Working with natural processes in lowland areas - Modelling, mapping & evaluating

Image: River Hull headwaters - Hull & East Riding Catchment Partnership

Dr Jessica Fox – Senior flood risk management officer, Hull City Council

In partnership with…

Funded by Environment Agency FCRM Flood Defence Grant in Aid
Consultants: Ove Arup, Sub-consultants: Energy & Environment Institute, University of Hull

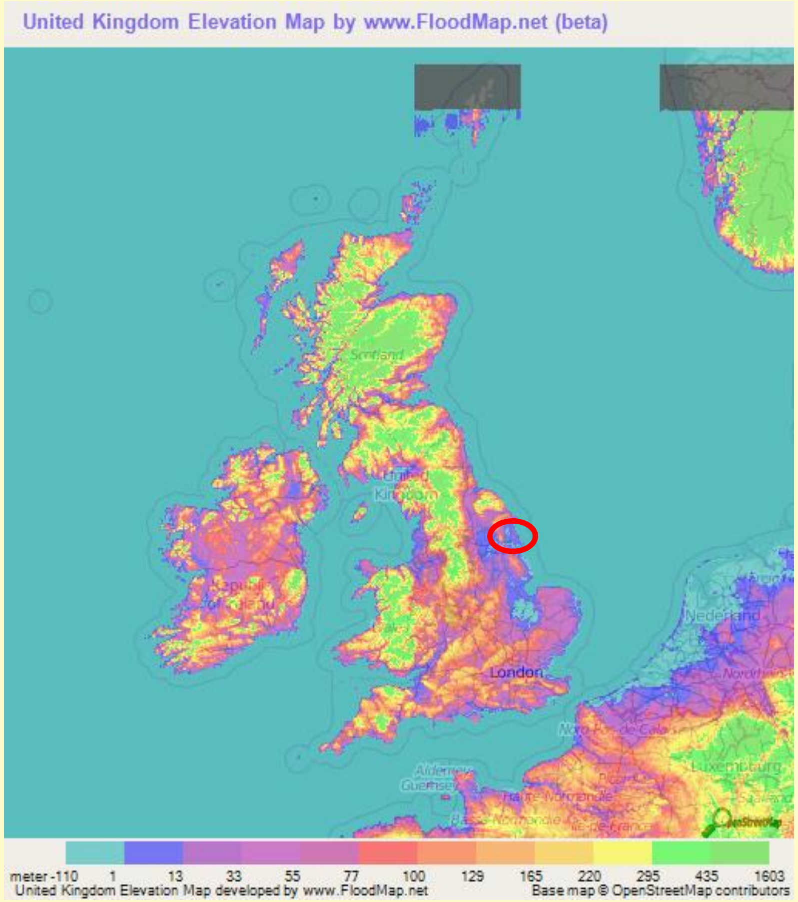
Overview

Images: left – Hull AquaGreen; right - flooding in Hull in October 2019 (Hull City Council)

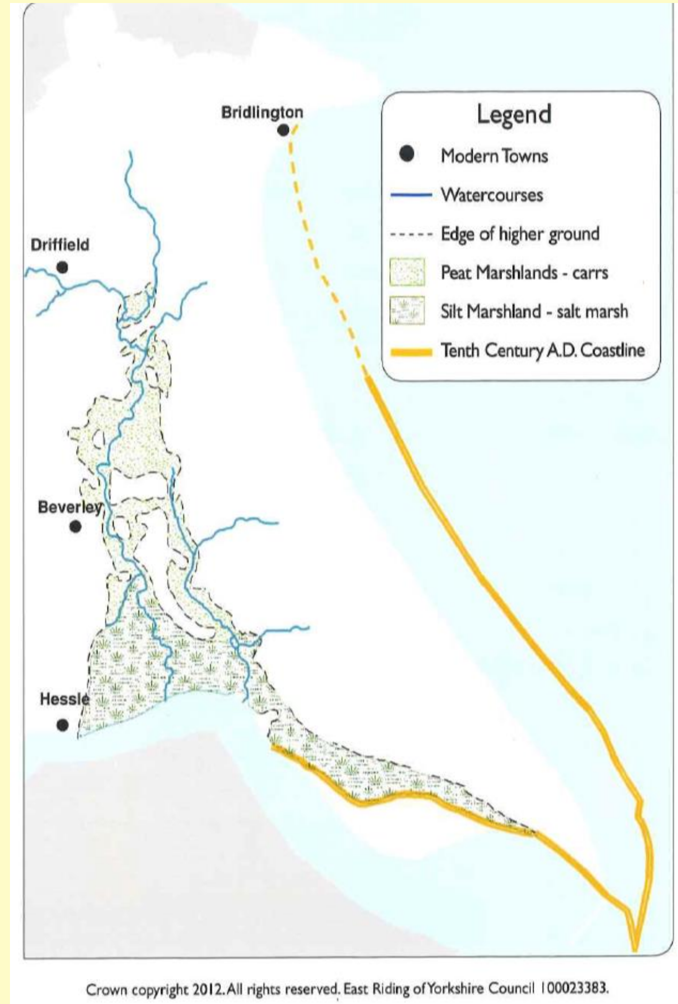
Study aim:

To provide an evidence base to demonstrate the extent to which NFM measures could reduce and attenuate peak flows along the River Hull

River Hull Catchment



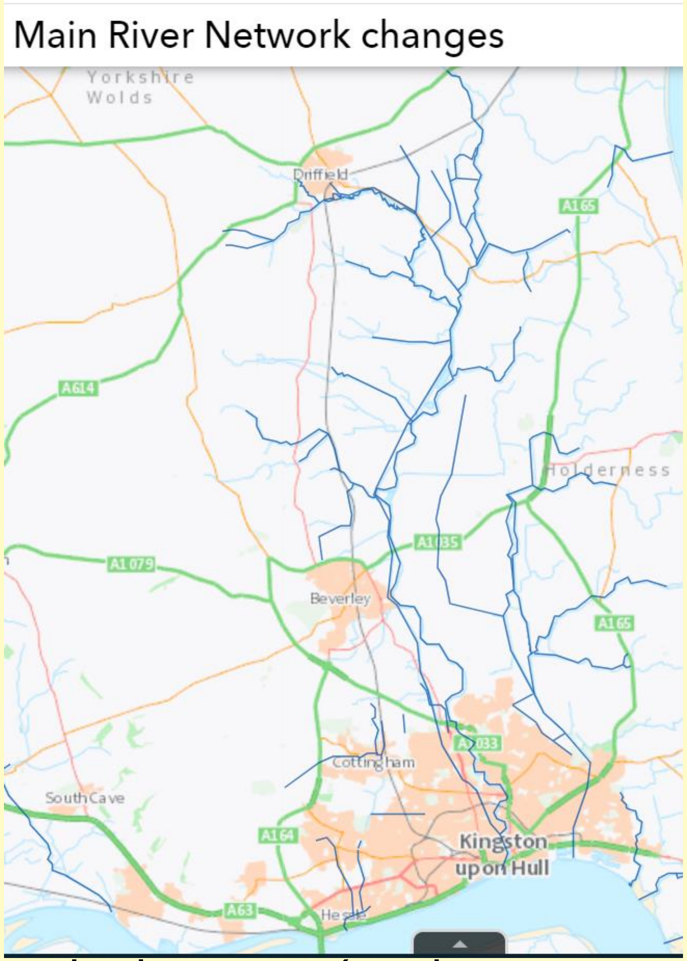
UK elevation map – floodmap



Historical drainage map of the River Hull catchment (River Hull Valley Drainage Heritage Group, 2013)

River Hull catchment

[River Hull NFM synthesis report](HCC, 2020)



Main river map (Environment Agency, 2020)

Overview
Catchment
Desk study
Modelling 1
Modelling 2
Modelling 3
Evaluation matrix
Recommendations
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Study rationale:

