Hydrogeological Disarrays in Buenos Aires Area and its Surroudings, Argentina

Il dissesto idrogeologico nella zona di Buenos Aires, Argentina

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ABSTRACT

As a consequence of the accelerated population and industrial growth in the Greater Buenos Aires (12,500,000 inhabitants), there was a intense exploitation of the semiconfined aquifer (Puelche aquifer) which generated extensive regional drawdown cones. In addition to the drastic declining of piezometric levels, an intrusion of saline water forced the closing of many exploitation wells. Another consequence of overexploitation was an acceleration of leakage from the phreatic aquifer through the aquitard, thus causing pollution with nitrates, HC's and heavy metal and a strong drawdown of phreatic levels. In order to compensate for the deficit caused by the depletion situation, surface water from two treatment plants in the River Plate was imported since 1980's. The closing of exploitation wells and the import of water brought about a rising of the phreatic surface when leakage ended, thus causing serious troubles such as waterlogging of underground facilities (parking lots, basements, power distribution installations), a situation that has become critical in many areas in the surroundings of Buenos Aires City.

RIASSUNTO

Negli ultimi anni, l'accelerato incremento demografico e l'intenso sviluppo industriale dell'area metropolitana di Buenos Aires (12.500.000 abitanti) hanno determinato il depauperamento del locale acquifero semi-confinato (acquifero di Puelche), con la formazione di vasti coni di abbassamento piezometrico regionale. La brusca caduta del livello piezometrico, associata ad intrusioni saline, ha reso necessaria la chiusura di numerosi pozzi. L'intensità dei prelievi idrici ha inoltre accelerato le perdite dall'acquifero freatico attraverso l'aquitard, causando inquinamento da nitrati, idrocarburi e metalli pesanti, e un forte abbassamento della falda. La carenza di acqua idropotabile dovuta all'impoverimento della falda ha reso necessaria, sin dal 1980, l'importazione di acqua superficiale da due stabilimenti per il trattamento delle acque che sorgono in prossimità del Rio de la Plata. La chiusura dei pozzi e il ricorso ad acque di importazione hanno determinato l'innalzamento del livello della falda freatica proprio nel momento in cui ne sono cessate le perdite. Tale nuovo equilibrio ha causato seri problemi, quali l'allagamento di strutture sotterranee (parcheggi, piani seminterrati di edifici, impianti della rete di distribuzione di energia elettrica). La situazione è attualmente molto critica, soprattutto in alcune zone della periferia di Buenos Aires.

Key words: Hydrogeological disarrays - overexploitation - saline intrusion - rising water levels - Argentina.

Introduction

The city of Buenos Aires and Greater Buenos Aires constitute the most important urban-industrial complex of Argentina, with more than 11,000,000 inhabitants.

Groundwaters from a semiconfined aquifer (Puelche aquifer) have been exploited since the middle of the 19th century for public service, which generated large regional drawdown cones. These drawdown cones reached a peak between 1920 and 1980 due to an explosive growth during and after the big world wars.

This paper analyzes not only the characteristics of the overexploitation that took place and its side effects (saline intrusion, contaminated waters access, etc.), but also the serious problems caused by the partial substitution of the groundwater and an ascension of the phreatic levels when leakage was reduced or stopped.

The phenomena that took place are analyzed, and a description of the general characteristics of the area and the local geohydrological system is given as an introduction.

1. General characteristics

The area is densely populated and it covers a surface of about 3,500 km^2, its average population density is of 3,150 inhabitants/km^2 with peaks of up to 17,000 inhabitants/km^2. There are 44,880 industries in the area [HERNÁNDEZ & GONZÁLEZ, 1997].

The climate is temperate and sub-humid to humid, with average rainfalls around 1,050 mm/year and a mean annual temperature of 16.9 °C. Real evapotranspiration reaches 780 mm/year, with a hydric surplus of 270 mm/year concentrated in the months between May and November.

