Removal of River Embankments and the Modelled Effects on River-Floodplain Hydrodynamics

H.M. Clilverd[1], J.R. Thompson[1], C.M. Heppell[2], C.D. Sayer[1], and J.C. Axmacher[1]

[1]UCL Department of Geography, University College London, Gower Street, London, WC1E 6BT, UK
[2]The School of Geography, Queen Mary University of London, Mile End Road, London, E1 4NS, UK

EGU2015-12974

Introduction

- The channelization and embankment of rivers has led to major ecological degradation of aquatic habitats worldwide. Floodplain restoration, through embankment removal and the reconfiguration of river channels, is now widely employed to re-establish river-floodplain connection.
- However the effects of river restoration on hydraulic, hydrological and ecological processes are often difficult to determine due to the infrequency of long-term monitoring before and after restoration.
- Hydrological models are increasingly used to better understand the effects of river restoration activities under a variety of hydrological conditions. This study uses hydrological models to assess the impacts of river restoration at Hunworth Meadows on the River Glaven, a small lowland, calcareous river in North Norfolk, UK (Fig. 1).

Research questions

1) What are the effects of embankment removal on key components of river-floodplain hydrology (e.g. water table elevation, frequency and extent of floodplain inundation, flood peak attenuation)?

2) How will embankment removal impact river-floodplain hydrology under a range of expected river flow conditions?