River Hull Advisory Board

River Hull Integrated Catchment Strategy

January 2015

Strategy Document

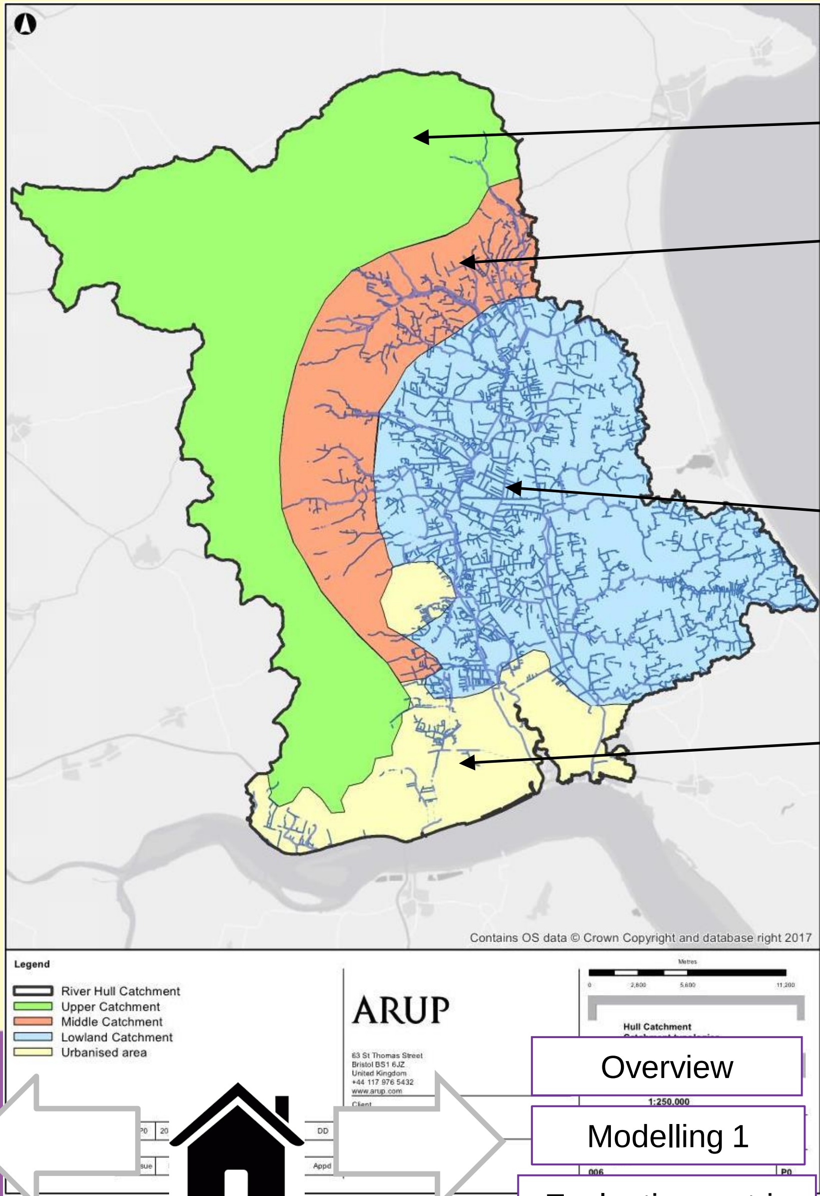
RHICS, 2015

Table 9 – Further development of initial flood risk management options

OPTION Label	Short Description
1a	Increased PS Capacity (Great Culvert and East Hull PS limited to 22 m³/s peak)
1b	As for (1a), with Tickton PS replaced with flap valve + weir
1b (22limit)	Variation of 1b, with East Hull PS limited to 22 m3/s peak
2	Holderness Drain reshaping/widening
3b	Holderness Drain offline storage - upstream of Tickton PS
4e	Offline storage beyond River Hull wetland
4f	Weel offline storage
4g	As for (4f), with increased Waterside PS pump persistence
5	Increased Waterside PS capacity
6	Hull Maintenance
7b	Raise Holderness Drain embankments below Great Culvert PS
7i	Raise Beverley and Barmston Drain embankments south of Beverley Beck
8	Upland natural attenuation
9	Holderness Drain Diversion
10	Upper Hull Diversion
11	Increased utilisation of Hull Tidal Barrier (ie lower activation threshold)
12	Upland natural attenuation combined with OPTION 1b, 4f and 7b
13	Bransholme-specific flood mitigation (increased PS capacity)
14a	Combination of (4f) and (11)
15a,b,c	Removal of Wilfholme and Hempholme pumping stations.

- Slow the flow of water through the catchment
- Store more water in the upland areas

Map of typologies



Upper catchment

Middle catchment

Lowland catchment

Urbanised area

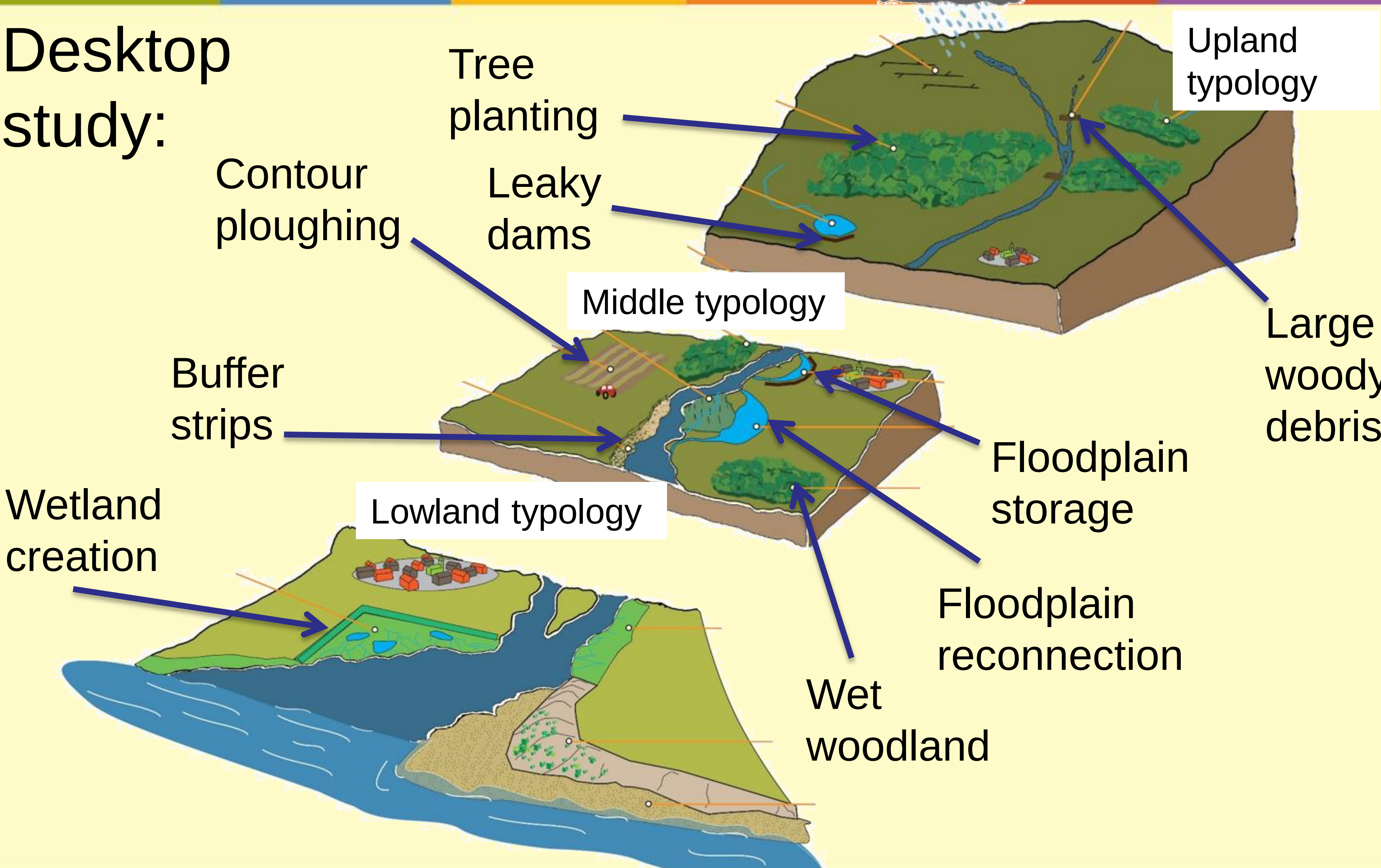
Remember: Despite the use of the word 'upper' it is still very flat across the catchment!

Why are we looking at NFM now??

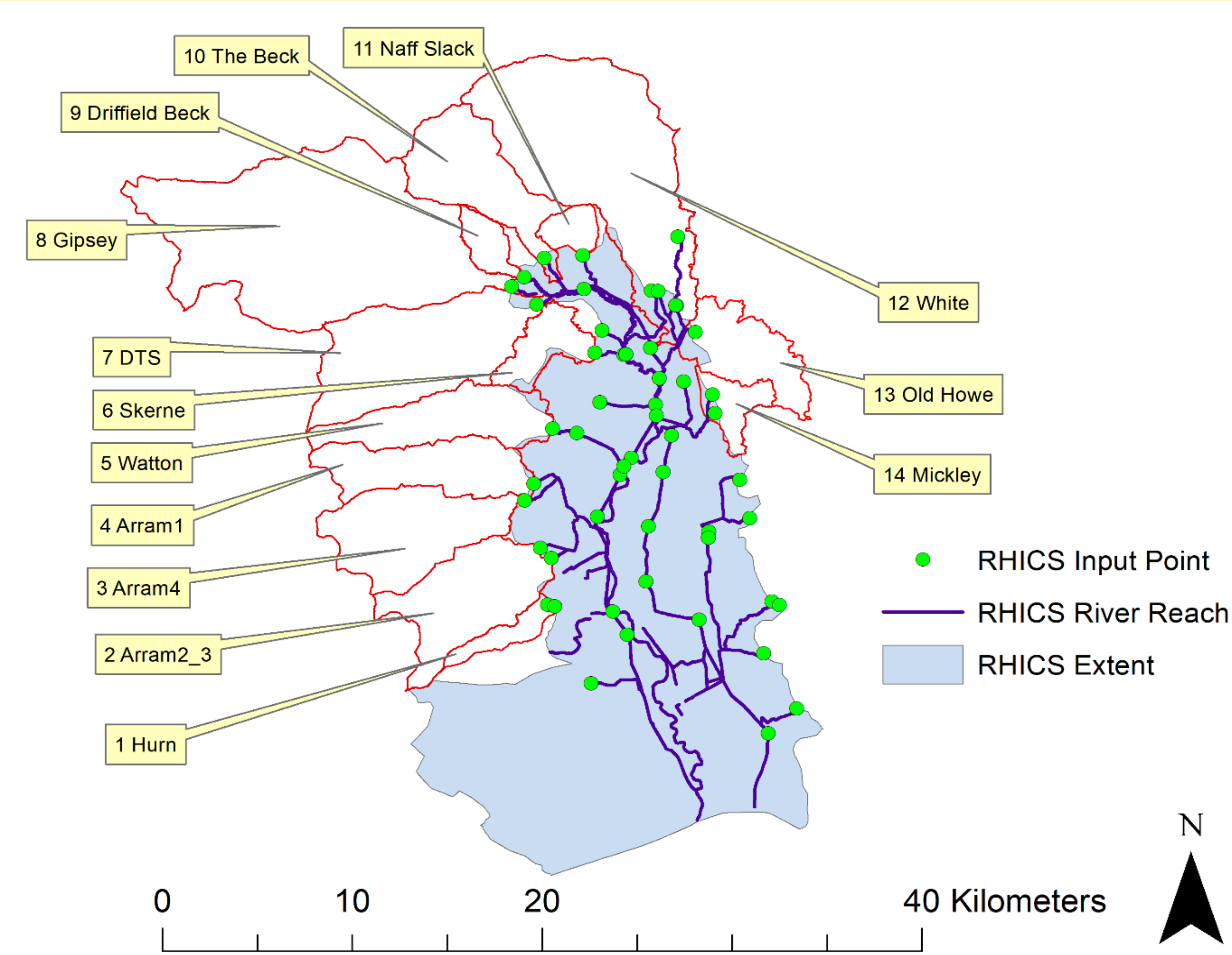
Clearly this amount of water cannot fit into the channel, but the water will keep on coming, so where is it supposed to go?

