Impact of climate change on a Mediterranean karst aquifer under active management: the example of the Lez spring in southern France

Key findings

- The Lez karst aquifer is under active management for supplying drinking water to Montpellier city – it is subject to the highest groundwater pumping in the world.
- The karst aquifer is highly complex with two different compartments and an impact of pumping at the regional scale.
- A new semi-distributed global modeling approach has been developed to simulate water levels in the different parts of the aquifer and the discharge rate at the spring.

Motivation

The Lez spring has been supplying the city of Montpellier since 1854. Prior to 1968, the resource was exploited through gravity abstraction varying between 25 and 600 l/s. In 1982, deep wells were drilled into the main karst drain upstream of the spring (Figure 1) to obtain a maximum yield of 2000 l/s. Today, the mean pumping flow rate is about 1050 l/s, which represents the highest pumping rate from a single point in the world. This kind of exploitation is called "active management", with a controlled water level depletion of the karst aquifer. Groundwater is abstracted at a higher rate than the natural discharge rate at the spring during summer. This creates storage capacities for infiltrating water during fall which usually comes with high rainfalls. During summer, a part of the abstracted water is diverted into the Lez river to ensure a minimum discharge rate for aquatic ecosystems. The main objective of our study is to develop a modeling tool that can simulate the complex hydrodynamics of the karst aquifer in order to compute the future impact of climate change and a potential increase of pumping rates on water levels and discharge.

Methodology

The developed hydrogeological model is based on our state of knowledge of the Lez karst system, which consists of two main compartments with very different hydrogeological characteristics: The western part is unconfined and constitutes the infiltration area of the aquifer while the eastern part is confined (Figure 2). The modeling was done using transfer methods implemented with TEMPO software (Pinault et al., 2001). This methodological approach, called inverse modeling, enables us to characterize the regime of complex hydrosystems that are found in karst as well as of

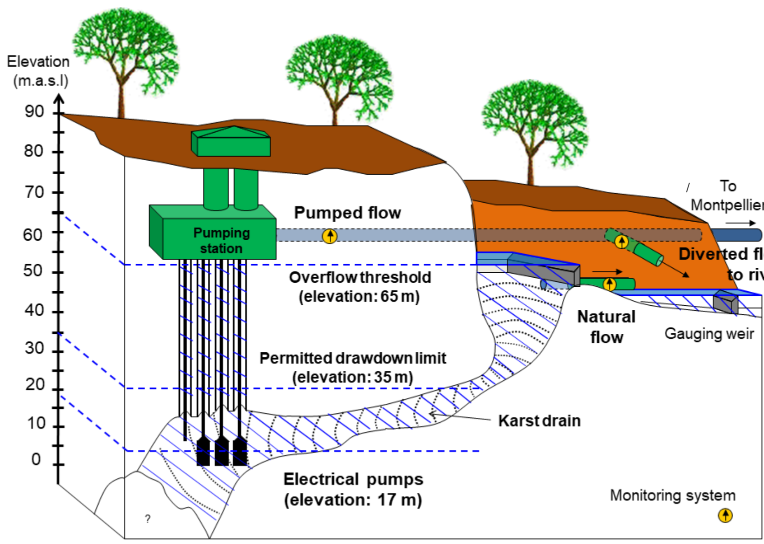

Figure 1: Pumping configuration at the Lez spring

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MedWater

TEMPO software

TEMPO is an inverse model that calculates unit hydrographs as well as the impulse response of fluxes from rainfall data, the purpose of which is hydrograph separation. Inverse modeling makes it possible to characterize the dynamic processes from which the properties of karst systems can be identified. The relationship between inputs and outputs is based on normalized impulse response functions, whose parameters are obtained through the inverse method. The mathematical development is based on the work by Pinault et al. (2001).

more homogeneous porous media. The transfer model we used is composed of four sub-models (or modules) to reproduce the hydrodynamic regime of a complex karst aquifer made up of two compartments and subject to an active management through pumping.

