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Wildfire, morphologic change and bed material transport at Fishtrap Creek, British Columbia

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ABSTRACT

In 2003, a wildfire burned nearly two-thirds of the Fishtrap Creek watershed, including the forested floodplain. Annually repeated surveys of the stream channel — combined with bed material tracer studies in 2006 and 2007 — indicate that the channel has become unstable and that the bed material transport dynamics have changed since the fire. Using these data, the morphologic changes have been quantified and event-scale bed material transport rates have been estimated for four post-fire freshets. The immediate response of the channel (during the 2005 and 2006 freshets) was a progressive shift in channel morphology from a relatively featureless plane-bed morphology devoid of significant sediment accumulations to a riffle-pool morphology in which bars cover a significant proportion of the bed. This transformation occurred in association with moderate bed material sediment transport rates and only minor bank erosion within the study reach. Extensive bank erosion occurred during the 2007 and 2008 freshets, producing a dramatic change in channel morphology and increasing the local bed material transport rates by an order of magnitude. Post-fire monitoring of streamflow and suspended sediment concentrations (a surrogate for upstream sediment supply) indicates that post-fire increases are not detectable (presented in Eaton et al., in press), and our analysis demonstrates that major morphologic changes can occur following wildfire even when the common external drivers of stream discharge and sediment supply remain unchanged.

1. Introduction

In 2003, a high intensity forest fire burned about two-thirds of the Fishtrap Creek watershed (see Fig. 1). Nearly all of the riparian vegetation on the floodplain near the Water Survey of Canada gauging station on Fishtrap Creek was killed during the fire. In order to take advantage of the opportunity to study the effects of fire within this gauged catchment on watershed processes in general — and stream channel dynamics in particular — a monitoring program was established soon after the fire. This paper describes the changes in channel morphology and in bed material sediment transport dynamics observed during the first five years of post-fire data.

Most previous field studies of stream channel change have focussed on the effects of varying the supply of water and/or sediment to a given reach: that is, they have focussed on the *exogenous* drivers of channel change. These studies have generally shown that a decrease in sediment supply will result in channel narrowing and/or vertical incision for single-thread streams (Surian and Rinaldi, 2003), along with the development of a coarse surface pavement in single-thread channels with a gravel bed (Liebault and Piegay, 2001), and a reduction in the braiding index for braided streams (Chew and Ashmore, 2001). Increases in sediment supply tend to produce channel widening, aggradation, avulsions, and often a reduction in the sediment calibre (Lisle, 1982; Pitlick, 1993; Church, 1995; Sloan et al., 2001), and often produce a braided channel pattern, as well.

Others have focussed on the effects of variations in peak flow (e.g. Baker, 1977; Gardner, 1977; Church, 1995; Eaton and Lapointe, 2001), in some cases over relatively long timescales (Brewer and Lewin, 1998; Jones and Harper, 1998). However, large increases in peak flows are often accompanied by large increases in sediment supply, and thus produce similar effects, such as widening, aggradation, and changes in channel pattern (Lisle, 1982; Pitlick, 1993; Brown et al., 2001). The effect of an increase in stream discharge is strongly dependent on the recent history of flows and the channel state, and in some cases, large increases in discharge have produced relatively minor morphologic changes (Gardner, 1977; Desloges and Church, 1992; Eaton and Lapointe, 2001). Reductions in flows typically result in a gradual narrowing of the channel, usually accompanied by the progressive encroachment of riparian vegetation (Church, 1995; Gaeuman et al., 2005), and a reduction in the level of geomorphic activity (e.g. Church, 1995; Jones and Harper, 1998). Interestingly, some long-term studies

