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Cassiraga, Eduardo; Sanz, David; José Gómez-Alday, Juan; Gómez-Hernández, J. Jaime

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GROUNDWATER MANAGEMENT IN SPAIN: THE CASE OF THE EASTERN MANCHA AQUIFER SYSTEM

BY EDUARDO CASSIRAGA, DAVID SANZ, JUAN JOSÉ GÓMEZ-ALDAY & J. JAIME GÓMEZ-HERNÁNDEZ

Socio-economic development in the Eastern Mancha during the last 50 years has been made possible thanks to the intensive use of groundwater for irrigation, mostly financed by the end water users. Unfortunately, this intensive groundwater exploitation has created problems, such as the continuing lowering of piezometric levels, and the disconnection of the aquifer from some riverbeds. As a result, groundwater management became an issue with a need to control how and when groundwater could be used. Users, managers and groundwater experts have implemented a series of rules with the aim of reverting the effects of the past 50 years.

The Eastern Mancha aquifer system (EMAS) is one of the largest carbonate aquifers in the southwest of Europe, with a surface of 7260 km^2. Located at the Eastern part of Spain, EMAS belongs to the Júcar river water basin (Figure 1).

From a geomorphological point of view, the area is formed by big hollows from the intra-Miocene age, filled with later materials, still maintaining its original disposition, resulting in a flat high plain. This high plain, at 700 masl on average, is broken only by the Júcar river valley, that crosses the system. Surrounding the plain, the relief is smooth, becoming more abrupt, together with complex tectonics, away from it (Figure 1).

In the EMAS, there are outcrops from the Mesozoic, and large Plio-Quaternary deposits. The sedimentary sequence makes a multilayer aquifer with complex interactions between the different aquifer layers. From a hydrogeological point of view, the EMAS is made up of three hydrogeological units separated by aquitards or aquifuges [2]. At the base, there is an impermeable formation of silts, clays and chalks from the lower Jurassic. The most important permeable facies in the system, for their lateral extension and thickness are: i) dolomites and limestones from the Jurassic (partly Dogger) throughout the entire system, working as free aquifer layer towards the outer limits of the system and confined elsewhere, with transmissivities around 10,000 m^2/day; the average thickness is 250-350 m, with a maximum value of 400 m; ii) dolomites and limestones from the upper Cretaceous, in the northeastern side, with thicknesses of 50-150 m, as conductive as the previous ones; iii) limestones from the Miocene, in the center, working as a free aquifer layer; their transmissivity is between 1,200 and 7,200 m^2/day. All these aquifer units are separated by aquitards or aquifuges from the lower Cretaceous and by detritus rocks from the Tertiary (Figure 2).

The system is laterally contained by impermeable borders with the exception of: i) the northeast border, which is the water divide of the Júcar and Guadiana rivers and which does not coincide with the groundwater water divide; Sanz [3] suggests that the groundwater divide should be located 8 to 10 km to the west with

