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Simulation of the impacts of projected pumped-storage operations on temperature and turbidity in the two affected lakes

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Pumped-storage systems are used to store electric energy as potential energy for release during peak demand. Increasingly they are also used to buffer intermittent power production from renewable energy sources such as wind or photovoltaics. For this reason, a growing market for pumped-storage systems is expected in the near future, and several such systems are currently planned in the Alps. Here we investigate the impacts of one of these proposed systems on temperature and turbidity in the two affected lakes. The upper of the two lakes is an artificial reservoir that receives large amounts of suspended inorganic particles from the partially glaciated watershed, resulting in high turbidity, especially during summer. The lower lake is much clearer and important for tourism and recreational fishing. The water will be both withdrawn and released within the hypolimnion of the lower lake to avoid an excessive increase of turbidity in its surface layer. The two lakes were simulated by two coupled 2D models using the software CE-QUAL-W2. Simulations were performed for the system with and without pumped storage for different hydrological conditions (dry year, wet year, average year) and for 29 years of meteorological conditions. The simulations showed that the pumped-storage operations lead to an increase in temperature in both lakes during most of the year. The increase is most pronounced in the upper hypolimnion of the lower lake towards the end of the stratified period. About half of the warming is due to the heat added to the water by frictional losses during the pumping or the release through the turbines. The remainder of the warming is from the more intense coupling of the water to the atmosphere while it resides in the shallower upper lake. These impacts on temperature are generally most evident during warm and dry years, when the coupling to the atmosphere results in the strongest heating and the effects are least concealed by the impacts of floods. The exchange of water between the two lakes will also lead to a reduction of particle concentrations in the upper reservoir by a factor of two to three, and to a subsequent accumulation of particles at the release depth below the thermocline in the lower lake. Surface particle concentrations in the lower lake are expected to increase by 0-2 mg/L during the whole year for all meteorological and hydrological conditions, except for a few higher peaks during flood events. The increased particle concentrations are expected to reduce the euphotic depth in the lake by $\sim$20%, i.e. by 1-2 m in wet years and by up to 4 m in dry years.