IWRA Online Conference
Addressing Groundwater Resilience under Climate Change
28-30 October 2020

(1) rylegejl@gmail.com
(2) UNESCO Chair "Appropiate Technologies for Human Development". Departamento de Geodinámica, Estratigrafía y Paleontología. Facultad de Ciencias Geológicas. C/Jose Antonio Novais 2. Universidad Complutense de Madrid. Ciudad Universitaria, 28040 Madrid, Spain. E-mail: pemartin@ucm.es

RESILIENCE OF GROUNDWATER ECOSYSTEMS TO PUMPING

A. de la Hera-Portillo(1), J. López-Gutiérrez(1), H.J.Henriksen(2), E. López-Gunn(3), R.N.Gejl(4), B.Mayor(3), P. Zorrilla-Miras(3), P.Martínez-Santos(5)

(1) Instituto Geológico y Minero de España (IGME)/Geological Survey of Spain. Ríos Rosas 23. 28003 Madrid.a.delahera@igme.es; j.lopezgu@igme.es;
(2) Geological Survey of Denmark and Greenland (GEUS). Oster Voldgade 10, 1350 Copenhagen, Denmark. E-mail: hjh@geus.dk;
(3) ICATALIST. Borni 20, 28232 Madrid. E-mail: elopezgunn@icatalist.eu; bmayor@icatalist.eu; pzorrilla-miras@icatalist.eu;
(4) E-mail: rylegejl@gmail.com;
(5) UNESCO Chair "Appropiate Technologies for Human Development". Departamento de Geodinámica, Estratigrafía y Paleontología. Facultad de Ciencias Geológicas. C/Jose Antonio Novais 2. Universidad Complutense de Madrid. Ciudad Universitaria. 28040 Madrid, Spain. E-mail: pemartin@ucm.es;

1. Introduction

- Aquifer's resilience, understood as the potential of the aquifer to sustain disturbances on the long term and to guarantee essential qualities and functions, provides a key tool when assessing sustainable groundwater management alternatives.
- However, aquifer's resilience analysis requires long-term trends based on good established observation networks.
- This poster presents two case studies: in Spain and Denmark. The Mancha Occidental aquifer (Spain) is an unconfined karstic aquifer, meanwhile the danish aquifers are a set of confined coastal aquifers.
- Selected data have allowed identified key variables whose evolution help to understand the aquifers' dynamics.

2. Methodology

- Long term trends analysis of quantity and quality data.
- Identification of key variables.
- Analysis of evolution of key variables (identification of thresholds) (Fig.1).

