component but these areas would be confirmed by Local Nature Recovery Networks.

Spatial prioritisation within catchments and sub-catchments

Even when catchments have been identified for NFM actions, these measures will have a greater impact in different places within the catchment. For example, it may not be cost effective to create an offline pond in areas where water doesn't flow during a flood event. Even measures that appear to be universally beneficial like tree planting will do more to slow down the flow of water in certain parts of a catchment than others. Equally, from a farming perspective, it may be more appropriate to put NFM measures in areas that are unlikely to affect agricultural production.

In order to address these issues farmers and land managers can be given advice and guidance by advisers who may help develop water management plans. Modelling can identify catchment flow pathways and even prioritise areas for different kinds of NFM feature. These will be discussed in more detail in section six.

4.2 When volume of water held back isn't the only consideration

NERC funded research looking at the effectiveness of NFM measures in holding back volumes of water is clearly an important factor when assessing whether an NFM measure is providing public goods. However, it is not the only factor that needs to be considered. Most NFM measures also provide public goods that are worth paying for irrespective of where they are located. For example, measures that improve soil structure may allow water to infiltrate and this may slow the flow of water. There are areas where this may help to reduce flood risk but other areas where this may not be the case. However, the other benefits of improving soil structure may include cleaner water, carbon sequestration and increases in biodiversity. These soil improvement measures should therefore be promoted across all landscapes and catchments irrespective of flood risk. There should be no spatial prioritisation for these measures. Consequently, there are a number of actions that, although they may be considered to be NFM measures, are appropriate for the Sustainable Farming Incentive[3] and be universally available to all farmers. Section six outlines which of the NFM measures may be appropriate for the Sustainable Farming Incentive

[3]Defra: https://defrafarming.blog.gov.uk/2021/02/23/the-new-sustainable-farming-incentive/

5 Discussion and application of NFM within schemes that reward environmental benefits

Despite the emerging evidence supporting the flood management, the impact of different measures will depend to a large degree on how they are applied. In order to ensure that the measures deployed through schemes that reward environmental benefits are most likely to provide alleviation from flooding, three recommendations will be made. These are:

- Actions and the schemes that they might fit into;
- The role of catchment advisers;
- Models to support understanding of NFM and to maximise the positive impact of interventions.

5.1 Actions and different schemes

NFM may be available across a range of schemes that reward environmental benefits. Some features might be included in several schemes. The schemes include:

1. Single Farm Incentive – Available for all farmers to take advantage of. These measures may be applicable across a wide range of habitats and farming types.
   NFM features that might feature within the Sustainable Farming Incentive include:
   - Winter cover crops
   - Hedgerow planting
   - Woodland planting
   - Buffer strips
   - Cross drains
   - Reduced stocking density or other holistic stock management options
   - Conservation tillage
2. Local Nature Recovery – Measures that are targeted according to local priorities. This is the scheme where the actions most often considered to be NFM measures are likely to sit.
   NFM features that might feature within Local Nature Recovery include:
   - Leaky woody dams
   - Offline leaky ponds
   - Bunds
   - Sediment traps
   - Woodland planting
   - In ditch features
   - Conservation tillage
   - River restoration
   - Reconnecting floodplains
   - Headwater management
   - Beaver reintroductions
3. Landscape Recovery – This scheme is aiming to carry out restoration of habitats or to provide public goods at a landscape scale. It is likely that tree planting and grip blocking (headwater management) will feature in this scheme.

5.2 Catchment advisers

The lessons learnt from the schemes that have Informed this document include the need for advice given to farmers and land managers to be of a high quality and backed up by support to implement NFM measures. This has been backed up by information provided by farmers and land managers at workshops. Finally, the take up rate of NFM measures within Countryside Stewardship has been exceptionally low, particularly those measures that are likely to fall within the Local Nature Recovery scheme. This was backed up by a local Natural England adviser who stated that without support for farmers to help them understand and implement NFM measures, they were likely to remain largely unused within schemes that reward environmental benefits.

This Test and Trial will be recommending that advisers are provided within catchments and sub-catchments to support the take up rate of NFM measures. This role could be taken up by Catchment Sensitive Advisers or provided by a third party such as a Rivers Trust, protected landscape, a Wildlife Trust or other similar organisation. The reasons that advisers are needed include:

- Farmers and land managers may not be familiar with NFM measures and may need advice about how they work to gain confidence that they are a feasible option.
- Advice about liability for failure of a feature may be needed.
- Advice on the best place to add NFM features may be needed.
- Support to find a suitable contractor may be needed.
- Support to gain the necessary consents may be required.
- Support for planning consent may be needed.

These were the reasons most often cited by farmers for not choosing NFM measures as part of their Countryside Stewardship agreements. If NFM measures become more commonplace and farmers and land managers gain more confidence in adopting them, this level of support could be reduced.

5.3 Communication Tool

Another means of providing decision support is to model catchments and sub-catchments to help identify where NFM measures are likely to be most appropriate. This can provide useful information to help support decisions and can be used either by a catchment adviser or by farmers or land managers if the information is easy to interpret.

