Development of a bank erosion modelling tool for informing catchment management.

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Introduction

Increased sediment loads within river catchments have several detrimental environmental effects. To comply with the EU Water Framework Directive (WFD) catchments should regulate sediment levels. Quantification of gaps between current and required sediment levels inform policy decisions. Modelling is used to predict changes in sediment concentrations in future climate and land-use scenarios and as a result of management options.

Aims of Project

Current sediment generation models do not explicitly include bank erosion as a sediment source. Channel bank erosion has been noted as a sediment source in several studies and in some catchments may significantly contribute to the total sediment budget (see Figure 1). Numerous factors influence bank erosion rates and as a result, the rate of channel bank erosion varies greatly between and within individual catchments. Therefore the aims of this project include:

- Analysis of relationships between bank erosion and controlling factors not currently included within bank erosion models
- Development of a regression equation and evaluation of the predictive capabilities of these factors
- Development of a computationally efficient bank erosion modelling technique which may be coupled to existing sediment generation models.

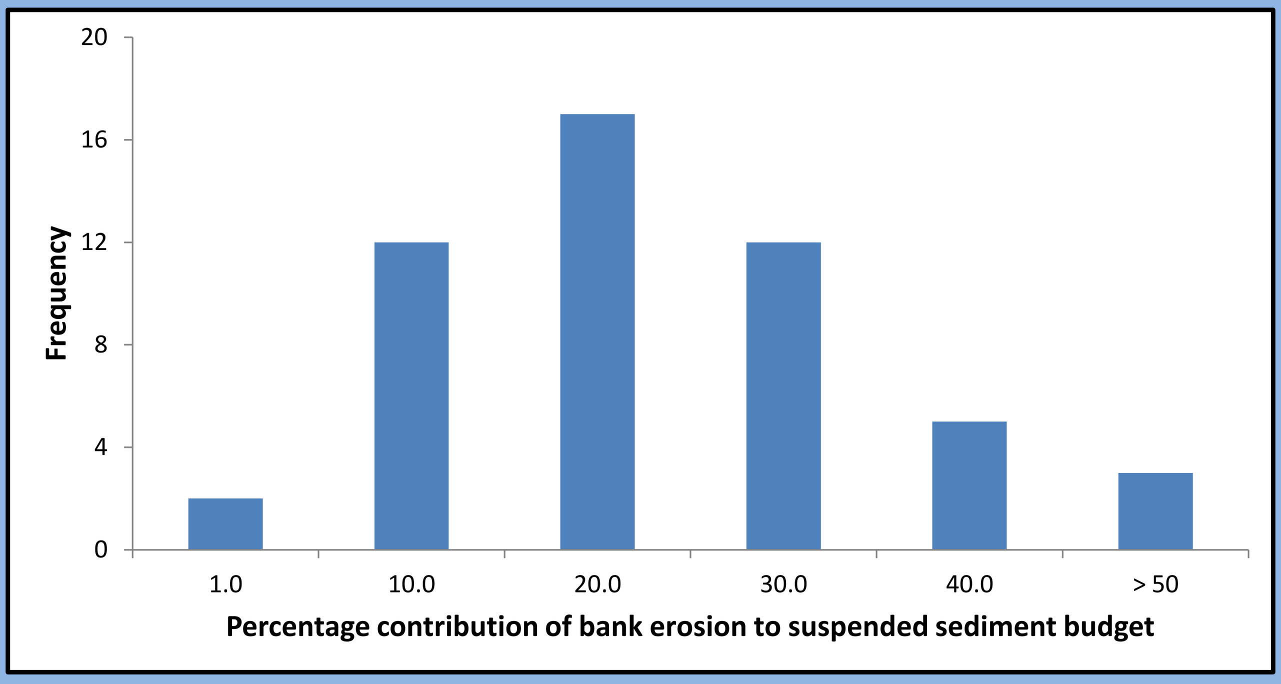

Figure 1: Histogram illustrating percentage contribution of bank eroded sediment to the catchment sediment budget for several UK catchments.

