PROCEEDINGS OF THE XXVII IAH CONGRESS ON GROUNDWATER IN THE URBAN ENVIRONMENT / NOTTINGHAM / UK / 21-27 SEPTEMBER 1997

Groundwater in the Urban Environment

Edited by
JOHN CHILTON et al.
British Geological Survey, Wallingford, UK

OFFPRINT

A.A. BALKEMA / ROTTERDAM / BROOKFIELD / 1997

Groundwater in the Urban Environment: Problems, Processes and Management, Chilton et al. (eds)
© 1997 Balkema, Rotterdam, ISBN 90 5410 837 1

Impact of rising piezometric levels on Greater Buenos Aires due to partial changing of water services infrastructure

Mario A. Hernández & Nilda González
Cátedra de Hidrogeología, Facultad de Ciencias Naturales, Universidad Nacional de La Plata, Argentine

ABSTRACT: The intensive exploitation, since the beginning of the century, of a semiconfined aquifer in Buenos Aires City (Argentina) and its surrounding areas has caused large drawdown cones by the coalescence of smaller ones. The population of the area is about 11 million inhabitants. The climate is subhumid-humid with a mean annual rainfall of 1050 mm/year and a surplus of 270 mm/year. Some of the effects caused by the intensive exploitation have been saline intrusion and leakage from the phreatic aquifer through the aquitard, which caused a fall of the water table. As a consequence of the demand increase and closing of production wells due to salinization and nitrate content, treated water from the La Plata River began to be imported. The recovery of piezometric levels has caused the phreatic levels to rise, with a serious impact on the urban infrastructure, established some decades ago. Based on successive flow-nets, on the system parameters T,S,K,K',T' and on the value of imported yields, a monitoring system with forecast capacity is proposed, as well as an operative model for phenomena control, using alternative pumping on both aquifers.

1 INTRODUCTION

The city of Buenos Aires and its urban surroundings (Fig. 1) are the areas with the highest demographic and industrial density in Argentina, with 10,835,000 inhabitants and approximately 44,880 industries in an area of 3,380 km^2. The average rainfall is 1050 mm/y and the excess rainfall - mainly from May to November - is 270 mm/y. The landscape is extremely flat (with a slope of 1.10^{-3}), and developed on Quaternary sediments following the right margin of the Río de La Plata River.

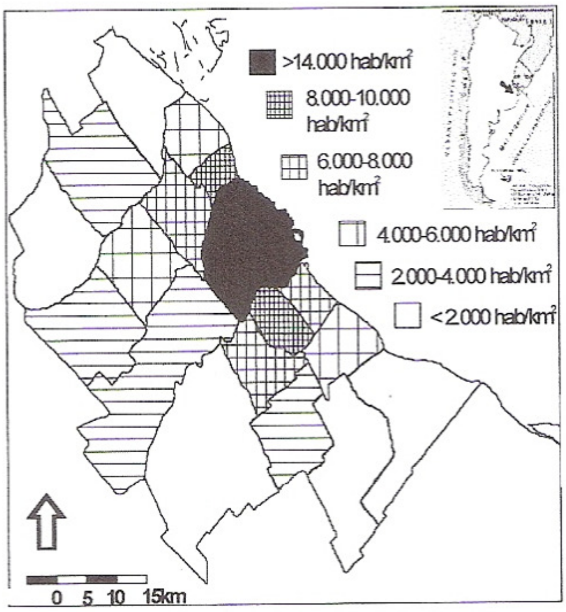

Figure 1. Location and demographic density.

The original supply of water obtained directly from the river and shallow wells since 1851 has been replaced by treated water from the river in Buenos Aires (future Planta Palermo Plant); and since the end of the 19th century in the city, and in particular the urban area surrounding it, it has been replaced by water obtained from wells in a semiconfined aquifer located 35 m deep. Groundwater is mainly used for public and industrial supply, the industrial growth of the area dating from the 1920s. There is also a strong horticultural use in the periphery of the urban areas (De Felippi et al 1991).