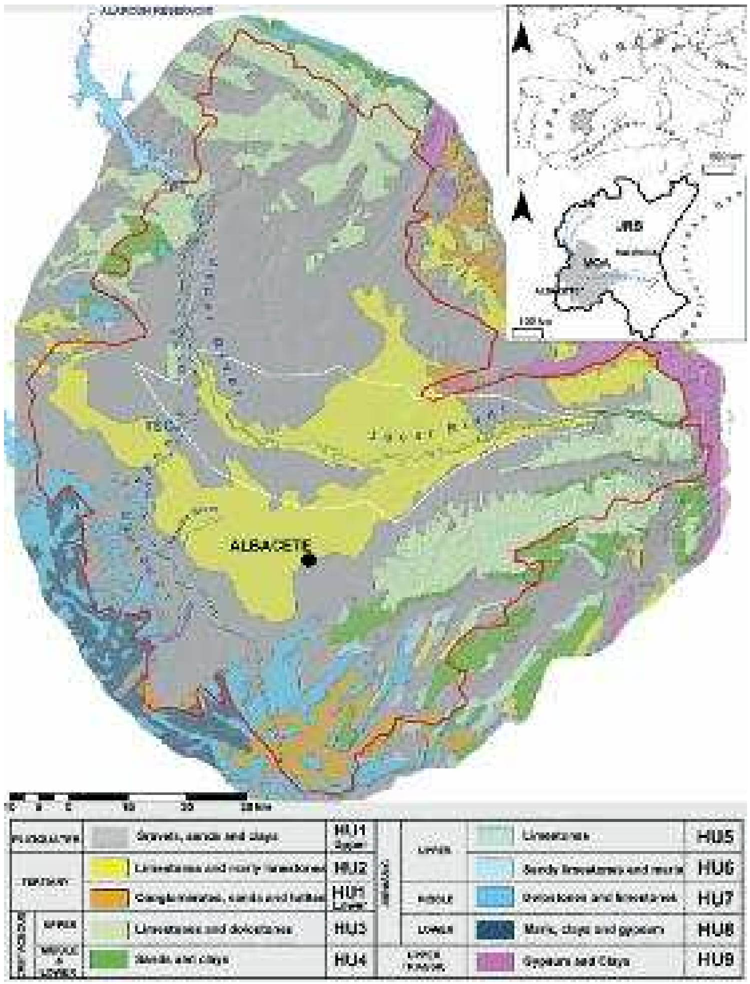
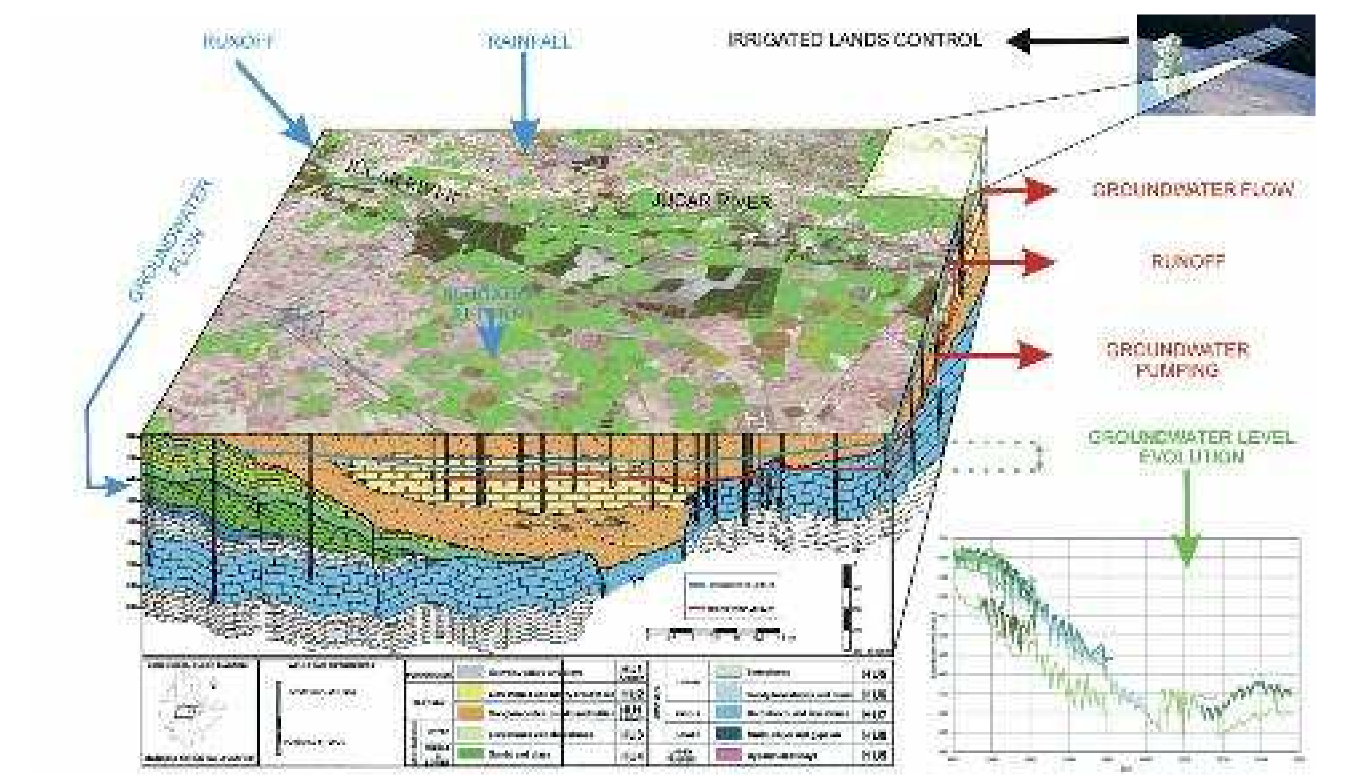


Figure 1. Plan view of the Eastern Mancha aquifer system with a simplified geological map (modified from [1])

Figure 2. Geological block diagram of the EMAS. Example of piezometric head evolution in one of the control points.



