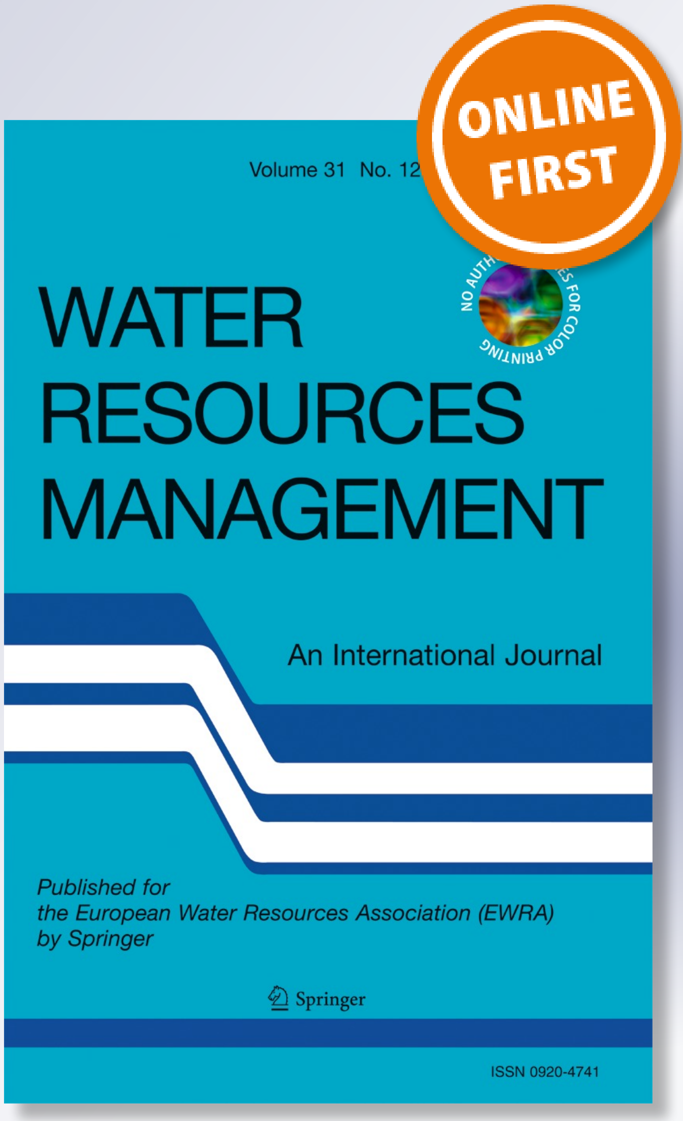
Lessons From Spanish and US Law for Adequate Regulation of Groundwater Protection Areas in Chile, Especially Drinking Water Deposits

Verónica Delgado, José Luis Arumi & Oscar Reicher

Water Resources Management
An International Journal - Published for the European Water Resources Association (EWRA)

ISSN 0920-4741

Water Resour Manage
DOI 10.1007/s11269-017-1761-z



Water Resour Manage
DOI 10.1007/s11269-017-1761-z

Lessons From Spanish and US Law for Adequate Regulation of Groundwater Protection Areas in Chile, Especially Drinking Water Deposits

Verónica Delgado[1,2] **· José Luis Arumi**[3,4] **·**
Oscar Reicher[1,5]

Received: 21 October 2016 / Accepted: 19 June 2017

Abstract The hypothesis of the present work is that the groundwater regulations of the Chilean Water Code are insufficient because they look only at quantitative aspects of interest to owners of water rights, but do not serve to protect the quality of the aquifer as a common good. To prove this hypothesis, a legal and technical review of how groundwater catchment protection areas are regulated in Spanish and US law, especially when used for human consumption, was carried out. After this review, we contrasted these regulations with Chilean standards, particularly the Water Code and Supreme Decree 203 of 2013. We concluded that there are at least two substantial differences: a) Chilean legislation does not impose any restrictions on the establishment of polluting activities near the drinking water collection point, emphasizing the quantity of the resource rather than the protection of its quality. The law prevents only the opening of new groundwater collection points near the first. In addition, b) the protection area is not variable; it always remains the same regardless of the intended objective, site characteristics or the speed at which a contaminant advances.

✉ Verónica Delgado
vedelgado@udec.cl

José Luis Arumi
jarumi@udec.cl

Oscar Reicher
oreicher@udec.cl

[1] School of Legal and Social Sciences of the University of Concepcion, Barrio Universitario s/n, Concepcion, Chile

[2] Universita Degli Studi in Rome, Rome, Italy

[3] School of Agricultural Engineering and CRHIAM of the University of Concepcion, Chillan campus, Concepcion, Chile

[4] University of Nebraska, Lincoln, NE, USA

[5] University of Concepcion, Concepcion, Chile

Published online: 26 August 2017

Keywords Protection areas · Groundwater · Water for human consumption · Protection perimeters · Groundwater catchments

1 Introduction

Chile needs an adequate model for groundwater protection, as was recognized in the recently published National Water Resources Policy (Ministry of the Interior and Public Security, 2015). After intense groundwater exploitation, there are several aquifers or sectors that have been overexploited, mainly in parts of the northern and central areas of the country, where there have been significant conflicts over water resources (Ministry of the Interior and Public Security, 2015).

Chile does not establish values for defining when groundwater is overexploited; rather, a specific study must be carried out for each catchment. This is due to the great climatic variability in the country, which ranges from the arid Atacama Desert to the humid forests of Patagonia (Arumi and Oyarzún, 2006); however, it is a revealing precedent that in January 2017, there were 153 hydrogeological sectors of common use in Chile in which restrictions had been declared and 6 in which exploitation had been prohibited (General Water Directorate, 2016).

