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The 2012 Seti River flood disaster and alpine cryospheric hazards facing Pokhara, Nepal

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We have identified the likeliest cause of the Seti River disaster of May 5, 2012, in which a flash flood killed or left missing 72 people. A cascade of deadly physical Earth processes combined with imprudent habitation on the lowest flood terraces and floodplain. The process cascade started with rockfalls into the Seti River gorge (observed via repeat ASTER imaging). The last rockfall—one to several weeks prior to the disaster-affected a knickpoint in the Seti River gorge and impounded glacial meltwater and spring snowmelt. The trigger was a large rock/ice avalanche originating from cornice ice on Annapurna IV, where part of the mass was channeled into the impoundment reservoir. That violent ground-surge event, plus possibly an air blast caused by a violent gravity flow of airborne debris—then burst the rockfall dam. This was not a glacier lake outburst flood. Glaciers were involved in the disaster by supplying meltwater, which was impounded by the rockfall dam, by triggering the disaster with collapse of cornice ice, and by contributing ice to the landslide and outburst flood. Debuttressing of moraine debris and ancient glacial lake sediment by retreat and thinning of glaciers also may have played a role—this is the only possible indirect link of the disaster to climate change. The rockfall and avalanche mass movements occurred independently of climate change. The narrow and easily blocked Seti River gorge was a key factor in the 2012 disaster, and it remains a unique component of this physiographic setting. A similar flood in this area may happen by a different cascade of Earth surface processes. An enormous mass of ancient unconsolidated glaciolacustrine and moraine sediment—many cubic kilometers—was discovered and is vulnerable to production of debris flows and hyperconcentrated slurry flows. Some aggravating processes occurring in the Sabche Cirque are related to climate change. Glaciers in that area are melting, and small lakes are forming. Although the lakes were not implicated in the 2012 disaster, the possibility exists for a small glacial lake outburst flood to trigger a larger mass movement. Such a debris flow could reach Pokhara directly. More likely, a debris flow in the Sabche Cirque could form another temporary and potentially dangerous impoundment dam in the gorge. Furthermore, the type of rockfall blockage that produced 2012's natural impoundment reservoir is likely to happen repeatedly. Hence, there is a high capacity of the Earth system in this area to produce comparable or even bigger flash floods or mass flows. The likelihood of a further disaster is magnified by imprudent habitation of the river channel and lower floodplain. Of all the changes to the Pokhara Valley, human encroachment on the flood plain is the factor most related to increasing vulnerability, but it is also the one factor that could be remedied by a complete ban on construction on lower terraces, if that is politically feasible. Warning systems could help, but fairly relocating people in jeopardy would be more effective. *Supported by NASA/USAID SERVIR Applied Sciences and USAID Climbers' Science.*