Plant management regimes and flow conveyance

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

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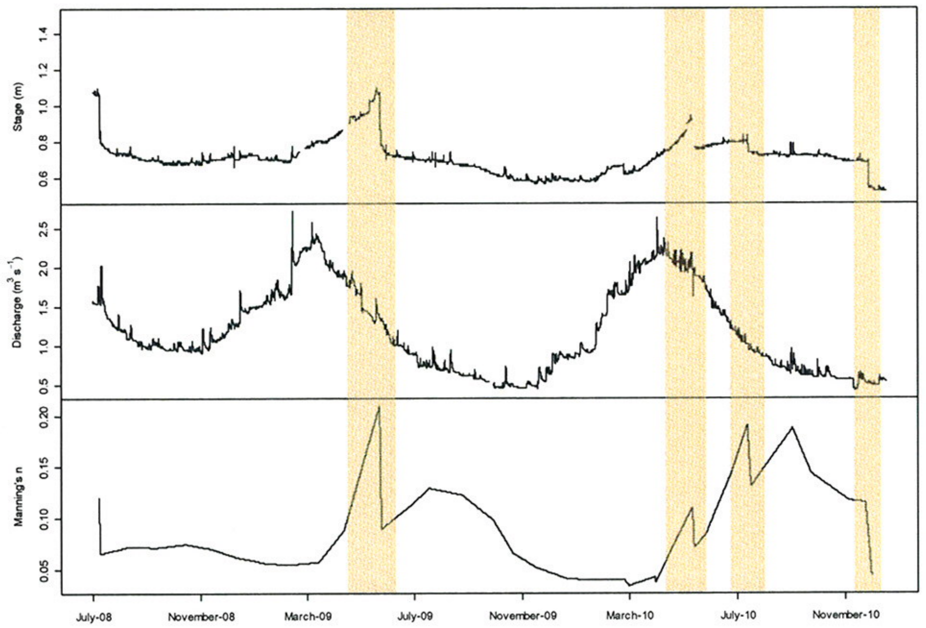
Rationale and experimental design

The Pitt Review on the summer floods of 2007 highlighted the management of channels and their aquatic vegetation as a serious issue. In-stream vegetation increases the resistance to flow, giving higher flood levels for a given discharge and leading to greater incidence of over-bank flooding. It is critical that the effects of plant growth on river flow hydraulics are better understood in order to provide a sound basis for their management.

The data presented here relates to a vegetation cut undertaken in November 2010. This is the first in a series of experiments taking place during 2011 to assess how different cut patterns affect hydraulic processes of varying scales.



Current Monitoring

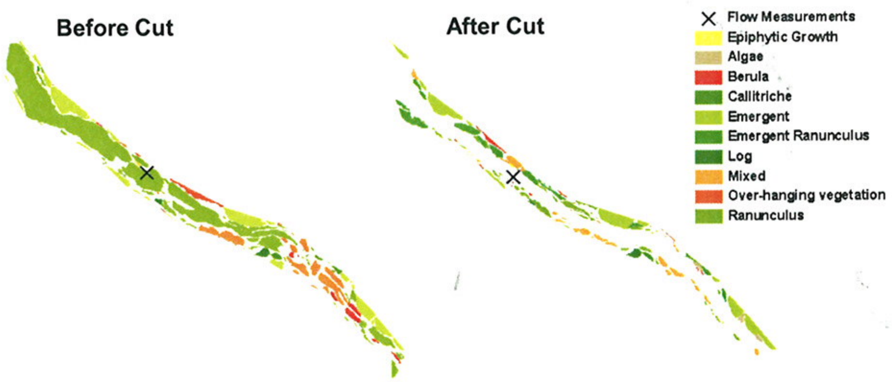
Observations on the River Lambourn since July 2008 have revealed the changing relationship between stage and discharge at the site. Areas highlighted indicate periods of growth leading up to a vegetation cut, with the associated changes in stage and the roughness coefficient Manning's n evident.

Vegetation cut patterns

The aim of the November 2010 cut was to remove accumulated sediment to maintain the status of the reach as a natural trout fishery. In future, cut patterns will be determined through dialogue with stakeholders. Initial contact has been made with the Association of Rivers Trusts (ART) both to investigate current practice and to determine the results of experimental patterns the ART would like to see trialled. It is hoped that another three cuts can be undertaken during the timescale of this project, dependent on conditions on the River Lambourn. Alternatively, such patterns could be tested within the numerical model being constructed.