Modelling catchments and providing options that might be appropriate in different locations can be expensive. However, there are other options that use widely available environmental data such as topography, land use type, soils and geology to calculate the suitability for different measures across an entire catchment. These algorithms can be applied over wide areas. This Test and Trial used a method known as HydroloGIS developed by Viridian Logic to model the Darent Valley. Other NFM pilot schemes have used different modelling tools to identify flow pathways and other useful features.

When presented at workshops farmer and land manager feedback was positive but most saw models as either a means of starting a conversation about NFM or a starting point that could be negotiated based on local knowledge of water on the site.

It is also possible to turn these maps into interactive 'Communication Tools' that a farmer or land manager can interrogate to choose NFM options that might be most effective on their land, find out more about the action, what the specifications are, whether consents are needed etc. The tool can even calculate the payments that would be due through schemes. This may help farmers and landowners to work more independently of catchment advisers and be a cost effective investment in catchments where NFM is being promoted.

As part of this Test and Trial, an information tool in spreadsheet form was created to provide additional information about different NFM measures. This is located at: http://bit.ly/NFMInformationTool This tool can be linked to a GIS based tool such as HydroloGIS to provide a tailored package of NFM solutions and information at a farm scale. This is the kind of solution that is referred to in this T&T as a 'Communication Tool.'

Models such as this can also be adapted as new income streams evolve. Examples of this may include carbon credits for woodland planted, biodiversity net gain payments or funding from third parties such as water companies.

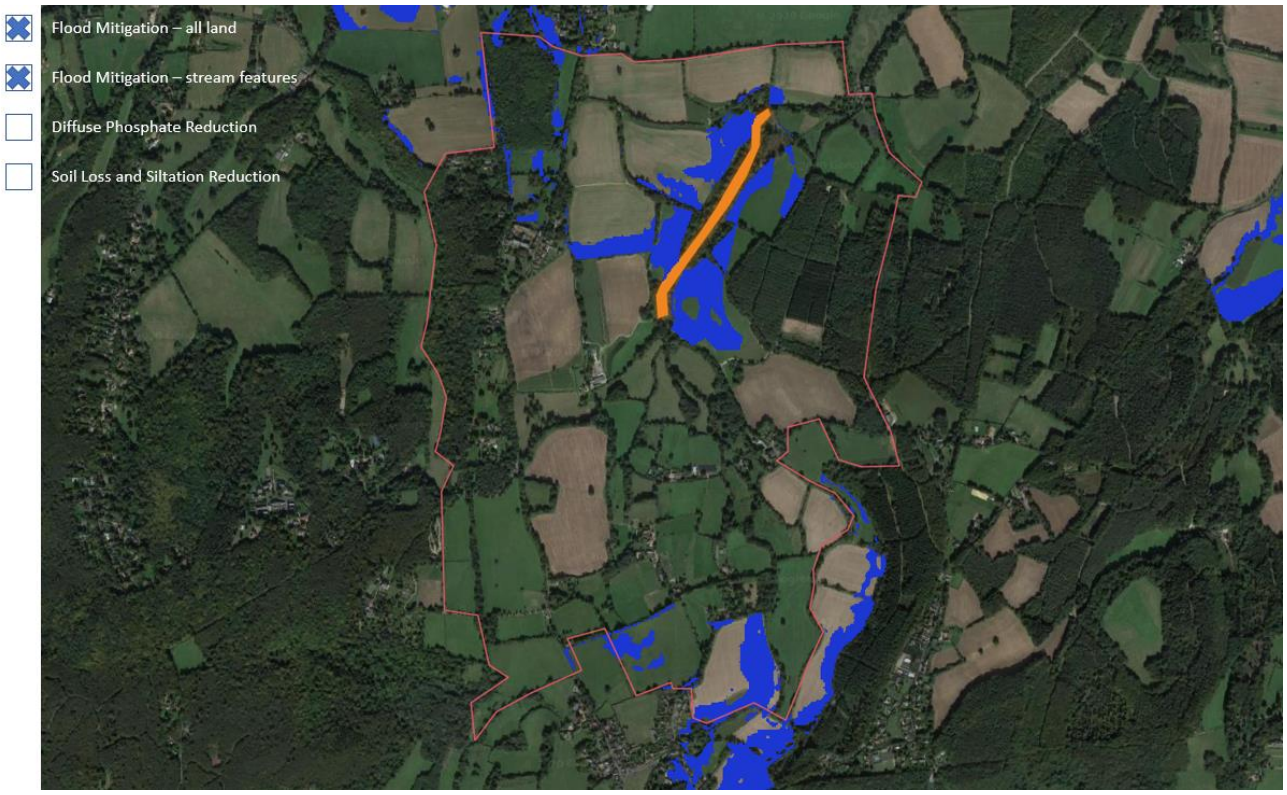

Figure 1: Flood mitigation and in-stream feature opportunities shown in HydroloGIS

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