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Geomorphological Response of the *Valnontey* River Basin (NW Italy) to the Extreme Rainfall Event of June 2024

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Abstract: Mountainous regions are now subject to more recurring flash floods than they were in the past decades. These recurring flash floods are attributed to short-duration extreme precipitation events, which are driven by climate change. Mountainous flash floods are far more hazardous as they trigger landslides, activate debris flows, and carry a large amount of dead wood, which can destroy entire valley infrastructure such as roads, bridges, and dams. Moreover, in response to these floods, valley rivers (confined or partially confined) also undergo geomorphological transformation, owing to debris flows. The sediment transportation activates processes like bank erosion, channel incision, bed alteration, and overbank aggradation both at the spatial and temporal scales. In June 2024, a mountainous flash flood led to dreadful destruction of the *Valnontey* catchment located in *Cogne, Valle d'Aosta* (northwestern Italian Alps). Not only was the valley infrastructure destroyed within a few hours, but the valley river network also experienced significant geomorphological changes due to the activity of debris flows and landslides. Intensive Post-Event Campaigns (IPECs) were carried out to quantify the flash flood and its geomorphological impacts in the *Valnontey* catchment. The 24-hour cumulative rainfall was estimated to be approximately 120 mm, and the reconstructed peak discharge ranged between 200 and 250 $m^3 s^{-1}$. This is why in alpine catchments, where the real-time data on flood events is almost absent, post-event studies of hydro-geomorphological response to extreme rainfall events can be extensively found in the literature. However, the impact of resulting geomorphological changes to a flood event, mainly the channel widening, is generally not considered in flood hazard assessment and mountain river basin management, and so the study of all associated factors to geomorphological changes during high-magnitude floods remains a significant research gap. In this study, the analysis of geomorphological dynamics and channel response to such a flood event has been performed, with a principal focus on channel widening. The widening, a geomorphic response to flood events, of the main channel in the *Valnontey* basin was investigated quantitatively through manual digitization of channel margins using GIS tools. The methodological framework was based on multitemporal high-resolution pre-flood orthophotos and a LiDAR survey acquired immediately after the flood event (August 2024). It was observed that the main channel was predominantly widened because of floodplain island erosion and bank erosion processes that supplied sediments to the main channel. Statistically, the channel

response, usually expressed as the width ratio (post-event width/pre-event width), was analysed in relation to channel bed slope and stream power. The results indicate that channel widening was controlled not only by extreme rainfall intensity and stream power (hydraulic factor), but also by morphological characteristics, including lateral confinement, channel bed slope, sediment availability, transport mechanisms, and hillslope–channel coupling.

Keywords: Alpine catchments; Extreme rainfall; Flash floods; Channel widening; Flood hazard