Chapter 2
Methodology

Abstract  An overview of the methodology is presented; according to the deductive, plausible reasoning, the results are the most plausible hypotheses, not categorical conclusions. The criterion of convergence of evidence from different fields of knowledge was adopted. Concerning the hydrometeorology, the main meteorological phenomena were analyzed, calculating evapotranspiration (potential and actual), as an approach to the water balance. The Comodoro Rivadavia weather station (1921–2010) was used, as it has the reliability, continuity and representativeness recommended by the WMO. Geomorphology, surface geology and soil characterizations were based on the data collected personally or by several authors. Subsurface geology was reconstructed using geological and geophysical well logs. Lithostratigraphic units were translated into hydrolithological units to define the physical component of the geohydrological system. Regarding the mobile component, recharge, circulation, and discharge were analyzed. As to the first process, the net vertical input was estimated, based on a serial water balance, classified rainfall events, and the specific phenomena occurring in arid areas. Circulation and discharge were identified by the potentiometric surface of wells and the construction of an equipotential diagram. The hydrochemical data was processed using the Easy_Quim 5.0 software to convert units to milliequivalents, calculate analysis error, construct specific plots and calculate ion ratios. Having defined the conceptual model and estimated the availability, the socio-economic context was analyzed. Attention was given to oil and gas production, including unconventional HC exploitation and the participation of groundwater, with a focus on conflicts between uses and how to manage them in the context of water governance.

Keywords  Deductive methodology · Plausible reasoning · Geohydrological system · Arid regions · Procedures

Conceptually, the general methodology used is deductive in character and, given that the fundamental subject of this research—that is, water—is eminently dynamic, the approach adopted is that of plausibility. The results obtained will therefore be the most plausible hypotheses, and not definitive and unchanging conclusions; in
In order to do so, the criterion of convergence of evidence from different fields of knowledge had to be applied.

As regards the subject of hydrometeorology, the analysis of the main meteorological phenomena (rainfall, temperature, wind, barometric pressure, relative humidity, snowfall and frost) was carried out, as well as the calculation of the evapotranspiration (potential and actual), with the consequent approximation to the water balance. At that point, the first difficulties arose, due to the great scarcity of basic information, since out of six stations of the Servicio Meteorológico Nacional (SMN; National Weather Service) that keep records within the basin, only two (Comodoro Rivadavia and Sarmiento) meet the World Meteorological Organization (WMO) requirements, whereas the records in the others are discontinuous, incomplete, or too brief.

Out of the nearby weather stations, the only ones that could have been used (Trelew, Puerto Madryn, Puerto Deseado and Gobernador Gregores) are distant or do not comply with the standards. However, they were useful for control and as a complement, but not for their application in equations. That leaves only Comodoro Rivadavia as usable, with records between 1921 and 2010. This weather station meets the conditions of continuity (90 years, as opposed to the 30 years recommended by the WMO), reliability (the data are cleaned by the SMN), and representativeness (as it is located in the geographical centre of the Gulf). Modular rainfall graphs were generated for the period and for decadal variations. For the other meteorological phenomena of interest, some illustrative graphs were also developed and, in the case of winds, graphs of velocity and direction.

One product of the hydrometeorological analysis is the water balance, undertaken by means of the well-known method by Thorthwaite and Mather (1955), which, even though it is not recommended for regions with extreme climates, at least facilitates the identification of periods with a possibly lower water deficit. In turn, the estimation of probable autochthonous contributions to the groundwater system could be carried out by means of the comparison with serial water balances using the Balshort software (Carrica 1993). It was applied to Puerto Madryn, which is near the basin, for a shorter period and, as it is a daily time-step model, it offers the possibility of quantifying the occasional winter excesses. It was also implemented in other nearby cases, using classified rainfall events (Hernández 2000); these are analyzed, together with the above-mentioned case, in Sect. 3.1.

The characterization of the geomorphology, surface geology, and soils was undertaken on the basis of personally collected information and other data produced by several authors, such as Feruglio (1949, 1950), Lesta et al. (1980), Cesari et al. (1986), Consejo Federal de Inversiones (1986), Homovc and Lucero (2002), Coronato et al. (2008), Hernández et al. (2008, 2009), Hernández et al. (2008), and Sylwan et al. (2011), among others. The personally collected data for different sectors of the basin, especially in the oil-bearing area, were corroborated and organized by region by means of freely available satellite imagery.

