HYDROGEOLOGICAL ANALYSIS OF UNDERGROUND WATER RIGHTS IN THE ALTO PUANGUE PROJECT, CURACAVI

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1. INTRODUCTION

Below is a hydrogeological assessment of the access to water resources of the underground water rights established in the Hijuela III Lepe Norte and Hijuela II Las Casas sectors, in farmland located in the vicinity of the sources of the Caren Stream, 5th Region.

The assessment includes the analysis of the availability of water in the hydrographic basins the water rights are applicable to and an estimate of the availability of water in existing sources.

Once the availability of water in the aquifer has been established, the study seeks to determine the situation of the underground water rights granted for 50 wells in the aforementioned properties. A cadastre of these wells was drawn up for such purposes, including their location, depth, diameter, maintenance status, static level and any other characteristics that may serve the purpose of the assessment.

The purpose of this study is to provide a document that will enable establishing the validity of the project's water rights, based on the real availability of water resources in the basin and its catchment status. The recommendations of this document set out the actions that will enable accessing the legally held resource, or at least ensure the flow required by the project.

II. WORK METHODOLOGY

a. Analysis of the information

The legal information provided by the client, the surveying documents, catchment statistics, reports of the National Water Board (hereinafter DGA) on the area and all other hydrogeological information related to the area were reviewed. This analysis enabled obtaining a basic topographical map drawn up by the IGM (Instituto Geografico Militar – Military Geographical Institute) setting out the boundaries of the related hydrographic basins and the location of the wells that are the subject matter of the water rights.

b. Site inspection

The information gathered was checked on site, verifying the main information regarding the wells. Four water samples were taken for chemical and bacteriological analysis pursuant to the Chilean Potable Water Standard.

The existing wells were visited on the site inspection, determining their main characteristics and location in UTM coordinates, diameters, operating conditions and static fluid level. This information is available in the attached documents.

c. Review of the water rights information in the National Water Board

The existing documents in the National Water Board that grant the right to check the water rights of third parties in the area were reviewed, together with all other information considered relevant to the project.

d. Review of documents in the Real Estate Registrar

Purchase and sale documents and water rights were reviewed in the corresponding Real Estate Registrar in order to establish the values of the transfer per liter/second in this basin.

e. Drawing up of the report

The corresponding report was drawn up with Conclusions and Recommendations.

III HYDROLOGICAL BACKGROUND INFORMATION OF THE AREA OF INTEREST

a. Overview

The area of interest has been analyzed from the hydrogeological and application for water rights standpoint in three main studies by the National Water Board, namely:

1. Technical Report SDT No. 250 of 2007 "Assessment of the maximum sustainability of the Puangue - Melipilla aquifer[1]"
2. Study No. 128 of July, 2008 "Declaration of the hydrogeological sub-sectors of common water rights of Puangue Alto, Pangue Medio, Cholqui, Popeta, Melipilla and la Higuera as restricted areas."
3. Technical Report DARH No. 360 of 2011 "Reassessment of the availability of underground water resources in the aquifer sectors of the Metropolitan Region, Puangue Alto, Puangue Medio, Puangue Bajo and La Higuera."

The area covered by this analysis is located above the aquifer denominated Puangue Alto in the Puangue-Melipilla sub-basin (DGA 2006), which is part of the Maipo-Mapocho basin. This sub-basin has a surface area of 3,363 km² and a legally established underground water demand of the order of 14,989 l/s, of which an estimated 3,636 l/s is for predictable use (DGA 2007).

[1] Geological unit that can store and transmit water

The main hydrological system of this sub-basin is the Puangue Stream, which runs in a general north-south direction. Its sources are located in the watershed of the aforementioned Mapocho-Maipo basin. The Puangue Stream runs a course of approximately 55 km to finally discharge into the Maipo River, 18 km downstream and to the west of the city of Melipilla.

The average precipitation for the Puangue-Melipilla zone, which is considered mainly pluvial, is estimated at approximately 350 mm per year, distributed fairly evenly throughout the sector.

The records of the Puangue pluviometric station on Route 78, which measures the flow of this stream prior to its discharge into the Maipo River, give an average flow of 16.19 m^3/sec between 1987 and 2004.

The National Water Board has divided the Puangue - Melipilla sub-basin into 7 aquifer sectors between its sources and its discharge, namely:
Puangue Alto, Puangue Medio, Puangue Bajo, La Higuera, Melipilla, Cholqui and Popeta.

b. Puangue Alto Aquifer

The fluvio-alluvial[2] deposits associated to the bed of the Puangue Stream in its upper reaches, between the locality of Curacavi and the sources located further north, are denominated the Puangue Alto Aquifer. Figure No. 1, Map Showing the Location of the Puangue Alto Aquifer

The Puangue Alto Aquifer has an estimated recharge area of 4.3 km².