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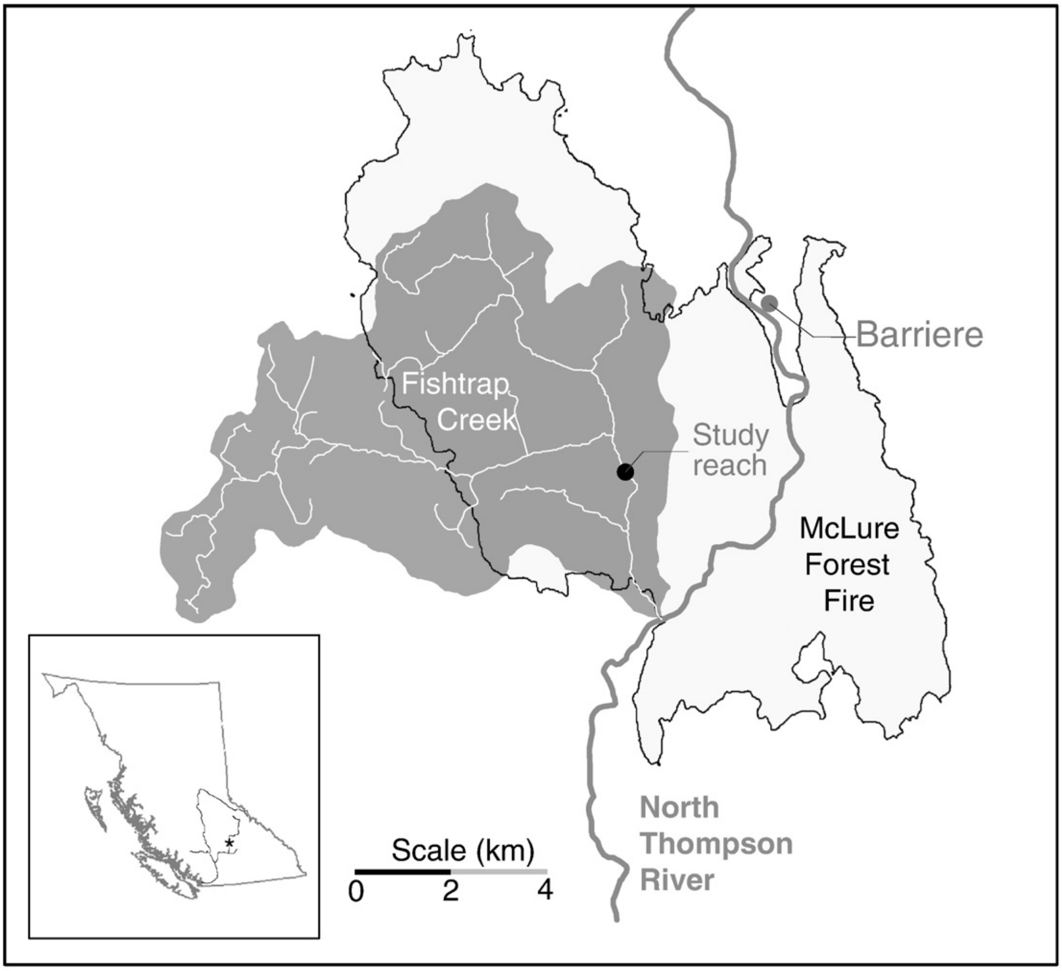

Fig. 1. Fishtrap Creek watershed. The extent of the McLure forest fire (which occurred in August 2003) is shown on the map, along with location of the study reach. The nearby town of Barriere is shown for reference.

have been able to associate oscillations in the channel morphology with cyclic changes in the flow regime and/or the sediment supply rates (Brewer and Lewin, 1998; Coulthard et al., 2000; Brown et al., 2001).

At Fishtrap Creek, neither significantly elevated peak flows nor increased sediment loads have been detected (see Owens et al., 2006; Petticrew et al., 2006; Eaton et al., in press). Despite this, the channel has become quite unstable since the fire. Eaton and Giles (2009) showed that changes in riparian vegetation could be sufficient to destabilize the stream channel, while Eaton (2008) used a rational regime model to demonstrate that Fishtrap Creek is much less sensitive to changes in discharge than either bank vegetation type or instream large woody debris volumes. Thus, the role of the boundary conditions within the reach, which constitute *endogenous* drivers of channel change, appears to be critical to understanding the changes documented at Fishtrap Creek.

There have been a few studies of the effect of endogenous drivers of channel change. Wathen and Hoey (1998) examined the impact of an endogenous sediment wave generated by a large flood on the local sediment transport rates in the years after the flood at Allt Dubhaig, Scotland. Gaeuman et al. (2005) observed the effect of changing riparian vegetation type and density on the channel pattern of the Duchesne River, Utah, while Brooks et al. (2003) documented a dramatic change in the morphology of the Cann River, Australia, as a result of disturbance of the riparian vegetation following European settlement. Millar (2000) also observed a change in channel morphology of a steep mountainous stream in British Columbia following removal of the riparian forest. These kinds of studies are retrospective investigations and have not been able to unambiguously link the observed channel change to changes in endogenous drivers because the exogenous changes are not known.

Studies that explicitly consider forest fires have focussed on: erosion of hydrophobic soils by overland flow (Inbar et al., 1998; Benavides-Solorio and MacDonald, 2001; Moody and Martin, 2001; Cerda and Lasanta, 2005; Desilets et al., 2006; Moody et al., 2008); the generation of debris flows from hydrophobic soils (Wells, 1987; Cannon and Reneau, 2000); or the aggradational landforms formed by post-fire increases in sediment supply to fluvial networks (Meyer and Wells, 1997; Benda et al., 2003; Legleiter et al., 2003). Furthermore, most of these studies tend to focus on fires that produce either a large increase in peak flows of a dramatic increase in sediment supply to the stream channel (see Wondzell and King, 2003). Thus, with the exception of some work looking at the large woody debris loads following a forest fire (Barro et al., 1988; Zelt and Wohl, 2004), the potential influence of the endogenous drivers, such as changes to the riparian vegetation, has not been well documented.

While many of the previously mentioned studies have associated changes in channel morphology with the sediment load imposed upon the channel (or equivalently, the discharge available to transport a constant, externally imposed sediment load), it is also possible to infer bed material sediment transport dynamics from measured morphologic adjustments (Neill, 1987). Researchers have been able to estimate sediment transport rates using repeated cross sections (Goff and Ashmore, 1994; Martin and Church, 1995), analysis of aerial