REGIONAL CLIMATIC CHANGE: IMPACT ON GROUNDWATER

Tullia Bonomi [(1)]; Angelo Cavallin [(2)]

(1) Dip. Scienze dell'Ambiente e del Territorio, Università Milano-Bicocca, Piazza Scienza 1, Milan, Italy, tullia.bonomi@unimib.it
(2) IDPA-CNR Milan, Environmental Geology Section, Milan, Italy, angelo.cavallin@unimib.it,

KEY WORDS: hydrogeological database, 3D model, groundwater resources.

INTRODUCTION

The regional climatic changes affect the trend of the underground waters as regards to the short and medium period. Extreme meteorological events, for abundance or shortage, can in fact produce on the hydrogeological system effects which can cause remarkable environmental impacts. The first case above all induces induced damages to the human underground or superficial infrastructures and possibly environmental problems (flooding, mobilization of polluting, etc.), instead the second case carves (aridity, water deficit etc.) on the availability of the resources and it can lead (excessive withdrawals, greater use of the resource for irrigations, etc) to socio-economical remarkable changes.

The study of these problems must foresee a few quantitative analyses to gather the space and time variability of the phenomenon:

- the quantitative identifying of the meteorological phenomenon;
- the quantification of the produced effects on the underground waters;
- the three-dimensional detailed rebuilding of the structural and hydrogeological characteristics of the system;
- the identification of the possible environmental impacts;
- the evaluation of the produced real damages.

QUANTITATIVE ANALYSY

The natural and/or antrophic changes in a hydrogeological balance determine modifications of the groundwater resources, both from a quantitative and qualitative point of view and must be evaluated in their reciprocal synergy to propose an adequate management of the resources themselves. On the other hand, climatic changes prime a synergy of situations, which will above all reflect on the balance changes for socio-economic changes of the balance voices (greater withdrawals, different managerial backgrounds of the irrigations, waters etc.). The simulation of different scenarios allows identifying the most critical areas and in consequence planning adequate interventions to mitigate the effects of such phenomena.

The proposed methodology joins the geological knowledge, the codified well data logs, Geographic Information System (GIS) and opportune software for 3D calculation (GOCAD), aiming to rebuild a detailed distribution of the hydrogeological parameters in the subsoil. These elaborations allow building a hydrogeological flow model on a large area with a particularized vertical subdivision of the aquifers. From a detailed flow model, local detailed transport models results may be realized to face local problems, using the model parameters of the flow general model.

GOCAD is an integrated computer application that offers advanced technology in 3D visualisation, interpretation and geo-analysis to the earth scientist and engineers. Its main advantage is the ability to integrate information from previously isolated sources (seismic, production data, geostatistical, simulations, etc.) and to unite them in a 3D georeferenced object.

The focus has been to combine a quantitative approach of the problem through the advanced three-dimensional distributed hydrogeological model. The complex flux work is shown in figure 1.

This study seeks to improve the hydrogeological model's applications by means of a more detailed definition of subsoil parameters. Parameterisation of aquifer materials is often dealt by mean parameters values assigned to hydrogeological formations or to hydrostratigraphic units present within the aquifers, derived for example from pumping tests or from field observations. The possibility of better define the spatial distribution of hydraulic conductivity and porosity based on the different percentages of heterogeneous materials such as gravel, sand and clay in fluvial and glacio-fluvial deposits can be achieved by quantitative 3D elaborations of the information carried by stratigraphic logs, stored and codified in a hydrogeological database.

APPLICATIONS

The proposed example is concerning the province of Milan, where the well logs for water were codified and registered in a hydrogeological database (beyond 3000 stratigraphic well data).

