Does re-meandering have an impact on flood risk reduction? A detailed case study from the Eddleston Water restoration project, Scotland

Le reméandrage a-t-il un effet sur la réduction du risque inondation ? Une étude détaillée du projet de restauration de la rivière Eddleston en Ecosse.

Isabelle Costaz[1], Andrew Black[1], Richard Williams[2], Chris Spray[1]

1 University of Dundee, Nethergate, Dundee, Scotland, DD1 4HN, United Kingdom
2 University of Glasgow, School of Geographical and Earth Sciences, Glasgow, Scotland, G12 8QQ, United Kingdom
i.c.m.costazpuyou@dundee.ac.uk

RÉSUMÉ

Le projet “Eddleston Water” fait partie du programme de recherche gouvernemental écossais portant sur les “Solutions fondées sur la Nature” et l’adaptation au changement climatique. Il s’intéresse à l’efficacité potentielle des mesures dites de gestion naturelle des inondations pour diminuer le risque vis-à-vis des populations aval et pour améliorer les habitats fluviaux. Démarré en 2009, il a permis la réalisation d’un nombre important de ces mesures (régulateurs naturels de débit, structures d’atténuation du ruissellement, mares, forêt alluviale, reméandrage) sur ce bassin-versant rural de 69 km² dans la région des Scottish Borders. Un programme de suivi de l’hydrologie, l’hydromorphologie et l’écologie a été mis en place pour évaluer l’impact sur le long terme de ces mesures sur la réduction du risque inondation et sur les milieux fluviaux. Les chroniques hydrologiques de ce réseau, sur la période 2011-2020 (2 années d’état initial, 7 années post travaux), sont analysées afin d’évaluer l’impact du reméandrage d’un tronçon de 1.5 km de la rivière (+18% de longueur) sur la réduction du risque inondation. Les résultats incluent l’évaluation des modifications de la forme des hydrographes, les changements géomorphologiques du tronçon d’après deux levés bathymétriques successifs, leurs effets sur sa capacité d’écoulement et la surface d’inondation, ainsi qu’une modélisation hydraulique 2D avant et après reméandrage.

ABSTRACT

The Eddleston Water Project is part of Scottish Government’s programme of research on nature-based solutions and climate change adaptation, with a specific focus on the potential effectiveness of Natural Flood Management (NFM) measures to reduce flood risk for downstream communities and improve riverine habitats. Begun with a scoping study in 2009, it has led to the implementation of a large number of NFM measures (high flow restrictors, run-off attenuation features and ponds, riparian woodland, re-meandering) in this 69 km² rural catchment, located in the Scottish Borders. An intensive monitoring programme has covered hydrology, hydro-geomorphology and ecology to assess the impact of the measures on flood risk reduction and river habitats on a long-term scale. Using the hydrological time series from the existing monitoring network (two years of baseline and 7 years post implementation), the impact of re-meandering a section of 1.5 km (+18% of the initial length) on flood attenuation over the period 2011-2020 is investigated. Results include the assessment of changes in hydrograph shape and peak flow values. Using topographic data from repeat surveys of the channel since the re-meandering took place, the geomorphological changes and their impacts on the river conveyance capacity and flood extent are presented. Finally, the changes in flood risk are investigated with a 2D hydrodynamic model of the river before and after re-meandering

KEYWORDS

Flood risk reduction, geomorphology, monitoring, re-meandering, restoration

1 INTRODUCTION

The Eddleston Water Project begun with a scoping study in 2009 has led to the implementation of a large number of NFM measures (high flow restrictors, run-off attenuation features and ponds, riparian woodland, re-meandering) in this 69 km² rural catchment, located in the Scottish Borders. The intensive hydrological monitoring network set up since the project inception and field-based work provide a valuable dataset. The focus of this PhD project is the re-meandered reach of the main channel over 1.5 km (+18% of the initial length). The impact this new channel might have on attenuating flood events is investigated over the period 2011-2020.

2 MATERIALS AND METHODS

The study was conducted on the Eddleston Water, north of the city of Peebles, where a section of 1.5 km of straightened channel has been re-meandered by stages between summer 2013 and summer 2016. The Q_{med} is now estimated around 11.5 m^3/s with an average channel width of 5 m at the studied reach.

Three methods were used to assess the role the re-meandering. Firstly, the empirical time series from the existing monitoring network (two years of baseline and 7 years post implementation) were analysed to compare different metrics before and after the re-meandering (peak travel times, rates of rise and fall, ratio of volume/event duration, ratio of peak flow/event volume, empirical median hydrograph shape). Secondly, a new topographic survey of the channel bathymetry was implemented in May 2020 and compared with a former survey done in April 2018. The geomorphic changes over this 2 years period were estimated using the GCD tool and the evolution of geomorphic units using the GUT tool. Thirdly, a 2D hydrodynamic model (HEC-RAS 6.0) was built to model design flow events (Q2y, Q5y, Q10y, Q20y, Q50y) with 3 different terrains: the straightened channel, the re-meandered April 2018 and May 2020 channels. The outputs were analysed to assess the potential differences in flood risks between the 3 channel morphologies.

