Hydrogeological model of a complex coastal aquifers: the case of Sibari Plain (Southern Italy)

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ABSTRACT

The increasing overexploitation of water resources is observed on a global scale in the previous decades; this trend involves the coastal regions of Mediterranean Basin (Van Beynen et al., 2012). As an effect of increasing groundwater withdrawals from coastal aquifers, the phenomenon of seawater intrusion is becoming a serious problem for most of the coastal aquifers, especially in the Mediterranean area The aim of this paper is to present the modeling of a coastal porous aquifer located in the plain of Sibari (Southern Italy). The model was implemented using piezometric historical data to establish the effect of seawater intrusion, since the well discharge was negligible (natural conditions) to the anthropogenic modification in subsequent decades, to be used for forecasting purpose and for evaluate the evolution of groundwater resource.

GEOLOGICAL AND HYDROGEOLOGICAL CONTEXT

The Sibari Plain is located in Northeastern Calabria Region and represents the most recent and northern sector of the Crati Basin (N-S tectonic valley controlled since Middle Pleistocene by normal faults). The evolution of Sibari Plain is controlled by NW-SE left strike-slip fault system active since Middle Miocene to Middle Pleistocene (Van Dijk et al., 2000).

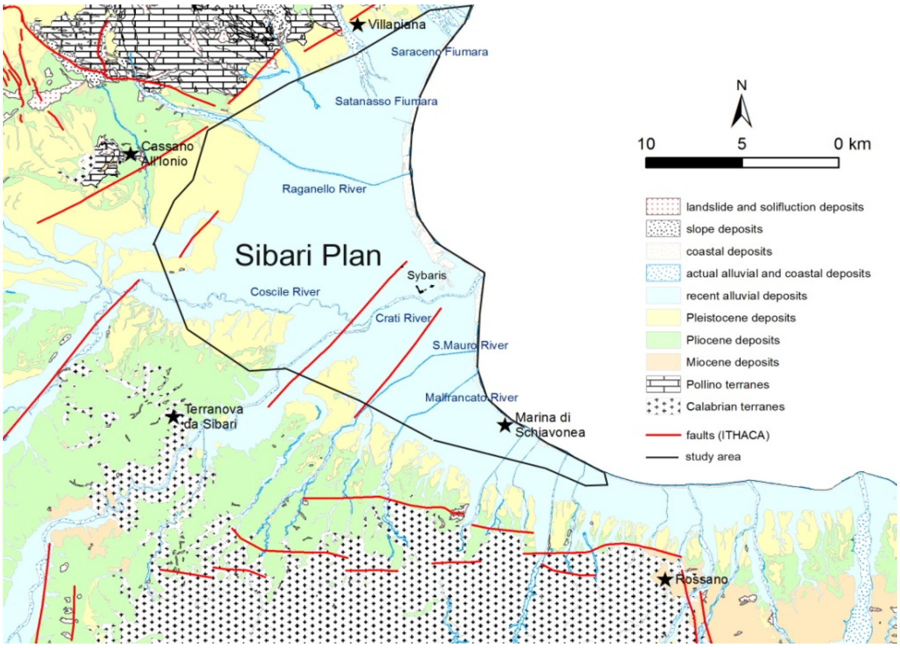

Figure 1. Geologic map of Sibari plain and study area.

The Tortonian-Messinian sediments represents the infilling of the Corigliano Basin, a wedge-top depozone located above thrust-sheet of the Calabrian Arc and southern Appennines terranes; it's composed by siliciclastic and evaporitic units passing upward to Pliocenic clays and marls with maximum thickness of 400m. The Pleistocene-Holocene succession, 1000-1500m thick, covers along a discordance surface the previous deposits and it is composed by alternation of sandy-gravelly and marly-clayey deposits. The Miocenic and Pliocenic sedimentary succession shows a lateral variability in thickness due to sin-sedimentary tectonic (Spina et al., 2011). The Holocenic evolution of the middle sector of the Sibari Plain is closely connected to building of the actual Crati Delta started about 6ky BP, which caused the coastal line advancing from the archeological site of Favella della Corte to the actual position covering about 7 km with the development of continental, paralic and coastal environments Study area is about 365 km^2 for a coastline of about 35 km (Figure 1). The area can be conceptualized into three hydrogeological complexes (from the top): Sand and Clay, Clay and Silt, Sand and Conglomerate, this last constituting the deep confined aquifer, the bottom of which is not well-defined. Shallow aquifer is predominantly fed by direct rainwater infiltration. In fact this aquifer exchanges water with drainage network but the total effect is groundwater feeds the river system of the plain (mainly the Coscile and Crati Rivers).Deep aquifer is fed by outflows of the mountainous aquifers as the case of limestone aquifer of Pollino Mount, and of shallow granitic aquifer of the Sila massif. The maximum piezometric levels of the deep aquifer are equivalent to approximately 40 m a.s.l., so in some areas it presents artesian feature. Water exchanges between the two aquifers are concentrated in the western or inland area, where the thickness of clay complex is lower. Both aquifers are used for irrigation discharge since seventies. On the base of these data conceptual model was achieved (Figure 2).