In addition to the conflicts over scarcity and competition for water resources among its main users (the mining industry, intensively irrigated agriculture and drinking water supply), there are also contamination problems (OECD, 2005).

The situation in Chile is actually worse if we consider that groundwater accounts for 40% of total volume of water for human consumption in urban areas, while in rural areas it accounts for 76% (Ministry of the Interior and Public Security, 2015). This high dependence is explained by the fact that 70% of the Chilean population lives north of the 36th parallel, which is an arid to semiarid zone, meaning that surface water sources suitable for drinking are scarce.

Further, Chile has not been able to secure the human right to water (for drinking and sanitation) in multiple zones where the production industry has access. The state must therefore assume the cost of providing water by transporting it in vehicles during several months of the year.

For this reason, emphasizing that the use of this water will progressively increase, the World Bank identified, among several challenges to overcoming these conflicts, the need to make groundwater management more sustainable. While acknowledging that the Water Code contains some tools that are useful in this respect, it notes that the biggest challenge is their implementation. It points out the most serious problems faced by the country such as lack of information (which is furthermore delivered in different formats, making it virtually useless), management tools and knowledge regarding the country's resources, that groundwater and surface water are not managed jointly, that there is very little control of legal and illegal extraction, that users have not organized themselves to assume the management of their water even when it is already being overexploited (except for specific and limited exceptions in which the state has financed the constitution of water communities), that the impact of irrigation technology subsidies with regard to their effect on overburdening and contaminating aquifers has not been studied and that there are no protection perimeters for drinking water sources (World Bank, 2011).

The World Bank guide from 2002, which contains recommendations for Latin American countries on the protection of groundwater quality, states that the risk of contamination from potentially polluting activities depends fundamentally on their location relative to the catchment area and, secondly, the mobility and dispersion of the pollutants involved in the local groundwater flow regime. As an important measure, it is recommended that protection perimeters be imposed around the catchment. Decades of experience in several countries demonstrate that it is an effective tool for achieving a balance between adequate protection of the resource and, to the greatest possible extent, economic activity (Martínez and García, 2003).

This work deals specifically with this protection measure, which, based on the work of Moreno and Martinez (1991), we have defined as an area around a catchment in which restrictions or prohibitions on the activities likely to modify groundwater quality are imposed through various protection zones in a graduated manner.

Regarding these determination perimeters, Martínez and García (2003) carried out a detailed review of the regulations in Germany, France, the United Kingdom, Ireland, Belgium, Holland, Italy, Portugal, Denmark, Switzerland, the United States, Canada and Australia. It was found that even though "the rules or standards used are very disparate" among the countries studied, it is typical to establish several areas or zones around the catchment, which can cover several square kilometers, where conditions or prohibitions are imposed on the activities underway or to be initiated, limitations which are attenuated as the distance from the catchment area increases. Chave et al. (2006) reached identical conclusions in a comparative study of protection areas in several countries.

In the zone immediately around the catchment area, the prohibition of activities is usually absolute. In the remaining areas, generally of varying dimensions in accord with the particular aquifer and the other factors already mentioned, the law (national, federal, etc.) or authority (usually regional, provincial or of the basin), which, in accord with its broad faculties, lists the activities that are prohibited or upon which some restrictions or conditions will be imposed.

The hypothesis of this work is that the groundwater regulations of the Chilean Water Code are insufficient because they look only at quantitative aspects of interest to owners of water rights but do not serve to protect the quality of the aquifer as a common good. To prove this hypothesis, we developed a comparative analysis of the laws that Chile, Spain and the United States have established to protect groundwater areas that surround drinking water wells.

2 Materials and methods

The approach is based on comparative law methodology, which is widely used in legal research (Fig. 1) and involves defining research questions (RQ) and answering them through the comparative analysis of the water laws of the selected countries. Once these questions have been answered in light of the regulations of these countries, the Chilean regulations are analyzed to determine if they apply to drinking water catchments and, if so, if they reduce the risk of contamination of these sources.

The research questions defined in accord with to the hypothesis and objective of this research are:

1. Is there a protection area for drinking water abstraction and, if so, what is its protection objective (water quality and/or quantity)?
2. Which legal body determines it and what limitations may be imposed on nearby polluting activities?
3. How this area is determined, in the sense of being fixed or variable?

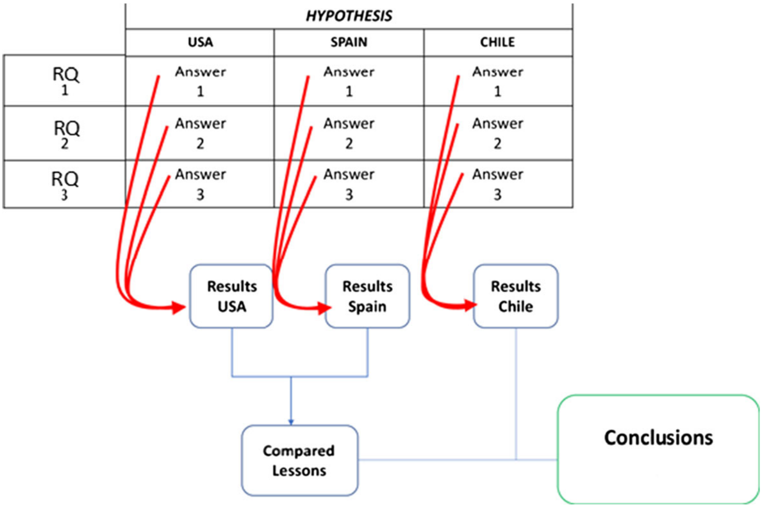


Fig. 1 Schematic diagram of the comparative law methodology used for this research. (RQ: research questions)

This study delves into the specific regulations regarding protection areas of drinking water catchments in Spain and the United States since they are two important models for Chile. Spain was chosen because Chilean water law follows its model (Vergara, 1991) and it was not included in the work of the Martínez and García (2003) on protection areas. The United States was selected because in recent years, the Chilean water authority has strengthened ties with the country in order to study its experience, especially in light of the severe drought affecting some areas of both countries, particularly California, to take on a water law reform in Chile, as explained in the National Water Resources Policy (Ministry of the Interior and Public Security, 2015).

