Development of a technique to model the volume of sediment generated by bank erosion processes within UK catchments.

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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 the 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 (Bull, 1997; Walling *et al*, 2008).

There are numerous factors influencing bank erosion rates which have complex inter-relations (see figure 1). 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.

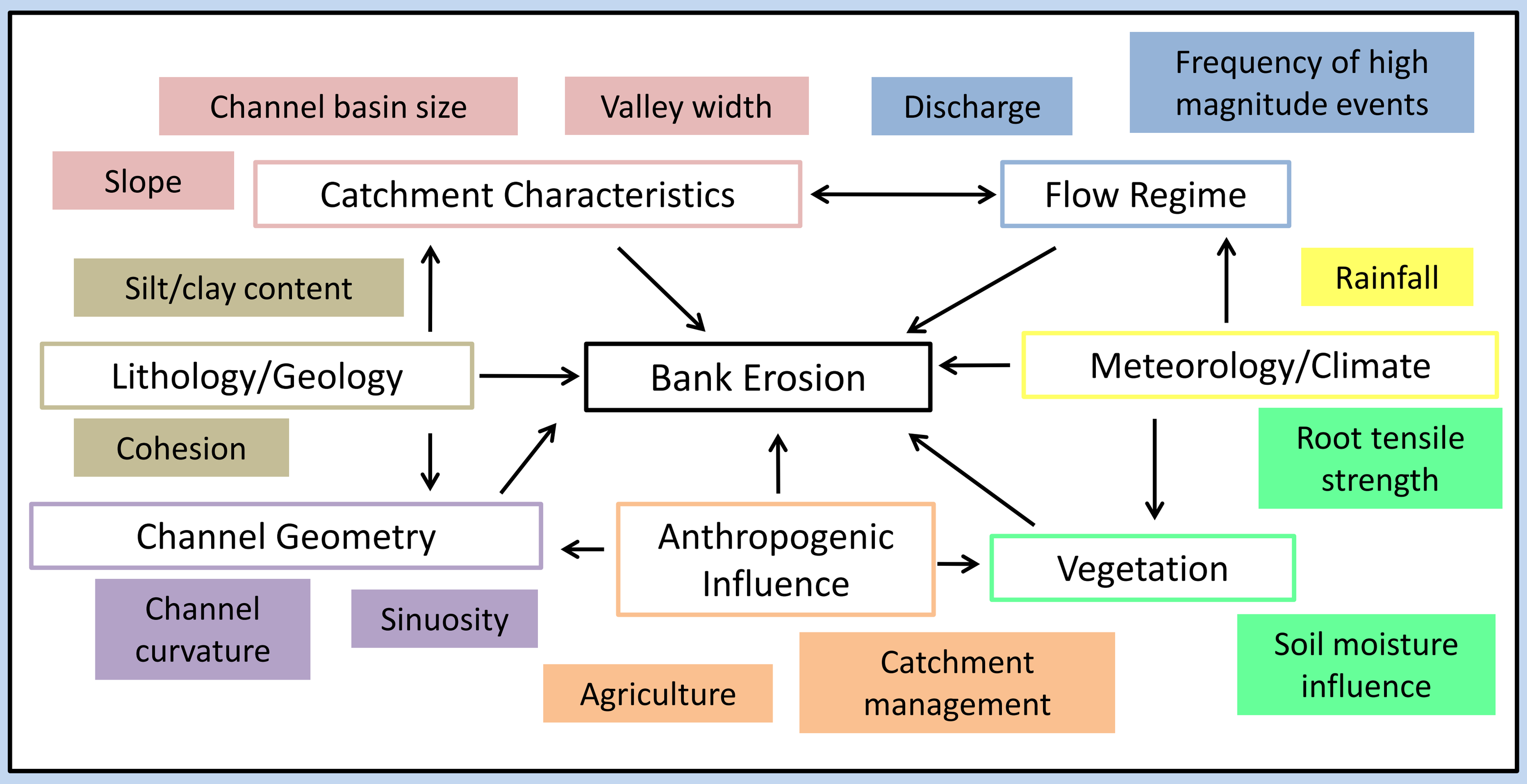

Figure 1: Factors influencing channel bank erosion.

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/m^3. From this, values of erosion in kg/ha/yr and bank retreat rates (m/yr) were calculated .

Estimates 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.