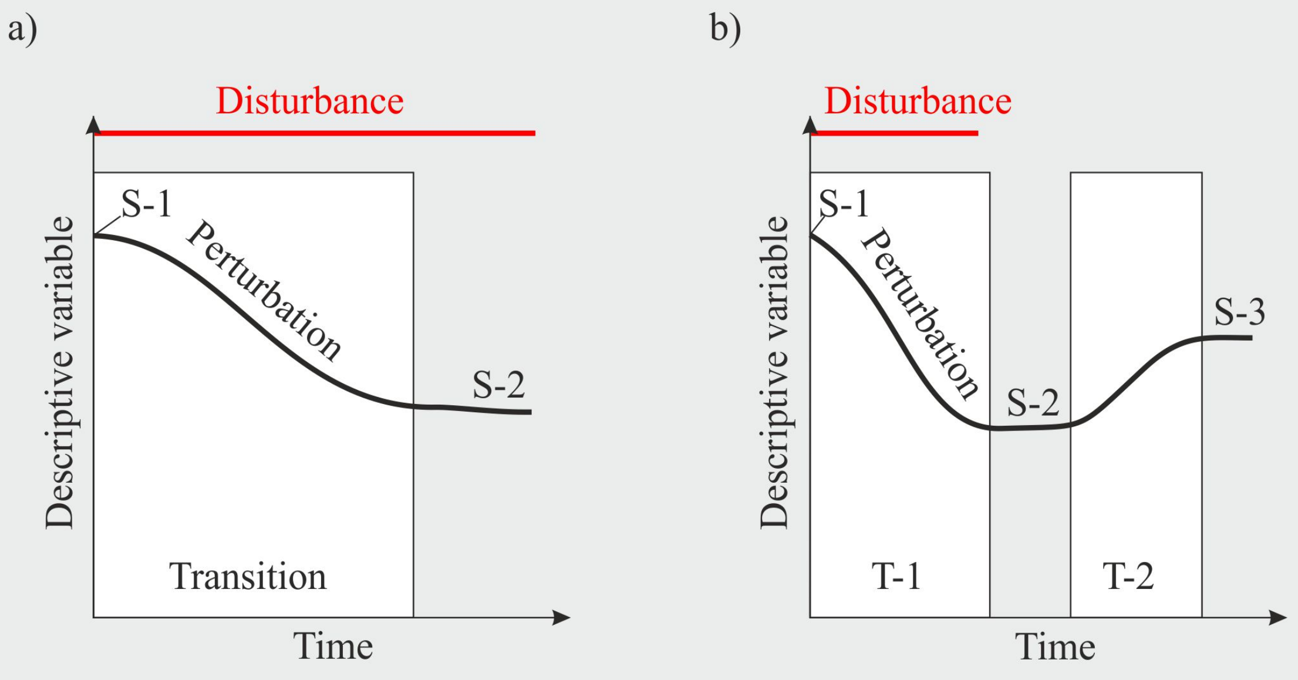


Fig. 1. Scheme of the aquifer resilience through the temporal evolution of a descriptive variable. The black lines indicate the time series observed of the aquifer system, and the red lines represent the time series of the underlying environmental conditions.
(a) In a theretical example, the pumping of groundwater from an aquifer (disturbance) prolonged over time will cause a water table depletion (parameter) which could reflect the aquifer response to the impact.
(b) If the pumping ceases (disturbance stops), the aquifer may recover a new equilibrium (State-3). Both behaviours (a and b) are useful to understand aquifer resilience and must be taken into account in the interpretation of the aquifer resilience (modified from De la Hera-Portillo et al., 2020a).

3. Results and discusion

Case study 1: Unconfined inland aquifer (Spain)

The Mancha Occidental aquifer (Fig. 2) is subject to a set of impacts (both climatic and anthropic). It is not possible to isolate just one of them for the aquifer's resilience analysis.

