Case study 11

Thames Headwater study - Oxfordshire

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1. Catchment summary

Study location

The project covers the Oxfordshire headwaters of the River Thames (Figure 1), although more detailed modelling was carried out specifically on the River Ray. The River Ray rises in Buckinghamshire and flows west into Oxfordshire. At Islip it joins the Cherwell which then flows into the Thames.

Catchment overview

There has been widespread and repeated flooding of the Thames catchment in recent years. The National Farmers' Union (NFU) is interested in exploring different ways of managing the flood risks that include better Working with Natural Processes (WwNP).

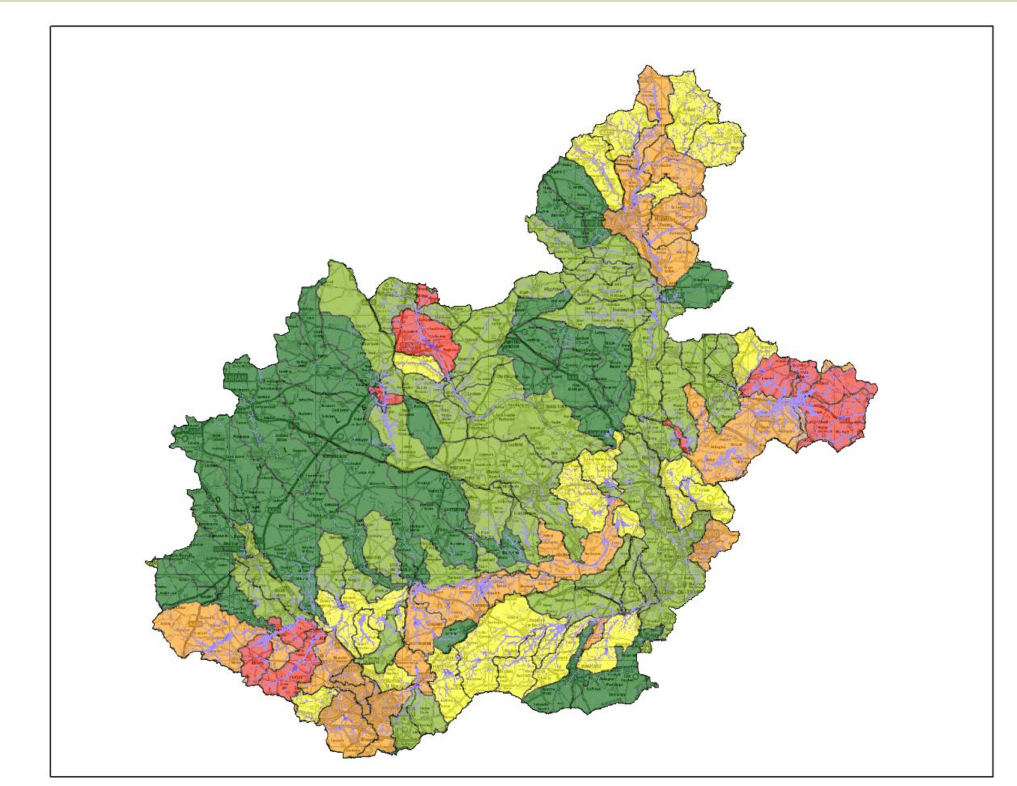

Figure 1: Location map of the Oxfordshire Thames headwaters themed by storage opportunities at a broad scale

Source: JBA Consulting

Study summary

JBA Consulting was commissioned to target different measures that include WwNP and more traditional channel maintenance options at a strategic level. This case study is about the WwNP aspects of the work. The project team worked with landowners/farmers to establish the feasibility of strategic opportunities for enhancing storage of water in the Thames headwaters.

Data mining the updated Flood Map for Surface Water map outputs for areas of 'ponded water' providing an opportunity for enhanced storage (pond excavation/low bunding) was performed using a tool called JRAFF (JBA Run-off Attenuation Feature Finder). This tool looks for areas of ponded water in the Flood Map for Surface Water map outputs that fall between 100m2 and 5,000m2, that are not in urban areas, and which are within headwater areas. These areas in the Ray catchment are identified in black in Figure 2. The identified opportunities for flood storage was entered in the Digital Terrain Model (DTM) and the 2-dimensional (2D) overland flow model, JFLOW (Lamb et al. 2009), was re-run.

The headwater catchments were monitored for the current and modified situations and the magnitude of flood peak attenuation was computed. A significant relationship was found between the level of flood attenuation expected depending on opportunity storage and several catchment descriptors including SPRHOST (Standard Percentage Run-off – Hydrology of Soil Types), BFIHOST (Base Flow Index – Hydrology of Soil Types) and URBEXT (Flood Estimation Handbook descriptor defining urban extent). This approach was then applied to the other Oxfordshire catchments not included in the detailed modelling of the Ray.

