Groundwater as an Useful Resource in the Adaptation to the Climate Change: The Case of the Sinclinal de Calasparra Aquifer (Murcia, SE Spain)

I. Alhama, G. García and T. Rodríguez

1 Introduction

1.1 The Sinclinal de Calasparra Aquifer

The Segura River basin covers the provinces of Alicante and Murcia, located in the southeast of the Iberian Peninsula. It is an eminently agricultural region, whose main water demand, around 86% (CHS 2015), is used for this purpose and entails a contribution to the national GDP of over 2000 million euros per year, with 90% of the production destined for foreign trade with Europe (MAPAMA 2017). The semi-warm mediterranean climate predominates in the basin, with average annual temperatures around 18 °C and rainfall ranging between 300 and 400 mm/year.

18 of the 57 aquifers defined in the basin are overexploited (Senent and García Aróstegui 2014). This situation is aggravated taking into account the data of the historical series of the Agencia Estatal de Meteorología; in the last 10 years, average temperatures and annual rainfall above 20 °C and below 300 mm, respectively, have been registered in different parts of the basin.

The Sinclinal de Calasparra aquifer (MAsub 70.022, Fig. 1) is located in the southern sector of the Segura River basin, northwest of the Region of Murcia. It has a total area of 332 km^2 and annual resources of 12 hm^3, sufficient to enable the Confederación Hidrográfica del Segura (CHS, hereinafter), which is the Basin Management Organism, to operate in a controlled and sustainable way. The river

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recharges the aquifer in some stretches, while in others the discharge occurs from the aquifer, as is the case of the Gorgotón spring area.

The aquifer is constituted by jurassic and cretaceous limestone and dolomitic rocks of medium-high permeability that reach 300 m of thickness (Fig. 2) and are connected to each other by tectonic accidents (Rodríguez Estrella 1974; IGME 1985). A third of its total extension behaves as a free aquifer, while the rest remains confined under miocene marls up to 500 m of thickness. The piezometric levels oscillate between 170 and 210 m above sea level, depending on the extractive regime and rainfall.

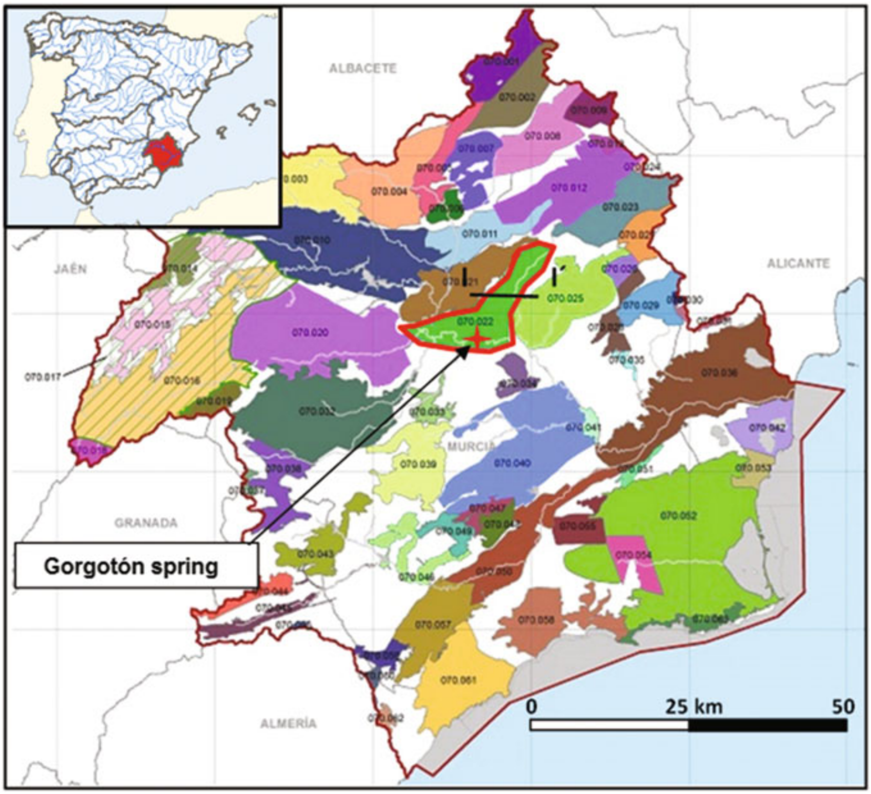

Fig. 1 Groundwater masses in the Segura River basin. The MAsub 70.022 and the Gorgotón spring are marked in *red*. *Source* https://www.chsegura.es and http://hispagua.cedex.es/datos/hidrografia