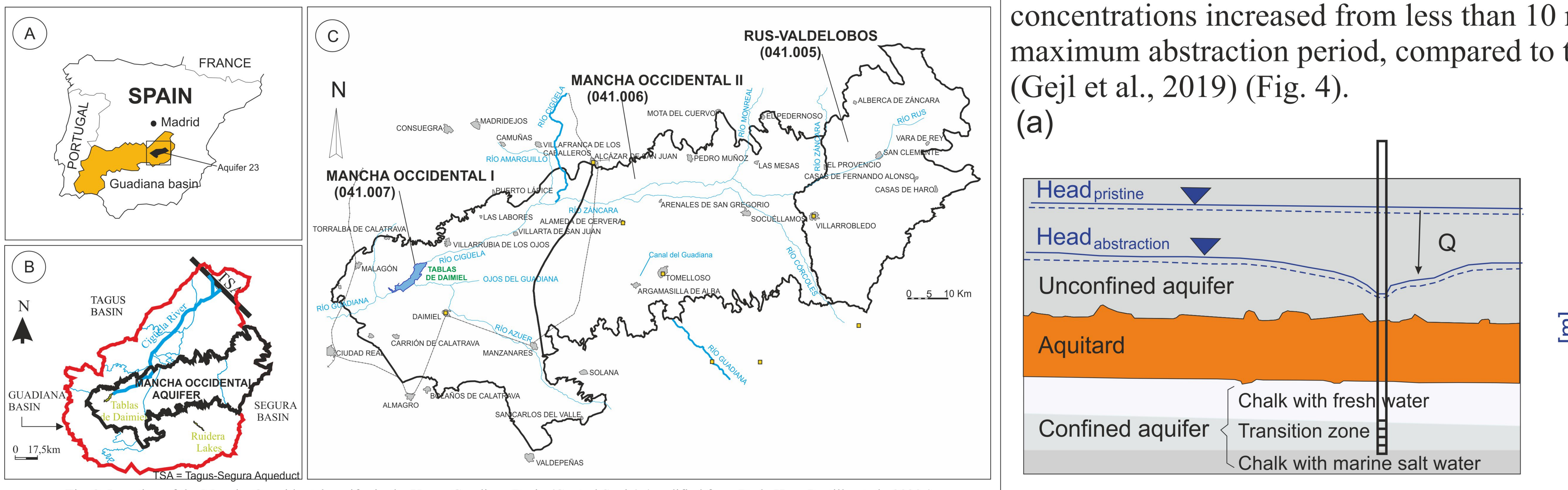
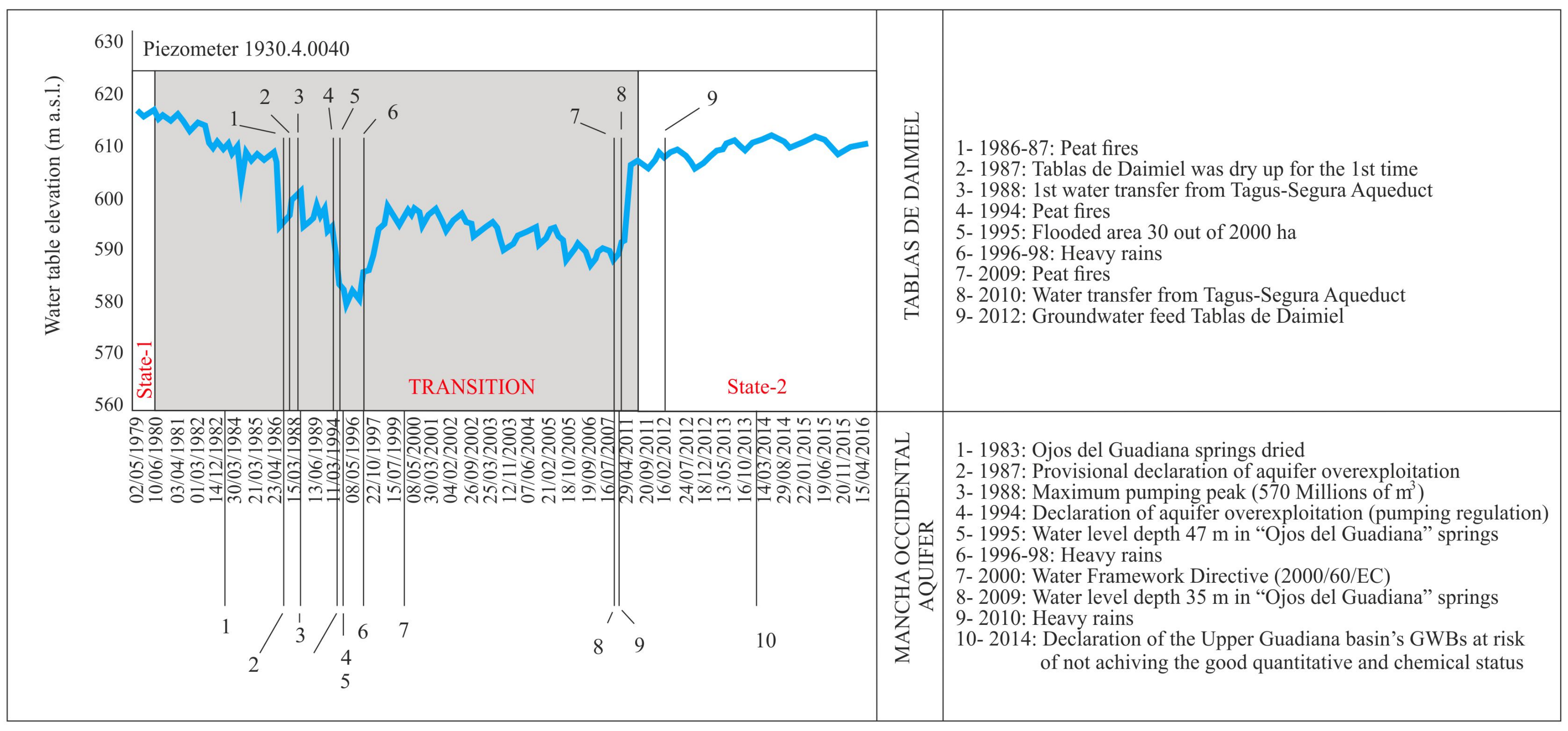


Fig. 2. Location of the Mancha Ooccidental aquifer in the Upper Guadiana Basin (Central Spain) (modified from De la Hera-Portillo et al., 2020c).