Subsurface geological information was more abundant, specifically in the oil and gas exploration and exploitation area (between the Deseado River, the Senguerr-Chico fluvial system and the 70° W meridian). Even though very good
data could be obtained from the geological profiles compiled, and from their interpretation and correlation, there is a confidentiality issue that limits their use, especially at depth. The contributions collected in Schiuma et al. (2002) and Sylwan et al. (2011) were of particular significance, as they were very helpful as regard this topic.

The main focus was on the lithological descriptions of the geological and geophysical profiles; the latter were used to identify transitions between the different units. Within the scope of geohydrology, the former were useful to transform the lithostratigraphic units (e.g. formations, members, etc.) into lithostratigraphic units (i.e. aquifers, aquicludes, aquitards and aquifuges).

The physical component of the geohydrological system of the basin could thus be identified and defined, verifying the conformation described by Hernández and Hernández (2013): an overlying basement constituted by the Jurassic Volcano-Sedimentary Complex (Complejo Volcánico-Sedimentario; Sylwan et al. 2011), with Precambrian and early Mesozoic igneous sections and pre-Jurassic sedimentary rocks, depending on the region under consideration.

As regards the mobile component of the system, and based on a conceptual model, the processes of recharge, circulation and discharge were analyzed. In the case of recharge, and given the extremely arid climate of the region, in order to estimate the net vertical input, extrapolations from a serial water balance and classified rainfall events were used, as mentioned above. But, above all, the occurrence of specific phenomena described by Hernández (2015) and Hernández et al. (2008, 2009) was recognized, such as a reduction in consumptive losses, rapid infiltration, rapid concentration, fluvial influence and delayed recharge.

The groundwater circulation and discharge phenomena were identified by using the potentiometric surface, constructed with values of the water level in wells generally used for HC exploitation, for water injection in oil fields, or drilled for environmental purposes by the oil industry; this information is therefore concentrated in the central and eastern sectors of the basin. Such values were calculated as the difference between the topographic height at well head and the depth measured in each, expressed with respect to the sea level.

The main difficulty was caused, apart from the spatial distribution of the information, by the characteristics of the wells regarding the validity of the hydrometric data, which led to a validation process in order to discard those with uncertainty. It should be taken into consideration that these wells are of interest to the oil industry, and that often there is no record of the aquifer sections of the wells of exclusive hydrological interest.

The result was an equipotential diagram based on the heights, with an equidistance of 100 m, given the scale and size of the area, and indicating flow directions. Another inconvenient was the lack of data on permeability ($K$) and transmissivity ($T$) coefficients, due to the absence of hydraulic tests adequate for quantitative purposes. In any case, they were sufficient to define the processes, estimate the flow velocity as a function of $K$, and establish the geohydrological conceptual model.
The same applies to the hydrochemistry, since—with few exceptions—the analytical information derived from the oil industry. In order to process such data, the Easy_Quim 5.0 (Vazquez-Suñé and Serrano-Juan 2012) free software was used. It is applied to the conversion of content units in terms of weight to milliequivalents (mg/L to meq/L), the calculation of analysis error and the validation of the data. It also allows the plotting of graphs with the results by means of the Piper, Schoeller-Berkaloff, and Stiff methods (Custodio and Llamas 2001). Besides, it offers ion ratios of interest, such as $r_{Na^+/K^+}$, $r_{Mg^{++}/Ca^{++}}$, $r_{SO_4^{2-}/Cl^-}$, $r_{Cl^-/CO_3H^-}$ and the ionic exchange index.

Once the conceptual model had been defined and the availability had been estimated, the socio-economic context was analyzed, with a focus on the production of oil and gas, which was characterized from its beginning in the study area.

The analysis included the involvement of groundwater in the different stages of oil projects: exploration, production, transportation, transformation and marketing, both regarding groundwater use and the impact of this activity on the environment and on aquifer protection. It aimed at focusing on the actual and potential conflicts between uses, and on how to attempt to manage them in the context of water governance.

A special circumstance that arose in the last few years relates to the real possibilities for the production of unconventional oil and gas from well-known source rocks. This has called for renewed efforts to obtain groundwater, given the larger volumes required and the above-mentioned scarcity of the resource. Therefore, a new methodological approach is developed, aiming at management optimization with the introduction of new tools.

References


Thornthwaite CW, Mather JR (1955) The water balance. Drexel Institute of Technology, Laboratory of Technology, Publications in climatology, Centerton, NJ, vol 8, no 1, 104 pp
Vazquez-Suñé E, Serrano-Juan A (2012) EASY_QUIM v. 5.0 www.h2ogeo.upc.edu
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