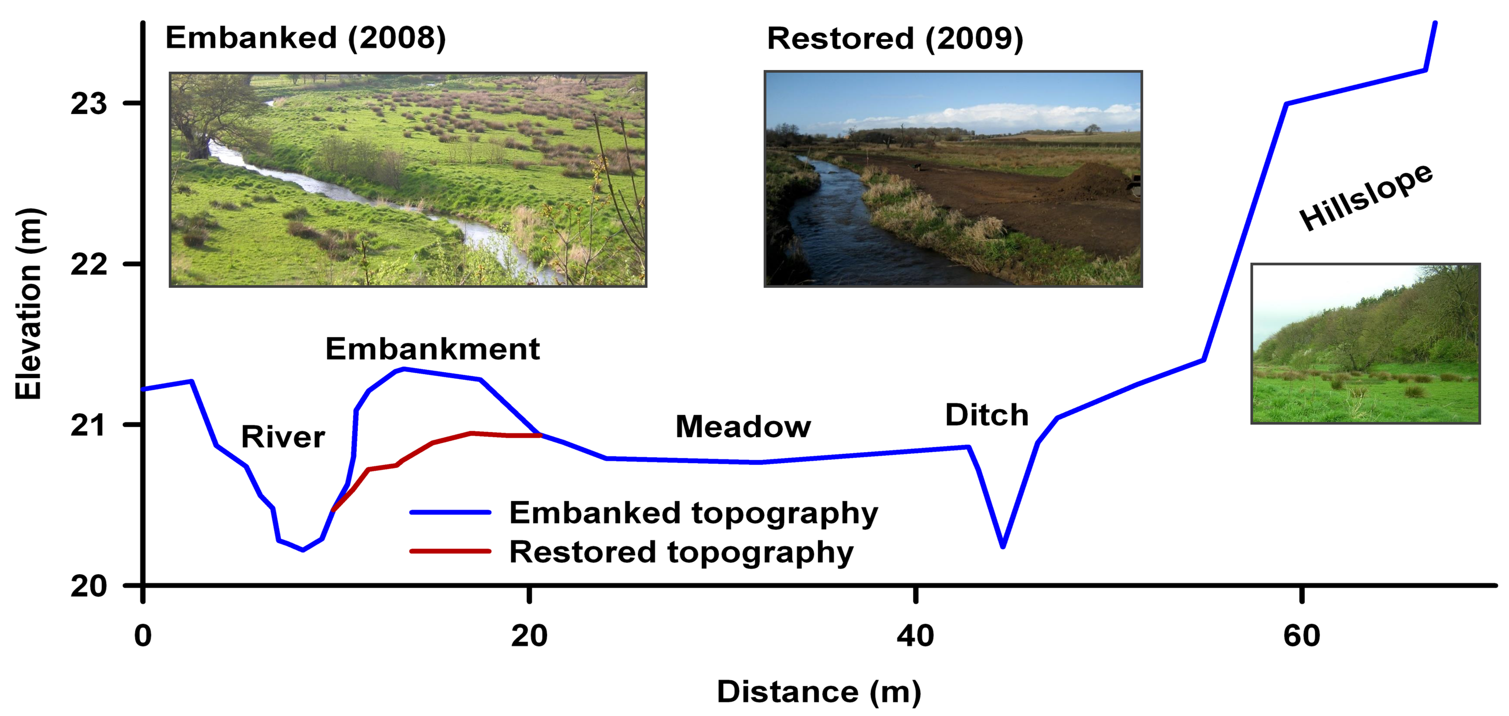


Figure 1: Cross-sections of the embanked and restored River Glaven floodplain.

Methods

- Coupled MIKE SHE/MIKE 11 hydrological/hydraulic models were developed for pre-restoration (embanked) and post-restoration (no embankment) scenarios on the River Glaven (Fig. 2).
- Surface topography and river cross-sections were surveyed using dGPS.
- Over three years of river discharge and, meteorological data, and observations of well water levels were, respectively, used to parameterise and calibrate/validate the models.
- Soil properties were varied during calibration but were guided by results from piezometer slug tests and measurements of the water release characteristic.
- Floodplain hydrology before and after the restoration were simulated under identical climatic conditions.