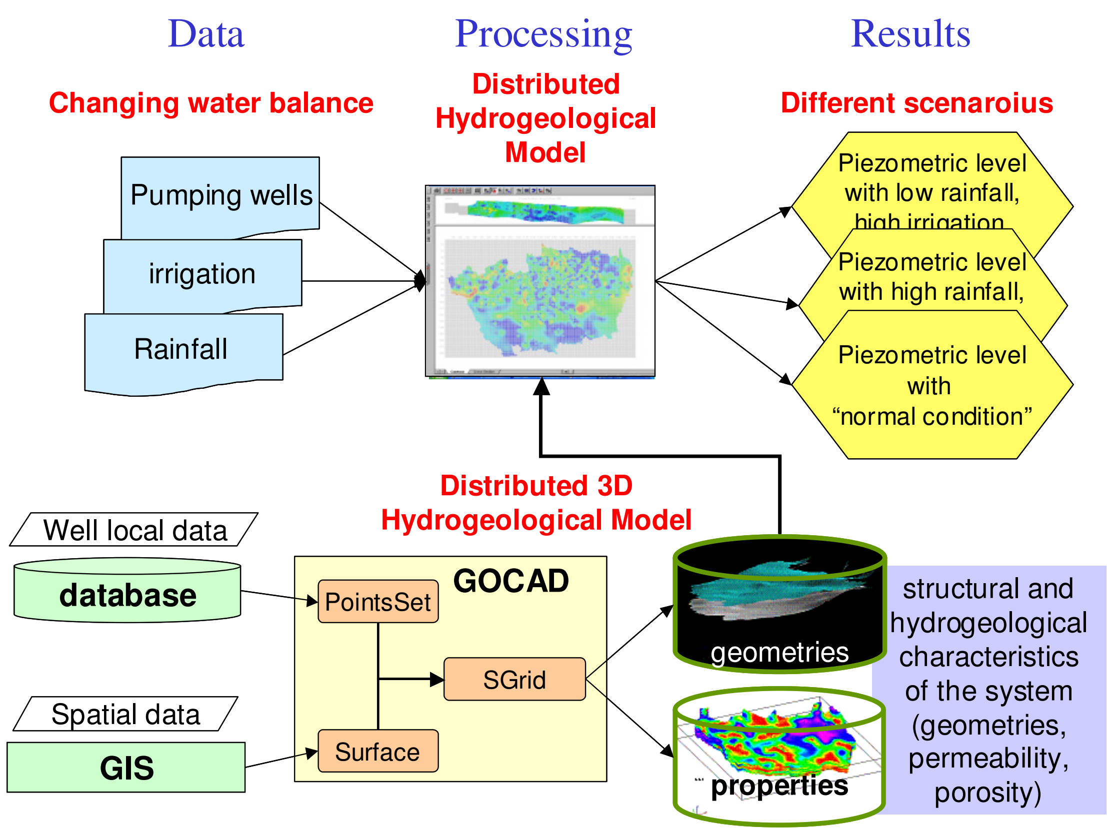

Figure 1 – Methodological flux work.

In the Milan Province a relationship between rainfall and groundwater table is observed, in particular, calculated on a secular sequence, during the period 1975-1979, two extreme meteorological events occurred:

1) precipitations for the five considered consecutive years, of about 30% higher than the average (annual average of 997 mm/y);

2) maximum precipitation in a month, October 1976, registered in all the stations of the area.

These events produced different effects on the hydrogeological system, but in both cases an increase of the groundwater level was recorded in all monitored wells, both in the provincial and urban area. Only in the spring zone, south of the area, were no effects observed. Such situations were reproduced with a simulation hydrogeological model MOFLOW for rebuilding the space distribution of the phenomenon in function of structural and hydrogeological characteristics of the system. Figure 2 shows the simulated piezometric level (m a.s.l.) after five years and figure 3 piezometric level increase (m) under the described conditions of previous point 2 and 3.

The model has been improved using the well logs data which allow to quantify in detail the hydrogeological structure of the studied area and to prepare detailed data input in order to improve the model results.

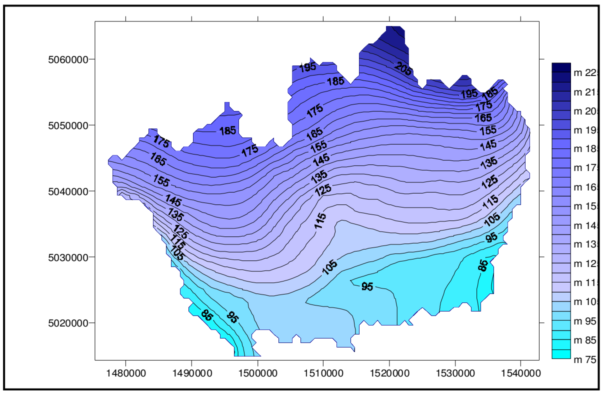

Figure 2 – Simulated piezometric head (m a.s.l.).

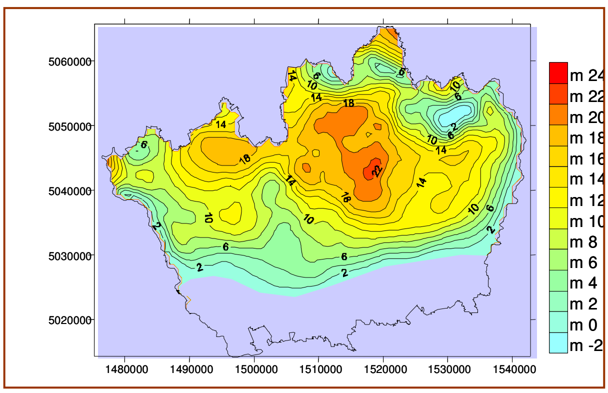

Figure 3 – Piezometric level increase (m).

3D TEXTURAL DISTRIBUTION

The 3-D aquifer characteristics analysis is obtained through several steps (figure 1): translating the stratigraphic well logs into alpha numeric codes; collecting and storing many well data into a database; converting the well data stored into GOCAD well object; importing and quoting the well data into GOCAD, where marker levels define the different stratigraphic layers; creation of PointsSet to elaborate 3-D surfaces representing the main structural features of the aquifer (Digital Terrain Model, DTM, aquifer bottom, water table); attributing the hydrogeological parameters value to each stratigraphic levels (porosity and hydraulic conductivity); defining a three dimensional grid (in the example 205 lines, 265 columns and 130 layers) assigning the hydraulic conductivity and porosity values to the grid nodes. In this way the aquifer characteristics distribution is calculated for the whole 3-D space of the hydrogeological system (figure 4) and it will certainly improve the next regional hydrogeological model.

