Geomorphology 118 (2010) 207–212

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Interdecadal patterns of total sediment yield from a montane catchment, southern Coast Mountains, British Columbia, Canada

Erik Schiefer [a,*], Marwan A. Hassan [b], Brian Menounos [c], Channa P. Pelpola [d], Olav Slaymaker [b]

[a] Department of Geography, Planning & Recreation, Northern Arizona University, Box 15016, Flagstaff, AZ 86011, USA
[b] Department of Geography, University of British Columbia, 1984 West Mall, Vancouver, BC, Canada V6T1Z2
[c] Natural Resources and Environmental Studies Institute and Geography Program, University of Northern British Columbia, 3333 University Way, Prince George, BC, Canada V2N4Z9
[d] Stantec Consulting Ltd., 4370 Dominion Street, Burnaby, BC, Canada V5G4L7

ARTICLE INFO

Article history:
Received 24 September 2009
Received in revised form 3 January 2010
Accepted 4 January 2010
Available online 11 January 2010

Keywords:
Sediment yield
Suspended load
Bedload
Dissolved load
Coast Mountains
British Columbia

ABSTRACT

We reconstruct sediment yield for a mountain watershed of western Canada since the mid-twentieth century from studies of annually laminated lake sediments, delta progradation, and solute transfer. Total yield averaged 320 ± 40 Mg km^{-2} a^{-1} and comprised ~35% suspended load, 50% bedload, and 15% dissolved load. Ratios between the individual yield components varied approximately threefold at interannual timescales because of significant variability in the suspended and bedload fractions. Asynchronous flux in suspended and bedload fractions through time arise from differences in sediment availability and transitory sediment storage in the channel. Periods of elevated yield coincide with rapid glacier recession, an extreme rainstorm, and a landslide. Our results indicate that in montane environments, extrapolation from even decade-long monitoring programs may lead to biased projections of long-term yield and delivery mode proportions if variations in sediment supply and catchment response to hydroclimatic and geomorphic controls are not considered.

© 2010 Elsevier B.V. All rights reserved.

1. Introduction

Sediment yield, defined as the total outflow of sediment from a catchment per unit time, integrates the intensity and pattern of catchment denudation and sediment delivery over time. Three components of sediment flux in rivers—the suspended load, bedload, and dissolved load—together represent the total fluvial delivery from a drainage basin. Mountain streams supply a disproportionate sediment load to continental margins, yet they are underrepresented in global monitoring programs (Milliman and Syvitski, 1992). Reconstructions of total yield are of interest for montane catchments because both the amount and the mode of sediment transport may be sensitive to land use and climate change (Slaymaker and Owens, 2004).

Most sediment yield data are derived from either suspended or dissolved river loads and rarely are all three components measured simultaneously (Walling and Fang, 2003; Meybeck and Vörösmarty, 2005). Short-term bias also impedes most monitoring programs, which limits their potential to infer long-term change in rates of sediment transfer (Caine, 2004). Accurate estimation of sediment yield from montane catchments is further complicated because transport formulae are notoriously unreliable and operational challenges impede conventional monitoring (Gomez and Church, 1989; Meybeck et al., 2003). Because of these limitations, ratios between river load components are commonly assumed to be constant over time, often with little empirical or theoretical support. In some cases, long-term yield records can be recovered from depositional systems, such as lakes and deltas (Duck and McManus, 1994; Loso et al., 2004; Pratt-Sitaula et al., 2007), which can address some of the limitations that face conventional monitoring programs.

In this paper, we examine the interannual variability of sediment yield for Fitzsimmons Creek, a mountain stream of western Canada, since the mid-twentieth century. We derive suspended, bedload, and dissolved load fractions of yield (respectively) from studies of lake sedimentation, delta progradation, and solute monitoring. The integration of these data presents a unique opportunity to assess the long-term dynamics of total fluvial load for the catchment. Our integrated yield record is related to hydroclimatic trends and geomorphic events to examine how these factors affect the quantity and mode of sediment delivery through time.