1.2 Exploitation Regime

The Sinclinal de Calasparra aquifer has been temporarily used in times of drought, taking advantage of the great hydric potential that it presents. The first time the CHS pumped groundwater in the Sinclinal was in the years 1984–85, doing it again from 1992 to the present, although not continuously (Fig. 3). The withdrawn groundwater is spilled to the Segura River so that, downstream, it can be derived from it for agricultural use. This also allows the river to maintain its ecological flow.

The groundwater abstractions have given water supply for irrigation and human consumption for the different watering communities and the populations of Murcia and Alicante. One of the most outstanding actions was carried out by the Mancomunidad de los Canales del Taibilla, dependent on the Ministry of Environment between the years 2004–2006, when a total volume of 110 hm^3 were

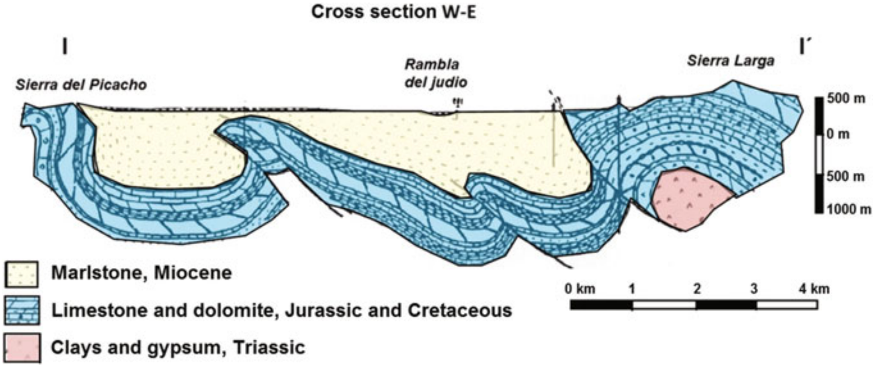

Fig. 2 Schematic geological cross section between the Sierra del Picacho and the Sierra Larga (see Fig. 1). Modification from Rodríguez Estrella and Conradi (2006)

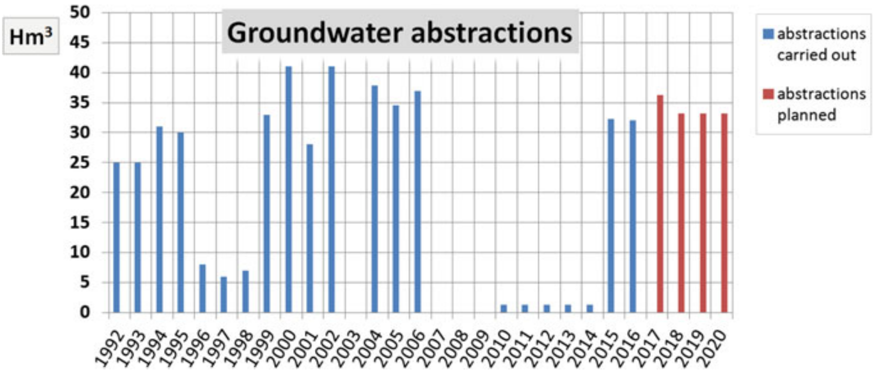

Fig. 3 Abstractions during the period 1992–2016. Also included the forecast for 2017–2020. 2003 and 2007–2009 data are not available