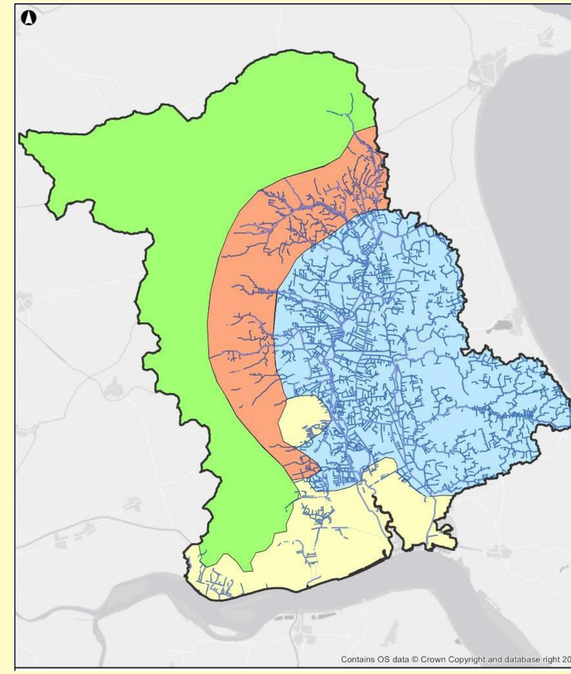
Image: Environment Agency Working with Natural Processes roadshow

Desktop study:



Modelling part 1 - Refinement of NFM measures & selection of sub-catchments for detailed modelling



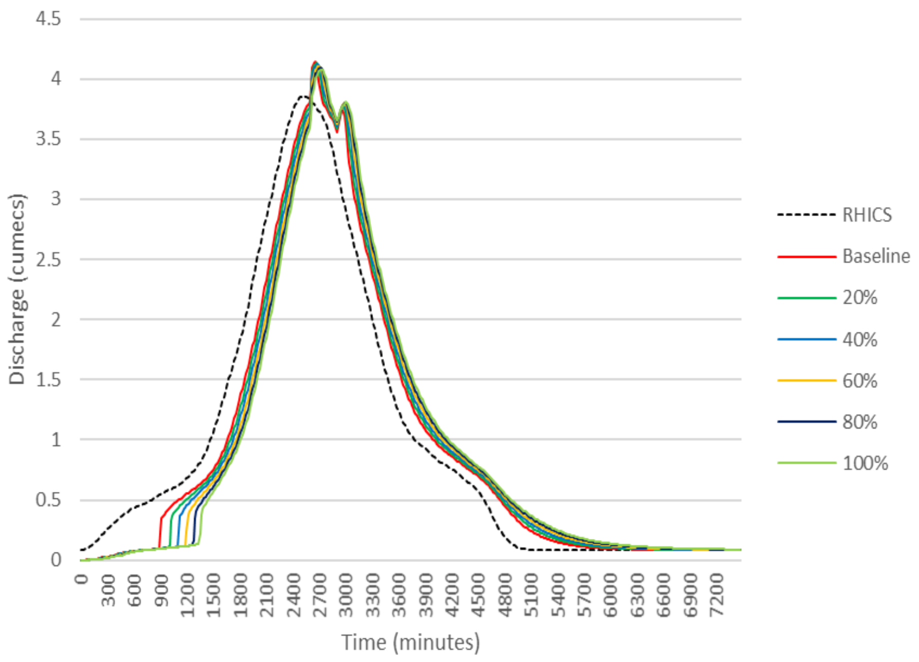


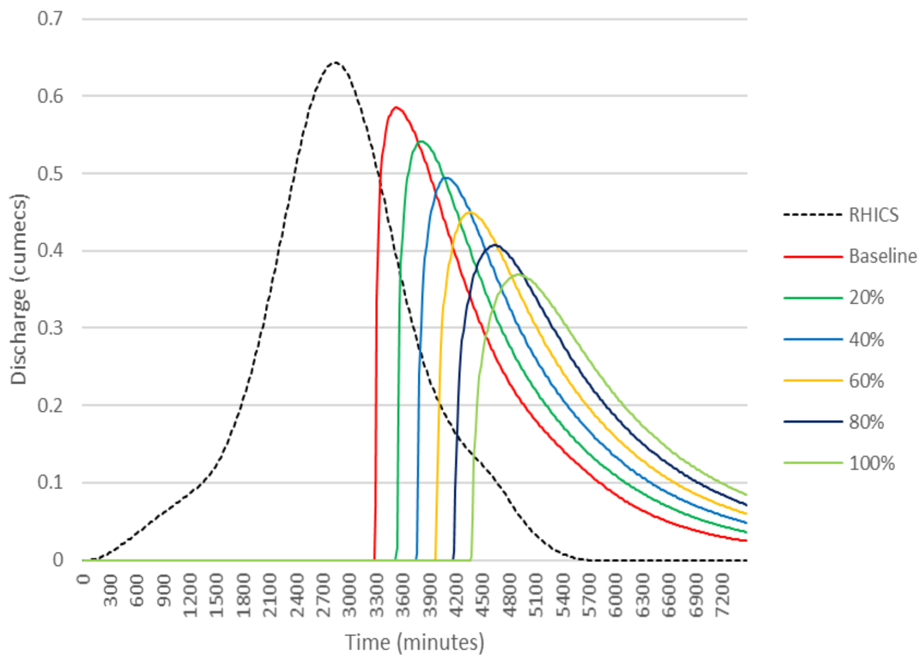
Location of the upland sub-catchments in relation to the RHICS model extent.

Upper sub-catchment modelling – based on 20% reforestation on 1 in 100 year event

Hurn
Created **2 flood peaks**
Delayed peak 1 by **15 minutes**

Arram1
Reduced peak discharge by **$0.04 m^3s^{-1}$**
Delayed peak by **270 minutes**

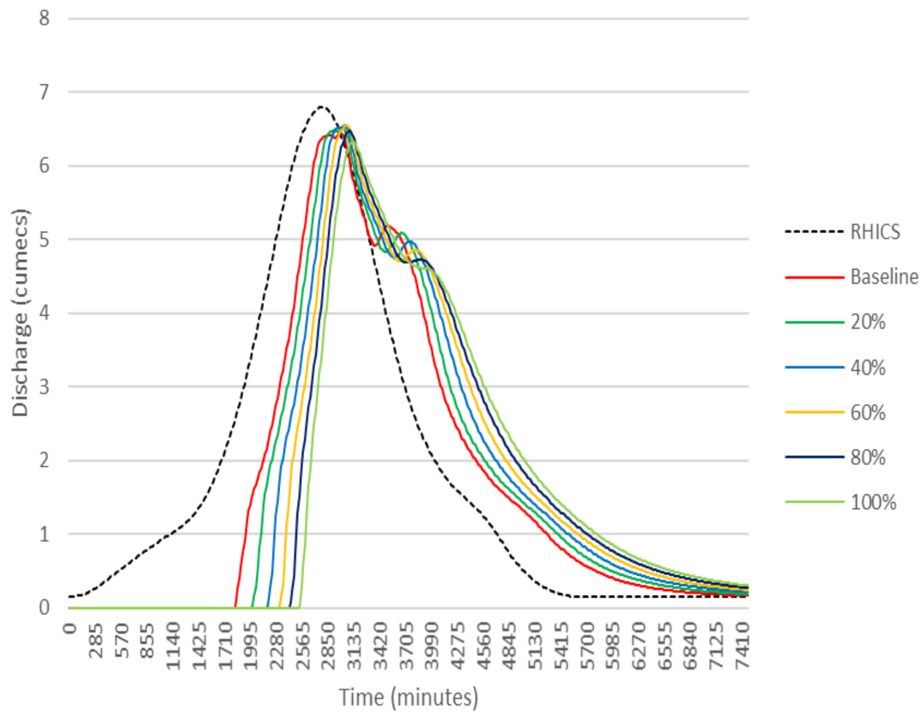


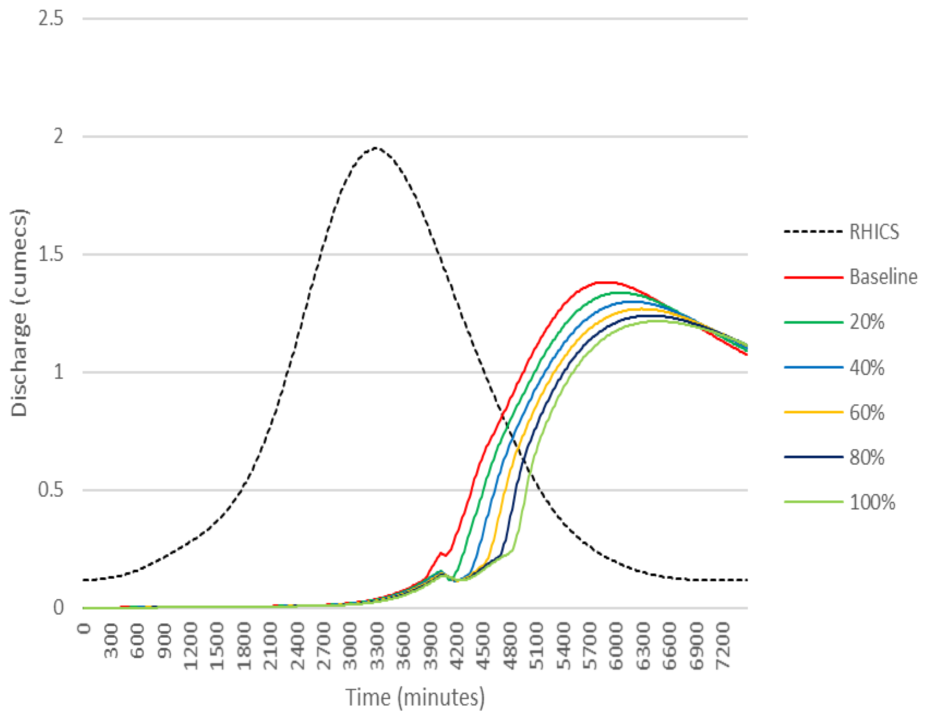


Upper sub-catchment modelling – based on 20% reforestation on 1 in 100 year event

Watton
Delayed peak by **30 minutes**
Created 2 peaks, both reduced and delayed

Skerne
Reduced peak discharge by **0.04m^{3}s^{-1}**
Delayed peak by **165 minutes**





Overview
Catchment
Desk study
Modelling 1
Modelling 2
Modelling 3
Evaluation matrix
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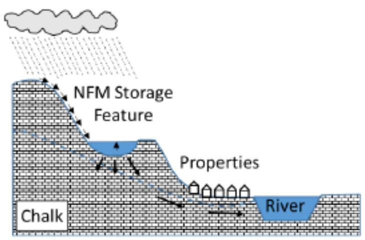
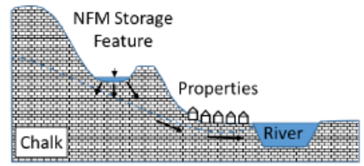
Hull City Council

Limitations to stage 1 modelling

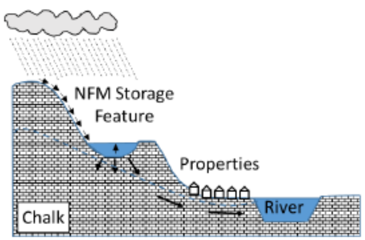
- Cascade of error and uncertainty from Caesar-Lisflood into the RHICS model
- Does not take into account groundwater or infiltration or other hydro-processes
- Hydrological benefits are likely to be greater if measures were implemented because:
  - Results are based on only 20% land use change
  - Infiltration into chalk and dry streams are not accounted for, the channels have water in them prior to running the model but in reality a lot of channels are dry, especially in summer



First intensive rainfall event and the NFM storage feature fills.