From a morphological viewpoint, it is a very gentle slope next to the Río de La Plata river (Fig. 1), crossed by streams and tributary rivers, which

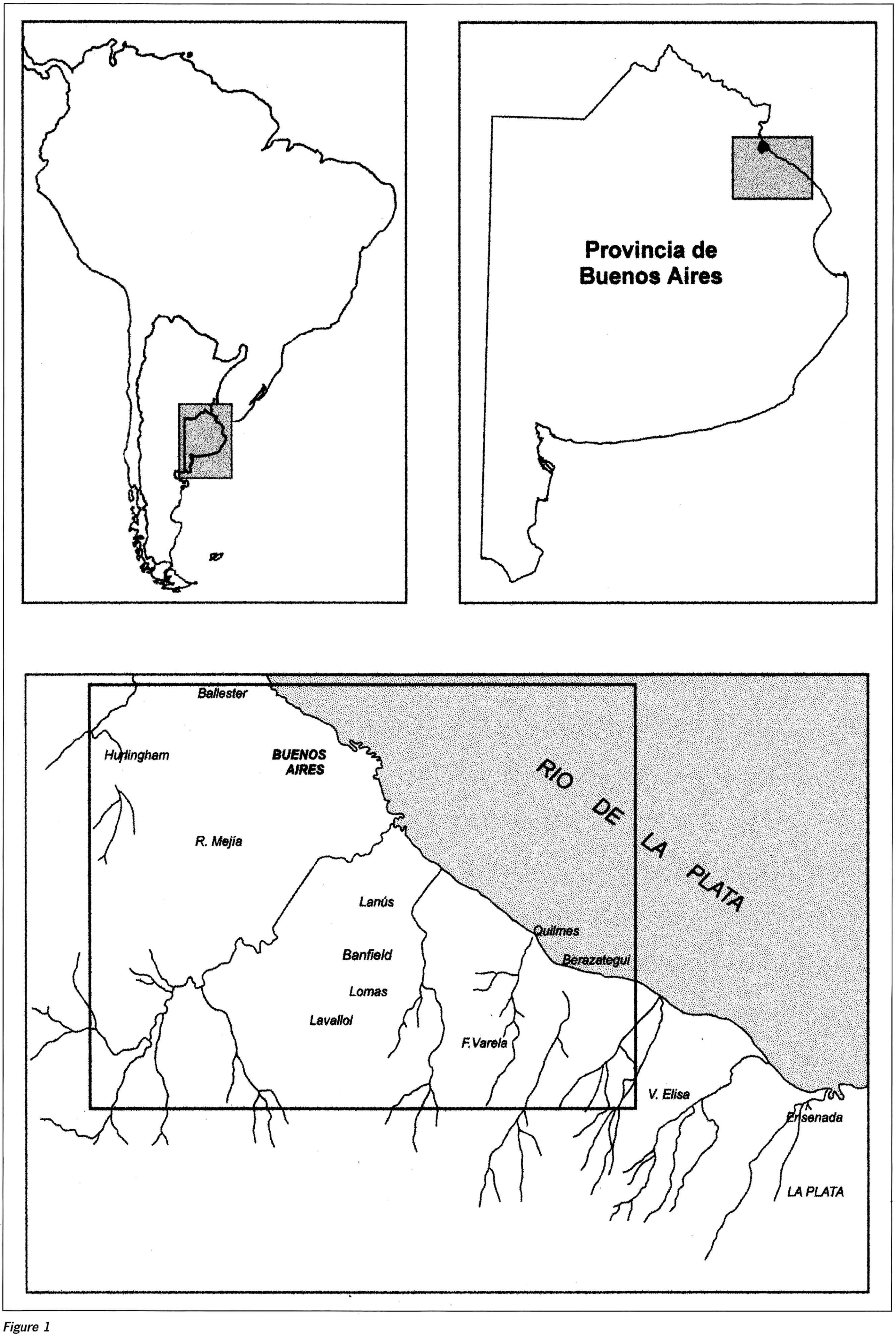
Provincia de
Buenos Aires
Ballester
Hurlingham
BUENOS
AIRES
RIO DE LA PLATA
R. Mejía
Lanús
Quilmes
Banfield
Berazategui
Lomas
Lavallol
F. Varela
V. Elisa
Ensenada
LA PLATA

Figure 1

originally were small effluents; the regional slope is of 1m/km.

