Geophysical Research Abstracts
Vol. 20, EGU2018-4574, 2018
EGU General Assembly 2018

Sediment continuity through the steepland sediment cascade: geomorphic response of an upland river to an extreme flood event

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Hillslope erosion and accelerated lake sedimentation in response to extreme flood events are often reported as the source and main stores of sediment in the steepland sediment cascade. Intervening upland valley fluvial systems (the transfer zone) have potential to influence sediment continuity during extreme events, but geomorphic response is rarely quantified. This research investigates the sediment continuity, in terms of sediment mass, through a flow regulated upland valley river system (St John's Beck) in response to the extreme Storm Desmond (4th - 6th December 2015) flood event in Northern England. Record rainfall totals caused widespread flooding across the Lake District upland region: 341.4 mm rainfall was recorded in a 24 hour period. The storm was the largest in a 150 year local rainfall series, and exceeded previous records set in the 2005 and 2009 floods. The impacts of the event along St John's Beck included widespread deposition of coarse fluvial sediment, erosion and scour of river banks and floodplains and destruction of infrastructure. A sediment budget was used to quantify geomorphic change and the main sediment stores during the event. Based on field measurements 5 100 $\pm$ 710 t of sediment was eroded or scoured from the river floodplains, banks and bed, and 6 600 $\pm$ 570 t of sediment was deposited in the channel or on the surrounding floodplains during the event. Bedload sediment transport rate out of the reach during the event was estimated at 370 t. This is less than 3% of the total mass of sediment eroded and deposited during the event, showing that sediment continuity through the upper floodplain transfer zone was highly inefficient. Channel confinement influenced the spatial distribution of deposition and erosional impacts. For example, sediment deposition was concentrated 1.5 – 4 km downstream where the channel becomes unconfined as natural floodplain width increases from 30 to 300 m. Riverbank erosion was concentrated on banks that had been artificially confined by protection structures. Long term flow regulation contributed to sediment aggradation in the channel prior to the event which acted as a source of sediment deposited on surrounding floodplains during Storm Desmond. The results demonstrate the importance of upland valley systems as a major sink of sediment during extreme flood events.