Bank retreat study of a meandering river reach case study: River Irwell

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Abstract
Lack of data is often considered a limitation when undertaking morphological studies. This research deals with the morphological study of a small river experiencing bank erosion for which only limited data are available. A reach of the meandering gravel-bed river Irwell (United Kingdom) is taken as a case study in order to analyze the bank retreat process that is endangering the stability of structures located in the area.

Two models of different complexity have been applied: A one-line meander migration model MIANDRAS and a 2D model built up using the Delft 3D software. The simple meander model produces satisfactory results in much less time using less data. The results show that the morphological development of the river may endanger the existing structures within the next five years, if no mitigation works are carried out.

Introduction
Free river meandering causes often a threat to existing structures along the river. To prevent problems, morphodynamic studies are useful. However, lack of data is often a limitation. The objective of this study is to determine a convenient type of modeling to assess future river migration trends of small meandering rivers with scarce available data. The study will be done by comparing two models of different complexity. For this purpose, a reach of the River Irwell, in the United Kingdom, is taken as a study case.

Material and methods
The two models are built using: MIANDRAS (Crosato, 2008,1990) and Delft 3D (Lesser et al., 2004). The first one is a one-line meander migration model in which channel migration is related to the mean bank flow properties. The second is a 2D model in which bank erosion calculated with the dry-wet cell method (Van der Wegen et al. 2008). The models are first calibrated on the period 2003-2006 and thereafter, they are used to simulate the future river changes for the period 2006-2010.

Study area description
The study area is located east of Rawtenstall, Lancashire, United Kingdom. The River Irwell has its origin in the Irwell spring, 427 m above the mean sea level and the total area of the river basin contributing to the study reach is 120.7 Km^2. Channel migration is rather fast in the last years and may endanger the stability of existing structures: a weir, the A56 motorway bridge and a railway embankment. The main river characteristics are listed in Table 1.

Table 1 Main characteristics of the study reach

Length study reach (Km)	1.00
Channel width (m)	11.80
Bed slope (%)	0.53
Mean discharge in 2006 (m^3/s)	3.50
Highest discharge (1996-2006) (m^3/s)	53.00
Bankfull discharge (m^3/s)	45.00
Mean sediment size D_{50} (mm)	11.20

Available data
A field survey was carried out in order to obtain more information about the river, such as the sediment characteristics. The topography data includes cross sections and LiDAR data, both of them property of The Environment Agency. A satellite image dated to June 2006 and a set of photographs of year 2007 are the only source of information of historic river planimetry. The main source of hydrological data is the Irwell Vale gauging station. A second source of information is an existing flow model.

Results
The models have been calibrated on the period 2003 to 2006. River alignment and bed topography computed with MIANDRAS are shown in Figure 1. The results are satisfactory because they match both bed topography, in terms of location of point bars and pools, and river alignment. Use of lower erodibility coefficients in areas with herbaceous vegetation and in the railway embankment contributed to better simulate the river behavior.

The one-line meander model predicts well the magnitude and location of the bars present in the river except bars 8 and 9 (Fig. 1). MIANDRAS does not have the option to model weirs, therefore the effect caused by the weir upstream of the bridge is not considered in the results. The back water effect of the weir reduces flow velocity and sediment transport capacity so that sedimentation takes place. As a consequence of flow velocity reduction the bar number 5 is larger than model prediction and bar number 9 does not exist.

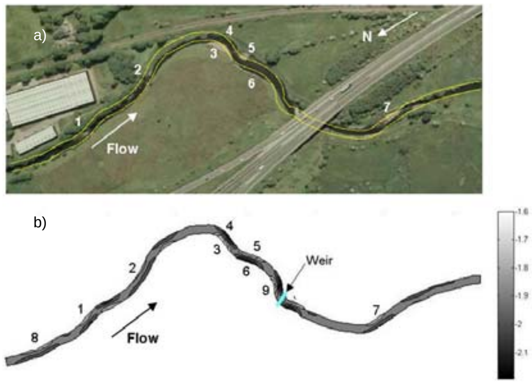

Figure 1 River characteristics in 2006 computed with MIANDRAS (a) River alignment (b) Bed topography.

River alignment and bed topography computed with Delft 3D are shown in Figure 2. The results show that the river becomes wider because the bank advance process is not taken into account and because the dry wet cell method promotes erosion even in straight reaches. The model assumes that the bank erodibility is uniform which may apply when the bank material is homogeneous, geotechnical properties are uniform and external loads and vegetation are the same along the river banks. However, these conditions are not the case of River Irwell. Therefore, uniform bank erodibility does not reproduce the river natural behavior.

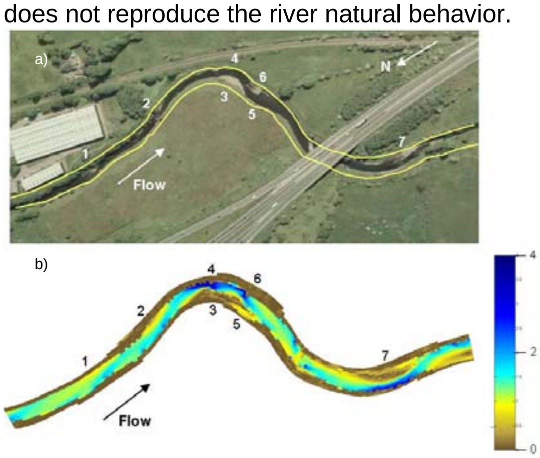

Figure 2 Characteristics in 2006 computed with Delft 3D (a) River banks alignment. (b) Bed topography.

The model reproduces well the reach downstream of the weir. However the results also show that point bar 3 is larger than the existing one. The erosion of the outer bank is overestimated in 4 which results in washing away bar 6. Additionally, the bank retreat process 5 that takes place downstream of the point bar 3 is not represented by the model and the existing pool is filled with sediment.

The future planimetric changes (Fig. 3) computed with MIANDRAS show that in 2010 the river starts to erode the area upstream and downstream of the weir. However, this is most probably overestimated. The model indicates that by year 2010 the left river bank might reach the railway embankment toe. The future planimetric changes computed with Delft 3D are characterized by non-realistic channel widening.

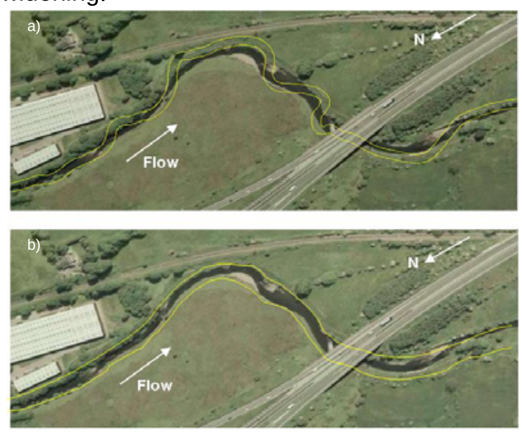

Figure 3 Irwell alignment prediction year 2010 a)MIANDRAS b)DELFT 3D

Conclusions

For the case of the River Irwell reach MIANDRAS appears the most suitable tool to compute the planimetric changes. Non-realistic widening obtained with Delft 3D model is due to the simplified bank erosion formulation and due to the lack of a bank accretion formulation. It is strongly recommended to include bank erosion and bank accretion in Delft 3D

Acknowledgements

This study was carried out with the support of UNESCO-IHE institute for water education, The Netherlands Fellowship Program and Edenvale Young.

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