Rainfall stops and water stored in the NFM storage feature infiltrates into the permeable soil and groundwater.



Second intensive rainfall event occurs and the NFM storage feature is near empty. Any additional water is stored in the NFM storage feature to mitigate the flooding of downslope properties and downstream flooding.

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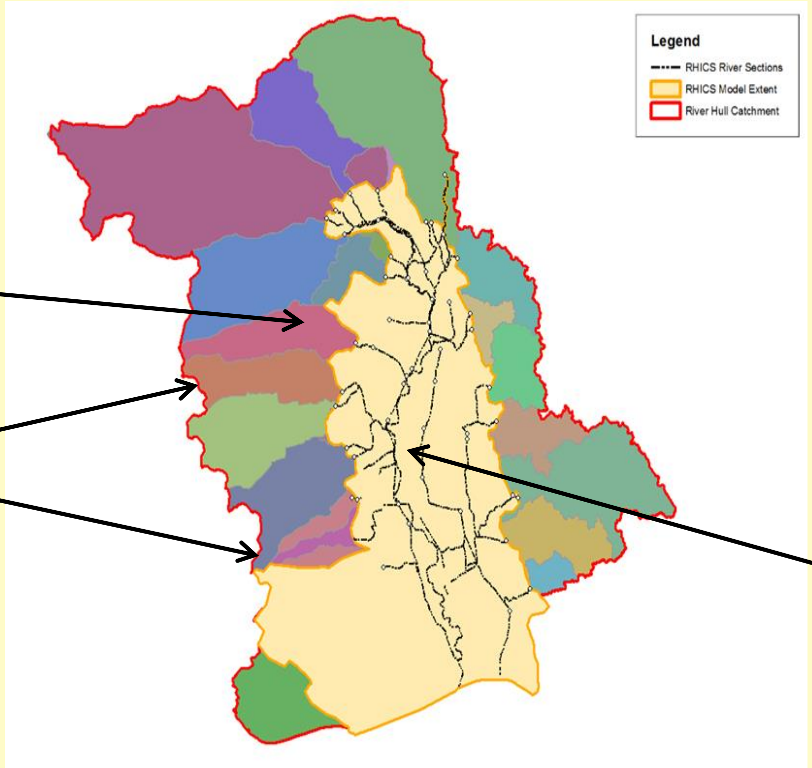
Selection of upper sub-catchments

Sub-catchments in the North & East are heavily influenced by groundwater

Watton

Arram



Leven Carrs

Sub-catchments in the west showed highest potential to delay timings of peak flows

Shortlisted NFM measures

Large woody debris

Leaky dams

Contour ploughing

Tree planting

Floodplain reconnection

Buffer strips

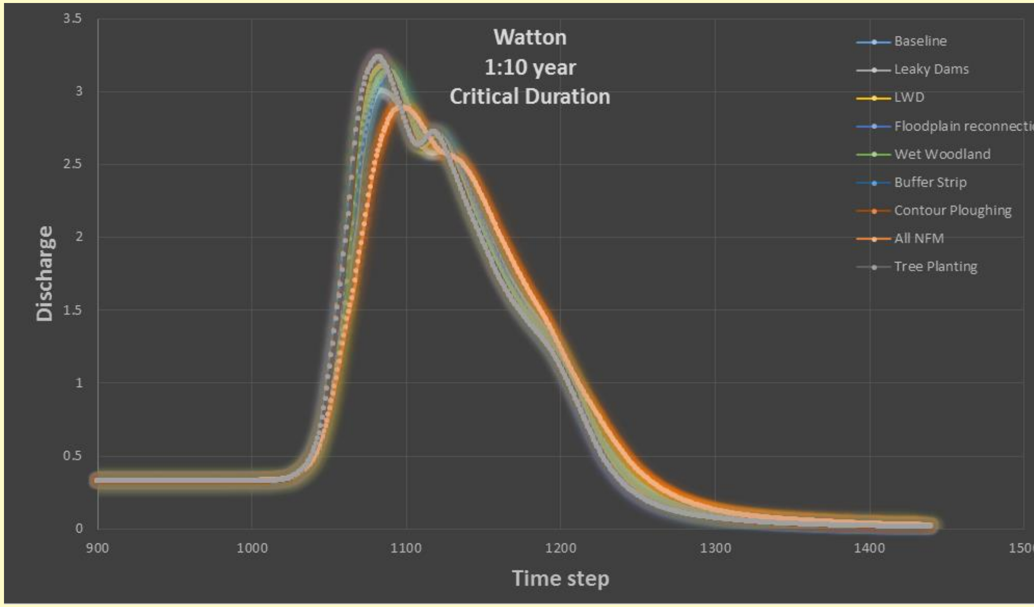
Wet woodland

Modelling part 2 - Detailed modelling of upper sub-catchments

- Used CAESAR-lisflood landscape evolution model (open source; Coulthard, 2019)
- Tested each shortlisted NFM measure individually and then all measures together to create hydrograph and calculate difference in peak flow and time to peak
- 2 scenarios ran:
  - 1 in 10 year rainfall event / 10% AEP, 24 hour storm event
  - 1 in 100 year rainfall event / 1% AEP, 3 day storm event

Watton sub-catchment

Intervention	Peak reduction (%)	Peak delay (mins)
Upland leaky dams	3.06	30
Middle typology leaky dams	3.65	45
Both leaky dams	**7.01**	45
Large woody debris	1.82	45
Floodplain reconnection	3.25	**105**
Wet woodland	2.71	**105**



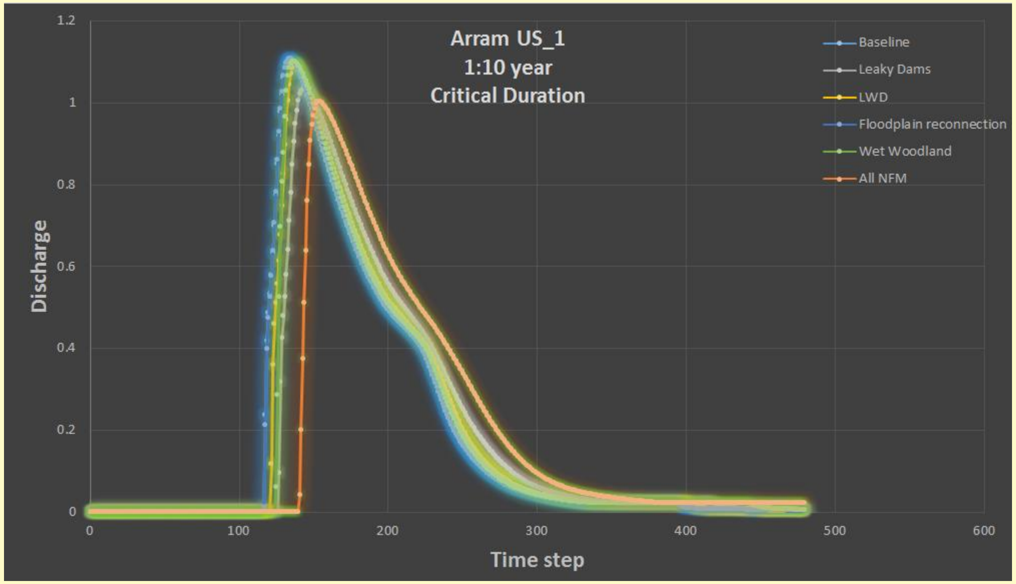
All NFM interventions collectively:

↓ peak flows by 10.56%

↑ time delay 225 minutes

Arram sub-catchment

Intervention	Peak reduction (%)	Peak delay (mins)
Upland leaky dams	4.53	45
Middle typology leaky dams	2.10	120
Both leaky dams	6.50	150
Large woody debris	1.04	60
Floodplain reconnection	-0.21	0
Wet woodland	0.39	45