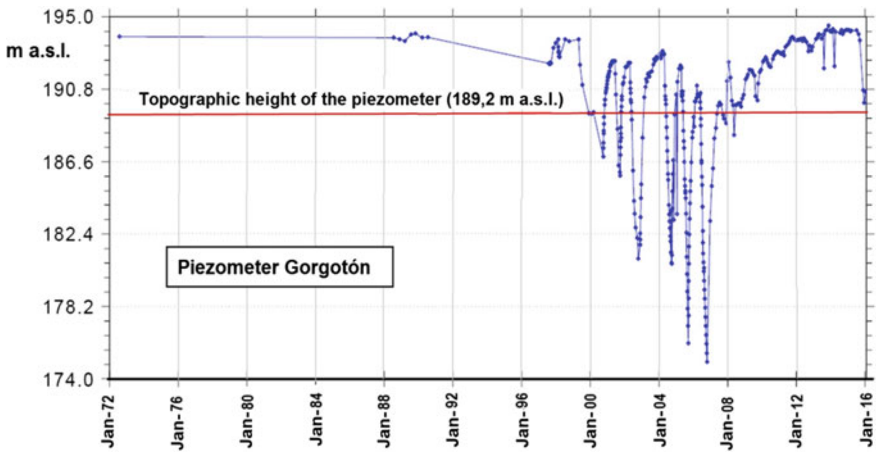

Fig. 4 Piezometric evolution in a piezometer located next to the Gorgotón spring

abstracted. This volume did not lead to long-term irreversible environmental effects, as evidenced by the recovery of the piezometric levels from 2007, reaching in 2010 a value similar to those before pumping (Fig. 4). Abstractions planned for the period 2017–2020 have been determined by the CHS taking into account the historical response of the aquifer in similar drought situations.

1.3 Objectives

The announced drought situation in the territorial scope of the CHS requires the adoption of exceptional measures for water resources management, including the use of groundwater storage. Numerical modelling should be carried out to quantify pumping effects on piezometry and surface water, so that environmental impact studies could be accomplished. The aim of the present work is to present a numerical model of the Sinclinal de Calasparra aquifer, based on previous models made by the IGME and the CHS. The model provides a tool for predicting the effects on the Gorgotón spring of the foreseen abstractions for the period 2017–2020, in terms of the recovery time of the upwelling.

2 Numerical Model of the Sinclinal de Calasparra Aquifer (2010–2030 Period)

It is known that at least two mathematical models of the Sinclinal de Calasparra aquifer have been carried out to date (IGME-DGA 2015). Since 2003, with special attention to the long periods of drought of 2006–2008 and 2011–2015 and with the idea of preserving ecological flows in the Segura River basin, updates and calibrations of the original models have been carried out. The models have simulated satisfactorily changes in piezometry and the behaviour of the spring during and after the studied periods.

The model presented in this work is based on the previous ones, although it has been recalibrated with recent piezometric data and incorporates hydraulic parameters from field tests. It has been made with Modflow (United States Geological Survey), in transient regime and without salt transport. The main characteristics of the model are presented in Table 1.

The studied period covers the years 2010–2030, with actual data of piezometry and rainfall from 2010 to 2016. The temporal distribution of the abstractions planned by CHS (the most important), together with the withdrawals from private wells and watering communities, is shown in Fig. 3. From 2020, only the volume granted to private wells is considered, 1.316 hm^3/year. The aquifer is highly regulated and controlled, so that the current and planned abstractions are supervised by the CHS. Findings and data related to aquifer management are available to the public through its website.