Methodology

Several channels from UK catchments were digitised in GIS from historical OS maps. Erosion area between time periods was calculated using an adapted method of simple polygon overlay analysis as described by Gurnell *et al*, (1994). This was converted into a mass of sediment using bank heights taken from River Habitat Survey data and assuming a bulk density of 1400kg/m3. Values of erosion in kg/ha/yr and bank retreat rates (m/yr) were calculated . for individual WFD sub-catchments, in addition to channel sinuosity, slope, confinement within the valley and upstream area . Relationships between these variables were analysed using correlation and regression techniques.

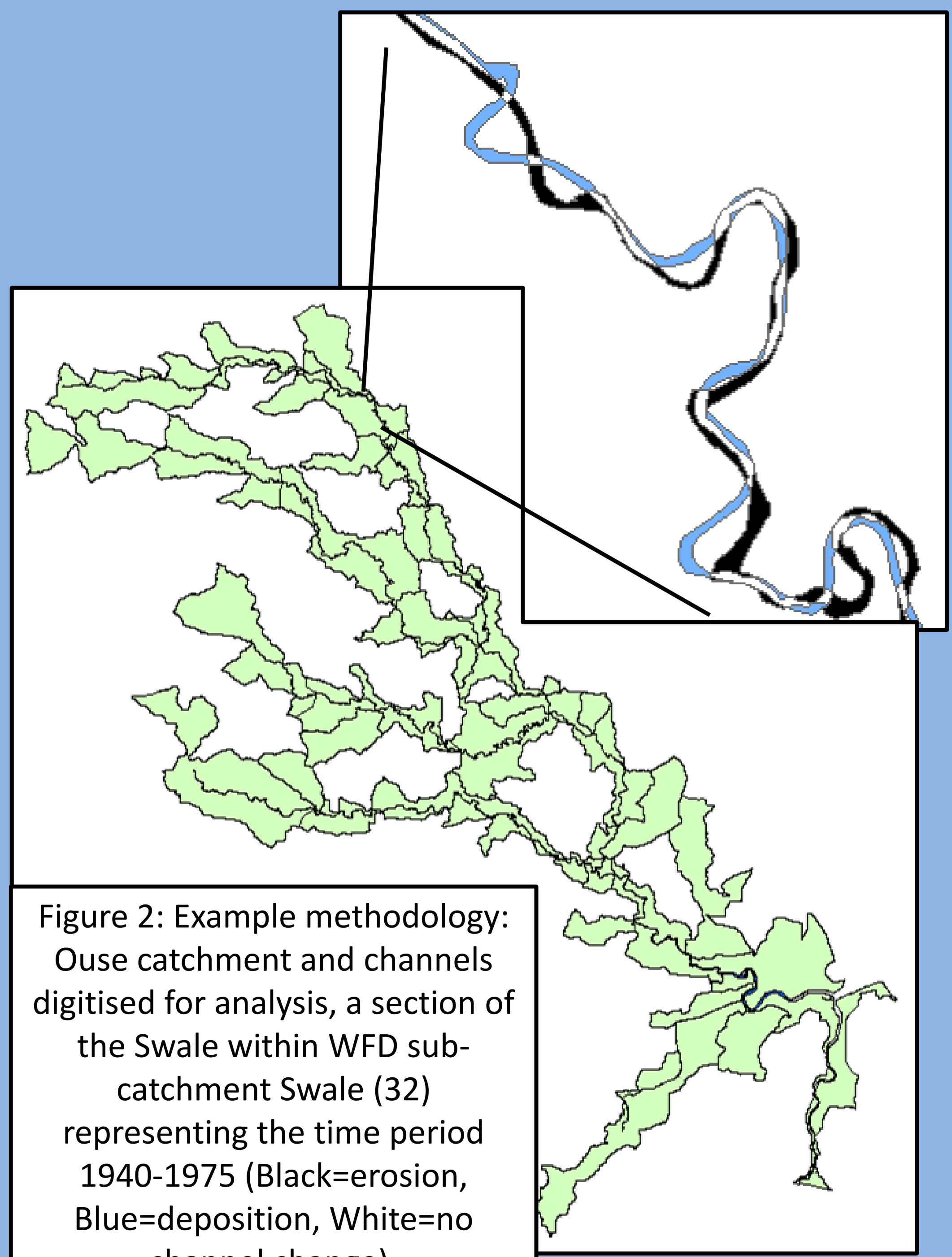

Figure 2: Example methodology: Ouse catchment and channels digitised for analysis, a section of the Swale within WFD sub-catchment Swale (32) representing the time period 1940-1975 (Black=erosion, Blue=deposition, White=no channel change).