The landscape has been modeled on quaternary sediments, with outcroppings of Pleistocene deposits *(Fm. Pampeano)* in higher parts, and Pleistocene-Holocene ones in the alluvial plain of the river and minor basins whose base is formed by a clayey layer 25 m deep.

Below that, between 33 m and 48 m, there is the *Arenas Puelches Formation,* clean, yellowish pluvial sands from the lower Pliocene-Pleistocene. They rest on marine sediments of the *Paraná Formation* (Miocene-Pliocene), with a clayey upper section and a sandy lower one, both of a blue-greenish color. A similar sequence but of a continental origin and reddish in color appears at higher depths (Olivos Formation, Miocene) up to 298 m, where the *Crystalline Basement* is reached in Buenos Aires (granites, migmatites and gneiss).

2. Definition of the geohydrologic system

The geohydrologic system identified based on the geologic description presents the following characteristics.

The unsaturated zone has a variable thickness between less than 1 m in alluvial plains and more than 15 m in exploitation zones.

The phreatic aquifer together with a semi-free one ("Pampeano") form a hydraulic unit that rests on the basal clayey layer of the *Pampeano Formation* of aquitard character. Then follows the semi-confined aquifer "Puelche", which carries fresh water except in the areas of the alluvial plain where it has brackish water. The lower limit is the clayey layer of the Paraná Formation, with aquiclude behavior; below it there is a confined aquifer ("Paraná") with brackish water. There is another aquiclude that covers the confined aquifer "Olivos" with saline water. The base of the system is the Crystalline Basement of aquifuge character.

The recharge of the system is regional and autochthonous for the active section, through the phreatic aquifer towards the Puelche by means of leakage. Both confined aquifers present an autochthonous recharge whose preferred areas would be located towards the West and Southwest.

The original discharge was towards the Río de La Plata, directly and through the base-flow of tributary rivers. The intense exploitation of the Puelche aquifer inverted the relation in the coastal area.

The geohydrologic parameters of the unit phreatic aquifer + semi-free aquifer are: Coefficient of Transmissivity (T) 50 m^2/day; Coefficient of Permeability (K) 5 m/day; Coefficient of storage (S) 2-5 . 10^{-2}. For the aquitard, values of Vertical permeability (K') of 4.5. 10^{-2} m/day and of Vertical transmissivity (T') of 3.10^{-3} day^{-1} have been obtained.

Mean geohydrological parameters for the Puelche aquifer are: T = 700-1,000 m^2/day; K = 30-50 m/day; S=5.10^{-3}-3 .10^{-4}. For the confined aquifer Paraná, values of T = 2,500 m^2/day y K = 50-70 m/day have been obtained.

3. Overexploitation and its side-effects

Since 1920 there has been a strong exploitation of the Puelche aquifer for public service and industrial use (ARTAZA, 1943); in the periphery of the phreatic + semi-free unit, however, there has been a decreasing use in time due to contamination problems.

The exploitation of the semiconfined aquifer caused drawdown cones, which expanded into great regional drawdown cones more than 40 m deep at the main apices (Fig. 2). In some cases, the drawdown reached the roof of the aquifer, thus changing its behavior to free in a punctual way [HERNÁNDEZ ET AL, 1991].

An initial effect of this exploitation was a leakage speed-up towards the Puelche aquifer, which caused in turn the water table to descend until almost disappearing in critical positions. Leakage from the phreatic aquifer also caused the access of polluting agents (mainly nitrates) towards the Puelche aquifer.

Another side effect was the intrusion of brackish waters from the area of the alluvial plain of the Río de La Plata river, where such hydrochemical characteristic is present due to the run and permanence of groundwater with minimal hydric gradients HERNANDEZ, 1978). The intrusion affected riverside towns (Avellaneda, Bernal, Quilmes, Berazategui), and specially the neighboring city of La Plata, where it covered almost half of the urban plant (Fig. 2)

In 1913, waters from the Río de La Plata treated at the Plant of Palermo began to be used, first in the city of Buenos Aires and then in Greater Buenos Aires. In 1979 a new Treatment Plant was built in Bernal (Fig. 2), the distribution of pluvial waters being expanded to the north and south of the area. A similar situation took place in La Plata at the expense of the Plant located in Punta Lara and working since 1955.