2. Study area and methods

2.1. General setting

Fitzsimmons Creek, the primary inflow to oligotrophic Green Lake, drains 95 km^2 of the south Coast Mountains near the resort town of Whistler, British Columbia, Canada (Fig. 1). Bedrock geology is typical of the Coast Plutonic Complex, consisting of granodiorite to quartz

* Corresponding author. Tel.: +1 928 523 6535; fax: +1 928 523 2275.
E-mail address: Erik.Schiefer@nau.edu (E. Schiefer).

0169-555X/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.geomorph.2010.01.001

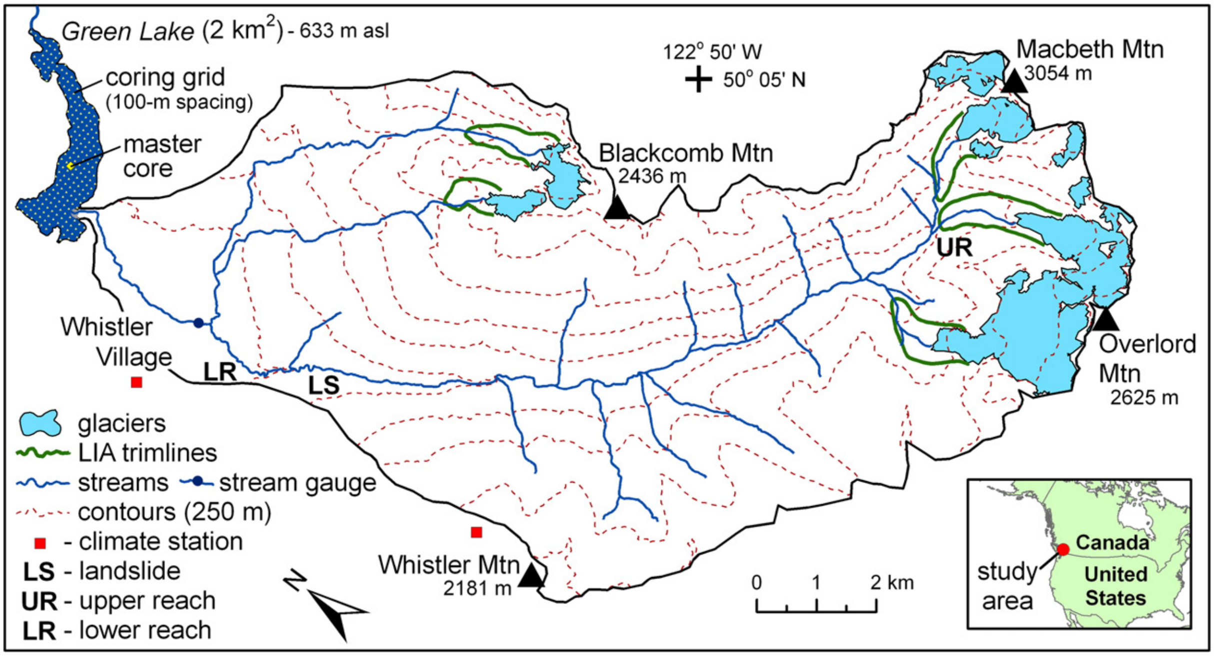

Fig. 1. Catchment area map for Fitzsimmons Creek, British Columbia, Canada. Percussion cores and recent gravity cores were collected from Green Lake at the site marked "mater core", where contemporary sedimentation has been representative of overall lake deposition (Schiefer, 2006a,b,c). LS marks the position of a deep-seated landslide within the Quaternary fill of the lower valley that was activated in August 1991. UR and LR are upper and lower reaches, respectively, of the creek where channel changes have been observed from historical air photos.

diorite intrusions with pendants of metasedimentary and metavolcanic rocks (Monger and Journeay, 1994). Major sediment sources to the creek include alpine glaciers, Little Ice Age glacier forefields, till and colluvium along valley margins, and incised Quaternary fill in some lower valley reaches. Glacier cover for the catchment was ~7% near the end of the twentieth century and ~15% during the early eighteenth century (Koch et al., 2007). Logging took place in the lower valley during the 1950s and 1960s, but most activity occurred on terrace surfaces decoupled from the creek.