Results

Correlations observed between variables and regression coefficients are indicated in table 1. Residual analysis indicates the model performs well and does not violate the assumptions associated with linear regression.

	Erosion kg/ha/yr	Width averaged retreat rate m/m/yr
Sinuosity	0.393*	-0.214
Slope	-0.028	0.263*
Upstream Area	0.311*	-0.544*
Channel confinement	0.087*	0.569*
R	0.461	0.812
R²	0.212	0.660

Table 1: Pearson's correlation and regression coefficients from analysis. Red asterisks indicate variables included in the final regression equation.

The results highlight the importance of bank erosion as a sediment source and variability of bank erosion within and between catchments. Statistically significant relationships were found between bank erosion rate and sinuosity, slope (width averaged retreat rate only), upstream area, and channel confinement.

The regression relationship of erosion in kg/ha/yr is weaker than that of width averaged retreat rate. This may be due to the lack of incorporation of changing channel depth within the model when calculating mass of eroded sediment, as one channel depth was assumed for each sub-catchment using RHS bank height data.

Relationship with Sinuosity

It was noted that the relationship with sinuosity is non-linear (see figure 3). Bank erosion increases with increasing sinuosity up to a threshold value, and then decreases with any further increase in sinuosity.

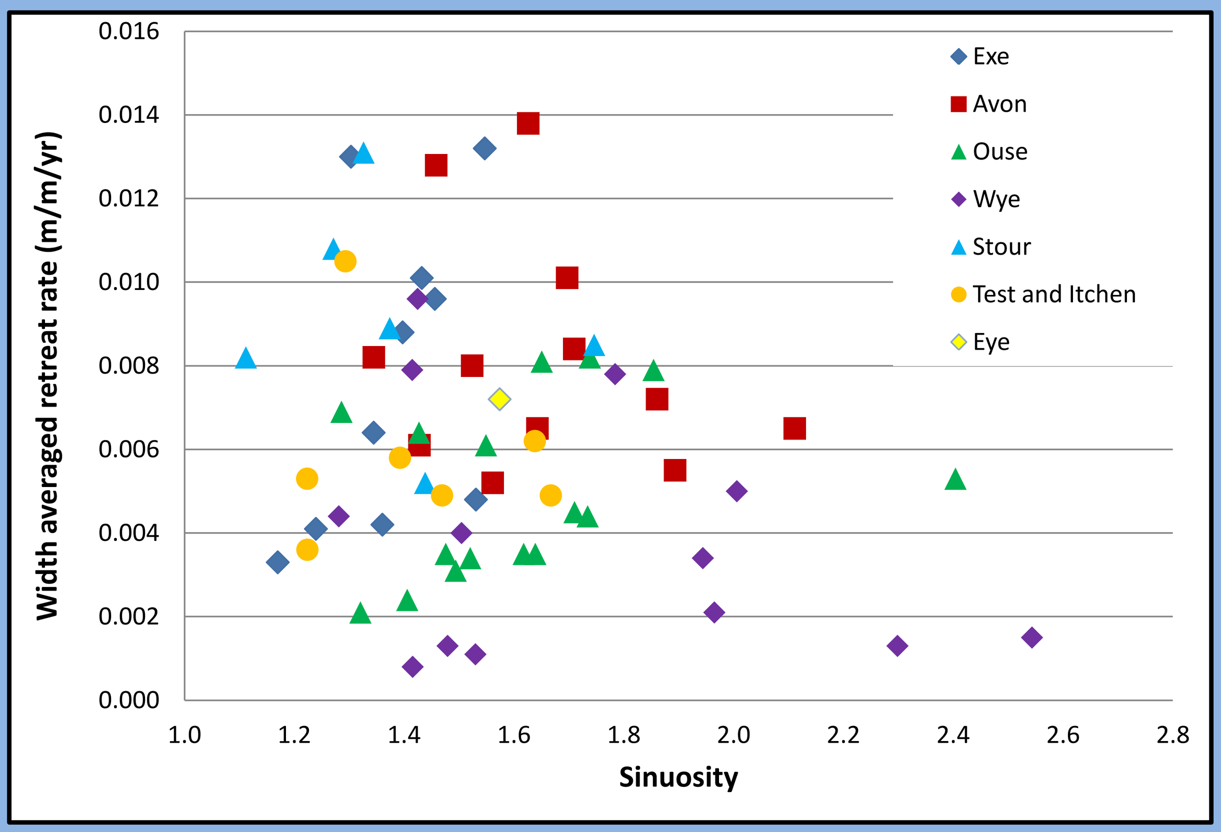

Figure 3: Scatterplot of sinuosity and width averaged retreat rate.

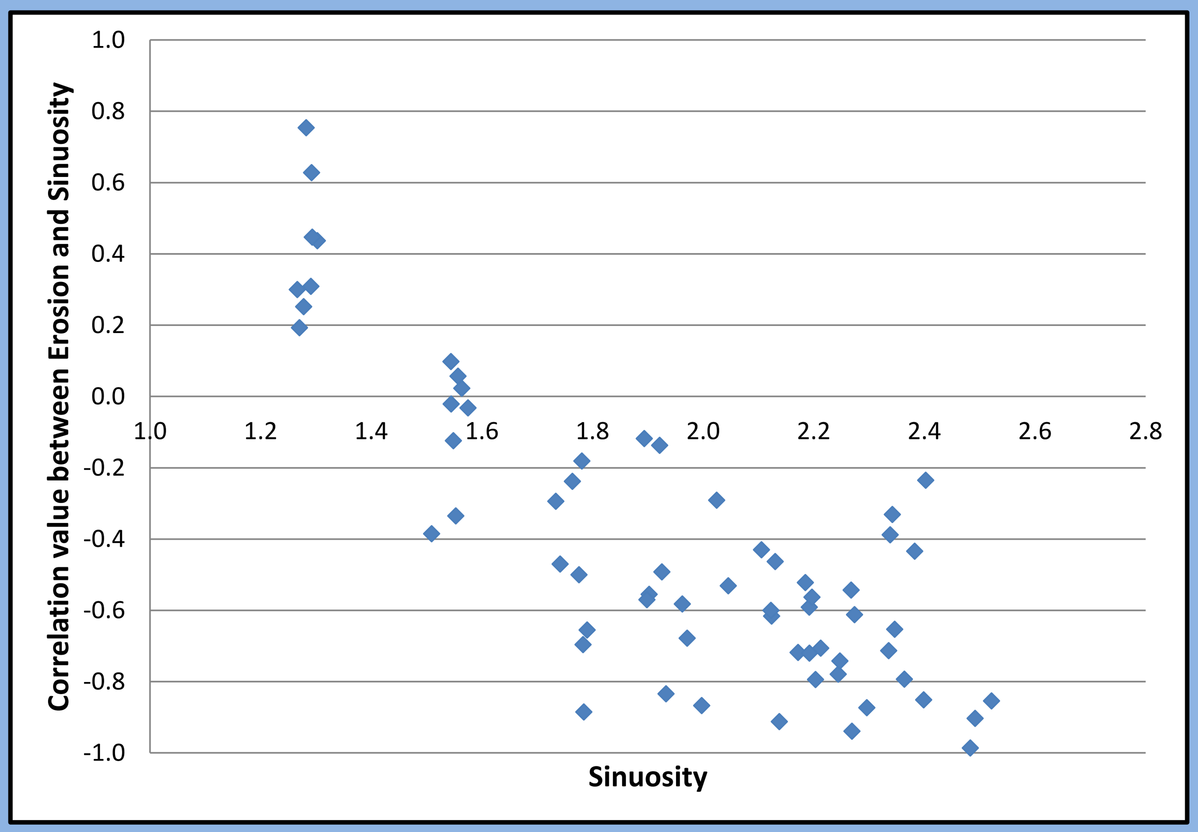

Figure 4: Scatterplot of sinuosity and correlation between sinuosity and erosion rate from Howard and Knutson model outputs.

