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## Enormous erosion in mining areas during the 2021 July flood in western Germany: Examples from the Inde and Erft River

Frank Lehmkuhl<sup>1</sup>, Georg Stauch<sup>1</sup>, Philipp Schulte<sup>1</sup>, Stefanie Wolf<sup>2</sup>, and Catrina Brüll<sup>2</sup>

<sup>1</sup>RWTH Aachen University, Department of Geography, Aachen, Germany (flehmkuhl@geo.rwth-aachen.de)

<sup>2</sup>RWTH Aachen University, Institute of Hydraulic Engineering and Water Resources Management

Extreme precipitation and resulting extraordinary discharge on July 15<sup>th</sup> 2021 caused serious flooding and erosion in the northern foreland of the Eifel Mountains, western Germany. We provide two examples of strong backward erosion and sedimentation events from two open cast mining areas in North Rhine-Westphalia (NRW). The first one from the catchment of the Inde River close to Lamersdorf and the lignite open cast mining Inden; the second one from the catchment area of the Erft River near the village of Blessem and the local gravel mining. On-site fieldwork was supported by surveys of unoccupied aerial systems (UAS). Subsequent structure-from-motion (SfM) analyses were compared with the 1 m digital elevation model of the state NRW to estimate size and volume of the erosion and to provide the basis for a geomorphological mapping approach.

At the Inde River between 1998 and 2005 a new river course was created due to the eastward extension of the lignite mining Inden. The 4 km long course of the Inde River was abandoned and today the river relocation, "new Inde River", passes the mining area in a ~12 km long river bend to the west. At the junction of the new and old river course a flood protection dam was constructed to avoid the flooding of the lignite mining. After heavy rainfall on July 15<sup>th</sup> bankfull discharge of the Inde River resulted in a spill over at the junction and the reoccupation of parts of the old river channel. As the lignite mining is more than 200 m below the surface, rapid erosion of the old channel and fast backward erosion creates a 540 m long gorge which was about 5 m deep. More than 500.000 m<sup>3</sup> of material were eroded and subsequently accumulated in the lignite mining area.

At the Erft River flooding of a 60 m deep gravel pit occurred and backward erosion quickly reaches the nearby settlement Blessem resulting in the destruction and damage of several houses. In Blessem, first the settling basin of the gravel pit was flooded on July 15<sup>th</sup> 2021, resulting in backward erosion of the flood protection dams and finally in a large canyon. An area of more than 7 ha eroded until a depth of 8 m to max. 14m and more than 530,000 m<sup>3</sup> sediment were transported into the nearby gravel pit. The new erosion level of the Erft River was about 3 m below its previous base. The original 60 m deep gravel pit was filled with water and about 30 meters of sediments. The digital elevation model and the aerial images indicate three morphodynamic phases of this flood event, with different direction of backward erosion and sediment transport.

Both areas show semi-circle like structures caused by the backward erosion at the headwalls. Immediately deposited material in the headwalls during the event slowed down the erosion processes. Both examples show the high risk and strong geomorphological processes in flooded open-cast mining areas with large base-level changes on short distances.