MONITORING OF A KARST COASTAL AQUIFER IN THE LONG-TERM BY ELECTRICAL CONDUCTIVITY PROFILES (SALENTO, SOUTHERN ITALY)

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1 Introduction

In coastal aquifers, many factors influence the 3D groundwater density distribution, including aquifer geologic structure, hydraulic field, sea-level oscillations, recharge, and exploitation. The combination of natural and human pressures controls the equilibrium between freshwater and salt waters. The response time to pressures and boundary condition variations, which come out as changes of width and elevation of the mixing (transition) zone, essentially depends on aquifer size and hydraulic properties of aquifer rocks. Groundwater depth profiles of Electrical Conductivity (EC) allow identifying the features of the transition zone between freshwater and saltwater (Tulipano and Tadolini 1982). Information on EC vertical distribution in a coastal aquifer can be gained from Observation Wells (OWs) reaching saltwater beneath freshwater. This study deals with the evolution over time of the transition zone in OWs belonging to the regional groundwater monitoring net of the Salento karst coastal aquifer (Southern Italy). For brevity's sake the analysis will concern in detail several EC depth profiles carried out from 1974 to 2021 in an OW (LR, Red Lake).

2 Materials and method

2.1 *Framing the study area*

The karst coastal aquifer of Salento coincides with the geological basement of the Salento Peninsula, which is a carbonate formation of the Upper Cretaceous–Palaeocene comprising layers and banks of fractured and karstified limestone and dolomitic limestone. Miocene and Quaternary deposits (calcarenites, sands and clays) partially cover the carbonate basement (Figure 1), while gentle folds, as well as normal and strike-slip faults disrupt it. Groundwater generally flows in a phreatic aquifer, with max hydraulic heads around 3 m AMSL and low hydraulic gradients, which locally turns into a confined one because of low permeable carbonate layers or when the carbonate basement top is below sea level. The hydraulic conductivity, which is highly anisotropic because of the combination of major and minor discontinuities and surface and subsurface karst features, conditions the groundwater flow. Lateral seawater intrusion and saltwater up-coning cause diffuse groundwater salinization from the 1960s because of groundwater over-exploitation from licensed and unlicensed wells.

2.2 *Observation wells of Salento peninsula and EC profiles since 1970s*

Some OWs, which reach saltwater beneath freshwater in the Salento Peninsula, were drilled in the 1970s to monitor and analyse the dynamics of groundwater salinization of the Salento aquifer. Since their drilling, the monitoring, including EC profiles, occurred discontinuously. We selected the 1LR OW, which is in the middle of the peninsula, to show the potential of EC profiles in describing the evolution over time of the groundwater density stratification. Compared to the other OWs of the net (Figure 1), it has the highest number of EC profiles (26) spanning over 47 years. The 1LR OW has screens throughout the aquifer and crosses a saturated zone with prevailing horizontal flow and negligible vertical currents. These features allow us to consider it a reliable site for measuring environmental heads (Fidelibus and Tulipano, 2014). We evaluated the reliability of the set of EC profiles, which were performed over time with sensors of variable accuracy and realized considering different measure frequencies along the vertical dimension, and corrected the EC measurements for the temperature. Then we calibrated EC vs. Total Dissolved Solids (TDS) by using chemical analyses of periods corresponding to profiles, which allowed us to select nine EC values from 0.65 to 47 μS/cm (and nine corresponding TDS values from 0.4 to 40 g/L). Then, we retrieved from each EC profile the elevation of the finding of those pre-defined EC values and combined the information in a graph. The vertical evolution over time of EC has been compared with groundwater level measurements made with a hand-held equipment on the same dates as the profiles, and with the Standard Precipitation Index (SPI precipitation-based index measuring severity and duration of meteorological droughts, McKee et al., 1993) calculated on monthly precipitation (rain-gauge station located nearby 1LR OW, location in Figure 1) for an accumulation period of 12 months (SPI - 12 months).

