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An investigation of controlling variables of riverbank erosion in sub-tropical Australia

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ABSTRACT

A large proportion of the uncertainty surrounding catchment sediment budget modelling has been attributed to sediment supplied from riverbank erosion. Some of the variables influencing riverbank erosion are bend curvature, specific streampower, riparian vegetation, and in some instances sand and gravel extraction. The empirical relationship between these variables and observed riverbank erosion across 78 km of the Upper Brisbane River, Australia was investigated. No significant relationship was found between curvature, specific streampower and riverbank erosion. The role of riparian vegetation relative to sediment supply from riverbank erosion varied with spatial location, susceptibility of a reach to erosion, and human disturbance such as sand and gravel extraction. Despite not having data on substrate type the model described approximately 37% of the variation in observed riverbank erosion. It appears that inclusion of a management practice factor in riverbank erosion models is justified, where appropriate, and may improve model performance.

1. Introduction

In many regions around the world water quality has been impacted by point and diffuse sources of pollution. While progress has been made reducing point sources of pollution, management of diffuse source pollution still presents a significant challenge (Duda, 1993). Consequently management of diffuse source pollution has been the focus of substantial government investment (NLWRA, 2001; US EPA, 2003). The sediment component of diffuse source pollution is commonly measured through suspended sediment yield, which is typically defined as clay and silt sized material moving in suspension in river flow (Wilkinson et al., 2009). Heightened suspended sediment yield can adversely impact aquatic biodiversity and ecological function (Bilotta and Brazier, 2008); reduce storage capacity of reservoirs (Lu et al., 2004); and increase water treatment costs (Holmes, 1988). The relationship between processes which deliver sediment to a river and consequent downstream suspended sediment yield is often complicated by the large spatial scales over which these processes operate and the presence of sediment depositional areas (Wilkinson et al., 2009). Catchment scale sediment budget models are therefore commonly used to capture the relationship between sediment sources, transport pathways and sinks (Wilkinson et al., 2009).

Catchment sediment budget models are frequently used to target management actions and inform policies aimed at reducing suspended sediment yield (Lu et al., 2004; Hughes and Croke, 2011; Wilkinson et al., 2014). These models are often based on a combination of erosion and sediment transport physical process knowledge, and empirical data (Wilkinson et al., 2009). The inclusion of physical process models allows the suspended sediment yield response to potential management actions to be estimated (Wilkinson et al., 2014). The physical process models assume that suspended sediment yield is limited by supply from hillslope, gully and riverbank erosion sources (McKergow et al., 2005; Wilkinson et al., 2009). Obtaining data to validate modelled sediment supply from these erosion sources at a catchment scale is a recognised limitation of these models (Wilkinson et al., 2009; Hughes and Croke, 2011).

A large proportion of the uncertainty surrounding catchment

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sediment budget modelling has been attributed to sediment supplied from riverbank erosion (De Rose et al., 2005). For example Bartley et al. (2008) found modelled riverbank erosion rates underestimated observed rates over 14 km in Northern Queensland, Australia (Fig. 1). It is important to understand the cause of this uncertainty as evidence suggests that riverbank erosion is the dominant source of sediment in many Australian rivers (Wasson et al., 1998; Prosser et al., 2001). Due to the historical difficulty of obtaining empirical riverbank erosion data at large spatial scales, sediment budget models attempt to capture the primary controlling variables affecting riverbank erosion rates (Wilkinson et al., 2009). Some commonly used controlling variables of riverbank erosion are bend curvature, streampower and riparian vegetation.

The relationship between riverbank erosion and bend curvature has been studied extensively (Ikeda et al., 1981; Nanson and Hickin, 1986; Darby et al., 2002; Tal and Paola, 2007). These investigations range in complexity and are generally approached from either a geomorphological or fluid mechanics discipline (Seminara, 2006; Camporeale et al., 2007). An assumption common to many of the approaches is that flow remains constant (Camporeale et al., 2007). Bend curvature is not included in many sediment budget models; however it is commonly examined in relation to riverbank erosion rates.