The general information obtained for this aquifer indicates that its maximum capacity is in the order of 65 m in sectors located north of the locality of Curacavi. It has also been established that in most of the wells in the upper reaches of the Puangue Stream there is an important aquifer in the first 20 m of the sedimentary sequence.

This aquifer has high transmissivity[3] of more than 800 m²/day. The information on static fluid levels of the aquifer show that they remained relatively stable in the region until 2007.

All the water rights that are the subject matter of this analysis are associated to wells in this aquifer.

[2] Fluvio-alluvial deposits: Sediments associated to river flows
[3] Transmissivity: Capacity of the aquifer to transmit water horizontally

The mathematical hydrogeological model constructed by the DGA in 2007 shows that the maximum sustainable flow for this aquifer is 472.56 l/s with an effect of 9.0 5% on surface flows, which is considered acceptable.

IV. LEGAL STATUS OF THE HYDROGRAPHIC BASIN OF INTEREST

As the agency in charge of granting water rights in accordance with the availability of the resource, the National Water Board issued 3 reports (which were mentioned previously and which are important to highlight), which enabled estimating availability and decreeing a restricted area for new water rights in the upper reaches of the Puangue Stream.

Figure No. 4 of Report No. 128 defines the areas covered by each one of these aquifers, which has enabled determining that the water rights that are the subject matter of this study fall within the area associated to the Puangue Alto Aquifer. A maximum sustainable exploitation of 484.41 l/s, equivalent to 15,276,354 m^3/year, has been estimated for this aquifer, which does not cause effects beyond the limits established for surface water courses. The committed demand (granted water rights) to June 30, 2010, was 35,512,119 m^3/year, considerably higher than what was defined as sustainable.

This is why DGA Resolution No. 241 of 2008, amended by resolution No. 231 of 2011, establishes a restricted area in the sector, which means that new permanent water rights cannot be granted, with no possibility of granting provisional water rights.

V. ANALYSIS OF THE EXISTING WELLS BELONGING TO THE PROJECT

a. Overview

From the information provided by the client, the water rights granted in these properties could be established, together with their collection points, the number of files in which they were processed and the agency that granted them.

The public information regarding the availability of water resources, the water rights granted and the criteria for granting them were also reviewed.

The project has access to 420.31 l/s which were granted in 14 separate processes, one of which was by a judicial ruling. 10 of the remaining water rights were granted directly by the DGA and three were granted by the Appeal Court of Santiago, since the DGA initially denied them. They were initially subject to an appeal for reconsideration submitted in the offices of the DGA and subsequently turned down. A remedy of complaint was then submitted, which was finally accepted by the court.

All these processes were rejected by the DGA for the same reason, namely that the wells were located in the basins of the Puangue and Caren Streams and it could not be established whether there was interference between the river and aquifer. According to the DGA, the granting of these water rights would undermine the previously granted

surface water rights and the full use of these rights could generate conflicts with the users of the surface waters downstream.

The water rights granted by the DGA amount to **295.25 l/s** and the rights granted by the court against the opinion of the DGA amount to **138.38 l/s**.
A summary of these water rights is presented in Table No. 1, which shows that ten wells have water rights for more than 10 l/s and that the maximum flow granted corresponds to the well assigned the number 22, with 33.32 l/s.

b. Site inspection

The sector being studied was visited on August 14 and 20, 2013, to establish the existence and status of the wells located therein and take water samples from 4 of the wells for their physical, chemical and bacteriological analysis.

Table No. 2 shows the main characteristics of these collection points. In the table it can be seen that the maximum flow is granted at Well No. 22, which is next to a canal, so part of the authorized flow could originate in the canal.

All the wells with water rights are physically on the property and apparently have sufficient amounts of water for extraction.

The recharge area for these wells is approximately 1.6 km^2.

VI. ANALYSIS OF UNDERGROUND WATER PRICES IN THE SECTOR

a. Background information

Due to the fact that new water rights cannot be granted in the sector under study, a water market has developed, which can be analyzed considering the transactions performed. These transactions are reflected in the Water Rights Registry of the Real Estate Registrar of Casablanca.

Water rights have not been granted in the basin since 2007, and the transactions performed from 2005 to date were reviewed.

