The development of private bore-wells as independent water supplies: challenges for water utilities in France and Australia

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Chapter 7

The development of private bore-wells as independent water supplies: challenges for water utilities in France and Australia

Jean-Daniel Rinaudo[1], Marielle Montginoul[2], and Jean-François Desprats[1]

Abstract

In developed countries, a number of factors are leading a growing number of households to drill private boreholes as independent water supplies. This chapter describes this phenomenon based on two case studies conducted in Southern France and Western Australia. It shows that, while the development of private wells was encouraged by the authorities in Perth, it is a major source of environmental, public health, economic and social concern for French water utilities. Household's motivations to develop independent supply are then investigated. We finaly discuss how water utilities need to adapt their management practices (setting tariffs, demand forecasting and resource protection) to take into account this phenomenon.

1. Introduction

From the 1930s to the 1960s, significant financial and technical resources were devoted to the development and geographical extension of public water distribution networks. In most developed countries, governments promoted the development of centralised technical systems allowing economies of scale. Water and sanitation services were delivered within private or public monopolies at municipal, metropolitan, or regional scales as part of a broader extension of welfare-state principles (Graham 2000). These services were then considered a public or quasi-public commodity, i.e. freely available to all individuals at equal cost and with standard quality within specific urban areas. For millions of inhabitants, access to public water supplies increased the availability, reliability, and quality of the water supply. This was clearly perceived as progress by households who previously relied on independent water supplies such as shallow wells, rain water cisterns, or even purchased water. These independent water supplies were then often abandoned or only kept operational for non-domestic uses, particularly in rural areas.

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A half-century later, access to an abundant, reliable, and safe water supply distributed by public water utilities is taken for granted by populations in developed countries. Water services can be relied on more or less implicitly and tend to become 'invisible' to users who know very little about how the service is produced. However, a number of factors are leading growing numbers of households to seek cheaper alternative water-supply sources as a substitute for scheme water. Unlike 50 years ago, there are now several efficient and affordable technological solutions available which households can use to create their own independent water supply. Examples include rain-water harvesting systems (with filtering and pressurising systems), grey water recycling systems, and private bore-wells – the focus of this chapter. Often, the substitution is only partial, and households continue to use small volumes of tap water for purposes requiring high-quality water, while they use their own supply system for others (such as garden irrigation and toilet flushing). Total substitution is possible if a household decides to invest in a water purification device (e.g. a reverse osmosis set up), several sorts of which are now available for domestic use at reasonable prices.

Worldwide, the development of domestic groundwater self-supply as a substitute for public water supply has occurred in very different institutional, economic, and climatic contexts. In some countries considered a source of problems (e.g. France, Belgium), in others it has been promoted (e.g. Western Australia). This chapter analyses this emerging trend based on examination of three situations in Southern France (Section 2) and one in Western Australia (Section 3). We then investigate households' motivations to develop self-supply and bypass collective scheme-water systems (Section 4) before highlighting challenges water utilities will need to overcome when confronted with this new social phenomenon.

2. Southern France

Context

In France, approximately 98% of the population use water delivered to their homes by public water purveyors. Users generally benefit from high-quality water services at prices that are relatively low compared to other European countries[3]. However, the rapid increase in water rates that occurred in the 1990s has provided households in detached or semidetached housing units with incentives to drill private bore-wells. Montginoul & Rinaudo (2011) describe this evolution in regions that have very different climates, economics, and demographics. The trend took place relatively unnoticed by water managers and government authorities because households typically failed to declare their bore-well despite a legal obligation to do so.

Although relatively uncommon, official bore-well declarations can be informative as to the type of bore-wells drilled by households. Figure 1 presents an analysis of the depth of bore-wells declared between 2008 and 2013 (July) in the Languedoc–Roussillon region of Southern France. The figure shows that a majority, 52%, attained depths of 50 m or less, while 36% drilled to depths of 50–100 m. A minority, 12%, went deeper than 100 m. Note that the cost of a bore-well is not directly

[3] According to NUS consulting European water price barometer (2009), the average water price in France is 10% lower than the European average (3.09 against 3.44 €/m^3) and far below German and Danish prices (respectively 5.29 and 6.42 €/m^3). The study is based on an analysis of the 5 largest cities in 10 EU countries, covering a total population of about 40 million inhabitants (Germany, Belgium, Denmark, Spain, Finland, France, Italy, the Netherlands, the United Kingdom, and Sweden).