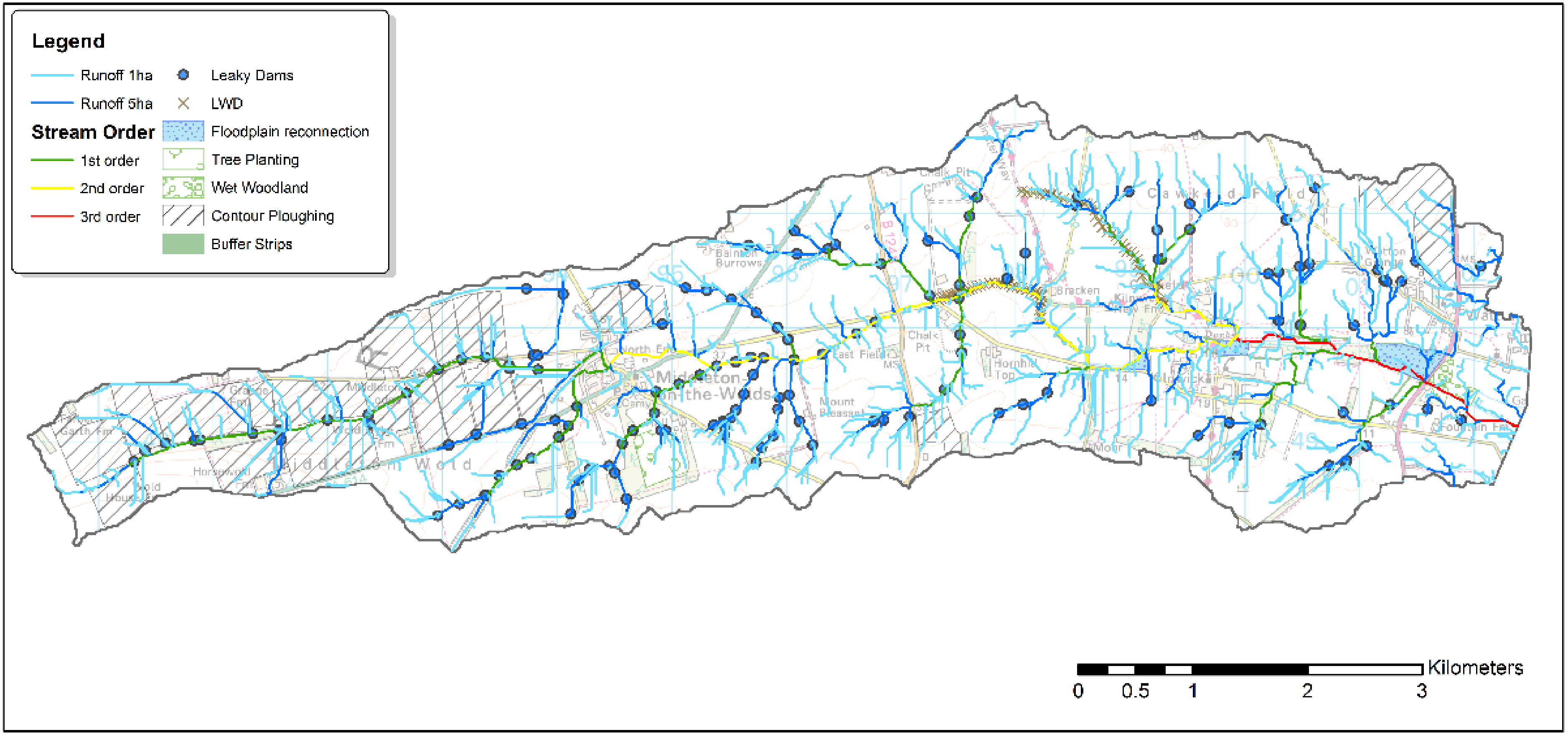


All NFM interventions collectively:

↓ peak flows by 9.23%

↑ time delay 300 minutes

Opportunity map – Watton sub-catchment



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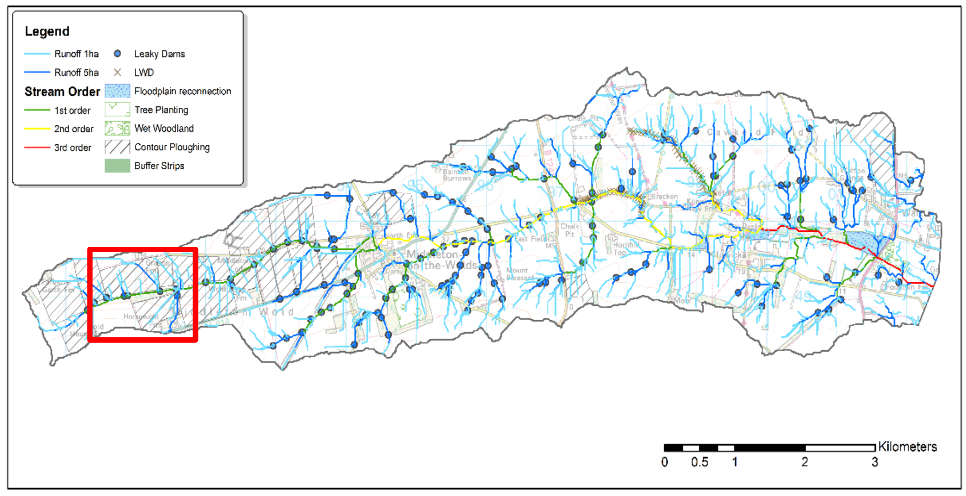
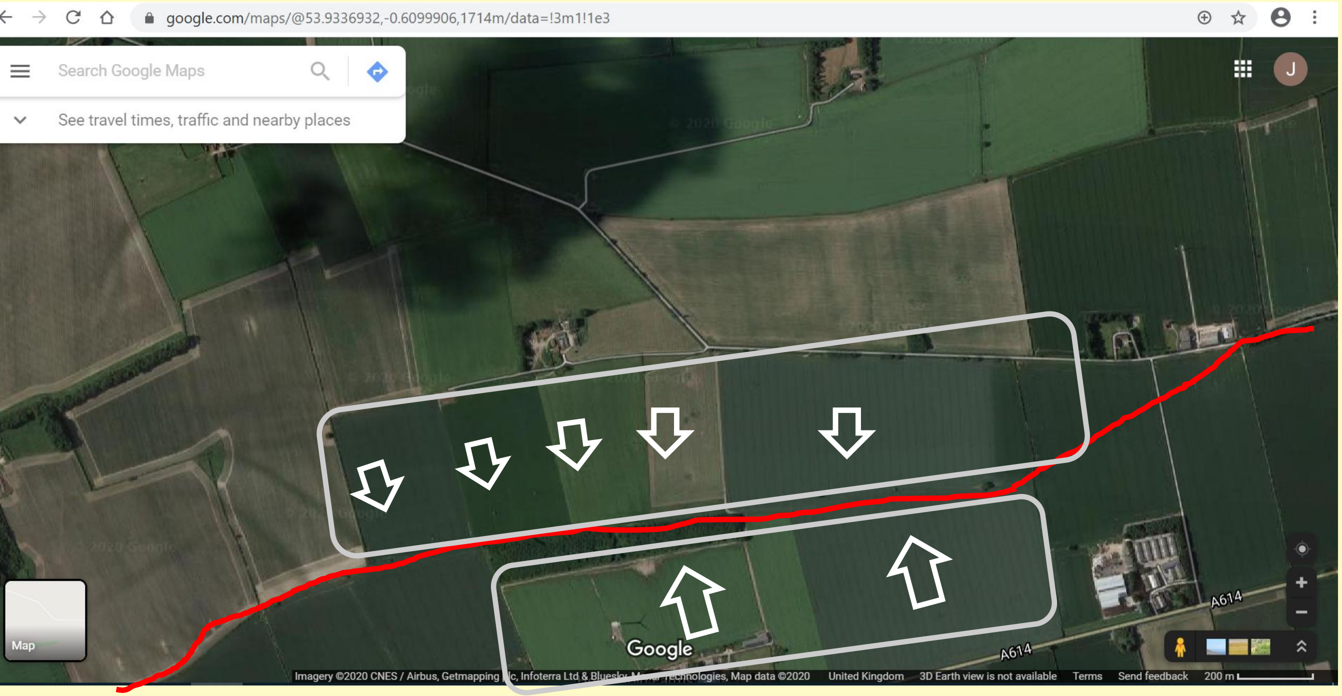


Contour ploughing

- zero costs
- Very unlikely risk of ‘tipping over’
- Immediate soil management benefits



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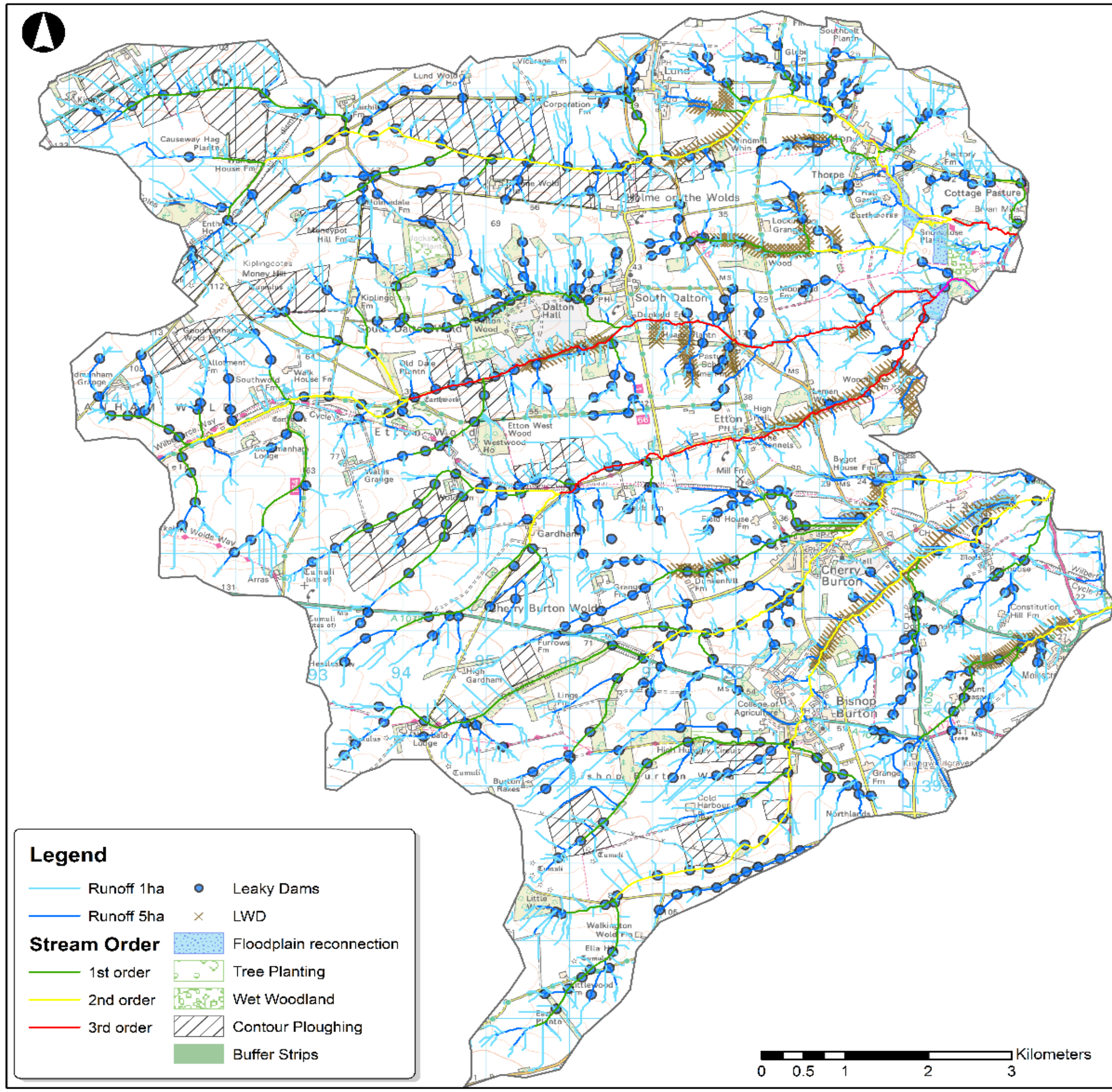
Opportunity map – Arram sub-catchment