The same research questions are answered regarding Chilean law, in which the regulations basically refer to the "water rights" protection area to determine if this area applies to drinking water catchments, and if so, if it allows the risk of contamination to be assumed.

Specifically, this research examines the Chilean Water Code and the new rules contained in Supreme Decree No. 203/2014 of the Ministry of Public Works, which approves regulations on groundwater exploration and exploitation standards (hereinafter D.S. 203/2014), including medicinal waters (Supreme Decree No. 106 of 1997 of the Ministry of Health, which approves regulation of mineral waters, hereinafter D.S 106/1997), and very briefly, protection and restriction areas regarding drinking water intakes contained in Chilean Standard 777/2 of 2000, Drinking Water - Sources of Supply and Collection, Part 2: Groundwater Collection (hereinafter NCh 777/2), which is a law that is in full force but not applied in practice, the legality of which is questioned in this study.

As for the novelty of the approach, there are no studies that refer to protection areas for drinking water abstraction sources in Chilean regulations and compare them with foreign law. There are only old works that criticize the existing standards (Pinto, 1993); the subject was not taken up with this approach in the most recent legal studies of groundwater in Chile (Rivera, 2015; Rivera, 2016).

3 Results

This section includes two parts. In the first part, the results of the analysis of Spanish and US legislation is presented, answering the previously stated questions. In the second part, Chilean regulations are reviewed in a more detailed manner. Finally, in the discussion and conclusions, they are compared with the analyzed foreign law.

3.1 Comparative Law: Spain and the United States

As stated, Spain was chosen because the Chilean water law follows its model and the United States was chosen because the Chilean water authority has strengthened ties with the country in order to study the experience of the latter to take on a water law reform in Chile in light of the severe drought in some areas of both countries.

3.1.1 Spanish Law

Framework Directive 2000/60 of the European Parliament and the Council (to be implemented from 2001 to 2015) requires member countries to achieve good qualitative and quantitative groundwater status.

Doing so requires countries to implement a series of programs and lines of action, none of which (with minor exceptions) have been implemented in Chile. Thus, as a roadmap for the country, the following actions are required:

a) An initial characterization of all groundwater bodies and further characterization of those presenting risk;
b) A study of the repercussions of human activity on groundwater status (including collection points where over 10 m3/day are extracted for consumption by more than 50 people, the points of direct artificial recharge and land uses of the feeding zone of the body of water);
c) The impact of the groundwater level on surface water and associated ecosystems;
d) The impact of pollution on groundwater quality;
e) The registration of areas declared "special protection areas" to protect their groundwater or conserve the habitats that depend on them, including those marked as areas specially destined for the collection of water for human consumption, requiring that a summary of the record is included in the hydrological basin plan.

For the bodies of water that will be used for human consumption in the future, it is recommended that member states set up protection perimeters. It is stressed that that the purpose or objective is twofold: "to ensure the necessary protection of bodies of water and avoid quality deterioration" (article 7 N° 3) (López-Vera, 2002).

To comply with these new guidelines, Spain, in Article 12 of Legislative Royal Decree 1/2001 of July 20, by which the revised text of the Water Law was approved, provides that the aquifers or geological formations through which groundwater circulates are public property and imposes on the property owner a prohibition on executing any kind of work that is not intended for extraction or water use or that may disturb its regime or degrade its quality.

Basin organizations must determine the protection perimeters of aquifers. When they are declared overexploited or at risk of overexploitation (article 28), a management plan for the recovery of the aquifer or hydrogeological unit must be approved within two years. In the meantime, the agency may establish the necessary limitations on extraction as a preventive and precautionary measure to protect groundwater from the risk of contamination. The basin organization may determine the protection perimeters within which infrastructure construction, aggregate extraction or other activities and facilities that may affect groundwater quality require the authorization of the basin organization (article 56).

In fact, river basin management plans must consider protection perimeters and measures for the conservation and recovery of the affected resource and environment (article 42 letter g), with the understanding that the watershed is as an indivisible management unit.

Using this methodology, bodies of groundwater of various areas (from 1225.4 to 257,597.4 ha) were defined and each aquifer was described. Then, water uses (for supply, irrigation, environmental purposes, etc.) and potential risks such as industry, transport or hazardous waste were identified.

To comply with the duty to prevent deterioration of water quality (article 7 of the aforementioned directive), a water quality study is required and 4 types of protection zones are established: Zone 0 (sanitary protection), Zone 1 (microbiological protection), Zone 2 (dilution and control) and Zone 3, which is the basic enclosure of the protection perimeter. Each has different objectives and, therefore, different dimensions and constraints.

For example, in Zone 0, the aim is protection against spills that could directly affect water testing. In this case, a fixed perimeter is established (10 m), within which any kind of activity that is not directly related to the maintenance and operation of testing is banned.