From this review it could be determined that:

- 6 water rights transactions were detected in the Curacavi Valley that were not associated to the property, without considering water rights for real estate developments.
- The water rights transactions included 2 for 5 l/s and four others for 4 l/s, 2 l/s, 0.2 l/s and 7 l/s.
- The prices of these water rights vary between Ch$ 2,500,000 for 0.2 l/s in 2012 to UF 100 for 5 l/s in 2011.
- In 2011 Sociedad Agricola el Pangue Limitada bought 5 l/s for Ch$ 45,000,000 and then sold those same 5 l/s plus another 2 l/s for Ch$ 30,000,000 in 2013.

- The biggest water rights transaction, 30 l/s, is associated to the sale of the property in which leasing contracts have been entered into (s), which makes it difficult to separate the values assigned to the property and the water rights.
- Condominio Lomas de Curacavi, which has water rights in the Los Naranjos Ranch, sells properties with water rights that vary from 0.56 l/s to 0.83 l/s at prices between Ch$ 386,000 and Ch$ 576,000.

We also had access to the value of the water rights in this sector established for Aguas Andinas by the Superintendency of Sanitary Services for the calculation of its tariffs, which was set at UF 62, which is the amount determined for all water rights transactions. Nonetheless, it is worth mentioning that Aguas Andinas is not a strong buyer in this sector.

b. Conclusions

From the above, it can be concluded that:

- The market is very incipient and irregular
- Water rights are generally sold together with a property, as an incentive for buying the property.
- Water rights transactions are usually very small and mostly destined to the consumption of suburban country plots.
- The most probable liter/second value of water not associated to properties would be the 62 UF per liter/second established for the area by the Superintendency of Sanitary Services.

VII. CHEMICAL QUALITY OF THE WATER

Four water samples collected on August 20 from four wells located at different points of the property were analyzed in accordance with the Potable Water Standards to determine the quality of the water. This analysis included a bacteriological analysis.

From this analysis it was concluded that:

- All the samples comply with the chemical parameters of the standard.
- Only one sample taken from a well in the Caren Stream sector does not comply with the physical parameters regarding odor (it should be odorless).
- Two wells, Well No. 1 and Barrancon, comply with the turbidity requirements of the bacteriological analysis.
- Escherichia Coli is absent in only one well in the Caren sector, which is therefore the only one that meets the bacteriological requirements.
- There is an excess of turbidity, total coliforms, fecal coliforms and escherichia coli in the well used for the house.

The certificate of the laboratory responsible for the analysis, with the results obtained, is presented in the corresponding appendix.

VIII. CONCLUSIONS

1. All the underground water rights reviewed in this report and the documents provided by the client are for the collection of underground water in the fluvio-alluvial aquifer located in the sector denominated Puangue Alto, Curacavi.

2. According to the Technical Report of the National Water Board "Assessment of the maximum sustainable exploitation of the Puangue-Melipilla Aquifer," of October, 2007, the sustainable exploitation in the Puangue Alto sector is 484.4 l/s, which have been fully distributed in the water rights granted to date.

   The aforementioned report states that the area is closed for new water rights applications, which was confirmed by a DGA resolution in 2011. It is also closed for provisional water rights applications (water rights that are granted for a specific period of time to determine whether they affect other rights. If no other rights are affected, usually over a period of 5 years, such rights can become definitive).

3. The project's water rights are equivalent to 80% of the flow considered sustainable for the entire aquifer.

4. The area in which the project has water rights ([5]) has a recharge of approximately 40% of the recharge of the entire aquifer. It must be pointed out that there are additional water rights in the sector that share the same recharge area.

5. Ongoing exploitation of the project's water rights is not sustainable according to the parameters of the DGA. The sustainable flow is most probably of the order of one third of the water rights legally granted.

6. All the water rights reviewed have an associated collection point on site, which can apparently provide water. It is unknown whether all the collection points are capable of providing the flow granted by law.

7. The use of the rights associated to the basin of the Puangue Stream, which most probably interfere with surface flows, could generate conflicts with users of surface water downstream. (In dry years the surface water could disappear and surface water users would then blame the underground water users located upstream).

(5) Recharge: The amount that enters the aquifer, usually expressed annually.

8. The quality of the water sampled at 4 points only meets the chemical requirements of the Chilean Potable Water Standards. Three collection points do not meet the bacteriological requirements, and where bacteriological requirements are met, physical requirements are not.

9. The sale value of each liter/second of underground water in the basin is approximately UF 62.

IX. RECOMMENDATIONS

It is recommended to verify the capacity of the aquifer by means of pumping tests at at least two points with the greatest concentration of water rights with significant associated flow volumes.

It is recommended not to consider more than one third of the project's underground water rights for permanent consumption.

It is recommended to treat the water destined to human consumption. The treatment would basically entail disinfection and removal of turbidity.

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