Meteorological records, obtained from 658 and 1835 m above sea level (asl) adjacent to the study catchment (Environment Canada stations 1048898 and 1108906, Fig. 1), show that the local temperate–maritime climate is subject to strong altitudinal gradients in temperature and precipitation. At 658 m asl, mean annual precipitation is 1230 mm (~30% snowfall) and mean monthly temperature ranges from 16.1 °C in August to −3.2 °C in December. At 1835 m asl, mean annual precipitation is 1560 mm (~70% snowfall) and mean monthly temperature ranges from 10.1 °C in August to −5.3 °C in January. Streamflow records in the region are characterized by low flows during the winter, high flows in the late spring and early summer during the freshet, and infrequent rainstorm-generated floods during the late summer and autumn (Schiefer et al., 2006). By volume, annual runoff is dominated by snowmelt-generated flows; however, highest magnitude discharges are associated with episodic, rainstorm-generated floods. Based on a streamflow record from 1994 to present (Water Survey of Canada gauge MG026), mean annual discharge of Fitzsimmons Creek near Whistler Village is $4\,m^3\,s^{-1}$, and the one-day mean annual flood is $17\,m^3\,s^{-1}$.

2.2. Suspended load

Most of the suspended load from Fitzsimmons Creek accumulates in Green Lake as annually resolvable couplets (varves) of silt and clay (Menounos et al., 2005). Evidence that the couplets represent varves include (i) independently derived ages obtained using ^{137}Cs activity of the sediments; (ii) the presence of two dated anthropogenic markers observed in some nearshore sediment cores; and (iii) new couplets being predictably observed in cores taken in subsequent years (Schiefer, 2006a). The lack of intervening water bodies or active floodplains between the lake and sediment source areas suggests that the intermediate storage potential of silt and clay is low.

Methods used to derive annual sedimentation rates for Green Lake from 1930 to 2000 are described in detail elsewhere (Menounos et al., 2006; Schiefer et al., 2006). Gravity coring was conducted on a 100-m sampling grid to examine sedimentation patterns at 202 sites in the $2.0\,km^2$ lake. Cores were split lengthwise with one-half repeatedly photographed while drying to reveal faint sedimentary structures only visible in a partially dried state, and the other half subsampled for bulk physical properties every 2.5 cm downcore using standard methods. Given the near absence of other sediment sources to the lake basin, we use the mass of fine sediments deposited in the lake as a surrogate for suspended sediment yield ($Mg\,km^{-2}\,a^{-1}$) from the catchment. Annual yields were calculated as the mean accumulation rate obtained from the products of varve thickness and dry sediment density for all of the sampling sites. Suspended yields were adjusted for the estimated trap efficiency of Green Lake according to capacity- and sedimentation index-based empirical relations developed for reservoir systems (Verstraeten and Poesen, 2000). The median empirical estimate for trap efficiency is $95 \pm 5\%$, which accords with sediment transport estimates based on weekly to monthly suspended sediment monitoring conducted on the lake inflow and outflow from 2000 to 2003 (Schiefer, 2004).

We extended the suspended yield record back to the early 1900s and forward to 2007 by comparing the yield chronology to sediment fluxes ($g\,cm^{-2}\,a^{-1}$) obtained by similar varve analyses from long (>1 m) percussion cores and more recently collected gravity cores at a master coring location (Fig. 1). The master core location was identified as the site most representative of lake-wide deposition following a detailed analysis of spatial sedimentation patterns within the lake (Schiefer, 2006b). An independent estimate of suspended yield, based on conventional stream sediment sampling and rating curve development, is also available for the period 1999–2002 (Menounos et al., 2006).

Download English Version:

https://daneshyari.com/en/article/4686062

Download Persian Version:

https://daneshyari.com/article/4686062

Daneshyari.com