The intensive exploitation of the resource caused the appearance of wide drawdown cones (Fig. 2) and the intrusion of saline groundwaters, which resulted in a considerable number of abandoned holes. In order to satisfy the requirements, the public service is being expanded by the use of surface waters from the Planta Palermo Plant and the construction of a new Plant (Planta Bernal),

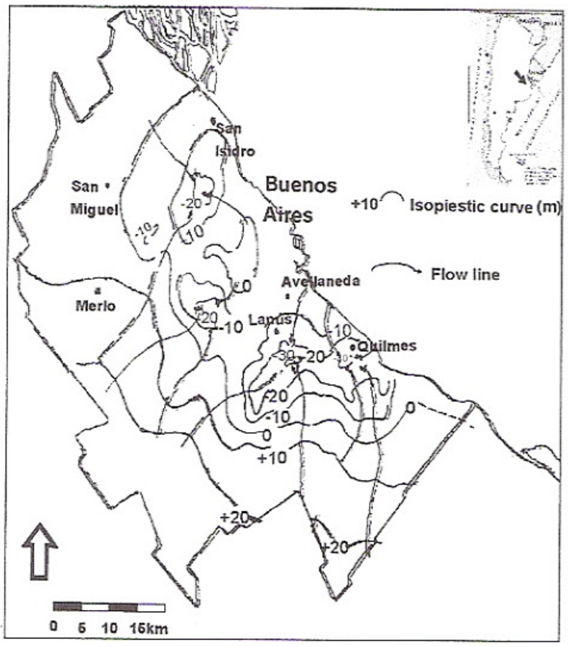

Figure 2. Piezometric map, Puelche aquifer.

from which vast volumes of inland water are imported.

The negative effects of this import - mainly the recovery of the piezometric and phreatic levels - on an urban and industrial structure established during a period of deep groundwater levels are here analysed.

2 GEOHYDROLOGICAL SYSTEM CHARACTERISTICS

The active geohydrologic sub-system is contained in continental Pleistocene sediments, except for the coastal area where there are outcrops of marine deposits.

The base of the active sub-system are marine clays (*Formación* Paraná, Pliocene) with aquiclude characteristics, under which aquifers are confined and saline. Above the sub-system there are pluvial sands (*Formación Arenas* Puelches, Lower Pleistocene) containing the semiconfined aquifer "Puelche", which is the main supply source in the region. The rest of the sequence up to the surface is formed by loessic silts (*Formación Pampeano*, Middle-Upper Pleistocene) containing two aquifers hydraulically very connected, the lower one, semi-unconfined, and the phreatic one, used only by the population without public service. The base of this formation is clayey to silty-clayey and acts as an aquitard of the Puelche aquifer.

Table I and Figure 3a show the characteristics and geometry of the system, indicating depths and thicknesses.

The average geohydrologic parameters for the area, obtained from numerous pumping tests, are shown in Table II.

The recharge of the system is local and regional, from the excess of the water balance. The recharge of the Puelche aquifer comes from the phreatic aquifer and through the Pampeano, by means of leakage through the aquitard. The normal transit time, about 500 years according to ^{14}C dated studies in the area, has been reduced due to the difference of the hydraulic head, consequence of the intensive exploitation.

The original discharge went to the Río de La Plata river and its tributaries, but, as illustrated in Figure 2, the existence of the great drawdown cones has inverted in many places the direction of the flow, and has turned surface flow into downward leakage (Hernández, 1975). The main discharge of the system is currently due to pumping. The annual volume obtained from the Puelche aquifer alone is greater than 900 Hm^3/year. Unfortunately, this evolution cannot be quantitatively demonstrated, since statistics of the extracted volumes are faulty in the case of the public service and non-existent in the case of the industrial sector - which is more than 30 % of the total.

Table I Geohydrological system.

UNIT	FORMATION	AGE	BEHAVIOUR	THICKNESS	WATER QUALITY
Phreatic	Upper Pampeano	Pleist-Holocene	Aquifer	variable (10m)	Fresh/Brackish
Pampeano	Pampeano	Pleistocene	Aquifer	15 m	Fresh
Aquitard	Lower Pampeano	Pleistocene	Aquitard	8 m	
Puelche	Arenas Puelches	Lower Pleist.	Aquifer	15 m	Fresh>Brackish
Marine Clays	Paraná	Pliocene	Aquiclude	20 m	
Paraná	Paraná	Pliocene	Aquifer	> 30 m	Saline

Table II: Characteristic geohydrological parameters.

UNIT	K (m/day)	T (m^2/day)	S (--)	K' (m/day)	T' (day^{-1})
Phreatic aquifer	5	50	1.10^{-1}		
Pampeano aquifer	10	150	2.10^{-2}		
Aquitard (lower Pampeano)				$4.5\ .10^{-2}$	$3\ .10^{-3}$
Puelche aquifer	30-50	700-1000	5.10^{-3}-3.10^{-4}		

Flow direction inside the system has evolved as shown in Figure 3. The phreatic levels were initially positive with reference to the piezometric ones of the Puelche. The value of the head difference grew with the exploitation, as well as leakage, with a descending vertical movement predominance.