Zone 1, on the other hand, is an area protects water from both microbiological and chemical contamination (low persistence pollutants) and in which processes such as inactivation, removal or dilution of the contaminant must be taken into account so as to allow appropriate action to be taken before a potential contaminant reaches the water collection point. Thus, its area is considered along with transit time (50–60 days). Restrictions in this zone are high.

Zone 2 protects the collection of non-degradable contaminants (heavy metals, hydrocarbons, organic compounds, etc.). Therefore, its area is wider and transit time is estimated at 5 years (allowing for time to develop or work on a contingency plan), with moderate restrictions on potential activities, etc. It considers the hydrogeological conditions of the feeding areas. Restrictions in this area are moderate.

Zone 3 is also variable, as it depends on extracted flow and the annual recharge of the aquifer and is not dependent on pollutant transit times.

Answering the research questions:

RQ 1: Is there a protection area for drinking water abstraction and, if so, what is its protection objective (water quality and/or quantity)?

The water regulations provide for "protection perimeters" for aquifers that are overexploited or at risk of overexploitation, expressly stating their dual purpose: to avoid deterioration of water quantity and/or quality). To this end, it is essential to have prior information, including at least an initial characterization of all existing groundwater bodies and the impact of nearby human activity, especially in areas with water destined for human consumption.

RQ 2: Which legal body determines it and what limitations may be imposed on nearby polluting activities?

These perimeters are determined by basin organizations. They must be established in the respective hydrological plans, which must also consider measures for the conservation and recovery of the resource. If this plan is not yet available and the aquifer is overexploited or at risk of overexploitation, this organization may establish limitations on extraction and, in order to protect its quality, establish protection perimeters, for which it must first authorize certain risky activities.

RQ 3: How this area is determined, in the sense of being fixed or variable?

Protection areas are determined according to each body of water. Therefore, there are several areas or zones around the catchment, with the first one fixed and others variable, in which the basin organization may impose conditions or prohibitions on activities that are underway or are planned for its surroundings, attenuating them as the distance from the catchment area increases.

3.1.2 US Law

Nearly a quarter of all fresh water used in the country is groundwater, and the application of groundwater protection rules falls to the EPA (Environmental Protection Agency). The Safe Drinking Water Act, since its amendment in 1986, establishes that the states can establish quality protection perimeters for wells for three-year terms, an arrangement known as the Wellhead Protection Program (EPA, 1990a, b). The 1996 amendment establishes two types of state water catchment protection programs: source water assessments, which are compulsory for the states, and source water protection programs, which are implemented through state and local (not federal) laws, both of which aim to impel the delimitation and implementation of protection zones. The Clean Water Act provides money for states in order to develop strategies for groundwater protection and authorizes other programs that prevent water pollution. Most states in the country possess regulatory standards for the protection of groundwater (EPA, 1990a, b).

Under the Safe Drinking Water Act, the protection of water wells consists of the protection of all or part of the area surrounding the well used for drinking water. The size of the protection area also varies by location, following the established factors of the goals of the state program, as well as the geological characteristics of the area.

It sets some protection criteria for each of the states such as: a) the definition of each well (a consideration that must also be taken into account for other sources intended for other uses susceptible to contamination, especially mineral waters that are packaged without disinfection); b) the identification of the contaminants that affect each well (contaminants that decay over time and non-degradable contaminants, the dilution of which should be considered dependent on the flow path); c) the proper placement of new water wells to increase the production of drinking water, and d) the control of activities carried out in the protected areas in order to protect their water supplies (EPA, 1990a, b).

With respect to economic implications, the definitions of the protection areas vary in the recharge capture zone such that the economic activities subject to the greatest land use restrictions are those closest to the source. Various criteria are considered to define the zones, the primary of which is a combination of flow time (horizontal) and flow distance (Foster et al., 2002). The criteria usually follow the recommendations of the EPA, and basically aim to establish the number of days that a contaminant takes to reach the well, which is equivalent to the Spanish concept.

As described by Foster et al. (2002), three primary concentric zones around the groundwater source are established:

a.- The immediate area or operational zone of the well, which is the innermost or closest to the well, and which is generally managed by the (natural or legal) person that performs the operation. Activities in this area are generally restricted, except those related to resource extraction. In general, however, a perimeter of 20 or 30 m is set;

b.- The nearby area or area of microbiological protection, designed to prevent the introduction of bacteria, viruses and parasites. It is fixed (an radius of 165 m or a groundwater transit time of 50 days);

c.- The total collection area, which is farthest from the water source and in which all aquifer recharge (from precipitation and/or surface water courses) is captured by the supply source of the considered water. This area is determined both by considering the water balance and geometrically through groundwater flow paths, with 10 to 20 years as the transit time.

Restrictions on activities in these areas are set by local bodies (municipalities) through a municipal ordinance for the protection of wells. Even in the case of the depletion of several aquifers in California, local restriction measures regarding water pumping have been deemed successful (Nelson, 2012).

Answering the research questions:

RQ 1: Is there a protection area for potable water abstraction and, if so, what is its protection objective (water quality and/or quantity)?

The drinking water regulations involve implementing “protection perimeters” around aquifers that can be used to capture drinking water. This was initially a faculty available to the states and since 1996 it has been mandatory. Its purpose is basically to avoid the deterioration of water quality.

RQ 2: Which legal body determines it and what limitations may be imposed on nearby polluting activities?

These perimeters are determined by local bodies (municipalities) through ordinances, generally following the criteria of the EPA. This means establishing at least 3 areas. The first must be fixed or variable the second and the third always variable, depending on the transit time of the contaminant, as is the case in Spain.

