ASSESSMENT OF GROUNDWATER RESOURCES IN AN INTENSIVELY IRRIGATED AREA IN GOLEGÃ-AZINHAGA REGION, PORTUGAL

Akram Hisham ALI MOHAMED[1], Luís RIBEIRO[1], Maria Paula MENDES[1]

1. *CERIS - Civil Engineering Research and Innovation for Sustainability, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais 1049-001 Lisbon – Portugal*

akram.hisham.db@gmail.com; luis.ribeiro@tecnico.ulisboa.pt; mpaulamendes@tecnico.ulisboa.pt

ABSTRACT

In the area of Golegã, the alluvial aquifer of the Tagus-Sado aquifer system is used to secure water needs by urban and rural uses. With high water needs, maize is the principal crop of the area and occupies 90% of the irrigated land. The objectives of this study were: i) groundwater recharge estimation of a typical hydrogeological year; ii) impact assessment of the water extraction for irrigation purposes in the Tagus alluvial aquifer and; iii) characterization of the interaction between this shallow aquifer and the rivers. A three-dimensional finite-difference groundwater model was used to deliver the intended objectives.

The median yearly recharge obtained was 255.5 mm/year corresponding to 44.6% of yearly precipitation. Groundwater flow modeling results show a general flow direction from the northwest to the southeast, in direction of Tagus river. During the irrigation season, the high demand in the southern part, where the pumping wells density is higher, promoted the lowering of groundwater levels up to 3.6 meters. This result showed that these pumping wells are inducing the main groundwater flow direction in the south and consuming water from the Almonda river from the west. This fact is interesting, as the Boquilobo Bog Natural Reserve lies in the south-western boundary of the study area along with the Almonda river. Overall, 69% of the water inflow into the aquifer system is coming from the adjacent Tagus-Sado right bank aquifer system.

Key-words: Alluvial aquifer system; groundwater flow model; steady state; water budget; unconfined aquifer

1. INTRODUCTION

The Water Framework Directive (WFD, 2000) states that the quantitative status of a body of groundwater may have an impact on the ecological quality of surface waters and its terrestrial ecosystems associated. This study addressed the quantitative attributes of groundwater resources in an intensively irrigated area by groundwater, where was assessed the hydraulic connection between the alluvial aquifer and Tagus and Almonda rivers.

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A three-dimensional finite-difference groundwater model was used to simulate the steady-state saturate flow.

2. CASE-STUDY

Agriculture is the main economic sector in Golegã, covering 95% of the study area (≅63 ha). In 2018, maize represented 90% of total land cover, followed by 6% of vegetable products and 4% of vineyards, olive trees and sunflowers (Fig. 1). This is a flat area with gentle slopes, bounded to the southwest by the Almonda river and to the east by the Tagus river. In this region Tagus river spreads out leading to sediment deposition in an alluvial plain that contains water at useable quantities. The shallow Tagus alluvial aquifer system belongs to one of the most productive hydrogeological units of Portugal mainland: the Tagus–Sado miopliocenic multi-layer aquifer system.

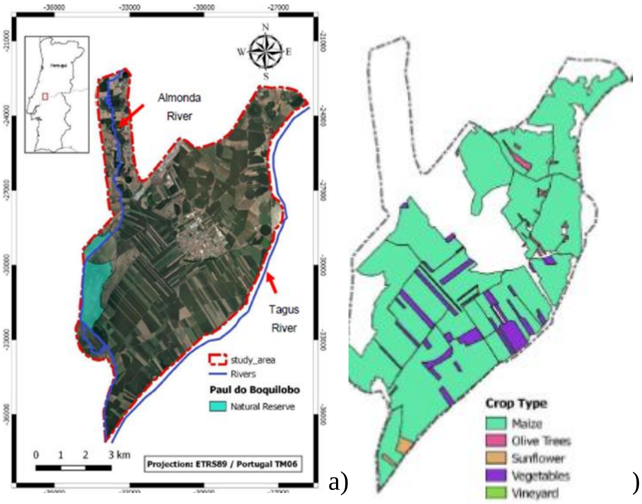

Fig.1 – Location of the case-study a) and main crops b).