4. Phreatic levels recovery. Physical and socioeconomic consequences

Due to the contamination with nitrates and the salinization of the main aquifer, public service perforations were gradually abandoned in urban areas, and the groundwater source was substituted by imported pluvial waters, disregarding the response the system could have.

In the meantime, the organism responsible for this exploitation was privatized and a regulatory body created.

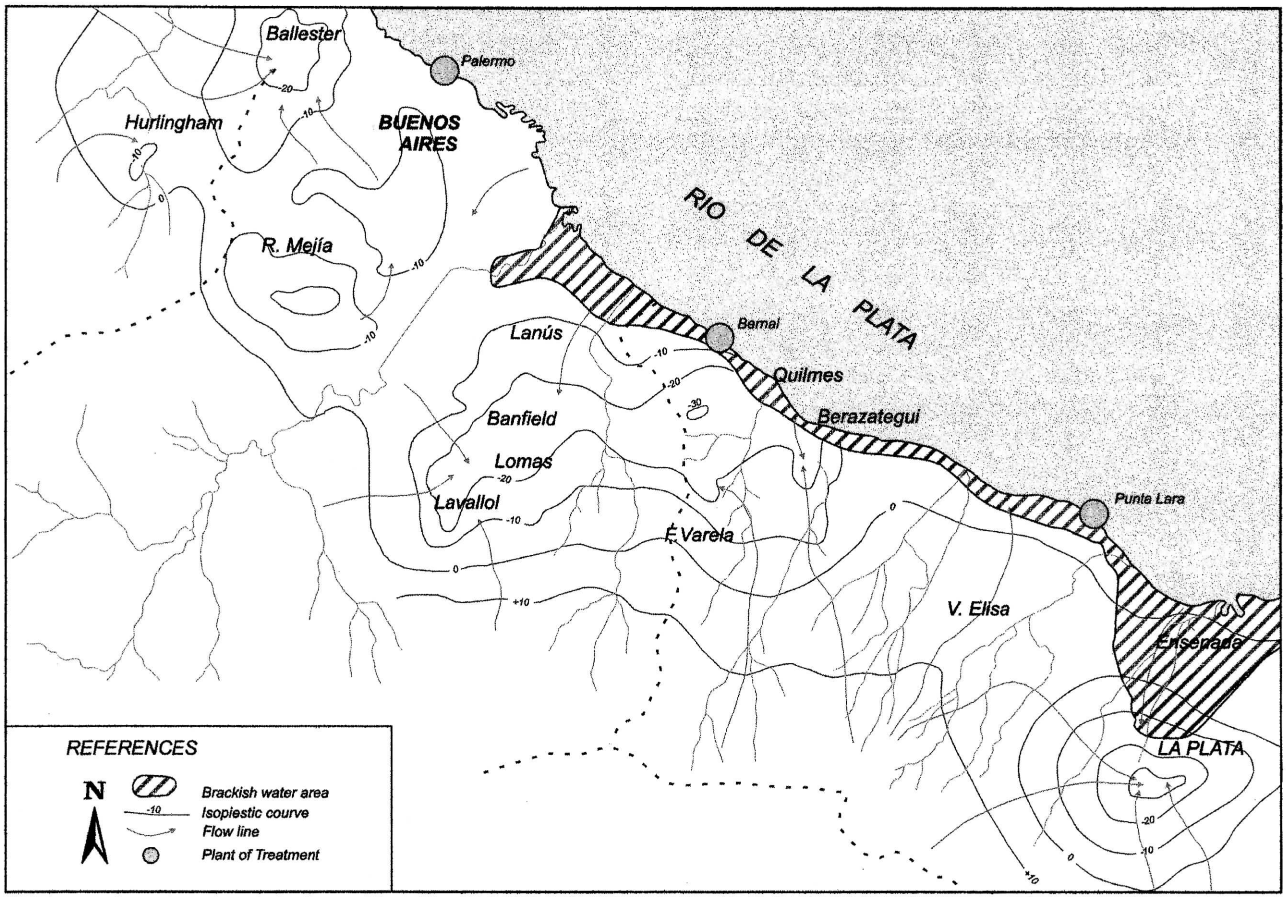

Figure 2

The recovery of piezometric levels due to the abandonment of the perforations caused the leakage from the phreatic aquifer to be progressively reduced, which resulted in an ascension of the water table (Fig. 3)