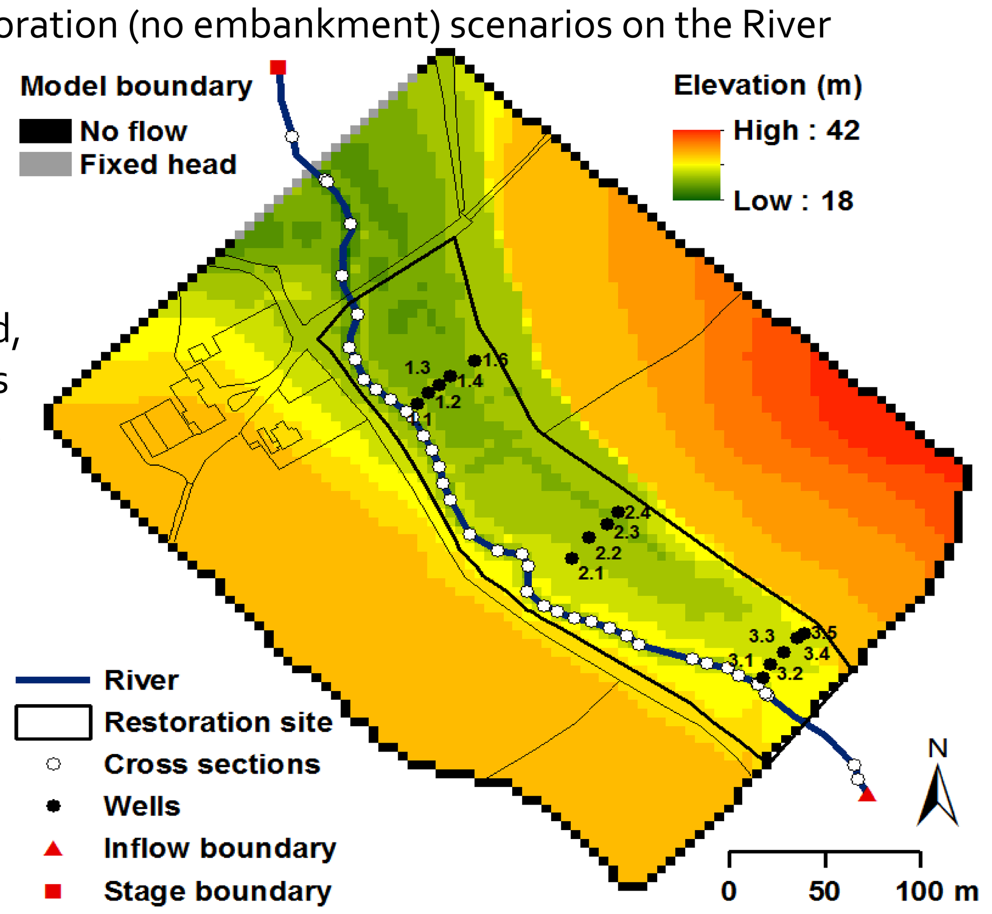


Figure 2: MIKE 11 river channel, cross-sections, and surface water boundary conditions of Hunworth Meadow superimposed upon the MIKE SHE model DEM (5 m grid).