3. HYDROGEOLOGICAL FEATURES

12 borehole log data were used to define the boundaries of Tagus alluvial aquifer within the area. Coarse gravel layers dominate the southern part, decreasing in thickness to east, where the two rivers meet. Also, the bottom clay layer has a larger expression in the southern part. The northern part is dominated by fine to coarse sand layers that decrease in thickness from west to east towards Tagus river. The Tagus alluvial aquifer system was modeled in a single isotropic layer (Fig 2). Considering the hydraulic conductivities reported by Almeida et al., 2000, 120 m/day was the initial value adopted. The rivers initial conductance value was set to 40 m^2/day.

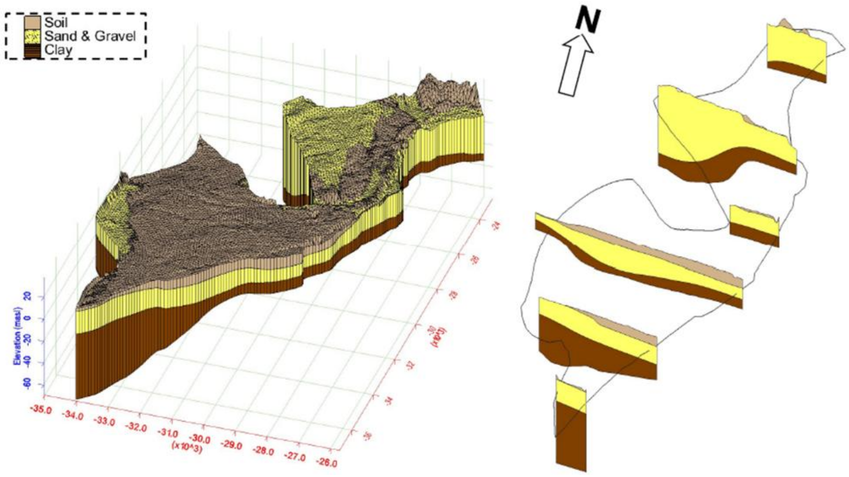

Fig 2- Geological Model (left) and cross-sections showing variation in layers' thicknesses across the study area (right)

The recharge of a typical hydrogeological year (hydrologic year of 2015/2016) was estimated based on MODIS global terrestrial evapotranspiration (ET) Product (Mu et al., 2013), and monthly precipitation. The median yearly recharge (R) obtained (i.e. R=P-ET) was 255.5 mm/year corresponding to 44.6% of yearly precipitation (P) (Ali Mohamed, 2018).

The pivot irrigation is more common in the northern part than in the southern part characterized by narrow plots and sprinkler irrigation systems (Fig 1). The pumping rates were established based on water needs of the irrigated crops, efficiency of irrigation systems and the irrigated plots area (total pumping rate of 109 619 m^3/day).

4. METHODS

A three-dimensional finite-difference groundwater model, MODFLOW (McDonald & Harbaugh, 1988), was used to simulate the saturate flow. A one-layer model was defined where the geological units of soil, sand, and gravel were combined. The model assumes that this unconfined aquifer has an isotropic behavior. The two rivers, Tagus and Almonda, were defined in the model as a river package as well as a small stream that cuts through the north part of the study area. The model was discretized in quadratic cells of 50 m. The study area was divided into three different zones to be able to analyze the individual contributions between Tagus and Almonda rivers and the Tagus alluvial aquifer. A steady-state model representing was constructed to analyze the groundwater flow. Five wells (four water levels measured in a field campaign and one from a piezometer of SNIRH monitoring network) were used to calibrate the flow model.

5. RESULTS

The groundwater flow model results can be previewed and analyzed considering the water budget and the flow between the surface and ground waters, and in terms of groundwater flow direction within the study area. To test the model performance and calibration, the sum of squared difference of observed head values and simulated head values (SSD) and Nash–Sutcliffe model efficiency coefficient (NSE) were computed. After running the flow model and the sensitivity analysis, the optimal values obtained were 160 m/day for the hydraulic conductivity and 150 m^2/day for the riverbed conductance.

An automatic parameter estimation method called PEST (Fig. 3) was then applied, resulting in the following improved values of NSE= 0.96 and SSE= 3.09. Groundwater flow modeling results showed a general flow direction from the northwest to the southeast, discharging in the Tagus River. The southern part of the study area demonstrated a significant change in the groundwater flow direction toward the center, where there is a high density of pumping wells. The pumping wells induce the flow to go diverge from all directions towards the center, resulting inflows from the Tagus river, Almonda river, and the constant boundary into the aquifer system. 69% of the water inflow into the aquifer system is coming from the adjacent Tagus-Sado right bank aquifer system. Rivers are the following contributors by 28% of the total inflow into the aquifer, out of which 88% is flowing from the Almonda river and 12% from the Tagus (Fig. 3). In the case of the Tagus river, the aquifer is losing more water than gaining.