While many studies have emphasised the link between small scale velocity distributions and riverbank erosion (ASCE, 1998; Darby et al., 2010), streampower is commonly used in catchment scale modelling as a measure of a river's ability to do geomorphic work (Leopold et al., 1964). Calculating specific streampower (ω, equation (1)) has the advantage of accounting for valley confinement on increased flow velocities. Bankfull discharge is commonly used to represent the most geomorphically effective discharge (Dury, 1961; Bartley et al., 2008; Wilkinson et al., 2009). Energy grade slope is an important component of specific streampower calculations, as it reflects the rate of energy conversion from potential to kinetic (Bagnold, 1966). Due to the difficulty of estimating energy grade slope it is common to use either channel slope (Knighton, 1999; Parker et al., 2011); water surface slope (Yang, 1972; Lecce, 1997); or bankfull flow water surface slope (Larsen et al., 2006). Each approach may be appropriate depending on the geomorphic behaviour of an individual river (Yang, 1972).

$$\omega = \frac{g\rho QS}{W} = \tau_0 \upsilon \qquad (1)$$

where ω = specific streampower (Wm^{-2}); g = gravitational constant (9.8 ms^{-2}); ρ = density of water (1000 kg^{-3}); Q = discharge (m^3s^{-1}); S = energy grade slope; W = flow width (m); τ_0 = mean boundary shear stress (Nm^{-2}); and υ = mean velocity (ms^{-1}).

The influence of riparian vegetation on riverbank erosion is dependent on a range of biotic and abiotic factors (Corenblit et al., 2007). Although most studies conclude riparian vegetation reduces erosion (Millar, 2000; Micheli and Kirchner, 2002; Brooks et al.,

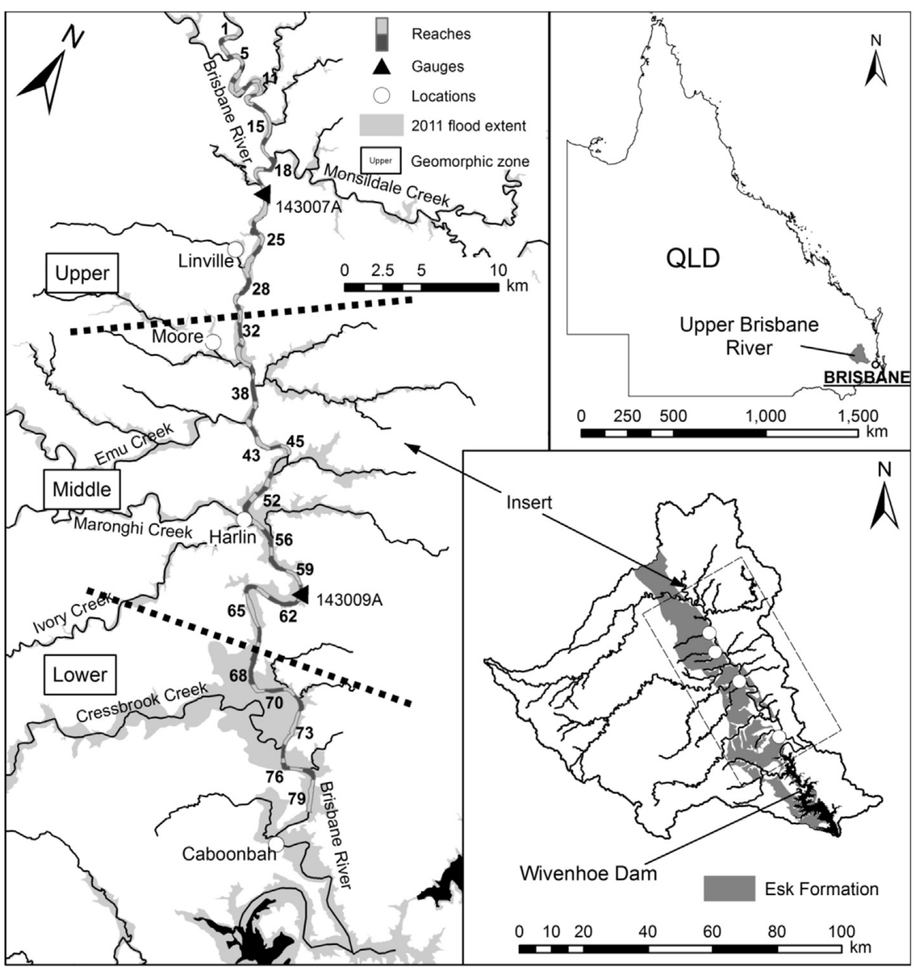

Fig. 1. Upper Brisbane River (UBR) study area showing reach divisions, gauges and major tributaries. Inset panels show location of study site within the UBR catchment, and location of the UBR catchment within Queensland, Australia.