The water of the phreatic and Pampeano aquifers contains sodium-calcium bicarbonate except for the areas near the river and its tributaries, where it contains sodium chloride. The water of the Puelche aquifer contains natural sodium bicarbonate, with the same exception as in the previous case.

3 EFFECTS OF THE INTENSIVE EXPLOITATION

The exploitation of the Puelche aquifer started growing during the 1920's, mainly due to World War I industrial growth and the resulting demographic explosion. This expansion of the use of the aquifer developed in a haphazard way due to the lack of norms for the optimisation of the location of industrial and service wells, which resulted in interference between the wells' drawdown cones. This provoked a progressive coalescence, which in time resulted in large, composite cones covering almost all the urban area surrounding the city of Buenos Aires (Fig. 2), especially the southern sector (Hernández 1978).

The apexes of the main cones reached -35m to -40m a.s.l., their original position being + 5m to + 15m. The drawdown lower limit was given by the top of the aquifer, where it behaved as a free aquifer. When the extraction rate was accordingly adjusted, the extension of the area was increasing due to the need of new wells and the incorporation, in the periphery, of horticultural irrigation with waters from the Puelche. Figure 3 a-b shows the evolution from an original situation corresponding to the end of the 19th century (Artaza 1943) to the 1980's, when it reached its maximum drawdown.

This in turn caused another, very important, effect: the intrusion of the saline waters (with sodium chloride) from the aquifer itself, lying on the alluvial plain of the Río de La Plata river and its main tributaries (discharge zones), saline due to a long run with a minimal final speed. Studies based on ^{2}H and ^{18}O isotopes showed the origin of saline waters, showing that salinization occurred due to a long residence time and not due to marine or paleo-marine waters (Hernández, 1978). This intrusion was one of the causes for the abandonment of the wells, along with the increment of the concentration of nitrates caused by the lack of a piped sewage system in 70% of the urban area and also due to the ingress of industrial polluting agents.

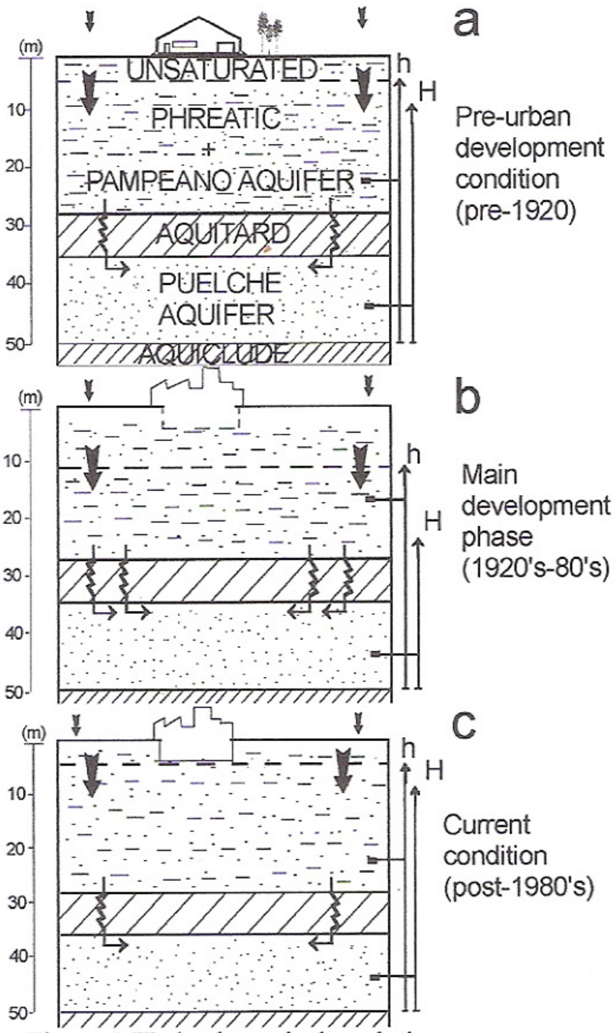

Figure 3 Hydrodynamical evolution.