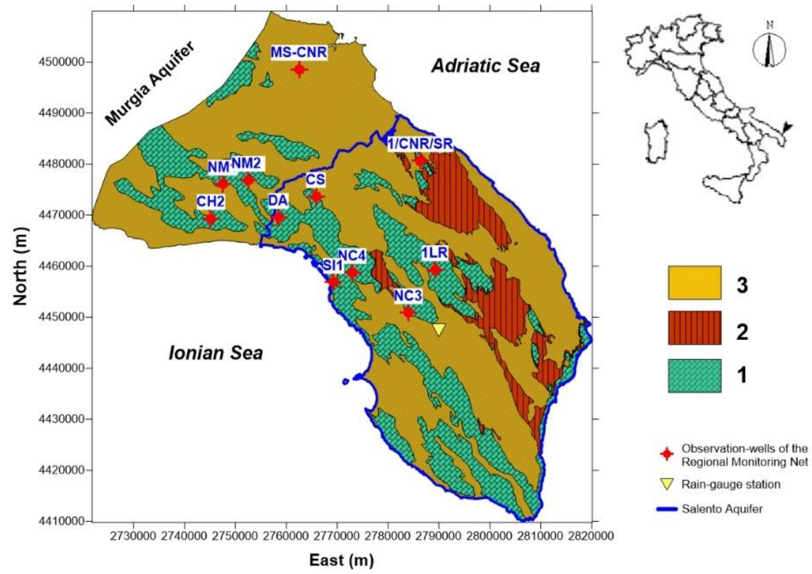

Figure 48. Schematic geological map of Salento Peninsula (Southern Italy); location of the Observation Wells (OWs) and rain-gauge station of Galatina. 1) Limestones and dolomitic limestones (Upper Cretaceous–Palaeocene), 2) Calcarenites and marly calcarenites (Miocene), 3) Calcarenites, sands and clays (Plio-Quaternary). Coordinate reference system is EPGS 3004 (Monte Mario/Italy Zone 2).

3 Results and discussion

Figure 2a displays the well-equipment and stratigraphy of 1LR OW and the specific conductivity at 20°C (x-axis in logarithmic scale) profiles. Figure 2b shows the change of elevation of the finding of the selected EC values over time. Overall, the graph highlights that the transition zone (between 0.5 and 40 g/L) migrated upwards in the 47 years of observation. The other OWs show similar behaviour (Tulipano and Fidelibus 2002). The freshwater column with EC < 0.65 μS/cm (TDS < 0.5 g/L) dramatically decreased during the same period, with disappearance of the pristine freshwater of low salinity. At the bottom of the well, the graph shows a change of salinity of saltwater, which overcomes the EC value of 47.85 μS/cm (TDS = 40 g/L) found in 1974, thus indicating mobilization of a saltwater older than the original one. Chemical analyses of salt waters confirmed, indeed, the saltwater increased age and longer diagenesis.