Community involvement

The project was initiated by the NFU which has a large number of members and included partners from the Environment Agency. Engagement meetings have been held with landowners to discuss and understand the feasibility of pond storage.

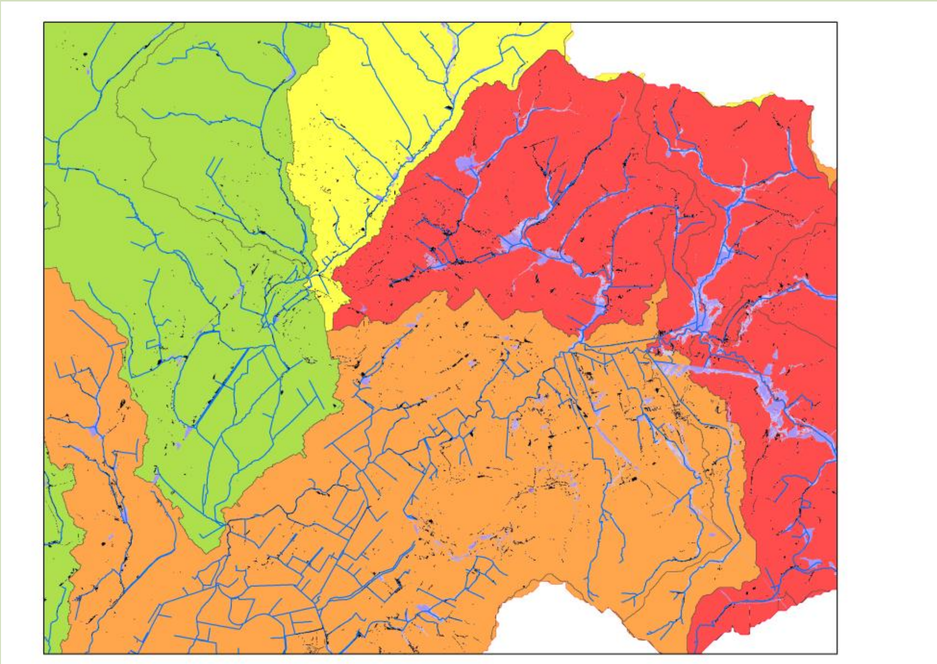

Figure 2: Distributed pond storage in the Thames Headwater catchment (shown in black)

Source: JBA Consulting

2. Data summary

Datasets and analysis techniques used

- The datasets used included:
- updated Flood Map for Surface Water map
- European Union's CORINE (CoORdination of INformation on the Environment) land cover database
- 2m resolution DTM – for 2D overland flood modelling
- Environment Agency's Defined River Network – for definition of headwaters and network
- synthetic aperture radar (SAR) data

CORINE (open data) was used to classify different land cover types. Flood Estimation Handbook (FEH) rainfall parameters and catchment descriptors were used for design flood estimation. The Revitalised Flood Hydrograph (ReFH) rainfall–run-off and losses approach was used. The losses were applied to the rainfall as for the blanket rainfall approach.

Data restrictions

Data licenses were required from a range of organisations.

3. Model summary

Catchment processes investigated

The catchment processes investigated study included:

- Run-off generation: The blanket rainfall approach used here is the same as that used in the creation of the Flood Map for Surface Water. For rural situations, the ReFH method was used to account for changes to soil infiltration rates and percentage run-off during an event. For urban areas (the approach does not seek storage opportunities here), there is a blanket percentage run-off and assumed drainage rate.
- Catchment/land use change: The quality of soils in the catchment was assessed at a coarse level and the potential for improvement/degradation was altered by changing the catchment descriptor, SPRHOST. This was then used to re-run simulations and enable the changes to agricultural damages to be assessed.

Model assumptions

A range of different probabilities for both surface water and fluvial flows were considered and long-term annual average property and agricultural damages were computed by integrating the impacts over a range or probabilities. Probabilities and consequences were explored, although system failure of any bunds was not considered explicitly.

The timing of the interactions of peak flows was considered; the approach used by JRAFF targets opportunities to increase storage in headwaters rather than part way down the catchment. The impact of flood peaks was also assessed at different monitoring cross-sections, so that any increase in peak flood due to constructive interference of peaks from tributaries could be detected.

Fragility was not considered. Storage opportunities are currently targeted at low risk pond excavation or shallow bunding up to a maximum of 1m, although this may be extended to 2m, as this was the maximum bund elevation in the Holnicote case study.

