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Groundwater flow systems in the great Aletsch glacier region (Valais, Switzerland)

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Groundwater flow systems in Alpine areas are often complex and challenging to investigate due to special topographic and climatic conditions governing groundwater recharge and bedrock flow. Studies seeking to characterize high-alpine groundwater systems remain rare, but are of high interest, e.g. for water supply, hydropower systems, traffic tunnels or rock slope deformation and landslide hazards. The goal of this study is to better understand the current and past groundwater flow systems of the UNESCO World Heritage mountain ridge separating the great Aletsch glacier and the Rhone valley, considering climatic and glacier fluctuations during the Lateglacial and Holocene periods. This ridge is crossed by a hydropower bypass drift (Riederhornstollen) and is composed of fractured crystalline rocks overlain by various types of landslides and glacial deposits.

Surface hydrology observations (fracture properties, groundwater seepage, spring lines and physico-chemical parameters) and hydropower drift inflow measurements contributed to the characterization of bedrock hydraulic conductivities and preferential groundwater pathways. Basic conceptual hydrogeological models were tested with observed drift inflows and the occurrence of springs using free-surface, variably saturated, vertical 2D groundwater flow models (using the code SEEP/W from GeoStudio 2007). Already simple two-layer models, representing profile sections orthogonal to the mountain ridge, provided useful results. Simulations show that differences in the occurrence of springs on each side of the mountain ridge are likely caused by the occurrence of glacial till (generating perched groundwater), the deep-seated sagging landslide mass, faults and asymmetric ridge topography, which together force the main groundwater flow direction to be oriented towards the Rhone valley, even from beyond the mountain ridge.

Surprisingly, the most important springs (those with high discharge rates) are located at high elevations above the terraces of Riederalp and Bettmeralp in or near steeply dipping fault zones striking parallel to the ridge, suggesting locally a near-surface groundwater table. Drying up of several of these springs (at lateral distances up to 4 km) after construction of the Riederhornstollen, as well as associated large tunnel water inflows, demonstrates large scale hydraulic connections along strike of these fault zones. The catchment areas of these springs have to be located close to the ridge crest, above the terraces of Riederalp and Bettmeralp, and extend over many kilometers. This fault system thus drains significant portions of the high-altitude recharge and induces a complex 3D groundwater flow field of the Aletsch area.

Variations in glacial ice extent due to different climatic conditions during the Lateglacial and Holocene periods were studied by varying the boundary condition of the great Aletsch glacier. Results have to be interpreted with care, as the glacier pressure boundary conditions were modelled like a lake. Detailed investigations of these boundary conditions have been initialized by glacier drillings equipped with melt water pressure sensors. With the simplified boundary conditions applied to the glacier bed, elevated ice surfaces during the Little Ice Age stage only slightly influence the flow field and total hydraulic head conditions on the NW side of the ridge. On the other hand, the Egesen stadial causes a fundamental change of the groundwater devide with all flow lines, even from below the Aletsch glacier, oriented towards the Rhone valley.