QUANTITATIVE EVALUATION OF THE PIEDMONT PLAIN GROUNDWATER RESOURCES AIMED AT THEIR CONSERVATION AND RATIONAL USE

CATERINA CAVIGLIA
Dipartimento di Scienze della Terra, Università di Torino, Via Valperga Caluso 35, 10125 Torino, Italy

The Po Plain groundwater resources have a basic importance, especially in the Piedmont region, because they represent the main source of drinking water supply. Deep aquifers have a primary importance because they represent a very large natural storage for water (70% of the Piedmont drinking waters comes from deep aquifers), and because they are more protected by anthropogenic contaminations than shallow aquifer by the presence of upper deposits of low permeability.

Groundwater, which represents most of the drinking water all over the world, is renewable in very long times and in the last decades it has been more and more exploited, even overexploited. Many aquifers have already reached a condition of overexploitation, caused by increasing water use and by climate changes. Even in the Po Plain there are several situations of overexploitation, that have already produced many negative effects, like reduction of rivers and springs discharge, subsidence, lowering of wells water level and progressive disappearing of typical springs of the Po Plain (called “fontanili”). Moreover, the excessive groundwater exploitation can produce collateral effects like salinization, which is due to agricultural practice of over-irrigation and to the excessive pumping that, in turn, causes high salinity water intrusion, not only in coastal zones.

The main targets of this project were the quantitative evaluation of Piedmont Plain groundwater resources and simulation of the possible consequences of their reduction, by using numerical models, like the MODFLOW code (McDonald & Harbaugh, 1988), that allowed to represent in three dimension aquifers, heads, and fluxes.

These flow models can predict the possible impact caused by sea waters rising, transport of pollutants and the possible pathways of contamination spread, as well as the effects of pumping wells on the aquifer.

The two case studies of the Po Plain will be presented here, the former in a situation of moderate exploitation of groundwater resources, and the latter in a condition of advanced overexploitation.

In the first case study, a flow and contamination model was applied to study the risk of potential contamination of the deep aquifers of an area located in the high plains of northern Piedmont, between the rivers Ceronda, Orco, and Po. In this heavily populated plain area, groundwater is vulnerable to contamination from the surface; moreover, the shallow aquifer is particularly vulnerable, since it is not protected by layers of low permeability and is directly connected to poor quality surface water. All the shallow aquifers of the Piedmont plain contain concentrations of pollutants (such as, nitrates, pesticides, herbicides, chlorinated solvents) above the maximum permissible concentrations (according to the Italian law; D.Lgs. n. 31/2001). The deep aquifers, more protected from the seepage of pollutants from the surface, due to the presence of low permeability levels, are generally not contaminated and they are among the most important sources of drinking water supply in Piedmont.

In order to evaluate water fluxes and contaminants pathways from the shallow aquifer to the deep aquifer a numerical model has been implemented, using the finite difference code MODFLOW. In the first step of the modeling procedure, the potential critical situations, in relation to the different hydrological conditions found within the territory of the Piedmont plain have been investigated; in the second step, the presence of mixed wells (multi-layered wells with screens in the shallow and deep aquifer), which can create passages of contamination from shallow aquifer to deep aquifer, has been modeled.

The modeled contamination, widespread in the Piedmontese plains, is mainly related to nitrates. Nitrate input is mainly due to animal manure and synthetic nitrogen fertilizers, as well as to domestic and industrial sewage effluent, and nitrates-rich rainfall (Debernardi *et al*., 2007).

The surplus value of nitrates was firstly obtained from their measured concentrations, based on the soil characteristics, then, by means of the model, the contaminant transport in the aquifer system was simulated. The aim was to investigate and quantify the transfer of pollutants between the shallow and the deep aquifers, in the presence and absence of inactive mixed wells.

We have analyzed various hydrogeological situations identified in the study area and more generally in the Piedmontese part of the Po Valley: for example, hydraulic gradient directed from shallow aquifers to deep aquifers and *vice versa*, and the presence of continuous and discontinuous low permeability levels.