Other concurrent factors that contributed to the ascension were the addition of the surplus of the imported waters, the lack of sewage in a 60% of the area, and finally, the implantation of a more humid pluvial period that raised the historic average from 1010 mm/ year for the period 1901/1970 to 1050 mm/year for the period 1901/1998.

It should be noted that urban infrastructure grew significantly during the period 1920/80, and buildings with cellars were built in centric sectors, whereas marginal population settled in lower areas, including the alluvial plains [HERNANDEZ & GONZALEZ, 1997]. In both cases, this happened with a depressed water table.

The main consequence of the ascension of the water table was then the flooding of deeper cellars and underground chambers, and the increment of problems in houses built in lower sectors. This phenomenon spread specially towards the south, until acquiring an important public repercussion.

As a way of attenuating this problem, pumps were installed in order to depress the water table, and then throw the extracted water to the pluvial network, but its effects are punctual and it would

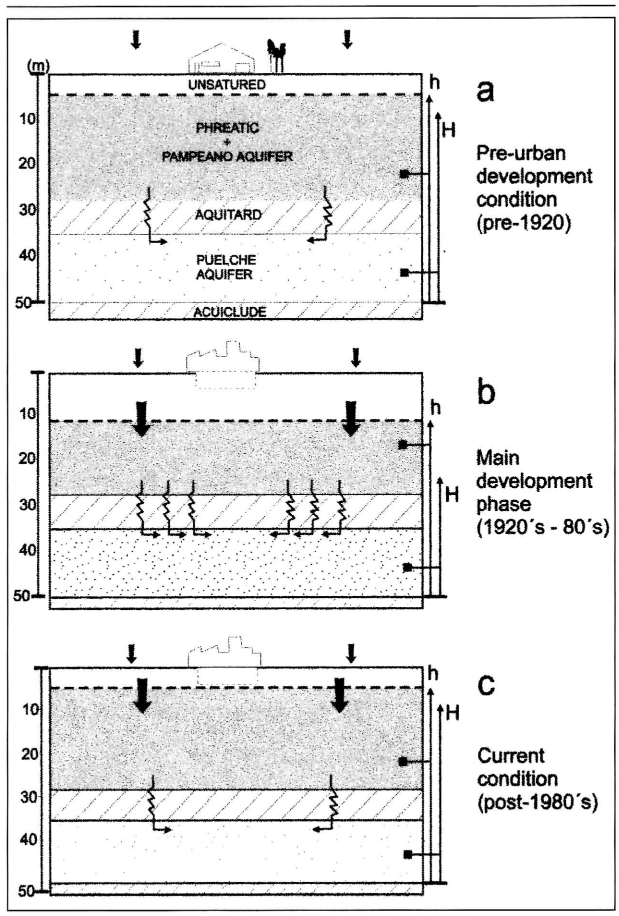

Figure 3

not be productive neither from an economic nor from an operational viewpoint, to place a growing number of pumps while the phenomenon increases.

In addition to infrastructure problems, this rise of the water table prevents the evacuation of cesspools, thus forcing locals, generally those with less resources, to a periodic sapping with its associated cost. The problem of waste waters evacuation causes also an undesired sanitary condition, especially in the event of prolonged storms.

The phenomenon is explained by different causes by the different parties (provincial and municipal governments, the company administrating the service, regulatory bodies, neighbors), according to their interests.

However, there is no doubt that the main causes are holes abandonment and sources substitution, since in sectors where there was no water importation and the pool of pumping holes is fully active, there are no such problems despite the fact that the climate is the same.