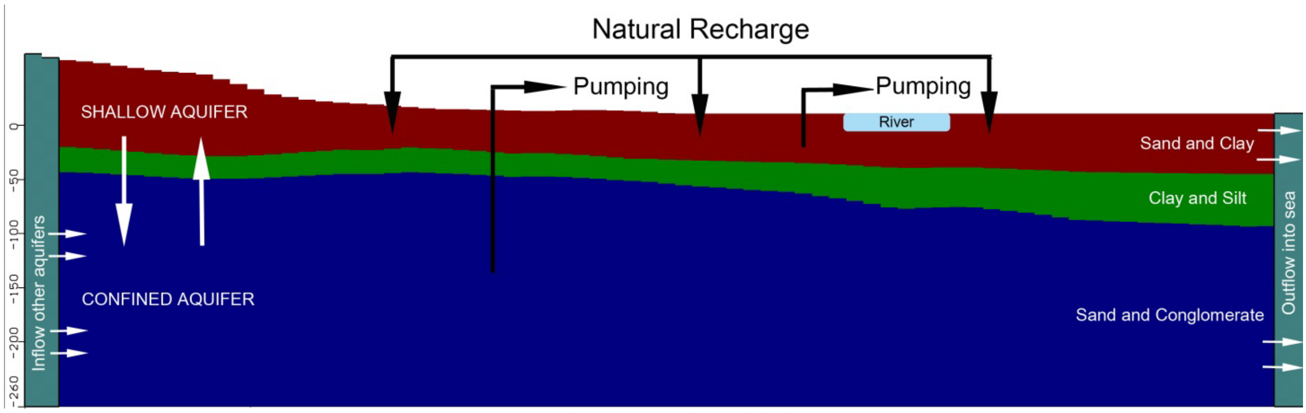

Figure 2. Conceptual model of Sibari plain. Schematic hydrogeological section W-E.

MODEL DEFINITION AND CALIBRATION

The computer codes selected for numerical groundwater modelling were MODFLOW and SEAWAT. The modeled aquifer area was uniformly discretized into a finite difference grid of 97,735 cells of 240 m x 350 m. For the vertical discretization, model was divided into five layers of variable thicknesses, defined on the basis of a multi-methodological geological survey. Climatic, hydrological, and agricultural datas were processed to define inputs for the numerical model. As boundary condition CHD cells (Constant Head Boundary) for the coastline and for the west border of Pollino Mount and Sila Massif were used. Modflow River Condition (RIV) was used to the simulate Crati and Coscile rivers. The riverbed altitude and the river water height of the main rivers were obtained through on-site surveys. The hydrological assessment of net rainfall and infiltration, using monthly and annual average precipitation and temperature datas for the period 1930-1975, was realized (Polemio et al., 2004; Petrucci and Polemio, 2007; Polemio et al., 2013). Data of 13 rain gauges, three of which were thermometric, were used (Polemio and Casarano, 2004). The rainfall and temperature were determined in each cell using a multiple linear regression as function of altitude. The mean annual rainfall ranges from 620 to 690 mm/y; the mean annual temperature ranges from 14.2 to 17.3°C. Evapotranspiration was determined using Turc method and ranges from 550 to 590 mm/y. Infiltration was calculated using an infiltration coefficient (IC) for each hydrogeological complex. The mean annual recharge, equal to 20 mm/y. Model was calibrated with PEST code with a correlation coefficient equal to 0.91, a RMS equal to 10 and is being validated with nineties years piezometric and concentration datas.