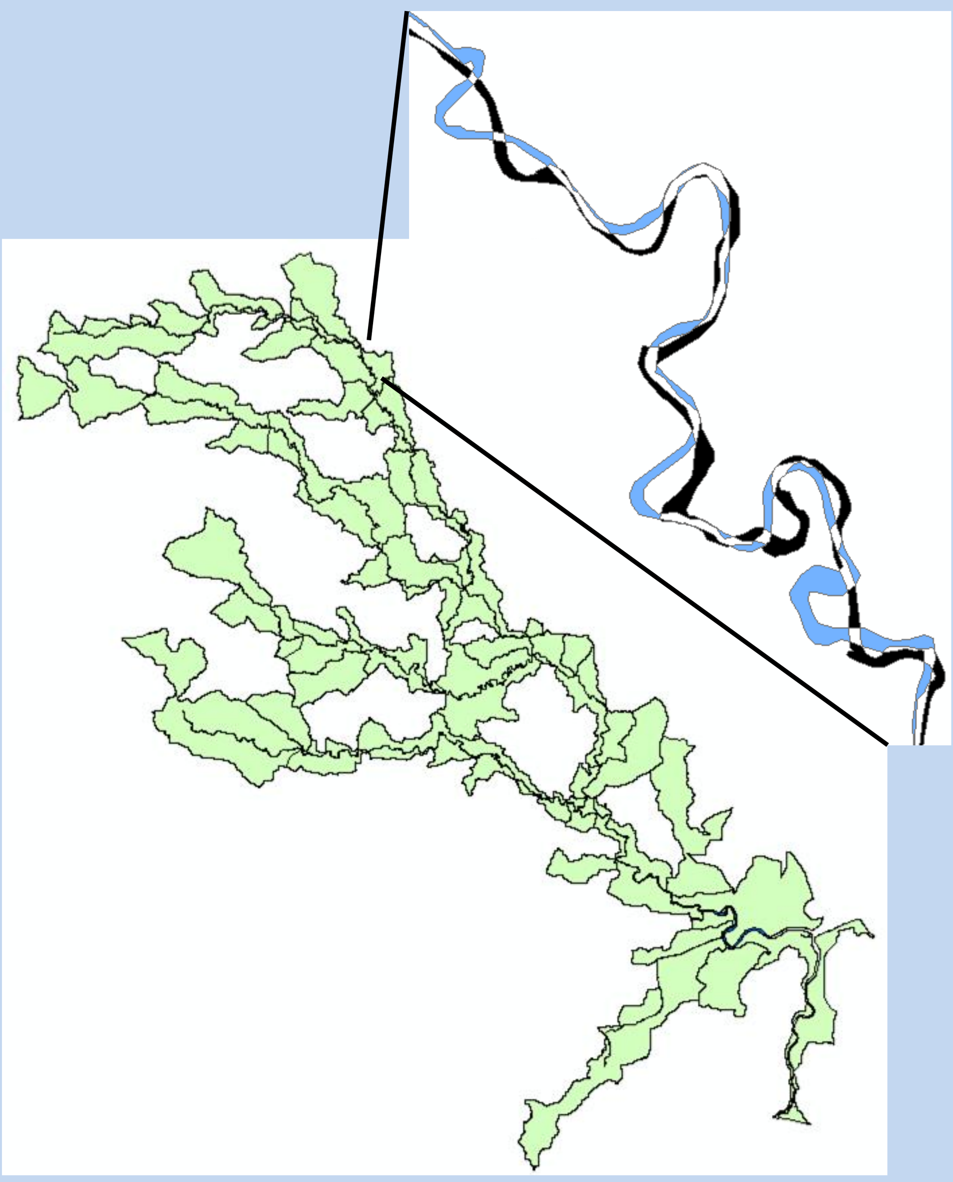

Figure 2: Example methodology: Ouse catchment and channels digitised for analysis, a section of the Swale within WFD sub-catchment Swale (32) representing the time period 1940-1975 (Black=erosion, Blue=deposition, White=no channel change).

Relationship with Sinuosity

It was noted that the relationship with sinuosity is only linear up to a threshold value, after which further increase in sinuosity does not results in an increase in bank erosion. The Howard and Knutson meander migration model (Howard and Knutson, 1984) was used to further investigate this relationship (see figure 3) and a threshold sinuosity value of ~1.5 was observed.

