

## **Changes to channel sediments resulting from complex human impacts in a gravel-bed river, Polish Carpathians**

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During the second half of the twentieth century, many sections of the Czarny Dunajec River, Polish Carpathians, were considerably modified by channelization as well as gravel-mining and the resultant channel incision (up to 3.5 m). This paper examines changes to the longitudinal pattern of grain size and sorting of bed material in an 18-km-long river reach. Surface bed-material grain size was established on 47 gravel bars and compared with a reference downstream fining trend of bar sediments derived from the sites with average river width and a vertically stable channel. Contrary to expectations, the extraction of cobbles from the channel bed in the upper part of the study reach, conducted in the past decades, has resulted in the marked coarsening of bed material in this river section. The extraction facilitated entrainment of exposed finer grains and has led to rapid bed degradation, whereas the concentration of flood flows in the increasingly deep and narrow channel has increased their competence and enabled a delivery of the coarse particles previously typical of the upstream reach. The middle section of the study reach, channelized to prevent sediment delivery to a downstream reservoir, now transfers the bed material flushed out from the incising upstream section. With considerably increased transport capacity of the river and with sediment delivery from bank erosion eliminated by bank reinforcements, bar sediments in the channelized section are typified by increased size of the finer fraction and better-than-average sorting. In the wide, multi-thread channel in the lower part of the reach, low unit stream power and high channel-form roughness facilitate sediment deposition and are reflected in relatively fine grades of bar gravels. The study showed that selective extraction of larger particles from the channel bed leads to channel incision at and upstream of the mining site. However, unlike bulk gravel mining, selective extraction does not result in sediment deficit downstream as large volumes of finer bed material are flushed out from the incising channel section. Grain-size analyses of bulk gravels and measurements of 100 coarsest particles within the channel sediment ranging in age from 5200 years BP to the present, performed in this deeply incised section, indicated that grain size of channel sediments changed relatively little since mid-Holocene to the 1960s, but has increased rapidly over the last half-century as a result of human interventions and rapidly progressing channel incision.

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