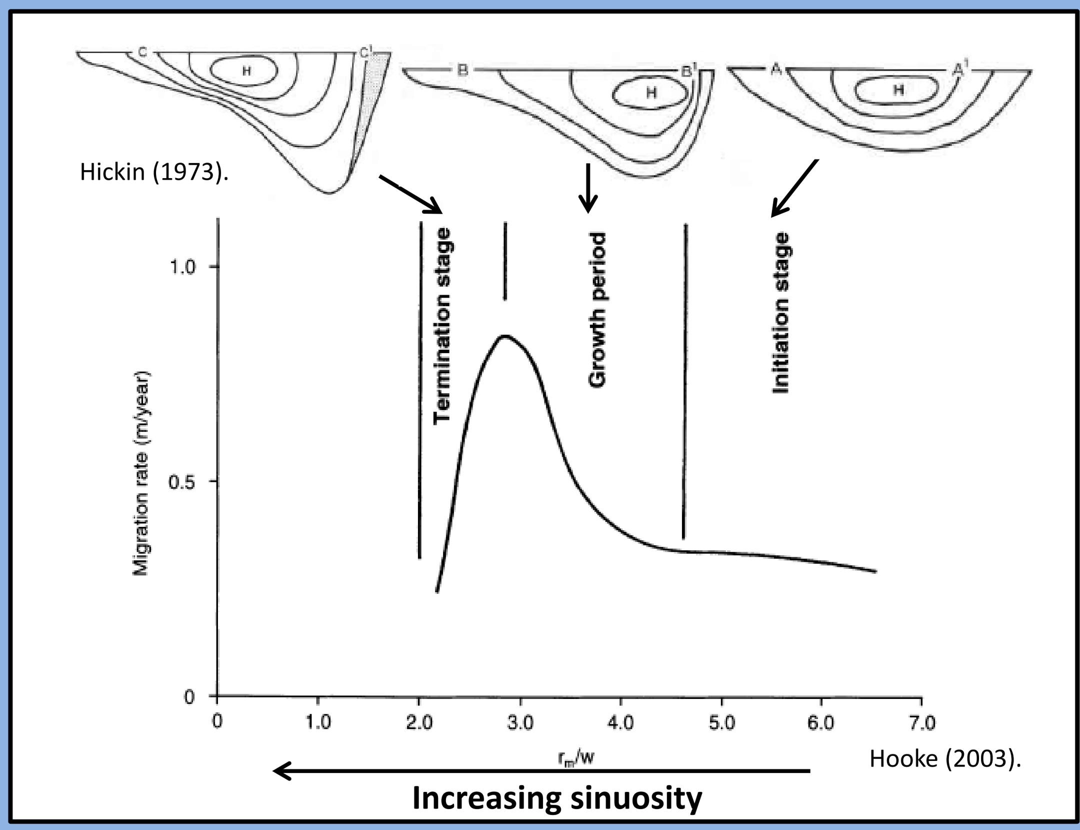

Figure 5: Relationship between radius of curvature and bank erosion, and changes in positioning of secondary flow.

The Howard and Knutson meander migration model (Howard and Knutson, 1984) was calibrated for UK channels and run using a range of calibrated parameter value combinations. The long-term relationship between bank erosion and sinuosity was then investigated.

The relationship between bank erosion and sinuosity is positive for values of sinuosity <~1.5, and negative for values of sinuosity >~1.5 (see figure 4). This is due to the change in positioning of secondary flow within the channel according to the sinuosity, or radius of curvature of the channel (see figure 5).

Further work

- Incorporate these factors into an existing bank erosion index.
- Incorporate within a flow routing model and couple with a floodplain sedimentation model.
- Couple to an existing sediment generation model to enable improved accuracy of sediment generation predictions.

References:

- Gurnell *et al, (1994) Channel planform change on the river Dee meanders, 1876-1992, Regulated rivers research and management* ***9, 187-204.***
- Hickin, E. J. (1978) Mean flow structure in meanders of Squamish River, British-Colombia, *Canadian Journal of Earth Sciences, 15****, 1833-1849.***
- Hooke, J. (2003) River meander behaviour and instability: a framework for analysis. *Transactions of the Institute of British Geographers, 28****, 238-253.***
- Howard and Knutson (1984) Sufficient conditions for River Meandering: A Simulation Approach, *Water Resources Research* ***20(11), 1659-1667.***