The increase of the hydraulic head difference between the semiconfined aquifer and the phreatic-Pampeano complex caused an acceleration of the leakage through the aquitard, with an important fall of the phreatic surface. Constructions realised during that period, as a consequence of the speedy urban and industrial development, found a non-saturated zone, where sub-surface structures were emplaced (foundations, subsoils, underground parking lots, boiler rooms, machine rooms, etc.). Excavations more than 10 m deep did not reach the phreatic level, which had declined to a greater depth due to descending leakage (Fig. 3b).

As a way of meeting the need for water, the service was expanded with surface water treated at the Planta Palermo and the more modern Planta Bernal (1979). This import of water introduced new contributions to the system from leaks and on-site sanitation returns, apart from the volumes no longer extracted due to this replacement, with the resulting consequences detailed in the following section.

4 IMPACT OF THE GROUNDWATER LEVELS RISING AND CONTROL PROPOSAL.

The first effect of the new situation was the recovery of the piezometric levels (Figure 4) when more than 150 wells were abandoned. The difference of hydraulic head grew gradually smaller, as well as leakage rate, and the phreatic surface slowly rose with the maintenance of the contributions to the system. In addition to this, there was a percentage of water imported to the local cycle, favoured in many places by the individual disposal of sewage waters due to the lack of a sewage system.

Thus, the phreatic levels reached the underground constructions, flooding subsoils and forcing permanent dewatering in the central sectors of some cities in the southern area (Hernández et al 1991). This is a new situation and tends to be general as rising levels become regional and the area served by pluvial waters spreads.

It is very likely that in the near future there will be also effects on the framework of the foundations and sub-pressure on the support structures. Figure 3c shows the current tendency of the behaviour of the system.

Since during the last few years the service and control of industrial waters passed from the public to the private sector, no corrective actions have been made in this regard in spite of the existence of a Regulatory Body. This Regulatory Body - which is supposed to control the operation of the service and which represents the State and the Provinces but not the users - has been so far concerned mainly with water charges, technical claims from the users, service improvement and fiscal issues rather than with the maintenance of the exploitation. Unfortunately, this situation is possible due to the weakness of the regulatory legal frame. On this basis, a proposal including follow-up and control actions, as well as norms to stop the advance of a situation which may cause a severe impact, are proposed.

4.1 Monitoring of the present situation.

A first, quite easily implementable step, would be to select existing, strategically located wells, and, when abandoning them, seal them only after placing a plastic observation pipe, so as to form a monitoring network to keep a piezometric and hydrochemical control of the Puelche aquifer. Small piezometers should be built near some of the active wells in order to perform pumping tests for a densification of the values of T, S, and K, and

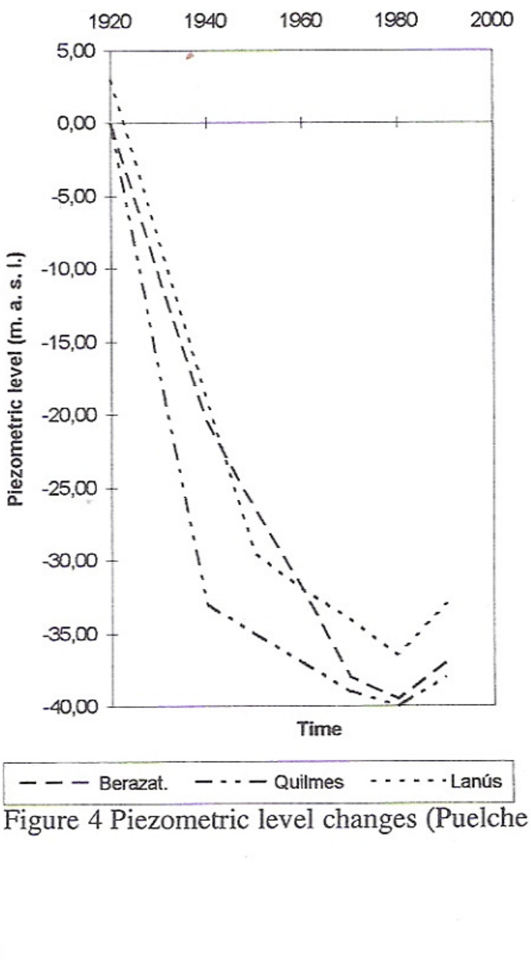

Figure 4 Piezometric level changes (Puelche Aquifer)

specially the aquitard coefficients T' and K'.