The Gorgotón spring has been simulated by means of a drain whose topographic elevation is similar to that of the ground surface. This tool allows the discharge of water from the aquifer to the river only when the piezometric level is above the ground surface elevation. The model itself calculates the discharge flows from the aquifer to the drain in each period. The model sensitivity mainly depends on the recharge from the rainfall, so that, in order to place the results in an unfavorable context, half of the one indicated in the basin hydrological plan has been

Table 1 Summary of the main characteristics of the model

Surface extension	346 km^2	Hydraulic conductivity *INPUT*	1.2–80 m/d
Deep extension	300 m	Hydraulic conductivity *OUTPUT*	2.4–100 m/d
Number of files	15	Rainfall recharge	10 hm^3/year
Number of columns	18	Recharge from irrigation	2 hm^3/year
Unit cell size	2000 × 2000 m^2	River infiltration	10.5 hm^3/year
No. calibration piezometers	6	Abstractions from pumping wells	0.3–5.9 hm^3/year
No. pumping wells	17	Effective porosity	0.02–0.26
Time period simulated	2010–2030 year		

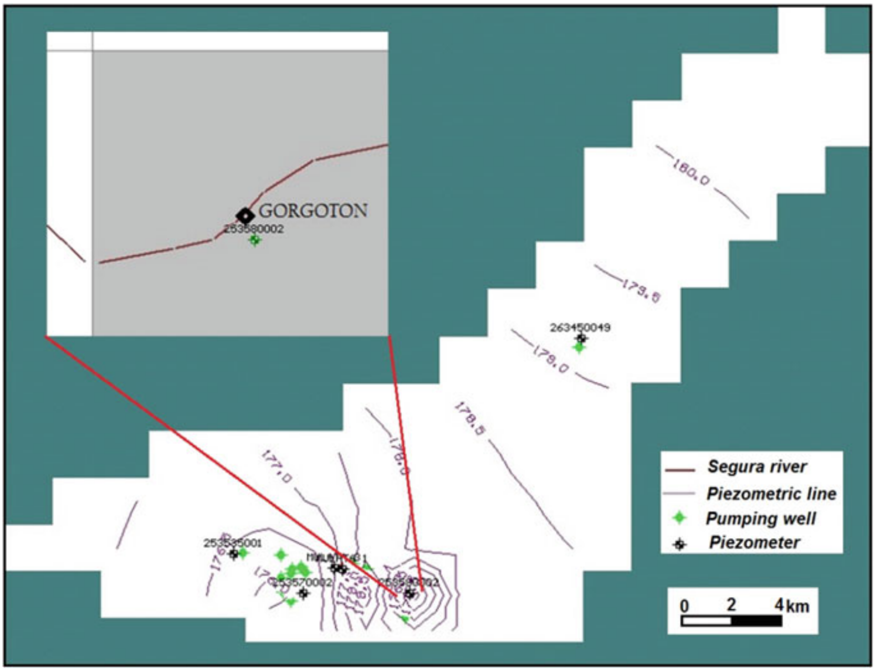

Fig. 5 Location of the calibration piezometers and pumping wells in the model. The piezometric lines correspond to the simulated situation in December 2015

considered. A detail of the extension of the model and the location of wells, piezometers and the spring can be seen in Fig. 5. The figure also shows the simulated piezometry in December 2017.

3 Results of the Simulation and Discussion

The time changes in the Gorgotón upwelling is shown in Fig. 6. The spring remains dry when the level of the piezometer of the Gorgotón, located 300 m from it, is below its elevation (189.2 m above sea level). It is estimated that the reappearance of the upwelling will occur a year and a half after the stop of the main groundwater abstractions. The recovery of the levels will take place five years later. These results are in agreement with the response of the aquifer in the action carried out in 2004–2006, when the recovery of the upwelling and the piezometric levels occurred one year and four years after the cessation of the pumping, respectively.

The average discharge volume of the spring before the abstractions that took place in 2015 (Fig. 7), ranges from 64,000 to 68,000 m^3/d, depending on the pumping regime of the private wells. In the period July–November 2015, there is a