Results

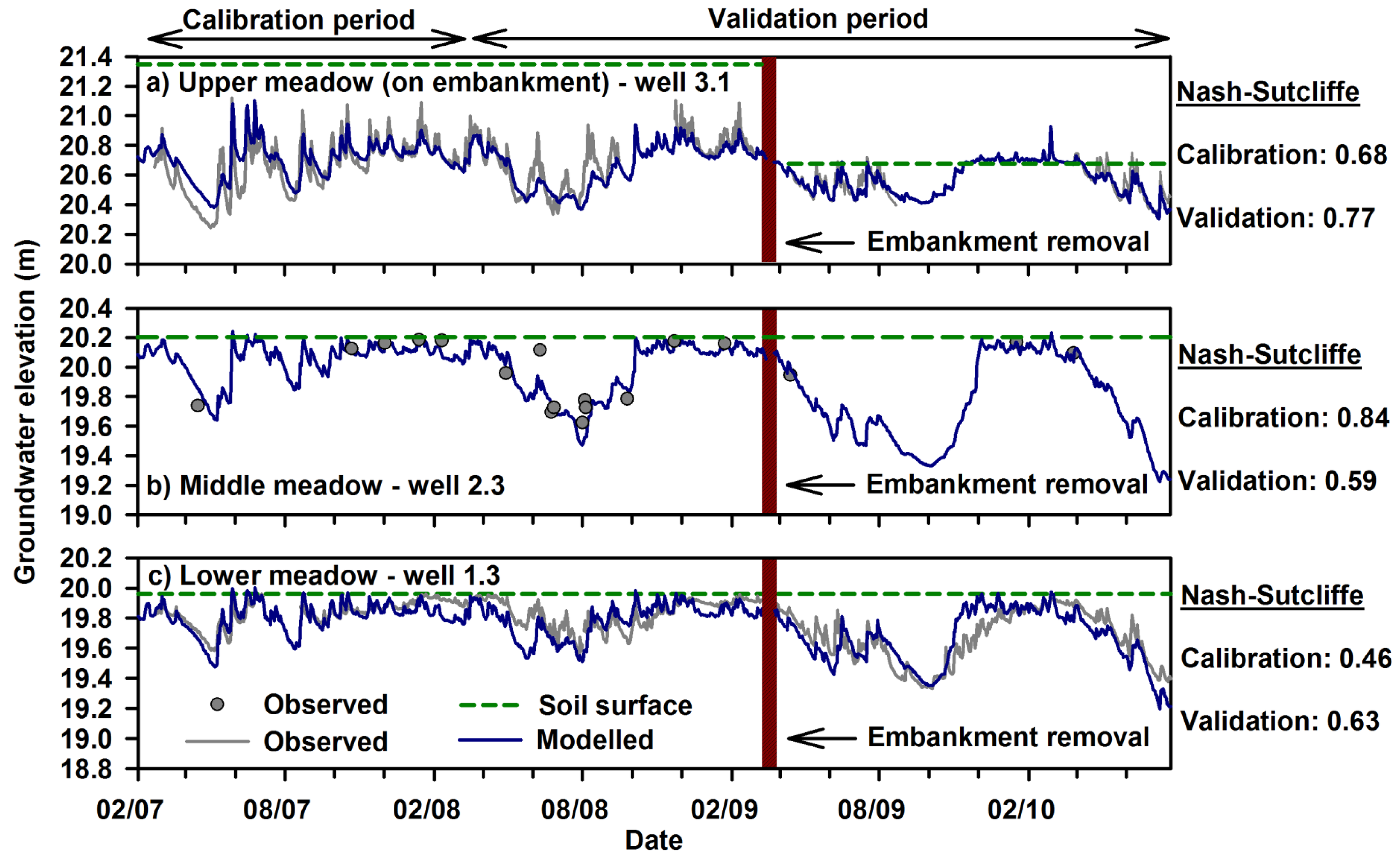


Figure 3: Observed and modelled groundwater depths for three representative wells on the River Glaven floodplain for the calibration and validation periods.

- Modelled and observed groundwater dynamics compared well and captured the rapid response of groundwater to high magnitude rainfall and river flow events (Fig. 3).
- The restoration resulted in higher (mean = 0.02 m) water table elevation (WTE), with the largest increases (max. 0.6 m) along the river banks. Slightly lower WTE occurred for short periods in the restored scenario following overbank flood events due to improved drainage (Fig. 4).

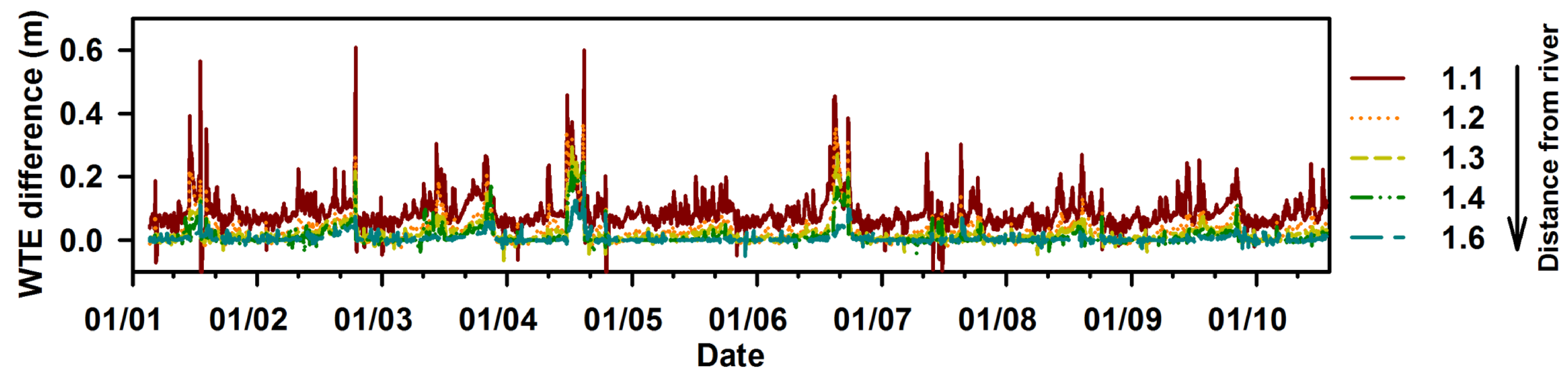


Figure 4: Time series of water table elevation (WTE) differences between the restored and embanked scenarios across the floodplain. Positive Δ indicates restored WTE > embanked WTE.

- Overbank flows did not occur in the embanked model. Removal of the river embankments resulted in frequent (0.22 year return period) localised flooding at the river edge and widespread floodplain inundation at flows greater than 1.9 $m^3\ sec^{-1}$ (Fig. 5 and Fig. 6).
- Large overbank flows were of short duration (<1 day), separated by large time intervals (2.9 year return period) (Fig. 5).