To complete the hydrodynamic scheme it would be necessary to drill some small-diameter, observation wells in the phreatic aquifer. The information obtained and the hydrometric series would be useful for the development of a 3D flow model which, once calibrated, would be used to simulate and forecast the evolution of the phreatic levels. The need for a 3D model comes from the fact that the main problems in the area are caused by vertical transference mechanisms (infiltration, leakage, level recovery), which cannot be directly reproduced in a bidimensional spatial model. Hydrochemical data are very valuable for the corroboration of the dynamic phenomenon in the initial analytical model and its refinement.

Model operation would be used to issue an early alert and to select the areas where control activities should be practised, since it is almost impossible to cover the whole area.

4.2 Control proposal

In some sectors, selected according to the model, a series of actions to stop the phenomenon could be put into practice, the most important being the installation of a piped sewage system in order to reduce the local recharge from water importation.

A recommended practice is to continue with the pumping in some of the wells to be abandoned in order to maintain the leakage rate. The volumes thus extracted would be sent to surface water courses (highly polluted in the area) in order to produce an ecologically useful dilution, or, alternatively, to pluvial drains. Obviously this operation should be suspended during the rainy season in order to avoid flooding in the area.

If these activities are combined with the simulation and forecasting model, pumping may even be automated with reference to a critical safety value, and in case of a dangerous rise, the phreatic aquifer could be also pumped (alternative pumping) by means of a close network of dewatering wells.

Since the adjustment of the model and pumping control activities will demand a certain amount of time, it is advisable to begin as soon as possible, with pilot tests run in the most critical sectors.

Naturally, these activities can only be carried out within a regulatory framework for a sustained use of the hydric resource. This framework does not exist yet, since the concession of the service of both surface and underground water supply has not considered the effects arising from a combined but not harmonic use of the resource.

Of course, financial support to solve the problem and to prevent its extension can only be granted if there are regulations to control water exploitation.

However, it is not likely that the correction of the situation will be achieved in the near future, since it was not included in the conditions of the concession. A negotiation process will be necessary in order to create this regulatory body.

Another factor of importance is the lack of participation of the users and scientists, as proclaimed at the Dublin'91 Conference. Technical knowledge is available, therefore the only step to be taken in order to correct the situation is the creation of a regulatory body.

5 CONCLUSIONS

The abandonment of the service wells in the urban area surrounding the city of Buenos Aires and their replacement by treated pluvial waters has caused a rise in the phreatic levels due to the recovery of the piezometric levels of the semiconfined aquifer, leakage having been reduced.

This rise of the level is causing important problems due to the flooding of underground constructions (basements, underground parking lots, machine rooms, etc.) in the central sectors, making dewatering pumping inside the facilities necessary. It is possible that in time there will be also effects on the foundations of the buildings and even sub-pressure on the structures.

The operation of a monitoring network using the existing wells, even those to be abandoned, would be useful to build and operate a three-dimensional simulation and forecasting model to select the sectors where control activities are necessary.

Pumping maintenance in selected positions and the use of the extracted volumes for an ecologically attractive dilution of the highly polluted water courses in the area is one of the recommended steps to be taken, this activity being controlled by the model itself.

It would be advisable to create a regulatory body that considers the participation of the scientific sector and the users in order to put these activities into practice.

REFERENCES

Artaza, E. 1943. *Saneamiento urbano en la República Argentina. Provisión de agua y desagües urbanos*. Cuaderno 6. Facultad de Ciencias Fisico-matemáticas. La Plata.

De Felippi, R., N. González, M.A. Hernández, V. Paredes y G. Pepe 1991. *Abastecimiento de agua en el Area Metropolitana de Buenos Aires y Gran La Plata*. Senado de la Nación-UN CEPAL-CELADE. Buenos Aires.

Hernández, M.A. 1975 *Efectos de la sobreexplotación de aguas subterráneas en el Gran Buenos Aires y alrededores. República Argentina.* II Congreso Iberoamericano de Geología Económica, I:435-450. Buenos Aires.

Hernández, M.A. 1978. *Reconocimiento hidrodinámico e hidroquímico de la interfase agua dulce-agua salada en las aguas subterráneas del estuario del Plata, Partidos de Quilmes y Berazategui*. VII Congreso Geológico Argentino, Actas, II:273-285. Buenos Aires.

Hernández, M.A., J. Fasano y E. Bocanegra 1991. *Prevención de riesgos en la recuperación de niveles piezométricos en áreas urbanas de Argentina*. Segunda Conferencia Latinoamericana de Hidrología Urbana, Actas, 130-138. ALFHSUD-UBA-IDRC. Buenos Aires.