For the impact evaluation of the extraction rates within the study area, a simulation was run with the output hydraulic conductivity values from the PEST simulation and with zero extractions. Significant drawdown, up to 3.5 meters, was estimated due to groundwater extraction in the southern part, characterized by narrow plots.

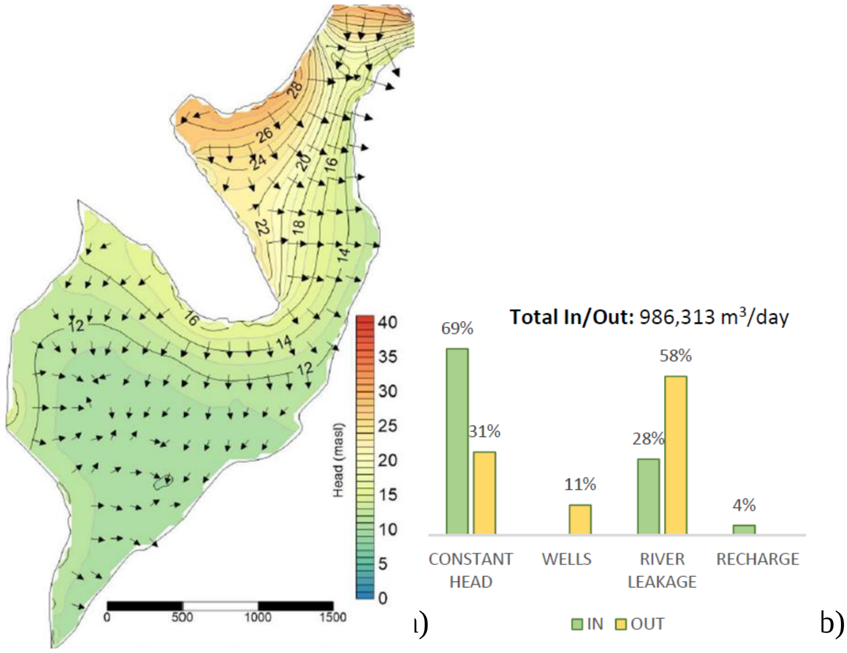

Fig. 3- PEST calibrated flow model (right) and global water budget of PEST calibrated Model (left)

6. FINAL CONSIDERATIONS

The lowest groundwater levels are located in the southern part, in the areas with the highest density of wells. The result showed that these pumping wells are inducing the main groundwater flow direction in the south and consuming water from the Almonda river from the west. This fact is interesting, as the Boquilobo Bog Natural Reserve lies in the south-western boundary of the study area along with the Almonda river (Fig 1).

7. REFERENCES

Ali Mohamed, A. H. (2018). *Assessment of groundwater resources in an intensively irrigated area in Golegã, Portugal Analysis of the impact of climate change and adaptation measures*. Instituto Superior Técnico, Universidade de Lisboa, Portugal.

Almeida, C., Mendonça, J. J. L., Jesus, M. R., & Gomes, A. J. (2000). *Ficha do Sistema Aquífero: ALUVIÕES DO TEJO(T7)*. Retrieved from https://snirh.apambiente.pt/snirh/download/aquiferos_PortugalCont/Ficha_T7.pdf

McDonald, M. G., & Harbaugh, A. W. (1988). *A modular three-dimensional finite-difference ground-water flow model*. United States: Department of the Interior,Reston, VA (US). Retrieved from https://www.osti.gov/servlets/purl/5842255

Mu, Q., Zhao, M., & Running, S. W. (2013). *MODIS Global Terrestrial Evapotranspiration (ET) Product (NASA MOD16A2/A3). Algorithm Theoretical Basis Document. Collection 5*. Retrieved from https://modis-land.gsfc.nasa.gov/pdf/MOD16ATBD.pdf

REGULATIONS

WFD, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000, establishing a framework for Community action in the field of water policy. Official Journal of the European Communities. 71 pp.