This approach was useful either to understand in which situations it is important to avoid the construction of mixed wells and to assess which interventions should be realized on the existing mixed wells, *e.g*., screens closure in the shallow or deep aquifer (Menegon *et al*., 2008).

The second analyzed situation concerned a case of overexploitation of the groundwater resources occurring in the deep aquifer located in the Plio-Pleistocene Asti Sands deposits and in the Villafranchian Complex deposits. This area is characterized by the concentration of a high number of wells, belonging to several aqueduct operators, which provide drinking water to 40 municipalities of the Asti province. The intensive exploitation since the early twentieth century have caused serious negative effects such as the lowering of the piezometric level and local subsidence problems (Beretta *et al*., 1999). Also in this case, a model of the area has been realized using the numerical code MODFLOW. A flux model, in steady and transient state, has been used to reconstruct the groundwater flow, in particular the deep aquifer flow, and then to study the evolution of the aquifer system over the time, starting from the situation prior to the development of the Valle Maggiore - Cantarana well field, until the current conditions. The model includes only the pliocenic sandy unit and the Villafranchian unit, because they contain a significant groundwater flux. The pliocenic and pre-pliocenic clayey-marly units are not represented in the model because they are characterized by low or very low permeability and they are considered as no flux cells.

The flux model has also allowed to realize some possible scenarios of interventions for the current condition of overexploitation, which comprise:

- the redistribution of existing pumping wells, with the disposal of some wells from the heavily exploited area of Valle Maggiore and the location of an equal number of wells with the same pumping rates in appropriate areas outside the Valle Maggiore well field;
- the reduction of 10% of the current withdrawals;
- the reduction of 25% of the current withdrawals;
- the reduction of 20% of the current withdrawals with a further redistribution of part of them;
- the reduction of the current withdrawals of 150 l/s, that would be supplied through the interconnection with the nearest Monferrato aqueduct.

The last configuration seems to be the best, since the piezometric level rises up in the heavily exploited area of 20-25 metres and, with the concurrent connection to the Monferrato aqueduct, the current amount of drinking water can be given to all the municipalities, without drilling any new well.

In addition to these scenarios, other measures for the mitigation of groundwater depletion and for a rational exploitation of this groundwater resource have been suggested, such as an improvement in the construction of new wells, the reduction of water losses from the aqueduct network, and the creation of a wide quantitative monitoring network in this sector of strategic importance for the groundwater resources of Piedmont.

REFERENCES

Beretta, G.P., De Luca, D.A.., Masciocco, L., Novo, M. (1999): Conoscenza e protezione dell'acquifero plio pleistocenico di interesse strategico dell'Astigiano occidentale e tutela del campo acquifero della valle Maggiore di Cantarana. *In*: "Atti del 3° Convegno Nazionale sulla protezione e gestione delle acque sotterranee per il III millennio (Parma 13-14 Ottobre 1999", Pitagora Ed. Bologna, *Quad. Geol. Appl*., **2**, 4.119.

Debernardi, L., De Luca, D.A., Lasagna, M. (2007): Correlation between nitrate concentration in groundwater and parameters affecting aquifer intrinsic vulnerability. *Environ. Geol*., **55**, 539-558.

D.Lgs 31/2001 (2001): Decreto Legislativo 2 febbraio 2001, n. 31. Attuazione della direttiva 98/83/CE relativa alla qualità delle acque destinate al consumo umano. Gazz. Uff. n. 52 del 3 marzo 2001, Suppl. Ord. n 41.

Mc Donald, M.G. & Harbaugh, A.W. (1988): A modular three-dimensional finite difference ground-water flow model. U.S.G.S. Techniques of Water-Resources Investigations, **6-A1**, 586 p.

Menegon, A., Clemente, P., De Luca, D.A (2008): Valutazioni sui problemi connessi con il flusso tra acquifero superficiale e acquiferi profondi attraverso pozzi per acqua e delle possibili strategie di intervento: il caso della Pianura Padana piemontese. *Giorn. Geol. Appl.*, **9 (2)**, 163-173.