RQ 3: How this area is determined, in the sense of being fixed or variable?

Through these same local ordinances, each municipality may impose limitations on nearby activities.

Finally, in Spain and in the United States, protection zones are generally variable and are determined according to factors associated with pollution risk. In addition, there are basin authorities or bodies endowed with powers to prevent particular land uses in the groundwater protection area. This does not occur in Chilean law.

3.2 Chilean Law

In 2000, Chilean Standard NCh 777/2 was enacted, which is officially enforceable but not applied in practice (Espinoza et al., 2004). This is because the standard loosely establishes prohibition zones for certain activities, but has a lower rank than Chilean law.

In reality, the groundwater protection areas around drinking water catchments are regulated primarily in the Water Code and the new rules contained in D.S. 203/2014 of the Ministry of Public Works, which approved regulations on standards of groundwater exploration and exploitation.

In addition, there are special rules for protection areas around the collection points of healing waters (D.S. 106/1997).

However, as we shall see, the Water Code actually regulates protection areas for water rights requests made by private parties to the General Water Directorate (hereinafter GWD) that enable them to extract water.

The 1981 Water Code distinguishes between surface and groundwater, and defines the latter as waters "that are hidden within the earth and have not come to the surface" (article 2).

Nonetheless, the regulations regarding protection areas are reduced solely to the following aspects: a) When water rights are requested, the protection area sought must be specified (article 140); b) When granting the water rights, the GWD must indicate "The name of the river bed or commune in which the uptake of groundwater is located, as well as its protection area" (article 149 N° 2). In addition, article 61 states that the protection area is one "in which similar works are prohibited," without further specifying how it should be calculated.

As seen, the Water Code has left to lower-ranking rules the detailed regulation of protection areas regarding rights for groundwater exploitation.

RQ 1: Is there a protection area for drinking water abstraction and, if so, what is its protection objective (water quality and/or quantity)?

As has been the case for years, Article 26 of D.S. N° 203/2014 establishes that a protection area consists of a strip of land or radius of 200 m. From a hydrogeological point of view, the determination of a fixed protection radius (in this case 200 m) lacks technical support (Pinto, 1993). The area of an aquifer that is affected by the extraction of water from a well is called the area of influence and its size depends on factors such as the volume pumped and aquifer characteristics given by the permeability of the material that composes it. For example, a wheel well from which water is pumped (less than 0.5 l/s) to irrigate a farm will have an area of influence of a few meters, but a deep well used to irrigate intensive agricultural production (pumping more than 50 L/s) may have an effect over several kilometers.

The arbitrary radius of 200 m has caused confusion and sometimes prevented companies from building wells for drinking water due to the existence of a water wheel used to feed a swimming pool for domestic use, even if there are no hydraulic connections between the two wells.

This is also important as a protection area of 200 m in radius is defined without considering that below a certain point, there may be different aquifers that are not connected. Aquifers are underground water storage systems (underground reservoirs), each with a different geological process. Therefore, along the course of the geological history of a certain territory, different aquifers with no connection to each other may have existed.

An example of this is the case of the Peumo aquifer (160 km2), located at 34.3° South, 71.3° West, about 100 km south of Santiago, Chile, which was studied by Arumí et al., (2009 and 2013). The groundwater system in the area consists of an unconfined aquifer that is recharged by the river, rain infiltration in winter and excess irrigation water during spring and summer. Groundwater flows along the valley following the direction indicated in Fig. 2a. Arumí et al. (2013) studied the effect of a drought on this groundwater system, finding that

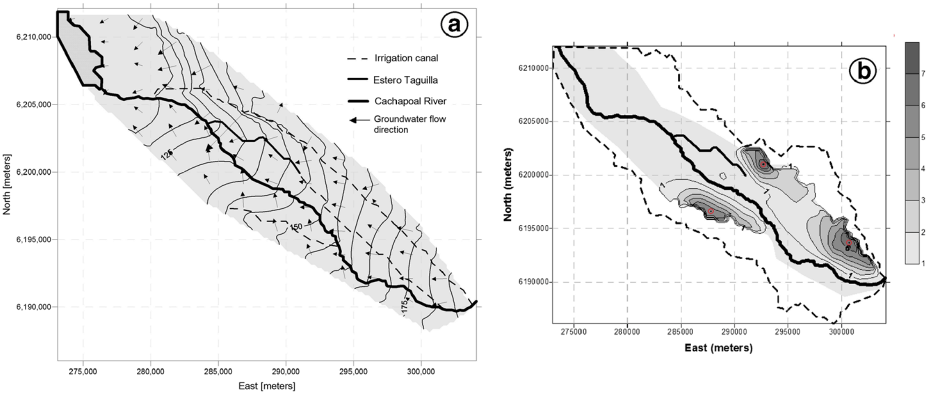


Fig. 2 **a** Groundwater flow direction toward the Peumo Valley; **b** Water table conditions of the main irrigation canals of the valley if the irrigation canals are lined and the wells are pumped at full capacity (slightly modified from Arumi et al., 2013)

wells used for drinking water supply can be depleted, as presented in Fig. 2b. In this figure, the black circles represent the 200-m protection areas; it can easily be observed that the area affected by the pump under drought scenarios is several times larger than the area that is depleted and where the water is taken from the drinking water supply. Therefore, the groundwater quality protection area must be up to 10 times larger than the standard 200-m protection areas.

