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
Overview

River Hull catchment

Desktop study

Modelling part 1 - NFM measures & sub-catchment selection

Modelling part 2 - NFM opportunity mapping

Modelling part 3 - Downstream benefits

Evaluation matrix

Recommendations

Summary

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 Network changes

Main river map (Environment Agency, 2020)
Study rationale:

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

Table 9 – Further development of initial flood risk management options

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

RHICS, 2015
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
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 m³ s⁻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 **0.04 m³ s⁻¹**
Delayed peak by **165 minutes**
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
Selection of upper sub-catchments

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

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

---

**Modelling 1**

---

**Modelling 2**

---

**Modelling 3**

---

**Overview**

**Catchment**

**Recommendations**

**Desk study**

**Summary**
Shortlisted NFM measures

- Leaky dams
- Contour ploughing
- Large woody debris
- Floodplain reconnection
- Buffer strips
- Tree planting
- 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

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Peak reduction (%)</th>
<th>Peak delay (mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upland leaky dams</td>
<td>3.06</td>
<td>30</td>
</tr>
<tr>
<td>Middle typology leaky dams</td>
<td>3.65</td>
<td>45</td>
</tr>
<tr>
<td>Both leaky dams</td>
<td>7.01</td>
<td>45</td>
</tr>
<tr>
<td>Large woody debris</td>
<td>1.82</td>
<td>45</td>
</tr>
<tr>
<td>Floodplain reconnection</td>
<td>3.25</td>
<td>105</td>
</tr>
<tr>
<td>Wet woodland</td>
<td>2.71</td>
<td>105</td>
</tr>
</tbody>
</table>

**All NFM interventions collectively:**

- ↓ peak flows by **10.56%**
- ↑ time delay **225 minutes**
## Arram sub-catchment

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Peak reduction (%)</th>
<th>Peak delay (mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upland leaky dams</td>
<td>4.53</td>
<td>45</td>
</tr>
<tr>
<td>Middle typology leaky dams</td>
<td>2.10</td>
<td>120</td>
</tr>
<tr>
<td>Both leaky dams</td>
<td>6.50</td>
<td>150</td>
</tr>
<tr>
<td>Large woody debris</td>
<td>1.04</td>
<td>60</td>
</tr>
<tr>
<td>Floodplain reconnection</td>
<td>-0.21</td>
<td>0</td>
</tr>
<tr>
<td>Wet woodland</td>
<td>0.39</td>
<td>45</td>
</tr>
</tbody>
</table>

**All NFM interventions collectively:**

- **Peak flows by 9.23%**
- **Time delay 300 minutes**
Opportunity map – Watton sub-catchment

Legend
- Runoff 1ha
- Runoff 5ha
- Leaky Dams
- LWD

Stream Order
- Floodplain recouperation
- Tree Planting
- Wet Woodland
- Contour Ploughing
- Buffer Strips

Overview
Catchment
Recommendations
Evaluation matrix
Modelling 1
Modelling 2
Modelling 3
Desk study
Summary
Contour ploughing

- Zero costs
- Very unlikely risk of ‘tipping over’
- Immediate soil management benefits
Opportunity map – Arram sub-catchment
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

<table>
<thead>
<tr>
<th>Point on map</th>
<th>10% AEP flow m³/s improved (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Watton)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>11.95</td>
</tr>
<tr>
<td>2</td>
<td>1.15</td>
</tr>
<tr>
<td>Point on map</td>
<td></td>
</tr>
<tr>
<td>(Arram)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>10.15</td>
</tr>
<tr>
<td>4</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Legend
- Arram sub-catchments
- Watton sub-catchment
- River Network
  - Primary River
  - Secondary River
  - Tertiary River

Task 2b key findings: River Hull benefits

<table>
<thead>
<tr>
<th>Point on map (Watton)</th>
<th>10% AEP flow m³/s improved (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.95</td>
</tr>
<tr>
<td>2</td>
<td>1.15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Point on map (Arram)</th>
<th>10% AEP flow m³/s improved (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>10.15</td>
</tr>
<tr>
<td>4</td>
<td>0.1</td>
</tr>
</tbody>
</table>
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
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

Overview
- Catchment
- Desk study
- Modelling 1
- Modelling 2
- Modelling 3
- Recommendations
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

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

Drawings of field corner bund: Alex Nicholson, Arup
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.


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

Add to the evidence base to help fill in gaps in knowledge.
The most suitable NFM measures for the River Hull Valley include:

1. Leaky dams
2. Large woody debris
3. Floodplain reconnection
4. Wet woodland
5. Buffer strips
6. Contour ploughing
7. 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 benefits
- Ecosystem service benefits
- Cost
- Funding opportunities
- Maintenance
- Life expectancy

Overview
Catchment
Desk study
Modelling 1
Modelling 2
Modelling 3
Recommendations
Summaries
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/