TABLAS DE DAIMIEL
1- 1986-87: Peat fires
2- 1987: Tablas de Daimiel was dry up for the 1st time
3- 1988: 1st water transfer from Tagus-Segura Aqueduct
4- 1994: Peat fires
5- 1995: Flooded area 30 out of 2000 ha
6- 1996-98: Heavy rains
7- 2009: Peat fires
8- 2010: Water transfer from Tagus-Segura Aqueduct
9- 2012: Groundwater feed Tablas de Daimiel

MANCHA OCCIDENTAL AQUIFER
1- 1983: Ojos del Guadiana springs dried
2- 1987: Provisional declaration of aquifer overexploitation
3- 1988: Maximum pumping peak (570 Millions of m^3)
4- 1994: Declaration of aquifer overexploitation (pumping regulation)
5- 1995: Water level depth 47 m in "Ojos del Guadiana" springs
6- 1996-98: Heavy rains
7- 2000: Water Framework Directive (2000/60/EC)
8- 2009: Water level depth 35 m in "Ojos del Guadiana" springs
9- 2010: Heavy rains
10- 2014: Declaration of the Upper Guadiana basin's GWBs at risk of not achiving the good quantitative and chemical status

Fig. 3. Water table evolution in a representative monitoring well (1930.4.0040) located near the Ojos del Guadiana springs and Tablas de Daimiel National Park (modified from De la Hera-Portillo et al., 2020a).

There is not a set of time series data to choose those variables most relevant for our resilience analysis. Groundwater level evolution (1970-2016) (Fig. 3) allows us to identify a transition period during which some events occur just before a change of trend in this variable.

A sufficient length of the time series is vital to be able to distinguish between different impacts.

The most frequent variable observed in hydrogeological studies are groundwater level fluctuations and periodical groundwater samples analysis. These are the variables controlled in most groundwater monitoring networks. It is important, therefore, to have good quality data records on groundwater abstractions to investigate the links between groundwater abstractions and their potentiometric surfaces.

Case study 2: Confined coastal aquifer (Copenhagen)

The potentiometric heads of the confined aquifers from 1940 until 2014 experiences a 2-14 m decrease in the nearby potentiometric surface compared to the prepumping potentiometric surface recordings, meanwhile sulphate concentrations increased from less than 10 mg/L to around 140 mg/L after the maximum abstraction period, compared to the earliest water quality parameters (Gejl et al., 2019) (Fig. 4).