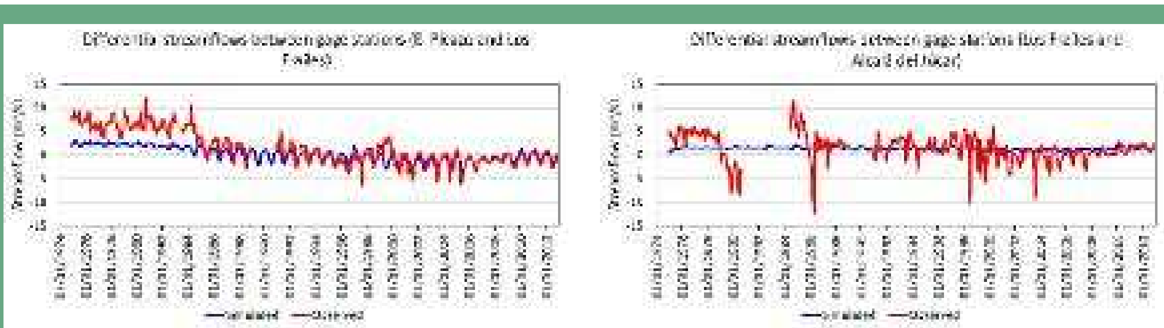


Figure 3. Differential streamflows between gage stations at two different stretches of the Júcar river. In red observed values, in blue simulated ones.

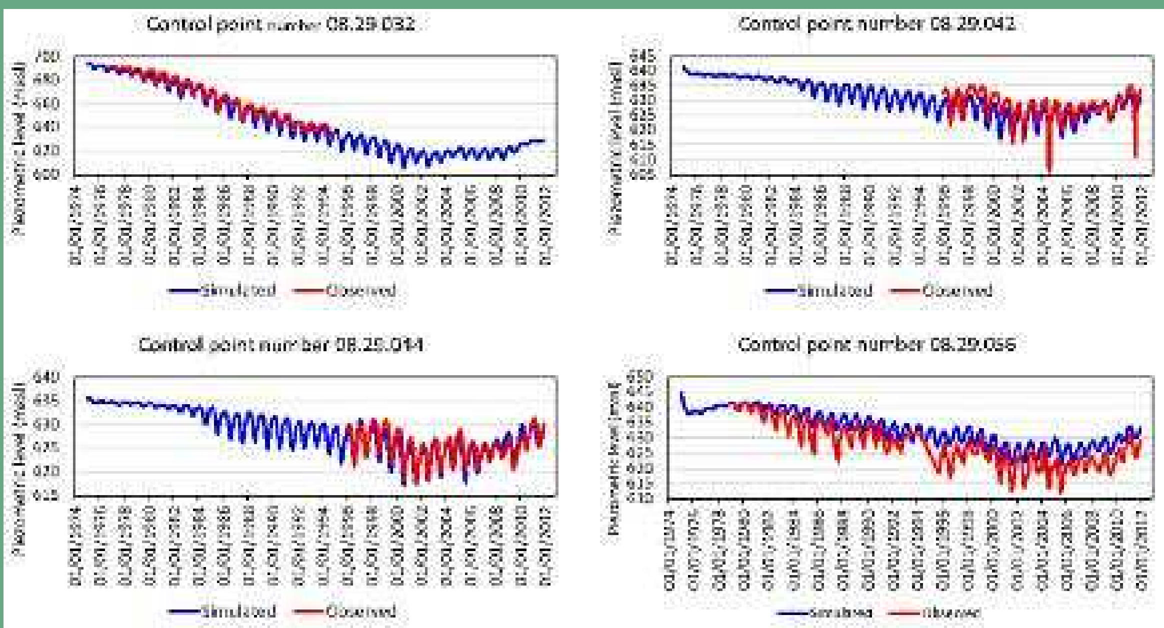


Figure 4. Observed (red) versus simulated (blue) piezometric levels at a few control points.

respect to the surface water divide, and possibly be variable in time; and ii) the southwest border, which is in contact with the aquifers of Jardín-Lezuza and Arco de Alcaraz that provide water to the EMAS. From a water balance point of view, under natural conditions, the main water input would be rain infiltration plus lateral inflow from the southwest aquifers, and the main water output would be the Júcar river.