Overview
Catchment
Desk study
Modelling 1
Modelling 2
Modelling 3
Evaluation matrix
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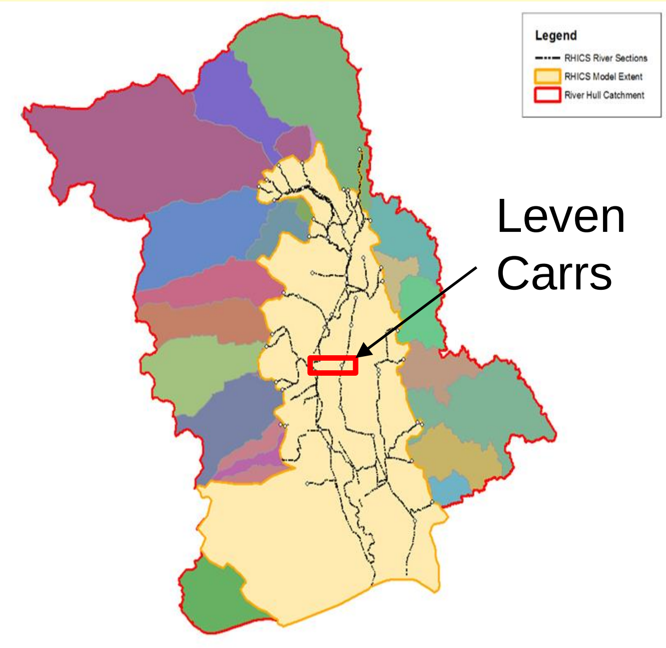
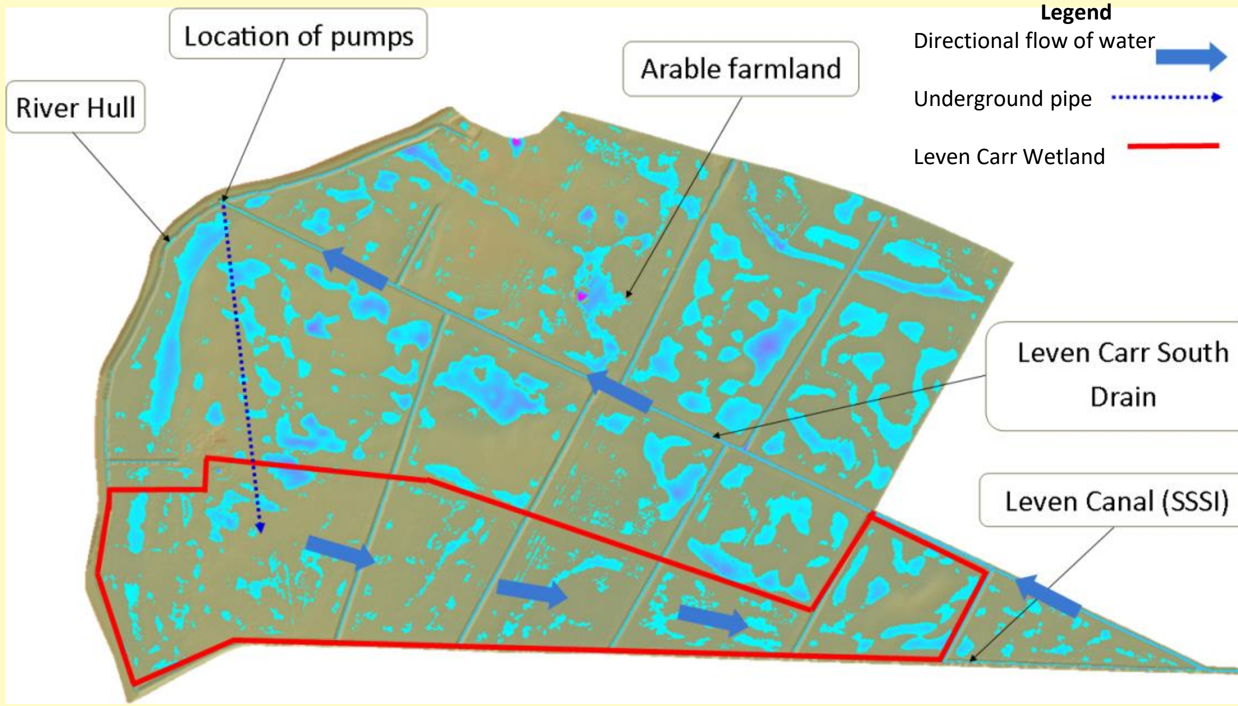
Hull City Council

Modelling of a pumped environment - Leven Carrs





(m³/hour)	Small pump (Capacity 60m³/ hour)	Large pumps Capacity 1200m³/hour)
None	0	0
Large pump only	0	2239
Small pump only	810	0
Both pumps	723	1516

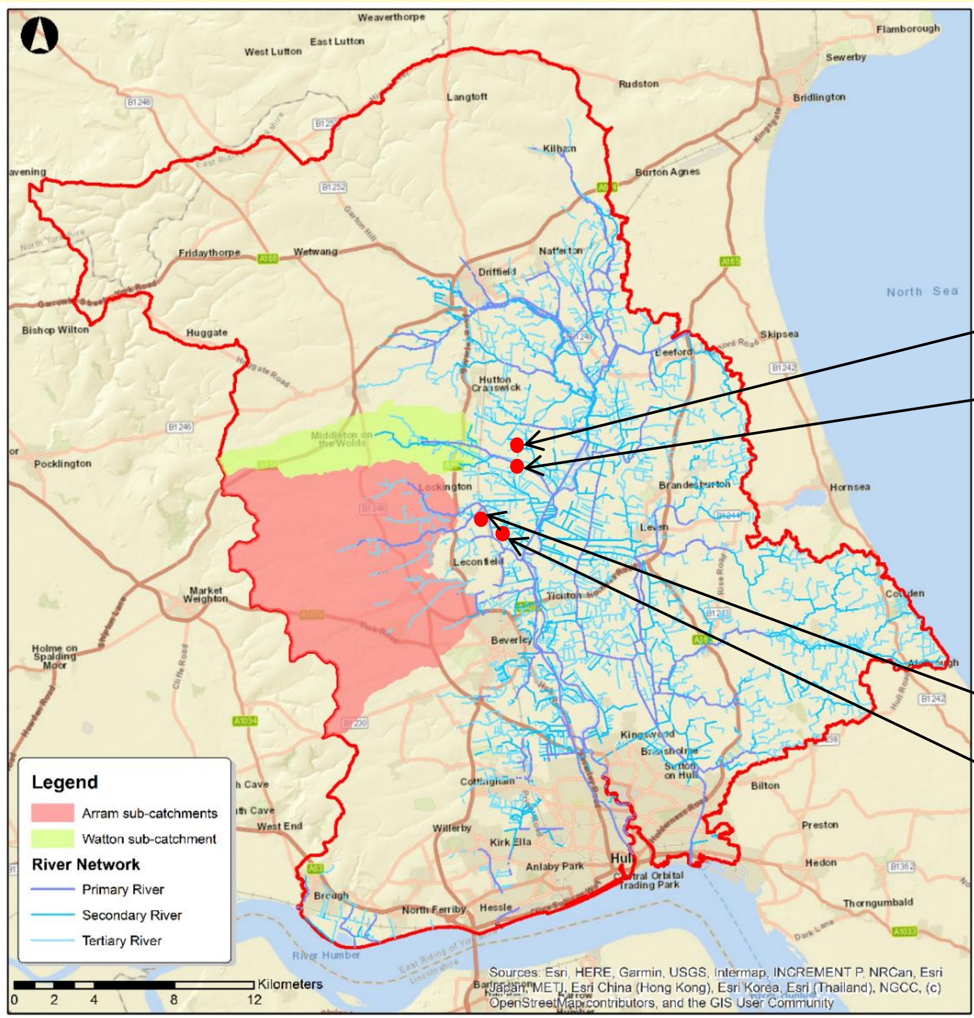
The wetland could provide storage for surface water for up to **29** hours before the electric pumps would need to come online

https://www.youtube.com/watch?v=YJpQPXQwxWw

Modelling part 3 – what effect does NFM in the upper sub-catchments of the River Hull have on the River Hull channel itself and does this extend into Kingston upon Hull?