Finally, regarding the interactions among several wells, the GWD states that for river-aquifer interference, it is necessary to study each situation, and establishes as a general criterion that an interference analysis shall be carried out when the surface runway presents continuous runoff and when the catchment is 200 m or less from it. Catchments located beyond the indicated distance shall not be considered to cause direct interference with the waters of the channel, except for those sectors in which technical studies have indicated that the radius of influence of the wells may exceed 200 m, which must be duly justified and supported in the corresponding technical report. For these purposes, the Jacob formula is used.

RQ 2: Which legal body determines it and what limitations may be imposed on nearby polluting activities?

We have just pointed out that, according to the wording of the Water Code, the protection area should be set in the resolution that grants groundwater rights or approves a change in collection points, in order to prohibit "similar works" (article 61). In other words, what is prohibited is merely the capture of groundwater by similar works.

The new regulation states that to determine this area, the collection point where the water right is requested must be physically located more than 200 m from other wells if rights to these deposits are legally established rights or going through the regularization process. That is, the logic of the code and regulation always grants protections to holders of water rights and ownership of water rights more than the water itself despite the potential risks to people and the ecosystem, which should be given more weight, according to the OECD (2005) and the World Bank (2011). In fact, article 20 letter f notes, as did R.E. N° 425/2008, that water rights may be given by the authority even if they do not comply with the standard distances, provided authorization is given by the holder of the affected water right, as if the protection area only serves to protect water rights and not the various uses of the aquifer in general. The only exception relates to protection of watersheds or springs, regarding which article 23 provides that the GWD may not give groundwater use rights at a distance of less than 200 m if injury or prejudice to third party rights is caused or the relationship between groundwater and surface water is affected, which may include water quantity and quality problems.

These rules do not clearly and explicitly indicate, as do those in other countries, that the establishment of this radius is meant to protect water quality, especially when a source of drinking water is involved. Nor do future reforms to the Water Code address this issue, as we have previously pointed out. Chilean legislation continues to be dominated by the concept of the exploitation of natural resources without recognizing advances in hydrological and environmental knowledge.

Only regarding medicinal waters (mainly springs), where a larger protection area may be established pursuant to D.S 106/1997, do the rules state that the purpose of this area is "to avoid works in the vicinity that may cause alteration, reduction or extinction of the source," giving it a much wider scope than article 21 of the Water Code, which is limited to prohibiting the “installation of similar works.”

In other words, it is easy to agree with the World Bank report, which says that Chile does not have protection perimeters to protect drinking water sources, notwithstanding the fact that, as will be seen below, a regulation formally exists, but is apparently not enforced in practice and is of dubious legality.

RQ 3: How this area is determined, in the sense of being fixed or variable?

Article 26 states that "The dimension of the strip or radius is 200 meters measured on the ground, with the exceptions referred to in articles 27 and 28 of this Standard."

The first exception, established in article 27, allows the entity requesting the constitution of water rights to also request a protection area with a radius greater than 200 m, provided such request is justified by a technical report containing the characteristics of the aquifer and groundwater uptake (article 27). This occurs when there is a well from which a large volume is extracted (more than 30 L/s) and where the depression wedge may be many kilometers in length. This case must be documented with a hydrogeological study (made by a competent professional) and pumping tests that consider observation wells.

The second exception, provided in article 28, was not expressly considered in R.E. N° 425/2008 and refers to protection areas for sources of thermal mineral waters that have been declared medicinal in accordance with the standards of D.S 106/1997. Article 3 of this decree requires that the application form include the documents that prove the existence of water rights pursuant to the Water Code and the protection area established by the GWD.

It is most important to note that article 6 of D.S. 106/1997 states that the GWD should set this protection area for medicinal waters based on the standards of the code, but indicates that this area shall be established "to avoid underground works in the vicinity, which may cause alteration, reduction or extinction" of the source, giving it a much wider scope than article 21 of the Water Code, which is limited only to prohibiting “the installation of similar works.”

3.3 Technical Standard Advancements in Chile

Paragraph 4.3 of Chilean standard NCh 777/2 regulates the "risk of contamination of surface waters for drinking water," establishing, among other protective measures, that "precautions must be taken in order to prevent chemically or physically undesirable liquid or gaseous pollutants from entering the uptake point during the construction or operation period. To this end, within the minimum area of 100 square meters surrounding the uptake of groundwater for drinking water, the establishment of any activity shall be prohibited during the period of operation (absolute prohibition zone)."

The standard adds that "in the feeding area of the drinking water catchment, the competent authority shall prohibit the establishment and operation of activities that discharge groundwater-polluting effluents into the soil or subsoil and that may make the water inadequate for direct consumption by the population. This special area should correspond to the feeding area for drinking water catchments defined by travel times that ensure that the eventual contaminant will not affect the quality of the water uptake" (letter f).

Consequently, the standard adds that possible interference between groundwater catchments projected according to the laws and regulations must be considered. In each case, the owners of the potentially affected water rights must be identified, the use made of the resource indicated and the magnitude of interference estimated. Interference with existing deposits, whether groundwater or surface water, must be avoided (article 4.5).

Coinciding with D.S. N° 203/2014, the regulation states that "the minimum protection area for wells must be a circle 200 meters in radius with the center at the axis of the well" (6.1.9 letter e). The important point is that if larger perimeters or protection areas are requested, the request should be justified "by contamination risk analysis or the interference of future neighboring wells," revealing that protection is for the aquifer, not only to prevent a decrease in the water flow but also to avoid source contamination, to the point of prohibiting activities that discharge into the soil or water and that may affect its quality.