In the middle of the 1960's, from initial hydrogeological studies, the significance of the EMAS as a water reservoir was recognized, with an estimate of exploitable resources of 350 x 10^6 m^3/year. This understanding, together with the discovery of submersible water pumps, cheap energy, and the relatively high price of crops, such as corn, produced a surge of well drilling by individuals, without much control by the water authorities, and the transformation of large areas into irrigated land. In the following years, a new legislation about water rights plus the lack of enough personnel to supervise the application of the new law, made the characterization, regulation and control of new wells difficult. The Mancha Oriental region suffered an important economic transformation driven by the development of 100,000 new hectares, most of them groundwater irrigated. In the first decade of the 21st century, groundwater extraction from EMAS was as large as 400 x 10^6 m^3/year, 98% of which went to irrigation. Extractions were not compatible with the estimated sustainable volume by [4] of 320 x 10^6 m^3/year, which, together with drought periods between 1990 and 1994, induced a significant drawdown in the piezometric level (as high as 80 m in some areas) and a reduction in the water flow from aquifer to the Júcar river (Figure 2).

The hydrogeological regime of the system has clearly been modified. Groundwater is now flowing to the cones of depression created by the extraction wells and the river-aquifer interaction has changed. The Júcar river changed from being a draining stream to a recharging one; the drawdown produced by the extraction wells prompted a recharge from the river to compensate for the large extractions. But the total rate of extraction was so large that in the 1990's the Júcar river, for the first time on record, went dry during the drought of 1990-1994. The point where the water table dropped below the river bed moved 20 km downstream with respect to its position prior to the beginning of the extensive pumping.

The Júcar Water Authority and the Mancha Oriental User Community realized the unsustainability of the situation and set a number of actions to revert the situation, namely: i) harmonization of the water rights and control of extractions by an annual exploitation plan agreed by all stakeholders, ii) improving the efficiency of irrigation systems, iii) importing surface water from outside of the system to replace some groundwater extractions, iv) replacing the Albacete city urban groundwater supply with water from the Alarcón reservoir in the Júcar river, v) buying (by the water authorities) some water rights during drought periods to reduce extractions. All these actions have had the intended effect as shown by the stabilization and initial recovery of the piezometric levels in the aquifer.

The Water Authority and the User Community established a collaboration agreement with the Universities of Castilla-La Mancha (UCLM) and Politècnica de València (UPV) to develop a numerical model using MODFLOW [5] and its graphical interface ModelMuse [6]. This model, which is calibrated and updated annually, serves to i) study the historical evolution of the aquifer under natural conditions, ii) understand the water balance of the system, iii) predict the state of the system, including both streamflows (Figure 3) and piezometric levels (Figure 4), iv) perform long-term scenario analysis and v) simulate the impact that actions such as well replacement or the buying of water rights may have during drought periods.

Model results have allowed a better understanding of the functioning of the EMAS and its interactions with the Júcar river, as well as to make predictions of how the different actions considered by the stakeholders will affect the system.

The Eastern Mancha Aquifer System is a clear example in which the awareness by stakeholders of a situation of unsustainability gives rise to collaboration among all concerned parties resulting in the acceptance of a set of necessary actions to prevent the continuous deterioration, and ultimately lead to the reversal of the depletion of the system. ■

Eduardo Cassiraga is an associate professor of Hydrogeology at the Universitat Politècnica de València (UPV) in Spain. He received a Hydraulic Engineering degree from the Universidad Nacional de La Plata, Argentina (1989), and a Ph.D. on Geostatistics from UPV (1999). He has been in the university since 1992, first as a PhD student and then as a professor. His lines of research are applied geostatistics, modeling of groundwater flow, modeling of precipitation with meteorological radar.

David Sanz has a Ph.D. in Geological Sciences by Complutense University of Madrid (Spain). He is an expert in Groundwater Modelling, Remote Sensing and GIS techniques. At present, he is assistant professor in University of Castilla-La Mancha. Current areas of research include the modeling of water resources (surface and groundwater) for agriculture.

J. J. Gómez-Alday has a Ph.D. in Geology from Basque Country University (Spain) and a master degree in Management in International Trade. He is an associate professor and director of Hydrogeology Group (University of Castilla-La Mancha). Research area include: transport, fate and natural attenuation of contaminants in natural systems.

J. Jaime Gómez-Hernández is a full professor of Hydrogeology at the Universitat Politècnica de València (UPV) in Spain. He received a Civil Engineering degree by UPV (1983), and an M.Sc. in Applied Hydrogeology (1987) and a Ph.D. on Geostatistics (1990) both by Stanford University. He joined UPV in 1994, where he has developed his research career in the fields of applied geostatistics, inverse modeling, stochastic groundwater modeling, and nuclear waste disposal. He has authored more than 100 publications in peer-reviewed journals.

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