The synchronicity problem, whereby WwNP measures can retard flows in one catchment which then unfortunately interact with peaks from other parts of the catchment, was considered. Here the key was to target storage in headwater catchments.

Model tools and assumptions included:

- FEH for estimation of fluvial design hydrographs and for modifying catchment descriptors to simulate measures
- JFLOW – surface water and fluvial approaches; 2D full shallow water equation solver
- JRAFF is based in ArcGIS and was used to data mine the Flood Map for Surface Water and map extra pond storage opportunities

The attenuation possible from implementing the storage identified by JRAFF can be seen for different return periods (RP 30 and RP 100) in Figure 3 for two storage areas.

A regression model relating the modelled attenuation as a function of opportunity storage, catchment area and FEH descriptors was developed. This attempts to account for the influence of scale and typology, and can be applied to other catchments without JFLOW modelling.

The relationships that relate the levels of attenuation achieved through pond storage opportunities identified using JRAFF are being stored in a geodatabase called the ‘JRAFF library’.

Data and model outputs

Model outputs included:

- updated JFLOW blanket rainfall model with current and WwNP scenarios for surface water modelling (see Hankin et al. 2008)

- updated JFLOW fluvial approach (used to derive the original Flood Map in 2004) with different scenarios modelled to reflect changes to channel capacity, urbanisation and land use management
- use of GIS tool in JRAFF to identify opportunities for storage of water – also identifies potential peak flood attenuation as a function of WwNP opportunity storage and catchment descriptors

Model performance

A geodatabase of catchment performance with and without catchment storage has been built up.

4. Lesson learnt

Choice of tools

- The blanket rainfall approach used in the generation of the Flood Map for Surface Water considers primarily surface water flooding and only considers soil losses by subtracting these from the rainfall storm profile. While this allows for a changing percentage run-off through the storm event, base flows are not explicitly modelled.
- The approach adopted helps to strategically identify relatively easy locations to store additional water (at locations where extreme flood water ponds are anyway) and ti understand the levels of attenuation that are subsequently possible.
- Generic but significant statistical relationships were found between attenuation and the explanatory variables of extra storage and several catchment descriptors. Although this was based on only around 20 subcatchments, with more modelling this approach would scale nationally to make use of the national 2m resolution Flood Map for Surface Water .
- Currently the approach adds a maximum of 1m additional storage at areas of ponded water, whereas it might be relatively easy to increase this to 2m – the maximum used in the Holnicote case study.

Catchment scale and typology

The approach developed in this project enables upscaling of information learnt about attenuation using detailed modelling to the regional or national scale using national datasets.

The typologies of the different headwater catchments investigated were taken into account in that the flood estimation takes into account the catchment descriptors such as SPRHOST and BFIHOST, which are strong indicators of different typologies.

Wider benefits

Long-term annual average agricultural and property damages were computed using the JBA in-house software called FRISM which implements the depth damage curves of the Multi-Coloured Manual developed by the Flood Hazard Research Centre at Middlesex University. The study also estimated the percentage area of catchments that the enhanced pond storage would need to occupy so that the dis-benefits of land sacrifice could be assessed.

The approach focused on agricultural damages saved but will also demonstrate the ecosystem benefits and dis-benefits associated with wetland creation and pond storage. Ecosystem services are discussed in relation to the WwNP land use changes. These are essentially:

- Wetland – improve wetland connectivity to construct seasonal or permanent features that store water, increase biodiversity and create green networks
- Storage areas – areas where existing storage could be expanded or new storage created to reduce the volume water in the channel
- Riparian woodland – investigated through modelling the impacts of tree planting in the areas identified by the Woodlands for Water approach (see Woodlands for Water case study)

Future research needs

A significant relationship was found between attenuation metrics (time-to-peak and peak flow reduction) and the amount of storage, area, and FEH descriptors (SPRHOST, BFIHOST, URBEXT) for the Ray catchment headwaters. This was applied to other headwater catchments in the rest of Oxfordshire. The relationship needs to be made more universal by incorporating the results from modelling from more catchments with different FEH descriptors before it could be applied, for example, nationally.

The approach could be applied to a range of WwNP measures, including soil improvement and afforestation. The approach provides one way to understand how attenuation for particular measures might change with catchment scale and typology.

5. Bibliography

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HANKIN, B., WALLER, S., ASTLE, G. AND KELLAGHER, R., 2008. Mapping Space for Water: screening for urban flash flooding. Journal of Flood Risk Management, 1 (1), 13-22.

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Project background

This case study relates to information from project SC120015 'How to model and map catchment processes when flood risk management planning'.

It was commissioned by the Environment Agency’s Evidence Directorate, as part of the joint Flood and Coastal Erosion Risk Management Research and Development Programme.

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