This standard, even though it is considered legally valid by the Ministry of the Environment, is not enforced in practice (Espinoza et al., 2004). In addition, it can hardly serve as a basis (due to its rank in the regulatory hierarchy, which places it below a law) for the health authority to effectively prohibit the establishment and operation of activities that would "degrade the conditions of the water and render it unsuitable for direct consumption by the population." In any case, its rules lag in relation to those in Spanish and US law and the methodologies used to determine the different variable protection zones.

4 Discussion

The main results of this research indicate a lack of protection perimeters for drinking water sources, a problem that must be addressed. Thus, we propose that the law adopt the same criteria currently established only in a technical standard, which ranks below a law.

It is therefore imperative to enact a rule of adequate rank that allows protection areas for drinking water abstraction determined according to modern methodologies and with explicit consideration of the risk of contamination and to enable the authorities to limit or impose conditions on existing activities in the context of integrated basin management.

However, it is important to keep in mind that the determination of these protection areas or perimeters in Chile will be difficult because, as reviewed in other countries, at least three factors are required that the country lacks:

First, information on the existence and quality of our aquifers is extremely poor (World Bank, 2011). In any case, one of the main goals of the Ministry of Interior and Public Security (2015) is to develop a study plan and updated cadaster of aquifers, existing wells, extraction levels, water quality and recharge levels as well as granted rights and pollution sources. For these objectives, the GWD, through Resolution N° 2.129 of August 16, 2016, ordered that the indicated owners of groundwater use rights must adapt their extraction control systems and periodically collect information.

Second, integrated basin management does not yet exist in Chile, nor does the current Water Code reform consider it.

Finally, the GWD faces serious technical, economic and legal problems such that Chilean doctrine speaks of an "institutional water crisis" (Vergara, 2015) and the government asked the World Bank for a study that ultimately proposed three alternatives: strengthen existing institutions, create a Subsecretary of Water within the Ministry of Public Works or, finally, create a Water Agency (World Bank, 2013).

In addition, the GWD has only "general" (Boettinger, 2014) or "lateral" (Costa, 2016) faculties and powers in the field of pollution prevention. Furthermore, groundwater communities, which are in charge of water management in Chile, are not yet organized, except in very specific cases. In any case, they do not have competence in environmental matters.

In the meantime, we suggest at least that the vulnerability of aquifers that are currently used to obtain drinking water be estimated and that they (and obviously those that will be used in the future) be protected through the tools offered by land use planning instruments (Plummer et al., 2011).

5 Conclusions

Comparative experience demonstrates that this criterion of setting protection perimeters around underground water catchments (used since the nineteenth century) has always looked to protect the uptake (well or runoff) from pollution by establishing that wells should be far from potential sources of contamination (López-Vera, 2002). In addition, these laws are inclined toward requiring water resources planning of the whole aquifer or river basin, requiring proper joint management of surface water and groundwater. In Chile, however, the existing standard looks only at quantitative aspects and directly protects the owner of water rights rather than water quality from deterioration.

The usual rule in other countries is to establish different areas around the well (the first fixed and the following variable in nature), in which local authorities, whether municipal or of the basin, can set different constraints on the potentially polluting nearby activities, in the public interest.

This process does not occur in Chile, at least not directly. The protection area established in the Water Code prohibits only "similar works" from being installed, meaning only other water catchments, with only quantitative aspects directly considered. In addition, it is a rule that establishes only a fixed perimeter or area, which may be larger but never smaller.

To make it larger, in any case, one must demonstrate that there is interference with other rights; the risk of contamination from nearby activities is not considered in the concept of interference.

Current legislation has not provided the authorities with effective legal and preventive power to prohibit or limit activities within certain perimeters where they may contaminate sources of drinking water. In short, the regulations of the code are insufficient because they look only at quantitative aspects of interest of the owner of the water use right but do not serve to protect the quality of the aquifer as a common good.

With the existing Chilean water regulations, restrictions on land use in the protection zones could only be established by law and not affect the ownership of the water rights in their essence. We propose that, together with the termination of this ownership right over a "common" resource such as water through a constitutional reform, it should also be stated at a legal level that the groundwater protection areas must not only consider effects on water flow or volume, but also protect the quality of the aquifer, especially when it provides drinking water, ensuring the human right to water with concrete measures such as those proposed here and not only with promises, speeches and timid reforms. It is also confirmed that in this matter, the Chilean Water Code places strong emphasis on the economic aspects of water rights commerce, but gives little attention to the code's effects on social equity, basin management, environmental protection and resolution of water conflicts (Bauer, 2004).

According to Nanni (2015), in other countries, such requirements have been challenged in courts for alleged inconsistencies with the constitutional standards that protect private property and require compensation payments when rights are denied, although these allegations abroad have usually been rejected due to the argument that regulating groundwater extraction arises from the need to safeguard the public interest (Nanni (2015), as should be resolved in Chile.

However, the determination of these protection areas in Chile will be difficult because there are some essential factors missing that are present in comparative situations such as having adequate information about the existence and quality of aquifers, managing them along with surface water with an integrated vision and a strong, modern institutionality that considers attributions in terms of environmental protection.