(Catch breath and take a refreshing sip of Dr Pepper)

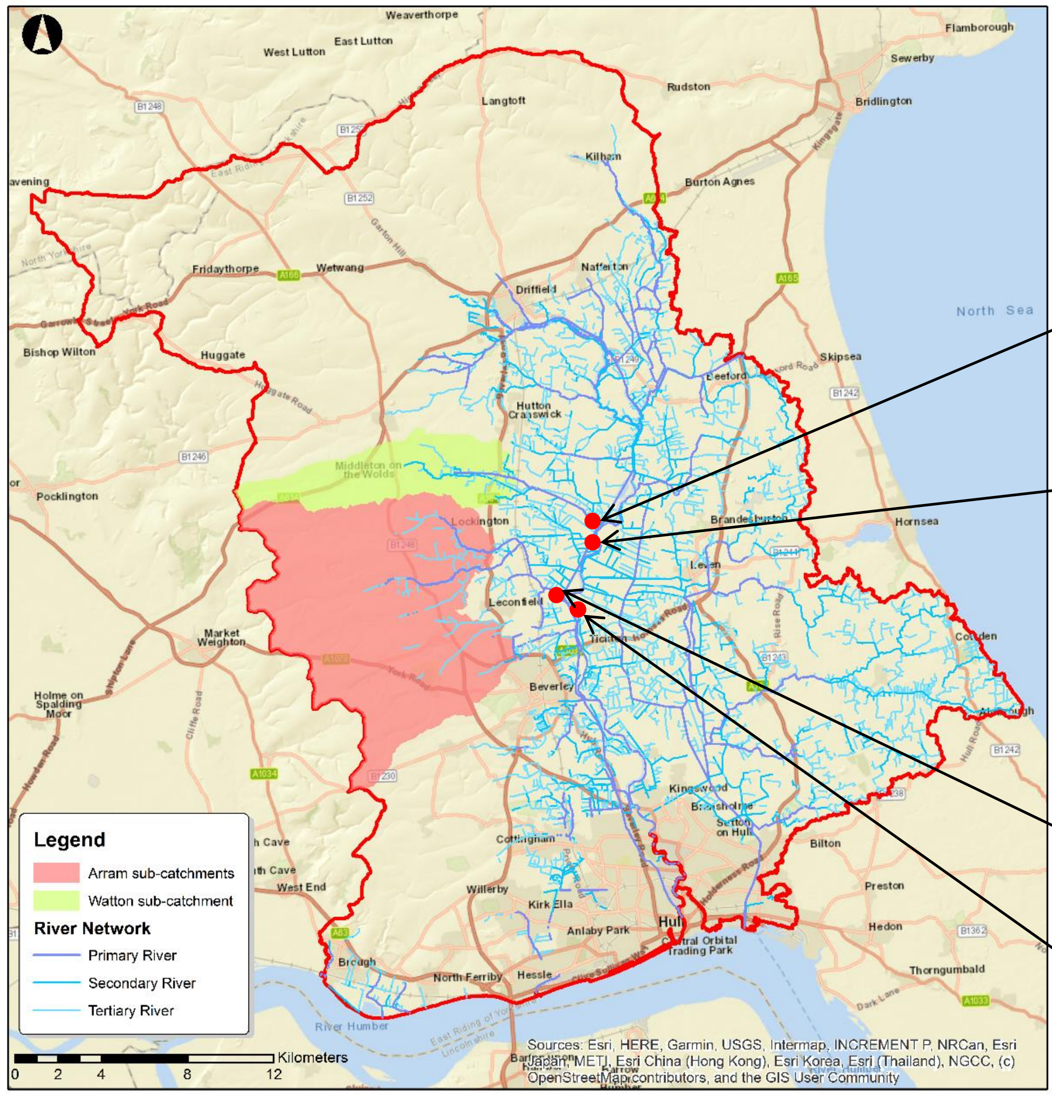
Modelling 3 - River Hull benefits



Point on map (Watton)	10% AEP flow m^3/s improved (%)
1	11.95
2	1.15

Point on map (Arram)	10% AEP flow m^3/s improved (%)
3	10.15
4	0.1

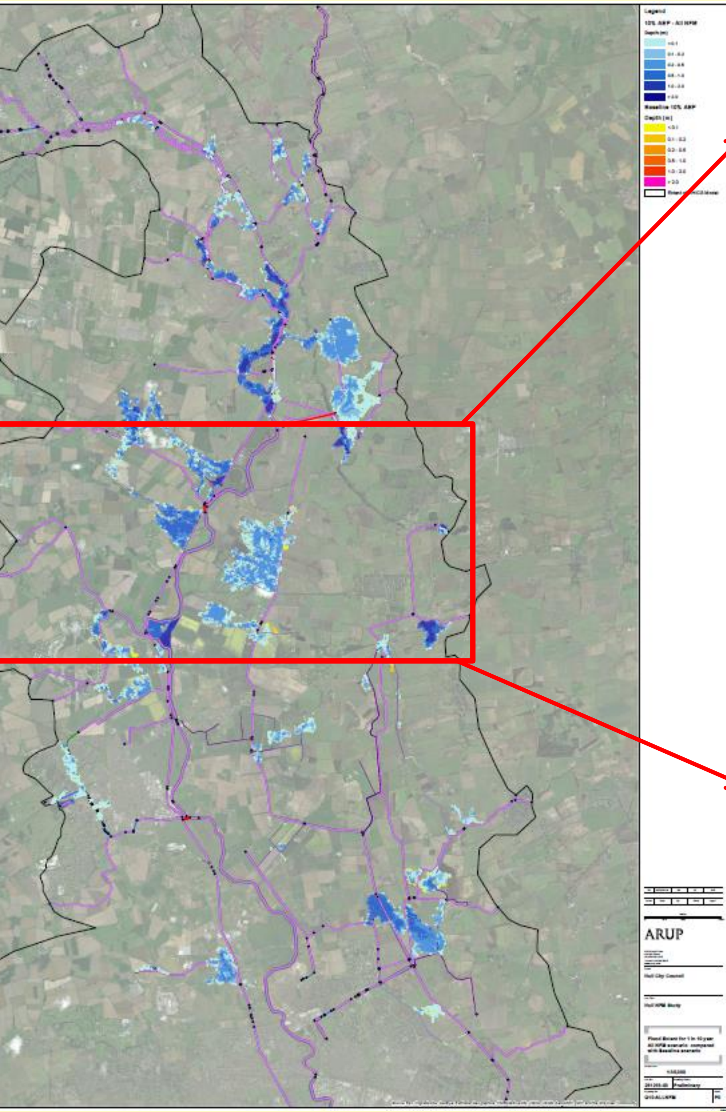
Task 2b key findings: River Hull benefits

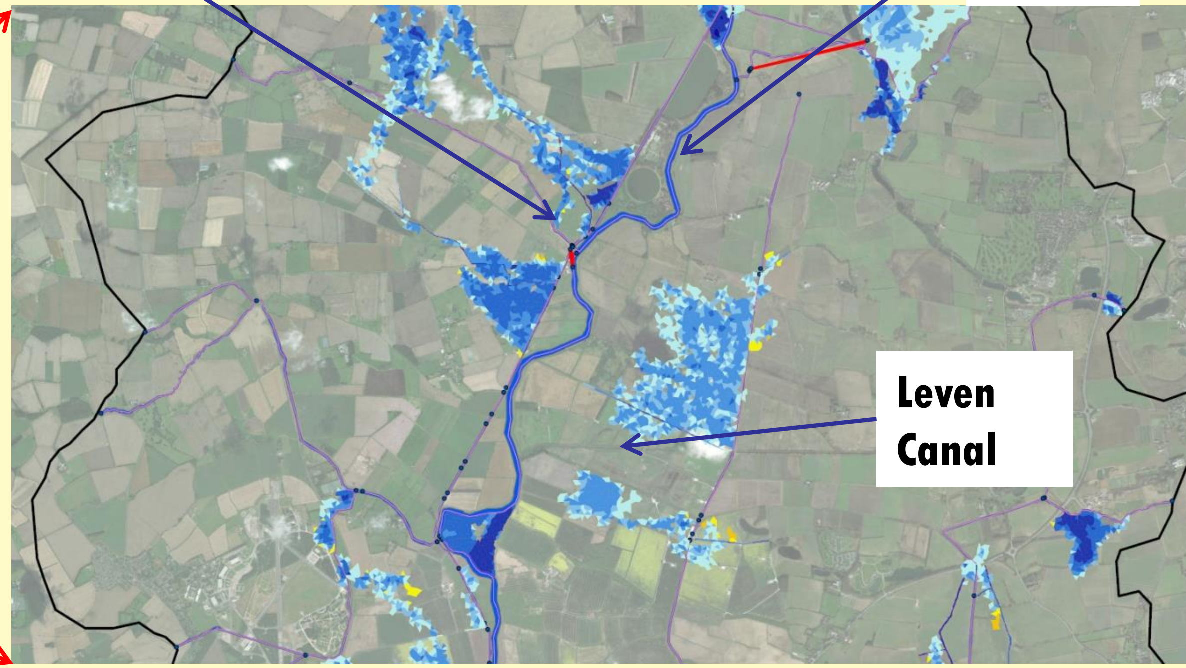


Point on map (Watton)	10% AEP flow m³/s improved (%)
1	11.95
2	1.15

Point on map (Arram)	10% AEP flow m³/s improved (%)
3	10.15
4	0.1

Task 2b key findings: River Hull benefits





Yellow indicates areas benefitting from NFM

~ 3 properties

Task 3 key findings:

NFM benefits
- Mainly environmental/ ecosystem services
- Flood risk benefits associated with properties at risk is low (~3 houses)
- Flood risk benefits to agricultural land (not counted) but likely to be considerable

FDGiA funding
- Likely to score low in the partnership funding calculator
- Alternative funding sources will be required

Alternative funding routes
- Non-flood focused funds
- Post-BREXIT government funding - ELMs

Overview
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Modelling 2
Modelling 3

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Evaluation

Given the modelling results, what does this mean for the future of NFM in the River Hull catchment?