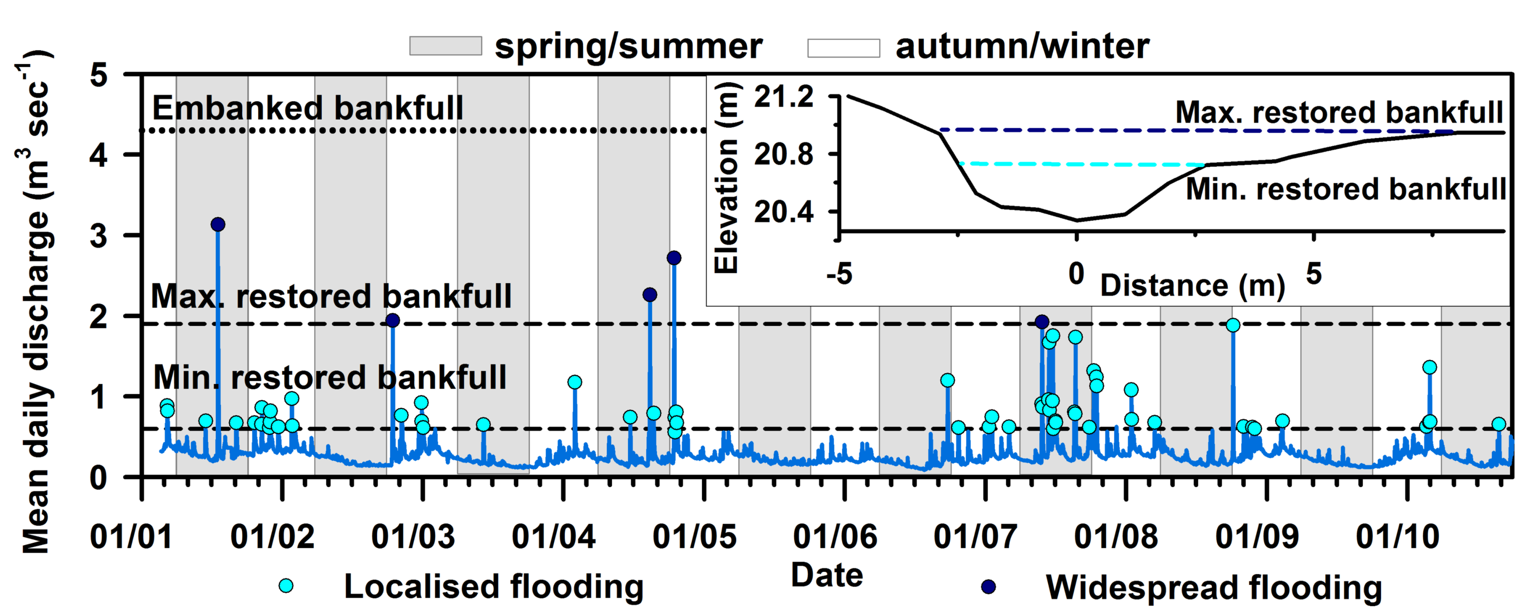


Figure 5: Mean daily river discharge from 2001 – 2010. Embanked and restored bankfull capacity is shown. Two thresholds are shown for the restored river, which correspond to the cross-section inset.