CONCLUSIONS

Extreme rainfall events create a great impact on the groundwater evolution, but all the different factors of the water budget contribute synergistically to the water table fluctuations.

The socio-economical development is determining many changers in custom (decrease in agriculture practice, changing tastes in food and clothing materials, decreasing of private pumping wells in urban areas, etc.).

It is necessary to combine hydrogeological and socio-economic modelling scenarios and the historical knowledge provides an important basis to forecast the future.

The use of distributed models can offer very practical work-instrument to forecast different hazard scenarios and to asset the groundwater development within urban planning.

The availability of a rich hydrogeological database plays a key role in the described work, as it represents an important source of input data to better implement groundwater flow models at a regional scale. Particularly the possibility of extracting the data for detailed depth investigation intervals appears to be needed when exporting refined transport models.

REFERENCES

ANDERSON, M.P., WOESSNER, W.W., 1992. Applied Groundwater Modeling, Academic Press, Inc. 381 pp.

BONOMI, T., CAVALLIN, A., STELLUTI, G., 2001. 3-D aquifer characteristics analysis using a well database and GOCAD. Impact of Human Activity on Groundwater Dynamics (Gehrels et al., eds). IAHS Publ. no. 269.

MALLET, J.L., 1992. Discrete smooth interpolation in geometric modelling. Computer aided design, 24, 178-11.

PECK, A., GORELICK, S., DE MARSILY, G., FOSTER, S., KOVALEVSKY, V., 1988. Consequences of spatial variability in aquifer properties and data limitations for groundwater modelling practice. IAHS Publication no. 175

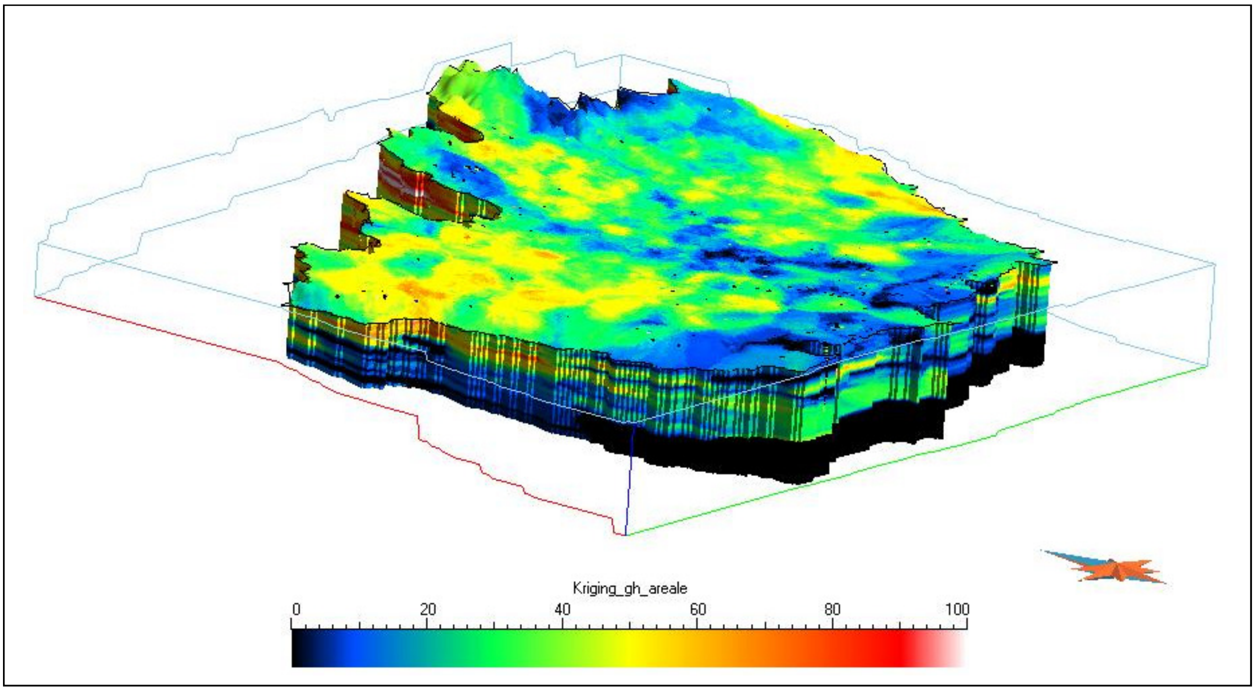

Figure 4 – Three-dimensional grid (205 lines, 265 columns and 130 layers) with representation of gravel content as percent, generated by GOCAD.