Acknowledgements The authors wish to express their gratitude for the support given by the Chilean Scientific Council (Conicyt) through the Conicyt/Fondap/15130015 project, which created the Center for Water Resources for Agriculture and Mining (CRHIAM) at the University of Concepción.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflicts of interest. vedelgado@udec.cl jarumi@udec.cl, oreicher@udec.cl

References

Arumí JL, Rivera D, Holzapfel E, Boochs P, Billib M, Fernald A (2009) Effect of irrigation canal network on surface and groundwater connections in the lower valley of the Cachapoal River. Chile. Chilean Journal of Agricultural Research 69(1):12–20

Arumi JL, Rivera, D, Holzapfel E, Muñoz E (2013) Effect of drought on groundwater in a Chilean irrigated valley. Proceedings of the Institution of Civil Engineers. Water Management Issue 166 WM5; Pages 231–241. https://doi.org/10.1680/wama.12.00064

Arumi JL, Oyarzún R (2006) Las Aguas Subterráneas en Chile. Boletín Geológico y Minero (IGME) 117(1):37–45

Bauer C (2004) Results of Chilean water markets: Empirical research since 1990. Water Resour Res 40:W09S06. https://doi.org/10.1029/2003WR002838

Boettinger C (2014) Variables ambientales en el Código de Aguas. Actas de las VII Jornadas de Derecho Ambiental. 359–376

Chave P, Howard G, Schijuen J, Appleyard S, Fladerer F, Schimon W (2006) Grounddwater Protection Zones, Protecting Groundwater for Health: managing the Quality od Drinking-Water Sources, OMS

Costa E (2016) Diagnóstico para un cambio: los dilemas de la regulación en Chile. Chilena de Derecho Journal 43(1):335–354

Environmental protection Agency from United States (1990a) Guide for Protection for Groundwater. http://espanol.epa.gov/espanol/agua. Accessed 21 Apr 2015

Environmental protection Agency from United States (1990b) "the tap water. What you should know." http://www.epa.gov/ogwdw/wot/pdfs/book_waterontap_enespanol_full.pdf. Accessed 21 Apr 2015

Espinoza C, Muñoz R, Lobos G (2004) Hacia una propuesta de zonas de protección de captaciones en Chile. Dissertation of IV Seminary Protección de acuíferos frente a la contaminación: protección de la calidad del agua. Lima, Perú

Foster S, Hirata R, Gomes D, D'elia D, Paris M (2002) Protección de la Calidad del Agua Subterránea: guía para empresas de agua, autoridades municipales y agencias ambientales. Publishing International Bank/World Bank, Washington, USA

General Directorate of Waters (2016) El Agua, un bien escaso. In: Atlas del Agua. p.94. http://www.dga.cl/DGADocumentos/Atlas2016parte3-17marzo2016b.pdf. Accessed 20 Jan 2017

López-Vera F (2002) Estrategias para proteger las aguas subterráneas de la contaminación. Latino-Americana de Hidrogeología Journal N° 2:9–16

Martínez C, García A (2003) Perímetros de protección para captaciones de agua subterránea destinada al consumo humano. Metodología y aplicación al territorio. Publishing of Geological and Mining Institute from Spain. Series Hidrogeología y Aguas Subterráneas, N°10.

Ministry of Interior and Public Security (2015) National Water Resources Policy 2015. https://www.interior.gob.cl/media/2015/04/recursos_hidricos.pdf. Accessed 22 Jan 2016

Moreno M, Martínez L, Navarrete C (1991) Guía metodológica para la elaboración de perímetros de protección de captaciones de aguas subterráneas. Publishing of Geological and Mining Institute from Spain (IGME), pp. 186 y ss

Nanni, M (2015). Legal Aspects of Groundwater Management: An Overview. http://hydrologie.org/BIB/Publ_UNESCO/SOG_Transboundary_aquifers_and_International_Law/Documents/Regional%20meeting%20Americas/Papers/Legal%20Aspects%20of%20Groundwater%20Management%20An%20Overview.pdf. Accessed 01 Dec 2015

Nelson R (2012) Assessing local planning to control groundwater depletion: California as a microcosm of global issues. Water Resour Res 48:W01502. https://doi.org/10.1029/2011WR010927

Organisation for Economic Co-operation and Development (OECD) (2005) Environmental Performance Evaluations. Chile. OECD Environmental Performance Reviews – Chile

Pinto J (1993) Política Nacional de aguas y el agua subterránea. Derecho de Aguas Journal 4:173–177

Plummer R, de Grosbois D, de Loe R, Velaniskis J (2011) Probing the integration of land use and watershed planning in a shifting governance regime. Water Resour Res 47:W09502. https://doi.org/10.1029/2010WR010213

Rivera D (2015) Diagnóstico jurídico de las aguas subterráneas. Ius Et Praxis Journal. https://doi.org/10.4067/S0718-00122015000200007

Rivera D (2016) Gestión colectiva y conjunta de aguas: perspectiva jurídica de una deuda subterránea. Derecho de la Pontificia Universidad Católica de Valparaíso Journal. https://doi.org/10.4067/S0718-68512016000100010

Vergara A (1991) Hipótesis para una reconstrucción histórica y dogmática del derecho de aguas, Jornadas de Derecho Público 1990 Journal, XXI, vol. II. https://doi.org/10.5354/0719-5249.1991.43559

Vergara A (2015) Crisis Institucional del Agua. Universidad Católica, Santiago, Chile

World Bank (2011) Diagnóstico de la gestión de los recursos hídricos. Publishing of World Bank, Departament of environment and sustainable Development. Region for Latin American and Caribbean. http://www.dga.cl/eventos/Diagnostico%20gestion%20de%20recursos%20hidricos%20en%20Chile_Banco%20Mundial.pdf. Accessed 01 Nov 2015

World Bank (2013) Estudio para el mejoramiento del marco institucional para la gestión del agua. Publishing of World Bank, Departament of environment and sustainable Development. Region for Latin American and Caribbean. http://documentos.dga.cl/ADM5439.pdf. Accessed 01 Nov 2016