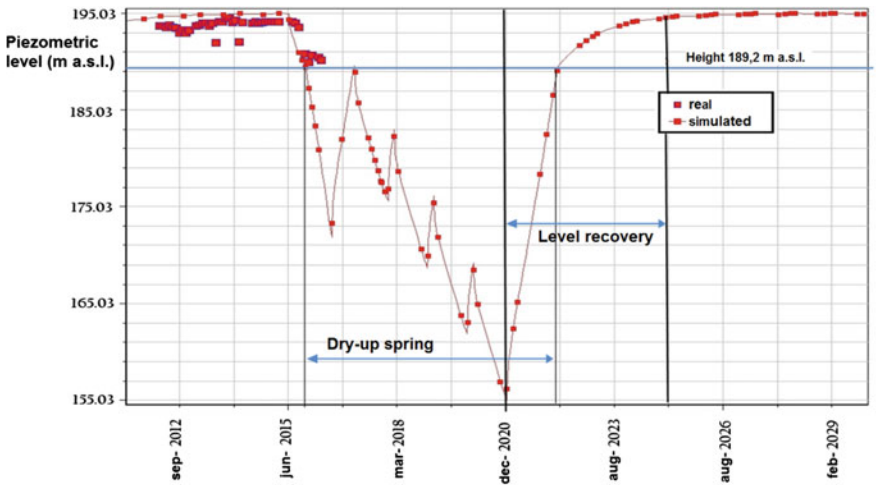

Fig. 6 Actual and simulated piezometry after the calibration process

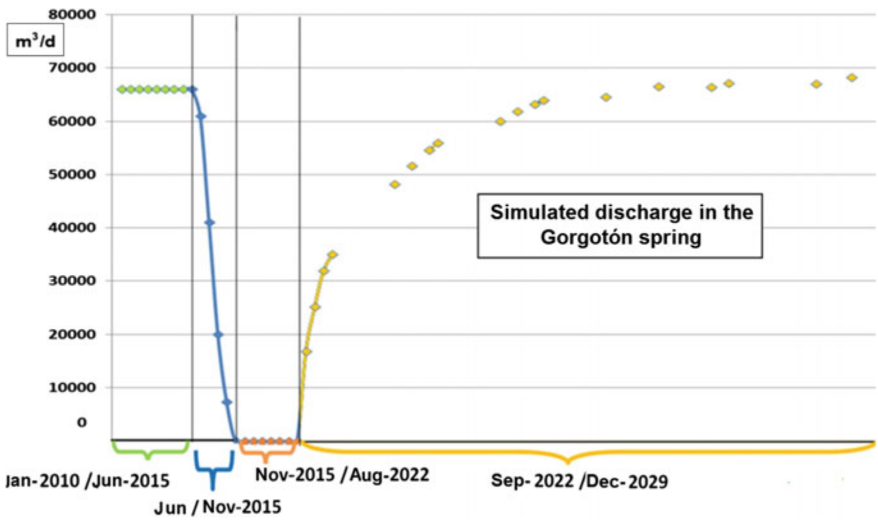

Fig. 7 Evolution of the discharge in the Gorgotón spring according to the simulation

gradual fall of the upwelling until its disappearance. This situation is maintained until September 2021, when a progressive increase of upwelling becomes noticeable until reaching, around year 2024, a steady value between 64,000 and 68,000 m^3/d.

The discharge from the aquifer to the river under natural conditions, without the effect of the pumping wells and according to the simulation data, would be around 22 hm^3/year; this is in agreement with the estimations given in previous studies, between 15 and 30 hm^3/year (IGME-IRYDA 1976).

4 Conclusions

Once declared the drought situation in the territorial scope of the CHS during the period 2015–2017 and as a requirement of the environmental impact studies, a numerical model of the Sinclinal de Calasparra aquifer has been made to quantify the effects of groundwater pumping on piezometry and surface. The model, based on previously verified numerical models to which piezometric data and updated hydraulic parameters have been incorporated for calibration, allows to predict that, according to pumping estimations for the period 2017–2020 (34 hm^3/year), the Gorgotón spring will discharge groundwater again in December 2020, a year and a half after the stop of the pumping. The spring will recover its usual discharge level (around 68,000 m^3/d) four years after the stop of the pumping.

In the case of the Sinclinal de Calasparra aquifer, its sustainable management through the intervention and supervision of the competent authorities (CHS), has made it possible to alleviate the worsening effects of drought in the agricultural sector, a major economic engine in the southeastern regions of the Iberian Peninsula. Numerical models are, once again, an essential tool for proper groundwater management.

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