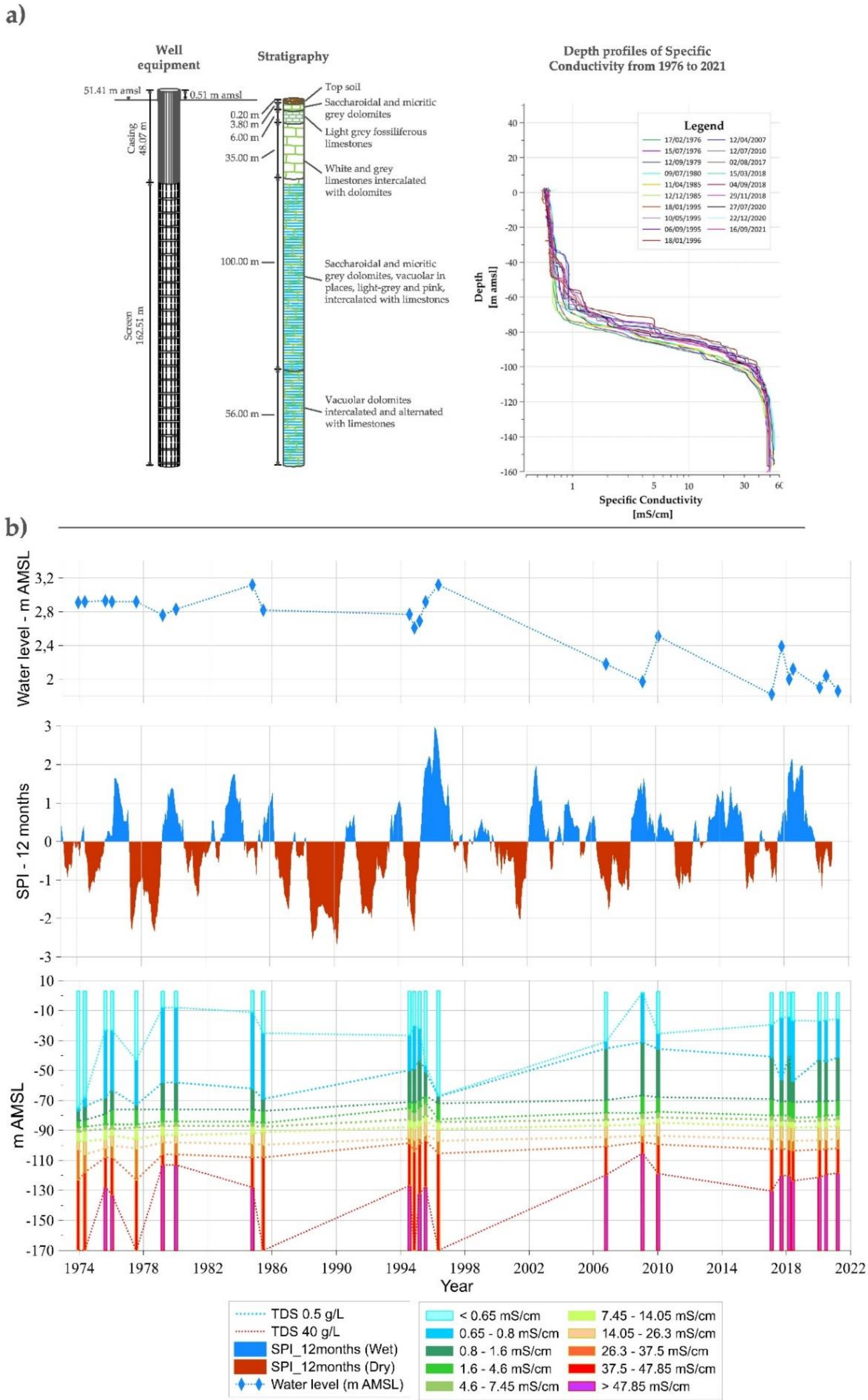

Figure 49. a) Equipment of 1LR observation well, stratigraphy and related EC profiles from 1976 to 2021; b) manual water level measurements, SPI – 12 months (referred to the rain-gauge station of Galatina), and vertical variation over time of EC.

The SPI highlights the alternation of dry and rainy periods. This alternation alone cannot explain the water level change, the upward migration of the transition zone, and the disappearance over time of pristine groundwater at the top of the saturated zone. When the climate is the only controlling factor, we might expect, with some delay compared to the input depending on the size of the aquifer, restoration of the natural density stratification after the drought period. Instead, we observe persistent signs of groundwater deterioration even during rainy periods following dry ones. This fact points out the role of groundwater over-exploitation that, in the last decades, did not stop but even increased just during drought periods. During the driest periods, such as those in the 1990s and 2000s, the withdrawal from licensed and unlicensed wells increased for responding to the concurrent water scarcity (Parisi et al., 2018). Figure 2b highlights that groundwater salinization, associated with the rise of the transition zone and drastic reduction of TDS <0.5 g/L water column, is not just a temporary condition. Overexploitation causes persistent and increasingly detrimental effects on groundwater quality that appear only mitigated by rainy periods, which do not succeed in restoring groundwater quality to undisturbed conditions since the prolonged and persistent groundwater stresses.

4 Conclusion

The transition zone dynamics can be followed by using EC periodical profiles. The experience gained in the Salento karst coastal aquifer shows that it is affected by a combination of natural and human factors. Although rainy periods seem to improve the qualitative and quantitative groundwater status in the short-term, the long-term status worsens because of persistent exploitation. The study suggests that control of water levels is not enough for managing groundwater, and that restoration of water levels does not guarantee the recover of groundwater quality. EC profiles help understanding the real groundwater condition. We should also consider that the reaction of a coastal aquifer system to pressures, as in all complex systems, depends on its history and size: thus, control frequency in other aquifers should adapt to local features.

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