Cellars of buildings in centric zones of cities such as La Plata, where there is a fully functional sewage system, were also observed. It is thus demonstrated that neither climate nor the lack of a sewage system are key factors, but they play a secondary role.

The identified socioeconomic consequences are:

- Physical and economic prejudices due to the need of keeping a depressed water table by means of pumping in cellars of public and private buildings.

- Economic prejudices for the affected population due to the need to drain their cesspools with increasing frequency, sometimes every other day.

- Sanitary risk of marginal population due to the impossibility of evacuating waste waters of cesspools and to the contamination of the phreatic aquifer in marginal areas.

- Growing public investment to increase pumping in order to depress the water table.

- Risk in underground buildings such as electricity and telephone chambers, ducts, and building basements.

5. Solution proposals

The scientific community has repeatedly proposed possible solutions or contention measures for this problem, but with no luck. Some of these proposals are:

- Updating geohydrologic studies in order to measure the problem (serial flow nets for the phreatic and Puelche aquifers, variation maps, chemical analysis and hydrochemical maps, pumping tests for the parameters of Coefficients of Trasmissivity, Permeability, Storage, Vertical Permeability and Vertical Trasmissivity, effective velocity, etc.)

- Mathematical simulation of the groundwater flow in 3D: proposal of a conceptual model, development of the model, and calibration.

- For each sector, setting a risk value or critical level above which the water table should not rise.

- Analyzing the feasibility of keeping the semiconfined aquifer pumped at strategic positions and with such a regime so as to keep the water table below the critical height.

- Using the evacuated water. When this water is not brackish, it could be used to water urban green spaces; when it is brackish water, it could be used for an ecological sweeping of rivers, streams and pluvial drainage. In both cases, it could be applied to other, non-fungible uses.

- Simulation of the studied solutions in the model. When these solutions are implemented in pilot sectors, follow-up and adjustment of the model and of the control operation of the levels.

Keeping a strategic pumping in the semiconfined aquifer allows for a regional control which cannot be obtained by depressing the water table. It also allows to stop the pumping during strong rains in order not to prejudice drainage and rivers, without causing an immediate recovery of the water table. This would not the case if pumping activities were carried out directly on the phreatic aquifer. This same advantage would apply to accidental blackouts for the pumps.

The phenomenon of rising levels is of a progressive nature, and the tendency is an increment of the surface affected, of the magnitude of the problems, and of the social and economic consequences, as long as no integral solutions are endeavored.

The scientific community and the University have the ability of carrying out these studies and projects, but there is still a great gap between scientific knowledge and the cluster political power - service companies - regulatory bodies.

The different participating jurisdictions (provincial, municipal, national, private), flaws in privatization contracts, and the limited role of regulatory bodies, together with the difficulty in attributing or taking responsibility, are the factors against taking the decision of facing the problem with an integral solution containing or minimizing the effects of the disarrays described in this paper.

6. Conclusions

Hydrogeologic disarrays in Buenos Aires and its surrounding areas took place mainly since 1920, due to the great demographic and industrial growth of the area.

The first disarrays (1920-1980) were caused by the overexploitation of a semiconfined aquifer, which led to an excessive drawdown of the piezometric levels (great regional cones) and to the drawdown of the water table due to an increase of leakage.

The overexploitation produced side effects such as the pollution of the aquifer, the distortion of the flow net and the intrusion of brackish waters.

Since 1980, the abandonment of holes due to salinization or contamination, and the importation of pluvial waters, caused the phenomenon of rising levels, which was worsened by sewage insufficiency and by the settlement of a prolonged humid period.

The consequences are the progressive flooding of cellars and other underground buildings, problems to evacuate waste waters in areas with no sewage networks, a sanitary risk for the population, and growing costs to fight the problems either individually or due to a public emergency.

No decisions have been taken that lead to an integral solution of the problems, and which include the scientific community as well as the use of modern tools and rational control techniques.

Jurisdiction clashes, the lack of a detailed legal framework, and the lack of definition to attribute responsibilities, contribute to the continuation of this situation.

In the meantime, the problems caused by the rising levels are growing, and as time goes by, it will become harder and harder to solve the problem.

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