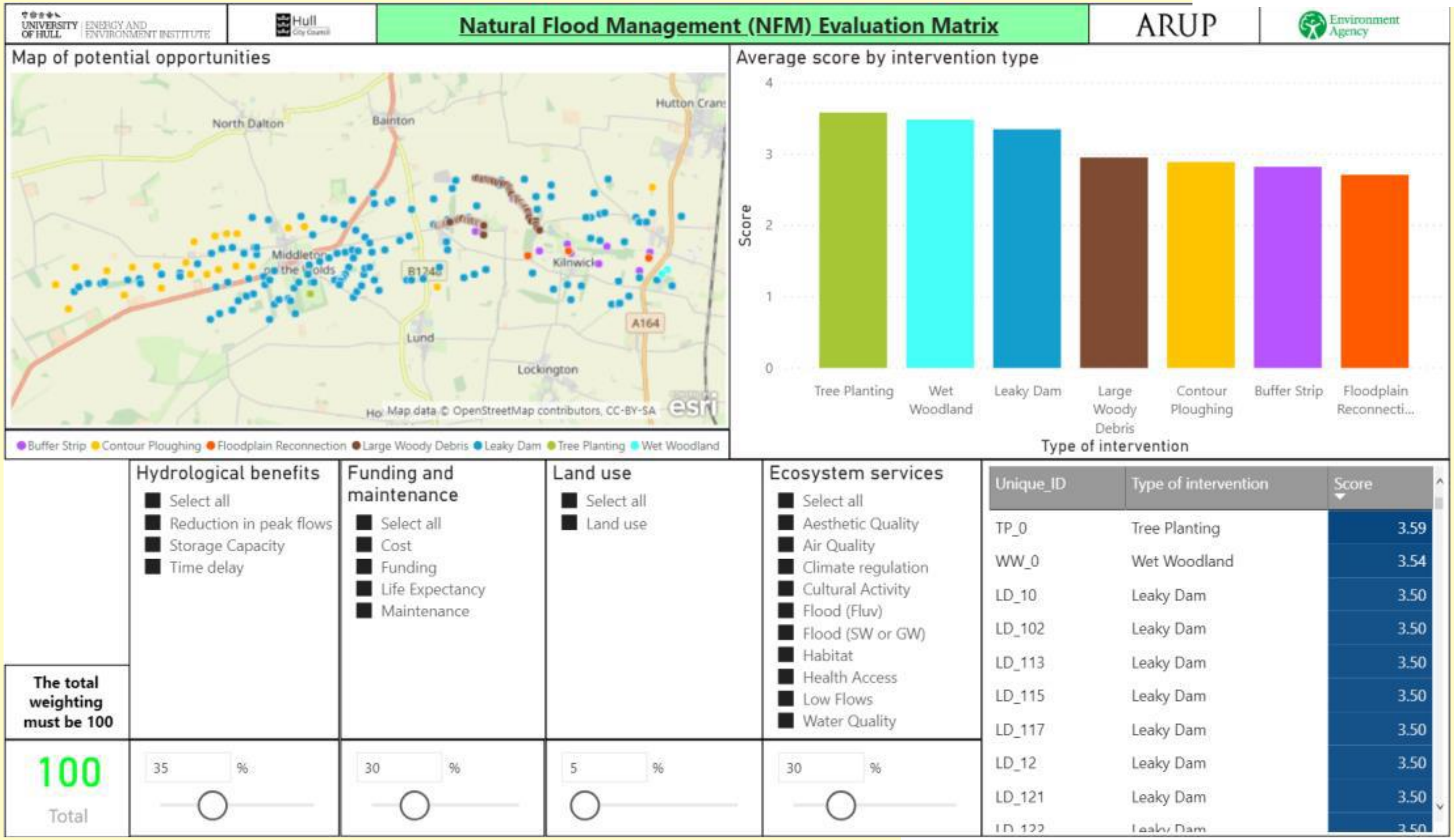
NFM evaluation matrix

Flood risk benefits	Reduction in peak flows & increase in time delay, storage capacity	Modelling from this study and GIS
Land use	Existing land cover	CROME
Funding & future maintenance	Estimated costs, funding opportunities, estimated maintenance & estimated life expectancy	Literature review inc EA WwNP, Yorkshire Dales Rivers Trust NFM lowland guide
Ecosystem service benefits	Water quality, habitat, climate regulation, low flows, health access, air quality, flooding, aesthetic quality & cultural activity	EA WwNP

NFM evaluation matrix

Interactive map of individual NFM interventions

Bar chart showing average score by intervention type



Weighting of main criteria can be changed & specific sub-criteria can be turned on/ off

List of individual NFM measures with locations ranked with highest score at the top

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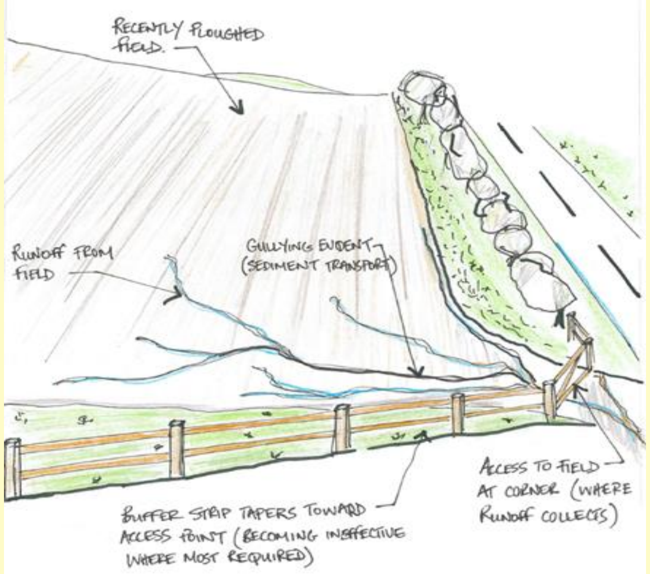
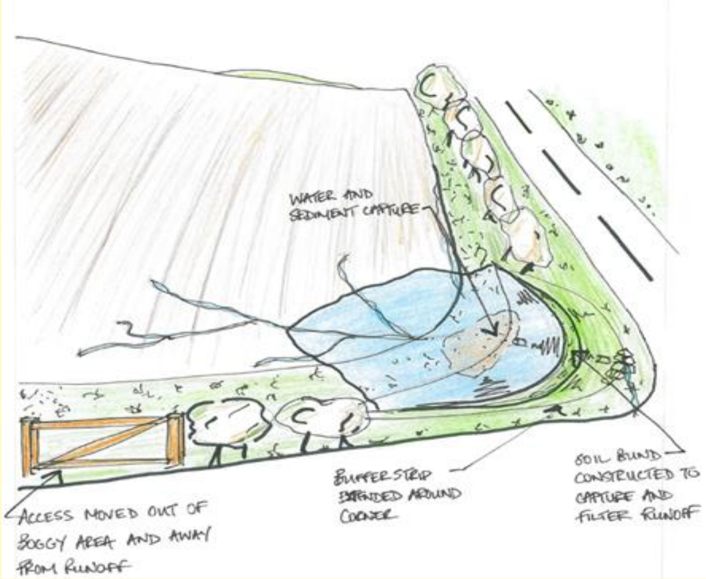
Recommendations – to progress to implementation

1. Consult opportunity maps when planning works in Watton and Arram sub-catchments

2. Influence land owners to consider earth leaky dams across fields/ in the corners of fields based on locations in opportunity maps





Drawings of field corner bund: Alex Nicholson, Arup

3. Use CHALKSHIRE initiative to promote sustainable land use practises to promote indirect/ direct flood benefits

4. Use NFM evaluation matrix to aid decision making processes

5. Use the Living with Water partnership to engage and promote the benefits of NFM in the River Hull valley using new Pathfinder project

Recommendations – on a wider scale

The project team are working to make the NFM evaluation matrix available open source online. Once this is available a link will be circulated – if you use the matrix please let me know what you used it for, how you used it and any pros and cons

National water management in lowland catchments working group:

https://www.shiregroup-idbs.gov.uk/natural-flood-management-nfm-working-with-natural-processes/

Key contact, secretariat – Steve Rose, JBA consulting, Steve.Rose@jbaconsulting.com

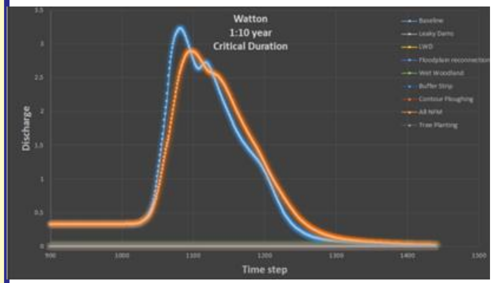
Add to the evidence base to help fill in gaps in knowledge

Non-technical executive summary

he most suitable
IFM measures for
he River Hull Valley
nclude:

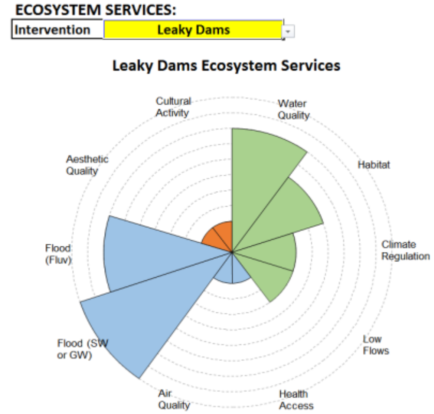
. Leaky dams
. Large woody
ebris
. Floodplain
econnection
. Wet woodland
. Buffer strips
. Contour ploughing
. Tree planting

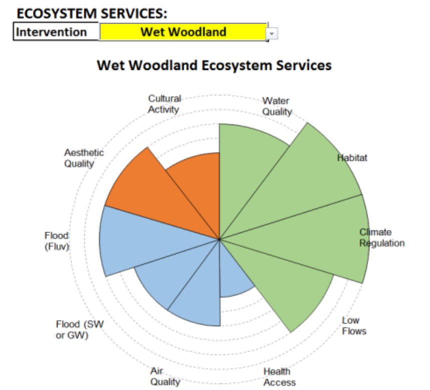
Flood risk benefits Modelled using 1 in 10 year rainfall event:



- ➢ 10.6% ↓ in peak flows
- ➢ 3.75 ↑ in time delay

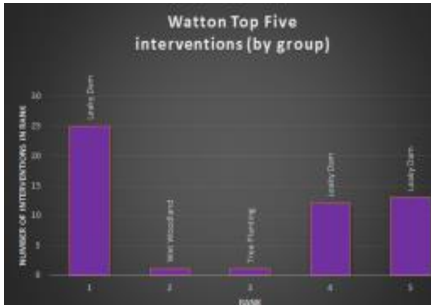
Ecosystem service benefits:





Evaluation matrix:

- ✓ Flood risk benefit
- ✓ Ecosystem service benefits
- ✓ Cost
- ✓ Funding opportunities
- ✓ Maintenance
- ✓ Life expectancy



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Thank you for listening

Any questions please e-mail me:
Jessica.Fox@hullcc.gov.uk

To download the project report and opportunity maps:

https://catchmentbasedapproach.org/get-involved/hull-east-riding/