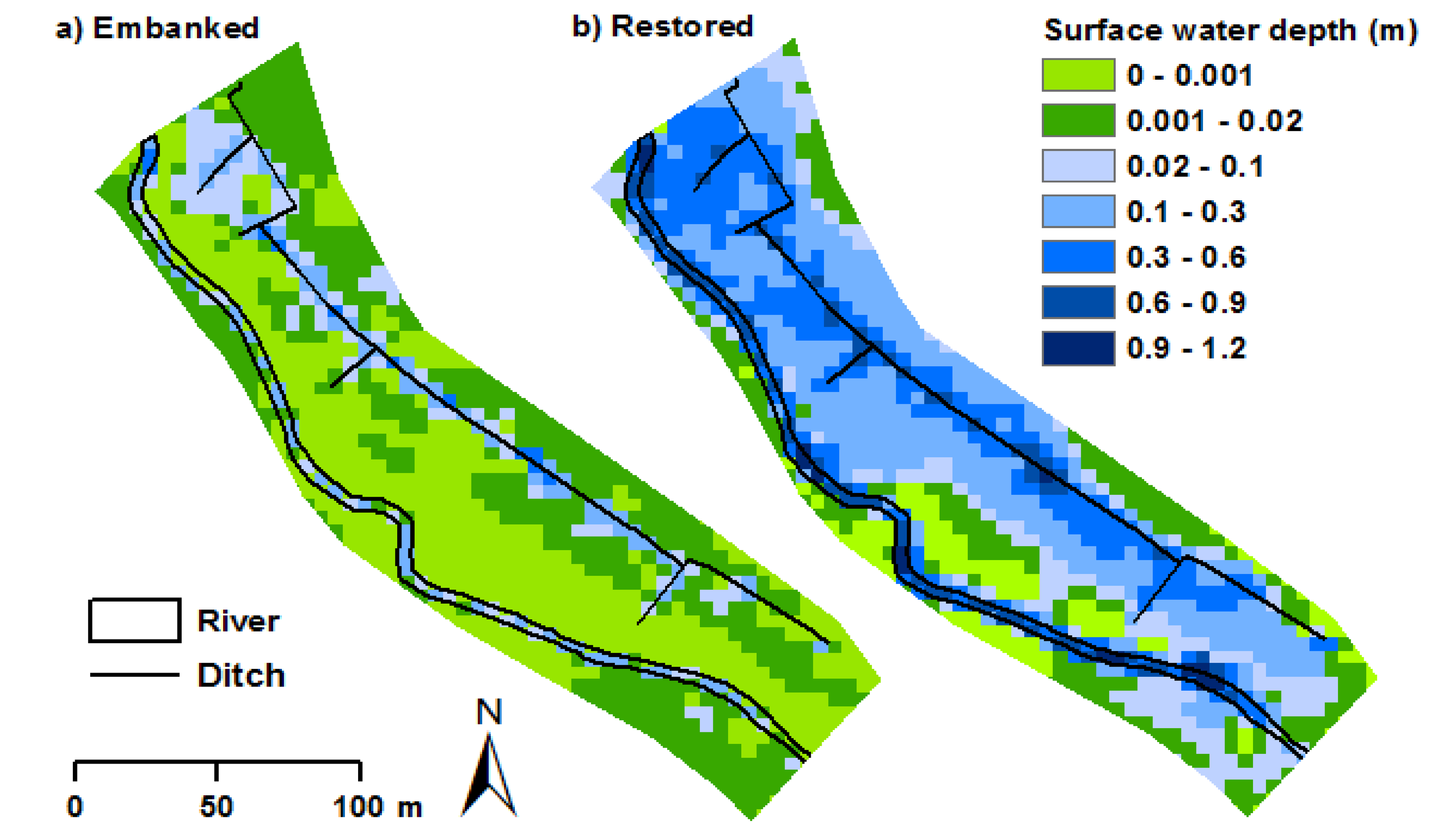


Figure 6: Comparison of surface water extent for the embanked and restored scenarios under identical climatic conditions (28/05/07; flow = 1.9 $m^3\ sec^{-1}$).

- Groundwater was the only source of flooding in the embanked scenario, whereas in the restored scenario inundation also occurred due to overbank flows (Fig. 6).
- Restoration increased surface storage two-fold during the highest river flows, and increased the volume of groundwater storage over the summer (Fig. 7).