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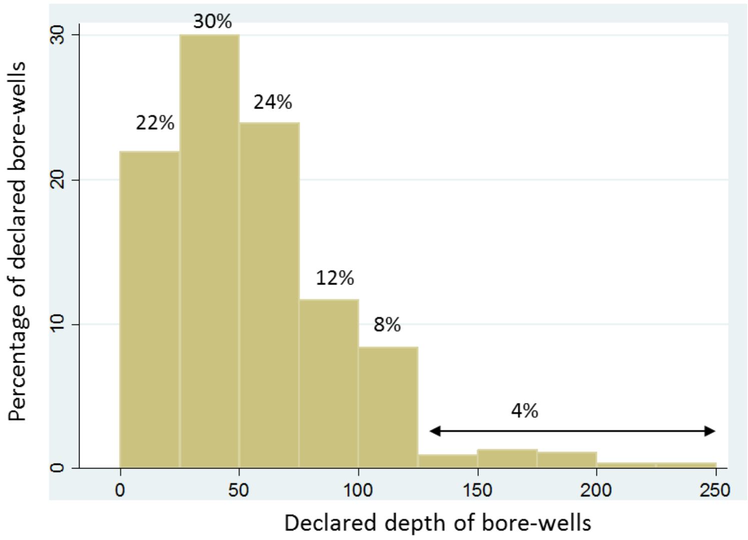
proportional to its depth: it also depends on the physical properties of the geological layers involved. Drilling in a sand aquifer or in soft alluvial materials requires expensive drilling techniques, while cheaper techniques can be used to drill through Jurassic limestone for instance.



Source: own elaboration from BRGM groundwater database (Banque du Sous-Sol), Languedoc–Roussillon region.

Figure 1: Declared depth of domestic bore-wells drilled in the Languedoc–Roussillon region. N=547, 2008 to 2013.

The intensity of the phenomenon

A series of case studies were recently conducted by the authors with a view to assessing the frequency of the phenomenon at a regional scale. Insofar as very few domestic bore-wells were declared to government and/or municipal authorities, an indirect method was developed to estimate bore-well density at a regional level. The methodology consists in calculating the profitability for the owner of drilling a bore-well, defined as the savings made on their water bill from substituting cheap groundwater for more expensive scheme water, minus the cost of drilling the well. Benefits were expected to be proportional to the price of scheme water, while the cost of the bore-well itself was taken to be proportional to the groundwater depth, adjusted to take into account the type of geological layer and uncertainty related to groundwater availability (for a detailed description, see Montginoul & Rinaudo 2011).

The methodology was applied in three counties in Southern France: Hérault, Pyrénées–Orientales, and Vaucluse (see Fig. 2).

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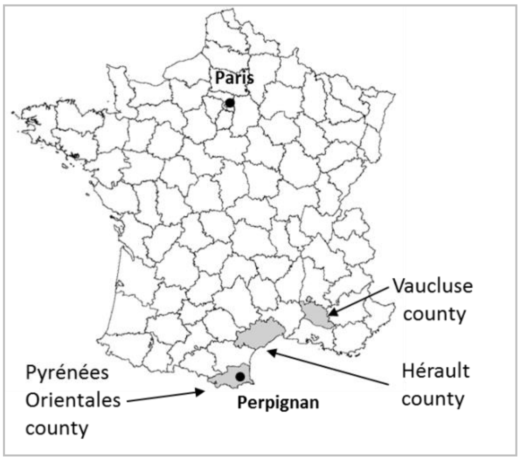

Figure 2. Locations of the three regional case studies.

Detailed results obtained in Vaucluse are presented in Fig. 3. The upper left map shows that the cost of drilling a well is relatively low in some areas (less than €5,000). The cost rises significantly in other zones where the geology is less suitable, water is at greater depths, and there is a higher risk of failure (a 'dry' well). The upper right map illustrates the variability of scheme-water prices, which exceed €4 per cubic meter (water, sanitation, and wastewater treatment included) in areas colored black. The lower left map depicts variations in the bore-well profitability threshold, defined as the minimum amount of groundwater that a household must substitute for scheme water in order to repay its investment. In areas shown in light grey, it is worth investing in a bore-well if the household uses at least 120 m^3 per year. Conversely, for areas colored in dark grey, constructing a bore-well is only profitable for households using more than 400 m^3 per year. The lower right figure presents an estimate of bore-well density, based on socio-economic information and the estimated profitability threshold (see Montginoul & Rinaudo 2011 for details). Density is expected to be very high (more than 50% of single-family homes equipped) along the Calavon Valley and in the Miocene groundwater basin (a region of Carpentras in the northwest of the map). Estimated densities were cross-checked with the staff of municipal water utilities, who confirmed the range of values. Based on this methodology, the estimated number of bore-wells in this area ranges from 14,000 to 21,000, corresponding to a density of 32–48% (calculated as the fraction of households living in detached houses).

