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Assessing the continuity of the upland sediment cascade, fluvial geomorphic response of an upland river to an extreme flood event: Storm Desmond, Cumbria, UK.

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Hillslope erosion and accelerated lake sedimentation are often viewed as the source and main storage elements in the upland sediment cascade. However, the continuity of sediment transfer through intervening valley systems has rarely been evaluated during extreme events. Storm Desmond (4^{th} – 6^{th} December, 2015) produced record-breaking rainfall maximums in the UK: 341.4 mm rainfall was recorded in a 24 hour period at Honister Pass, Western Lake District, and 405 mm of rainfall was recorded in a 38 hour period at Thirlmere, central Lake District. The storm was the largest in a 150 year local rainfall series, and exceeded previous new records set in the 2005 and 2009 floods. During this exceptional event, rivers over topped flood defences, and caused damage to over 257 bridges, flooded over 5000 homes and businesses, and caused substantial geomorphic change along upland rivers. This research quantifies the geomorphic and sedimentary response to Storm Desmond along a regulated gravel-bed river: St John's Beck. St John's Beck (length 7.8 km) is a channelised low gradient river (0.005) downstream of Thirlmere Reservoir, which joins the River Greta, and flows through Keswick, where major flooding has occurred, before discharging into Bassenthwaite Lake. St John's Beck has a history of chronic sediment aggradation, erosion and reports of historic flooding date back to 1750. During Storm Desmond, riverbanks were eroded, coarse sediment was deposited across valuable farmland and access routes were destroyed, including a bridge and footpaths, disrupting local business. A sediment budget framework has been used to quantify geomorphic change and sedimentary characteristics of the event along St John's Beck. The volume and sediment size distribution of flood deposits, channel bars, tributary deposits, floodplain scour, riverbank erosion and in-channel bars were measured directly in the field and converted to mass using local estimates of coarse and fine sediment bulk densities. During the event 5000 tonnes of sediment was deposited on floodplains surrounding St John's Beck; 65% of this sediment was deposited in the first 3 km of the reach downstream of Thirlmere Reservoir where the channel is unconfined and channel slope and capacity rapidly decrease. Flood sediment deposits were composed of a single layer of sediment of a similar grain size distribution (mean D_{90} 116 mm), with fines generally sparse. The main source of sediment deposited during the event originated from the channel bed and banks; 1500 tonnes of sediment was stored within channel bars. Approximately 2000 tonnes of sediment was eroded from the riverbanks during the event; with local lateral riverbank recession exceeding 12 m. An estimated 500 tonnes of sediment was scoured from the floodplains along the first 3 km of the reach downstream of Thirlmere Reservoir, with local floodplain scour around a bridge estimated at 300 tonnes. Overall, this sediment budget study demonstrates the importance of valley systems as a major source and sink of sediment along the upland sediment cascade during an extreme flood event.