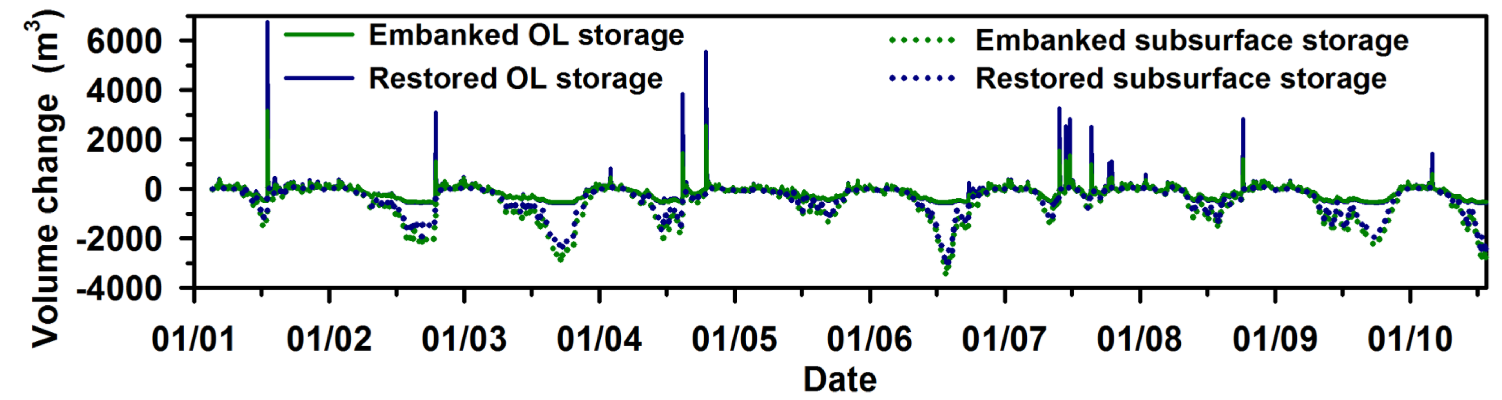
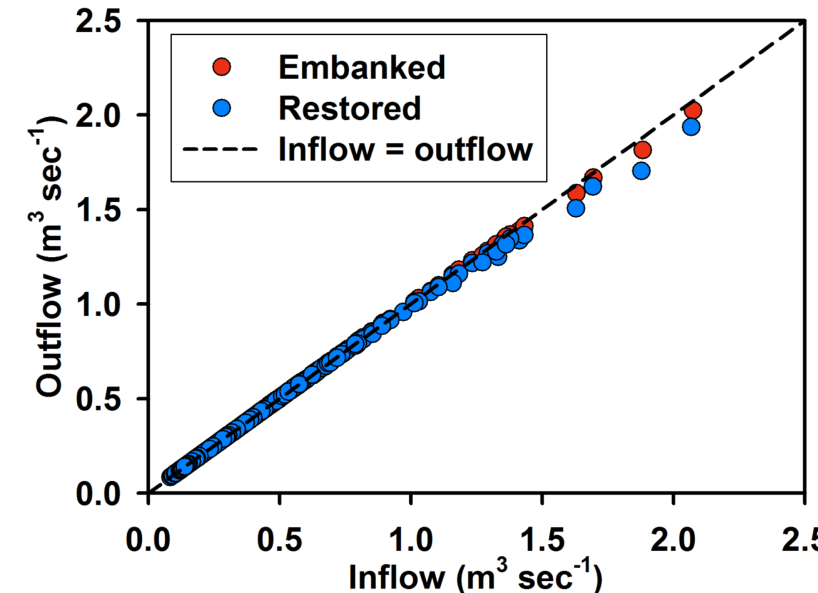


Figure 7: Times series of change in overland (OL) and subsurface storage for both scenarios.



- A minor reduction (max 6%) in peak flows occurred in the restored model during the largest overbank events (> 1.5 $m^3\ sec^{-1}$), likely due to the small size of the restored reach and increased drainage to the river (Figure 8).

Figure 8: Mean daily river inflow versus outflow in the embanked and restored scenarios.

Conclusions

- Hydrological/hydraulic models were successfully used to directly quantify the hydrological impact of embankment removal. These methods provided a useful tool for predicting response to restoration under a range of dry and wet conditions.
- Embankment removal provided the physical geomorphic conditions to allow regular over-bank flows, which increased river-floodplain hydrological connectivity. Expansive inundation and storage of floodwaters on the floodplain raised groundwater levels, and had a small effect on flood peak attenuation.
- The restoration created a more disturbance-based riparian zone that extended laterally, conditions important for the rehabilitation and maintenance of river health and ecosystem services. The hydrological results from this study are being used to predict the impacts of river restoration on soil physicochemical conditions and plant community composition.