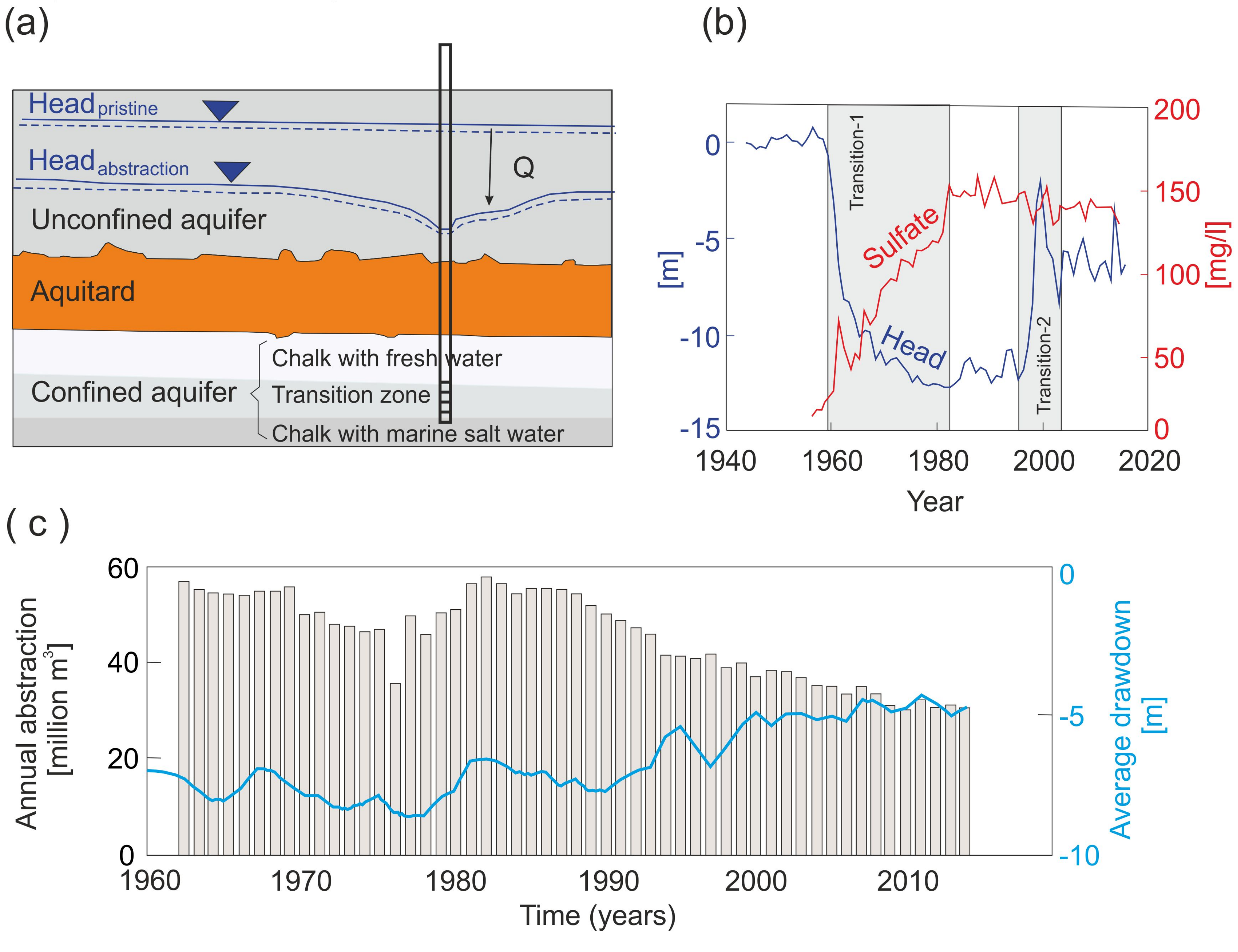


Fig. 4. Confined coastal aquifers around Copenhagen (Denmark) (modified from De la Hera-Portillo et al., 2020b).

Descriptive variables are potentiometric surface, vertical gradients and water quality parameters for the wells. Groundwater abstractions are an independent variable since the others vary depending on the extractions.

According to the system's changes, two transitions are recognised in the time series (abstractions, potentiometric surface and sulphate concentrations). T-1: goes from the pre-pumping conditions to during-pumping conditions (Fig. 4b). The associated changes show a steep decrease in the potentiometric surface versus an increase in sulphate concentrations. Meanwhile, the changes associated to T-2 show an increase in potentiometric surface versus a stabilization in sulphate concentrations (Fig. 4b).

Changes in the aquifer conditions during the pumping period show that pyrite oxidation was the main process affecting long term quality, as observed from increased sulfate and calcium concentrations. Therefore, changes in pyrite can indicate (un)sustainable groundwater abstraction in these confined aquifers.

5. References

Appelo, C.A.; and Postma, D. (2015). In Geochemistry, groundwater and pollution, vol. 2. A.A. Balkema Publishers, Leide.
Gejl, R.N.; Rygaarrd, M.; Henriksen, H.J.; Rasmussesn J.; Bjerg, P.L. (2019). Understanding the impacts of groundwater abstraction through long-term trends in water quality. Water Research 156 (2019) 241-251. doi: 10.1016/j.watres.2019.02.026.
De la Hera-Portillo, A.; Zorrilla-Miras, P.; Mayor, B.; López-Gunn, E. (2020a). The ecosystem resilience concept applied to hydrogeological systems: A general approach. Water 2020, 12, 1824; doi:10.3390/w12061824
De la Hera-Portillo, A.; López-Gutiérrez, J.; Mayor, B.; López-Gunn, E.; Henriksen, H.J.; Gejl, R.N.; Zorrilla-Miras, P.; Martínez-Santos, P. (2020b). Understanding the resilience of aquifers to groundwater pumping: a theoretical approach. Submitted to Water Resources Management.
De la Hera-Portillo, A.; Macallau Lópes, M.F.; López-Gtiérrez, J.; Orozco-Cuenca, T. (2020c). Assessing the conservation viability of the easternmost wetland of the Mancha Húmeda Biosphere Reserve (Spain). In: 2sd Euromediterranean Conference for Environmental Integration 10-13 October Sousse, Tunisia. Springer Nature.

6. Acknowledgements

This research has received funding from the European Union H2020 Programme under Grant Agreement No. 730497 for the reseach project NAIAD (Nature Insurance value: Assessment and Demonstration). The study reflects only the author's views and the European Union is not liable for any use that may be made of the information contained herein.