Results

Climate change scenarios from the Intergovernmental Panel on Climate Change have been downscaled at the karst catchment scale in order to produce temperature and precipitation time series for the period 2045-2065. The semi-distributed model was first calibrated and validated on past data time series of water levels and discharge measured for the karst aquifer (Ladouche et al., 2014). Then, the model was used to simulate the impact of climate and pumping change scenarios on water levels and discharge rates at the outlet of the karst aquifer. Figure 3 shows the simulated and observed water levels at the spring for the reference case (in blue) and the future case (climate change plus an increase of pumping by 20 %). These results are compared to two important levels: the present authorized drawdown limit into the karst drain and the elevation of the pumps. This provides a first idea about the sustainability of the aquifer's active management in the future. The simulations show that the Lez karst aquifer will be impacted by climate change and pumping increase in a way than can still be supported by the groundwater resource.

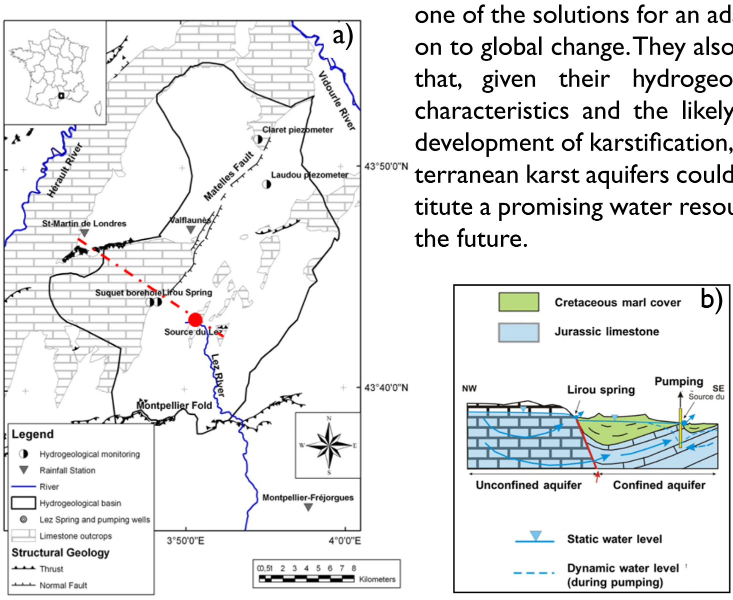

Figure 2: a) Hydrogeological map and b) cross section of the Lez karst aquifer (modified after Ladouche et al. (2014))

Application

The model shows that climate change would induce a decline of groundwater recharge, a water level decrease of 4 to 5 meters, and a decrease of 250 to 400 l/s of discharge rates during low flow conditions. The pumping system could even allow an increase of abstraction in the future, but a pumping test in real conditions is necessary to investigate the hydrodynamic properties of the aquifer in such likely lower level conditions. More generally, these results show that the karst aquifer's active management could constitute one of the solutions for an adaptation to global change. They also show that, given their hydrogeological characteristics and the likely deep development of karstification, Mediterranean karst aquifers could constitute a promising water resource in the future.

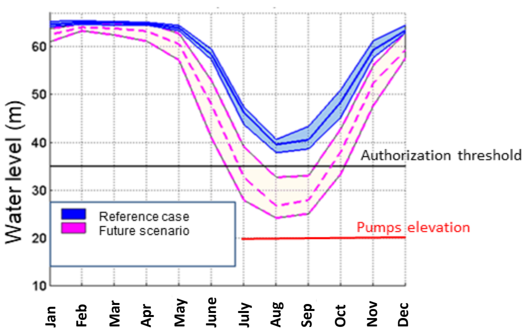

Figure 3: Observed and simulated monthly average water levels at the Lez spring (blue: reference case with present climate and exploitation rate; red: scenario with climate change and exploitation rate increase)

References

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