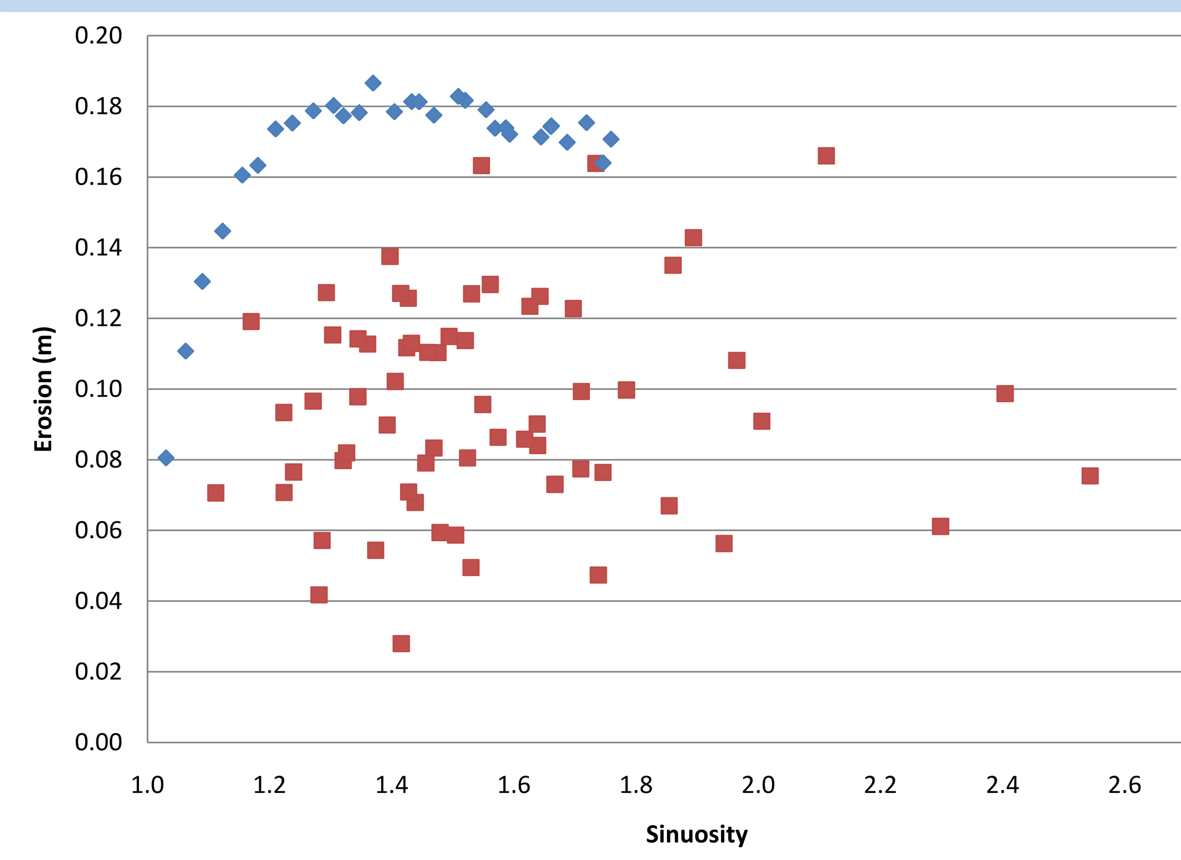

Figure 3: Scatterplot of sinuosity and erosion for Howard model output and GIS erosion estimates. Values of erosion and sinuosity from the model output were averaged from 200-500 iterations to allow for model initialisation.

Results

Bank erosion rates from GIS were calculated as a volume of sediment (kg/ha/yr) and also as a width averaged rate of bank retreat (m/yr). 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.

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

	Erosion kg/ha/yr	Width averaged retreat rate m/yr
Sinuosity	0.395*	-0.219
Slope	-0.047	0.196*
Upstream Area	0.314*	-0.482*
Channel confinement	0.101*	0.533*
R	0.460	0.812
R^2	0.172	0.660

The results highlight the importance of bank erosion as a sediment source and indicate a statistically significant relationship between bank erosion rate and sinuosity, slope (width averaged retreat rate only), upstream area, and channel confinement. However, when using width averaged retreat rate as the dependent variable, the regression statistic for sinuosity is not significant so it is removed from the equation.

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.

Residual Analysis

Within individual sub-catchments with high residual values, factors not included in the regression model were analysed including catchment geology and land use/cover using Land Cover Map 2007 and Digimap data. There was only one high residual (>2.5 or <-2.5) for each regression equation:

- Erosion (kg/ha/yr) regression: Wylye (11) = -3.14, model over predicts as channel banks within sub-catchment are covered with vegetation, decreasing erosion rates (Simon and Collison, 2002).
- Width averaged retreat regression: Bourne (5) = 3.39, model under predicts as chalk geology of sub-catchment of low strength, arable land-use and sub-urban areas, all increase bank erosion rates (Micheli *et al*, 2004; Nelson and Booth, 2002).

Further Work

The relationship between sinuosity and bank erosion will be explored further and the use of non-linear regression to represent this relationship will be assessed.

Individual sub-catchments with high residual values will be examined using the Howard and Knutson and Lancaster (Lancaster and Bras, 1992) models. As these models incorporate the effects of channel curvature and topographic steering on bank erosion the output from these models should explain some of the differences between the observed GIS and regression predicted values of bank erosion.

The bank erosion technique will then be coupled to an existing sediment generation model to provide improved accuracy of sediment delivery predictions.

References:
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