Vegetation Surveying

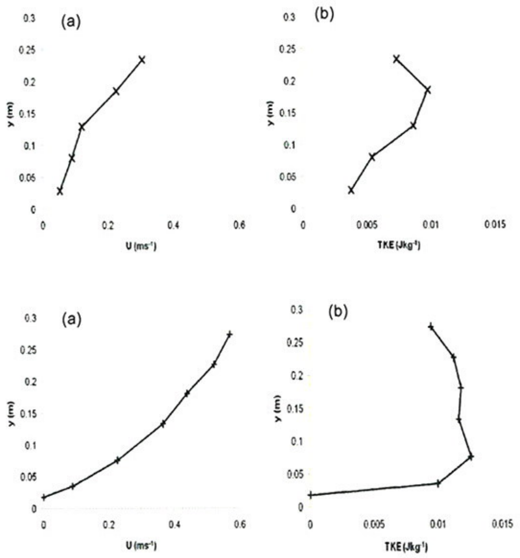
Data were gathered using a Trimble 5600 series Total Station. Plant stands were identified at the root and surveyed around their extent using regularly spaced points. The cut in November 2010 was performed along the thalweg to clear accumulated sediment whilst leaving refuge habitat for fish over the winter period.



Flow measurements

A number of measurements were undertaken using a Nortek 3D Acoustic Doppler velocimeter (ADV) sampling at 25Hz. Such a frequency was specified to allow the analysis of the turbulent structures contributing to fluid energy losses at the interface between the plant and open channel flow. Data collected will also be used for model validation. Data were processed using a phase space threshold despiking filter (Nikora & Goring, 2000). Locations of two of the before and after cut ADV measurements are shown on the vegetation survey above.

Example ADV measurements



y = flow depth; U= downstream flow velocity;
TKE = turbulent kinetic energy.

Before Cut:

(a) Velocity profile highly modified from the theoretical logarithmic profile.
(b) Turbulent kinetic energy increases at around y=0.2 due to the presence of vegetation upstream of the measurement point.

After Cut:

(a) Velocity profile conforms more closely to the expected logarithmic profile.
(b) Dominant source of turbulent kinetic energy appears to be the boundary roughness in the near bed zone.

Future modelling work

To analyse the effect of vegetation cuts at a reach scale, a 3D numerical model will be set up using the Phoenics Computational Fluid Dynamics code. The double-averaged (time & space) continuity and Navier-Stokes (DANS) equations will be used as they incorporate drag terms and porosity effects. The CFD code is extended to include macrophytes as follows:

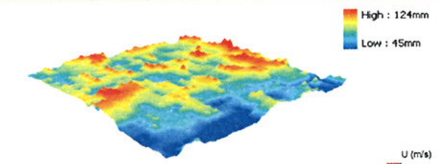
- Macrophytes incorporated as patches defined in the model mesh on a cell by cell basis.
- Reduction in volume of water per unit volume modelled as a spatially distributed porosity.
- Drag on vegetation modelled as a momentum sink term in the DANS equations . Drag is calculated as:

$$F_x = -\frac{1}{2} C_d S_f A_{px} \langle \overline{u_i} \rangle \langle \overline{u_x} \rangle$$

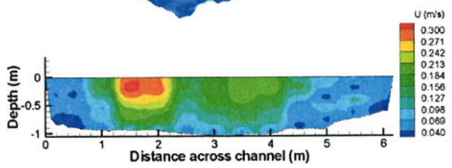
C_d = Drag coefficient; S_f = Sheltering factor;
A_{px} = Averaged frontal projected area in x coordinate direction;
$\langle u_i \rangle$ = Resultant time space averaged velocity

- Terms for turbulence production and dissipation due to vegetation are also introduced into the spatially averaged turbulence model equations.

Additional data required are: model domain (topography), boundary roughness (gravel bed), inlet conditions and vegetation extent in three dimensions. Examples of these are shown below.



Gravel roughness data have been collected to a resolution of 1cm using a point frequency frame at spatially distributed locations throughout the reach.



Inlet conditions have been measured using an Acoustic Doppler current profiler. Data here has been post processed using an Inverse Distance Weighting interpolation method.

The resolution of the mesh generated from topography data has been set as a cross stream spacing of 61 cells; a vertical spacing of 21 cells and a uniform downstream spacing of 0.25m. The reach totals 150m in length.

Trials using an underwater camera system to gain the third dimension of vegetation extent are under way. This work aims to assess what gap, if any, exists between the base of the plant stand and the river bed.

Conclusion

Vegetation in river channels represents a significant cause of energy loss. This research will aim to define an optimum method for managing aquatic vegetation to mitigate against these effects. Such management must be minimal in extent to help achieve Water Framework Directive targets.

References
Nikora, V., Goring, G.D. (2000). Flow turbulence over fixed and weakly mobile gravel beds. *Journal of Hydraulic Engineering, ASCE*, 126 (9), 679-690.

WHY: Should we be interested in the effects that aquatic plants have on river flow hydraulics?

BECAUSE: In-stream vegetation increases the resistance to flow, leading to a greater risk of over-bank flooding for a given discharge.

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