3 RESULTS AND DISCUSSION

Analysis of the empirical time series show mixed results, with among the 5 metrics used only two showing changes that are statistically significant between before and after the re-meandering. The increase in median peak travel time for in-channel events during the re-meandered period is statistically significant but limited (+23min). The ratio of peak flow value over event duration for in-channel events has decreased significantly (-14%). These results point towards an increase of flow attenuation linked to the re-meandering for in-channel events. However, for overbank events, only the peak travel time shows a decrease that is close to, but not statistically significant due to the re-meandering. The high flow events selected for this analysis are limited in number, size and samples size differ by season due to the local shift of climate. High flow events before the re-meandering were mostly summer events while it is the opposite since the re-meandering was implemented. That difference in seasonality might have affected the analysis.

Comparison of the datasets collected during the two topographic field surveys in April 2018 and May 2020 shows that the re-meandered reach has been degradational over this period, 4 years after the completion of the works (Fig.1a). Vertical incision is identified on the long profiles with erosion representing a Total Net Volumetric Difference of -471 ± 280 m^3 for a total of 635 ±320 m^3 (Fig.1b).

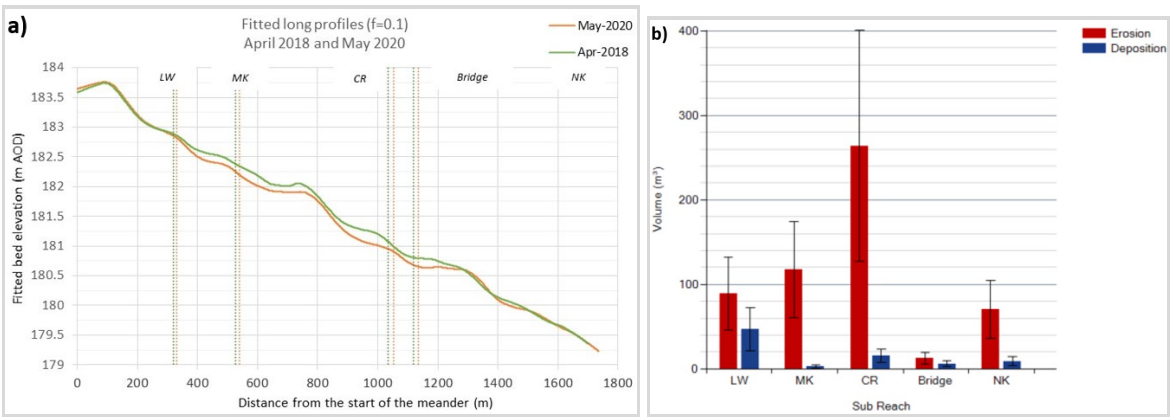

Fig.1 - Evolution of the re-meandered channel geomorphology over the period April 2018/May 2020 (with a Lowess smoothing method) a) Evolution of the long profile b) Thresholded volumetric change distribution by sub-reach (GCD Tool)

Bank erosion is the dominant process at play. Felled trees across the channel are linked to some local deposition. The geomorphic units have evolved between the two surveys by increasing their coverage (+10%), with their assemblage remaining over the period. These geomorphic changes are the result of a limited high flow regime with a total a 13 small high flow events over the period (between Q1y and Q2y) and only one Q2.5y event. They are slightly higher than the changes recorded at the Allt Lorgy restoration project in Scotland. The volume of sediment eroded is small in comparison to the volume of a flood event and might not be of importance to change the flood extents.

Results from the 2D hydrodynamic models are still being investigated. However, the first results suggest that the geomorphic changes between April 2018 and May 2020 are not significant enough to impact the dynamic of the flood, but the incision is decreasing the flood extent by not more than -4% for the smallest event (Q2y). Comparison to the straightened channel seems to show very limited signs of decrease in flood extent and peak flow (Fig.2)

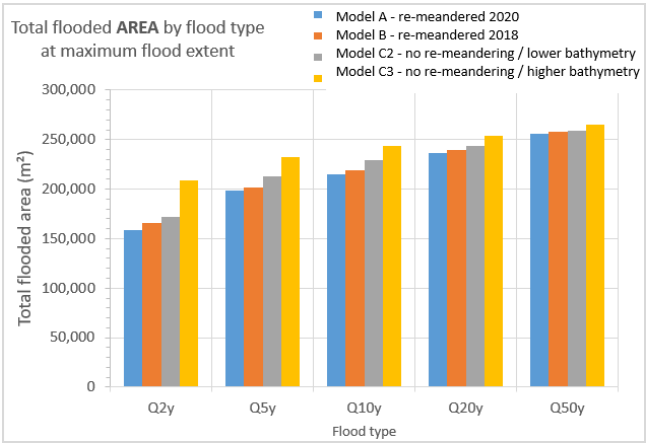

Fig.2 - Comparison of the maximum flood extent by flood size for all models

4 CONCLUSION

This PhD project will give insights into overall trends and the quantification of the impact such re-meandering can have on high flows. The findings tend to show that re-meandering a river with the characteristics of the Eddleston Water, over a final length of 1.5 km (+18% of the initial length) will have a limited impact on attenuating the flood risk.

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