Case study 15

Hodder Catchment land use change study - Lancashire

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1. Catchment summary

Study location

The Hodder catchment in north-west England with an area of 260km2. It has upland moorlands and rural farming mainly comprising sheep and cattle grazing (Figures 1 and 2).

Figure 1: Rural upland catchment

Source: JBA Consulting

Figure 2: Land use management

Source: JBA Consulting

Catchment summary

The River Hodder, a tributary of the Ribble, has a mixture of rural diffuse pollution and water discolouration issues. This can be a problem for water abstracted for drinking supply because removing the peaty colour can be expensive. Work has been done in the upper Hodder catchment to tackle this issue including grip blocking (drains), tree planting, and reduction of sheep and cattle stocking densities under the United Utilities Sustainable Catchment Management Plan (SCaMP).

Study summary

The study investigated the impacts of land use and management change on downstream flooding at different scales. The Hodder catchment was selected because of the extensive upland restoration works being carried out by United Utilities as part of its SCaMP.

A multiscale nested monitoring approach was adopted using the JBA hosted Electronic Project Record (http://scamp.jbahosting.com) to try and understand how the impacts (quantified in terms of changes to flow hydrographs) of land use change propagate downstream to larger scales. An important question identified in an earlier joint Defra and Environment Agency Flood and Coastal Erosion Risk Management R&D Programme report (O'Connell et al. 2004) is whether land use changes significantly influence impacts at the catchment scale.

Although the models used in this case study are academic in nature and not suitable for general application, they have demonstrated a technique for understanding how the impacts of land use change can be detected.

More information on this project can be found at:

- SCAMP website (http://corporate.unitedutilities.com/cr-scamp.aspx)
- Environment Agency report - SC060092 - Multiscale Monitoring of Land Use and Flooding (http://evidence.environment-agency.gov.uk/FCERM/en/Default/FCRM/Project.aspx?ProjectID=03FA994C-DB80-4931-8027-3A15DDB022B5&PageId=a0fe6dfc-506a-452c-9bff-a7ec06b4e6b0)

Community involvement

This project involved engagement with land owners. Monitoring was funded by the Environment Agency and modelling was funded by the Natural Environment Research Council's Flood Risk from Extreme Event (FREE) and the Engineering and Physical Sciences Research Council's Flood Risk Management Research Consortium 2 (FRMRC2) programmes (with Imperial College).

2. Data summary

Datasets and analysis techniques used

The modelling made use of the following datasets:

- Hydrology of Soil Types (HOST)
- Digital Elevation Model (DEM)
- Centre for Ecology and Hydrology (CEH) Land Cover Maps (LCM2000, LCM2007)
- extensive rainfall and run-off time series

Data restrictions

Licenses were required for HOST, LCM2000 and DEM. Other datasets are available via the Electronic Project Record (http://scamp.jbahosting.com).

3. Model summary

Catchment processes investigated

The investigation considered the following processes:

- run-off generation

- catchment/land use change and the role of the channel network in propagating impacts

Model assumptions

Custom models were developed for application at the catchment scale:

- a gridded model that examines the sensitivity of the hydrograph peak at the catchment outlet to spatial changes in flashy run-off generation (O'Donnell et al. 2011, Ewen et al. 2013)
- a distributed conceptual model developed using Bayesian procedures to combine different sources of knowledge – used to evaluate scenarios of land use change in the Hodder (Bulygina et al. 2012)

In addition, a small scale physics-based model was developed to examine the hydrological impacts of grip blocking at the small (hillslope) scale (Ballard et al. 2012).

In terms of flood risk management, the study evaluated changes in the flood hazard and the uncertainty in the parameters controlling run-off generation. A number of events with different magnitudes were used, but the approach did not extend to evaluating the full flood frequency curve

Analysis of the hydrographs obtained from a nested multiscale river gauging network did not detect any significant short-term impacts to flood peaks, except at scales well below 1km2. However, the impacts of certain land use management changes, including tree planting and stocking density reductions, may differ in the longer term.

Data and model outputs

An Electronic Project Record (http://scamp.jbahosting.com) was compiled which contains all the data and background information on the catchment and the investigations. This includes an extensive network of rainfall, flow and weather data.

Custom models ere used that simulated run-off generation and river routing so that the effects of land use management change could be investigated and compared with the flow monitoring throughout the catchment.

Model performance

System performance in terms of failure is not as relevant for land use change, although the timing of the interaction of flood peaks from different subcatchments as a result of measures can be examined. The study focused on changes to the flood hazard and did not address ecosystem services.

4. Lesson learnt

Choice of tools

The field monitoring methodology may be of use in informing future monitoring programmes. A model developed under the FRMRC2 programme (Environment Agency 2015) was extended into a tool for investigating spatial patterns of land use change on downstream flooding. This model allows the user to design patterns of land use change through a graphical user interface and visualises the impacts using a range of hydrographs; the software tools are available for download from the FRMRC webpages hosted on the Heriot-Watt University website (http://web.sbe.hw.ac.uk/frmrc/software_tools.htm?pane=1). The tool also incorporated a Bayesian approach to knowledge updating.

Catchment scale and typology

Consideration of scale was central to the study, which aimed to address the following question: how do the impacts of local scale changes in run-off impact at downstream flood sites? It was found that the Hodder response is flashy and can be modelled relatively easily, and that the flows scale simply with upstream catchment area. It was also found that, if peak discharges for a storm event are known at one gauge, then good estimates can be made for the peak discharges at all other gauges using a regression based on contributing catchment area.

Wider benefits

Ecosystem services were not considered directly in this study, although the information on distributed land use would be useful to help quantify these. The SCaMP project seeks to improve how Working with Natural Processes (WwNP) can improve drinking supply through, for example, tree planting which leads to habitat improvement and increased diversity.

Future research needs

The research shows that the Hodder flood response has a strong, simple sensitivity to weather variability but a weak, complex sensitivity to changes in land use management. These were investigated by using adjoint modelling, which had rarely been used previously in hydrologic modelling (Environment Agency 2015). This was combined with a new methodology for dealing with uncertainty (Bulygina et al. 2012), which provides an estimate of the sensitivity of a model output with respect to a model input. For example, to investigate the impacts of land use management on flooding, the sensitivity of a flood peak with respect to each parameter controlling run-off generation can be calculated. The adjoint model is created by differentiating the model source code, line by line, using a process called reverse algorithmic differentiation. The model is initially run forwards in time, tracking and recording the evolution of these derivatives and then, secondly, it tracks back in time to calculate the parameter sensitivities.

A core aim was to improve understanding of how impacts can propagate through a model and the catchment system across scales. Through the use of adjoint modelling, a concrete link was established between the parameters controlling run-off generation and the downstream flood peak.

5. Bibliography

The data from the project have also been used in the development of new models as part of the Natural Environment Research Council's FREE and the Engineering and Physical Sciences Research Council's FRMRC2 programmes.

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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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