RESULTS AND CONCLUSION

The water balance of both aquifers in natural condition was calculated (Table 1).

<table>
<tr><th colspan="4">Shallow aquifer</th></tr>
<tr><th>In or recharge</th><th>$10^6 m^3/y$</th><th>Output or discharge</th><th>$10^6 m^3/y$</th></tr>
<tr><td>rainfall infiltration</td><td>11.6</td><td>archaeological area</td><td>2.5</td></tr>
<tr><td>leakage from rivers</td><td>16.5</td><td>discharge for irrigation/drinking</td><td>13.1</td></tr>
<tr><td>Inflow from deep aquifer</td><td>3.23</td><td>outflow into rivers</td><td>15.5</td></tr>
<tr><td></td><td></td><td>outflow into sea</td><td>0.17</td></tr>
<tr><th colspan="4">Deep aquifer</th></tr>
<tr><th>In or recharge</th><th>$10^6 m^3/y$</th><th>Output or discharge</th><th>$10^6 m^3/y$</th></tr>
<tr><td>Inflow from upward aquifers</td><td>71.0</td><td>discharge for irrigation/drinking</td><td>-</td></tr>
<tr><td>Inflow from shallow aquifer</td><td>0.97</td><td>outflow into sea</td><td>68.69</td></tr>
<tr><td></td><td></td><td>outflow to shallow aquifer</td><td>3.35</td></tr>
</table>

Table 1. Main in/out of the shallow and deep aquifer determined by steady conditions of modeling.

Preliminary results of steady or (almost) natural flow conditions together with the spatial domain of groundwater salinity are now available as the modification up to seventies. A relevant decrease of piezometric surface and increasing effects of seawater intrusion were observed in the shallow aquifer (Figure 3). Low modification of piezometric levels and salinity were observed in the deep aquifer. These preliminary results and next result scenarios will be used together with on-going survey data to assess trend of future groundwater availability and quality.

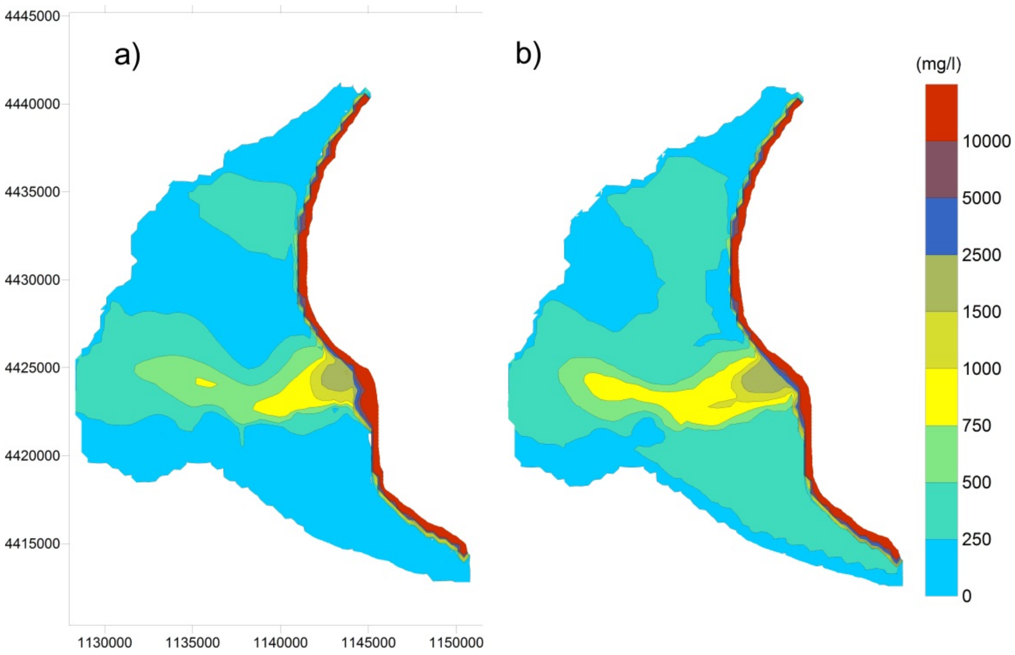

Figure 3. **Maps of salinity intrusion of shallow aquifer (historical scenarios) (a) Steady-state simulation (1930s); (b) results of the last year of transient simulation of 1970-79.**

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