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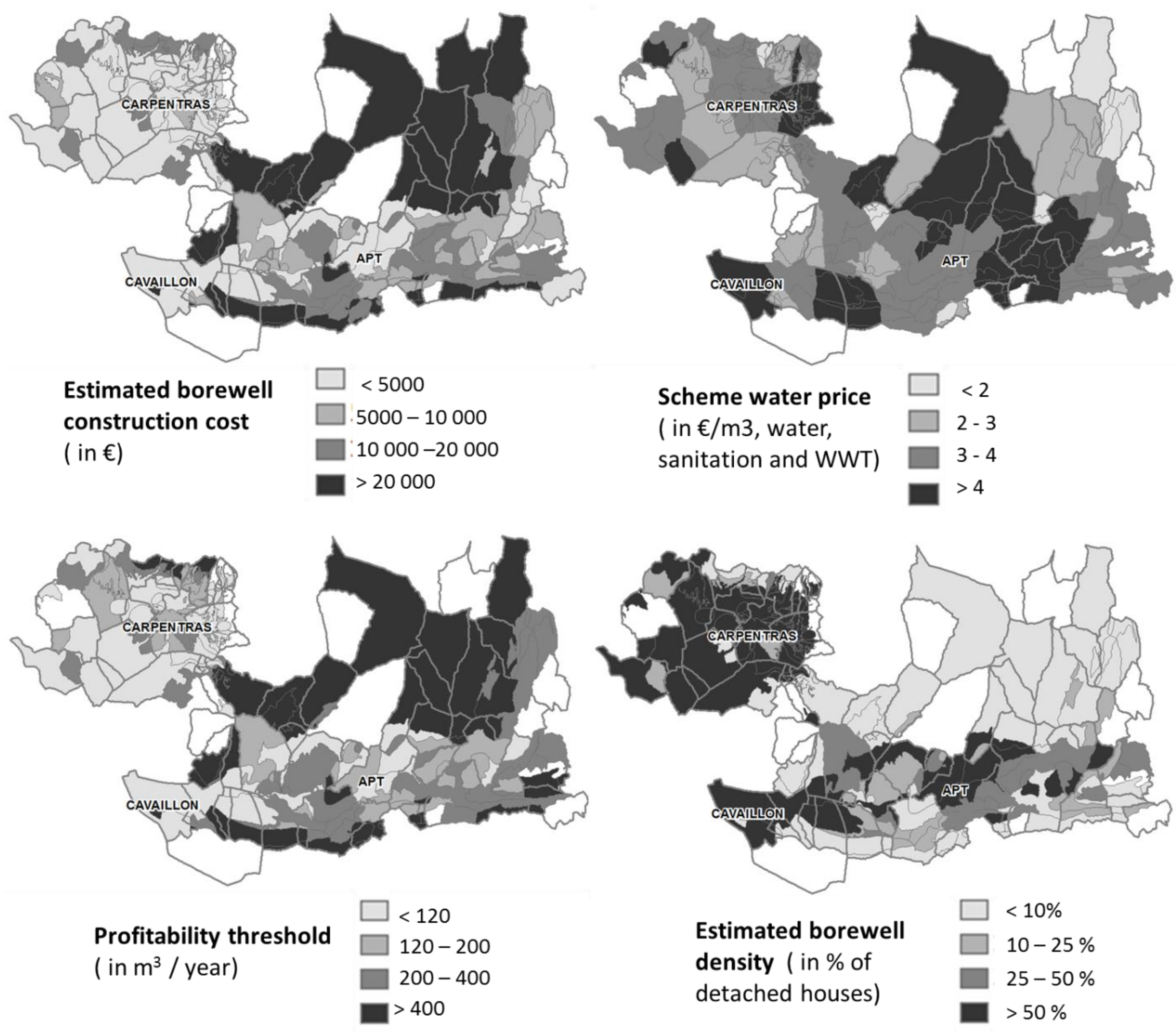

Source: Desprats et al. (2012)

Figure 3. Bore-well construction price, scheme-water price, profitability threshold, and bore-well density in the Calavon river basin and the Miocene aquifer basin, Vaucluse county, Southern France.

The same method was applied in two other counties in Southern France (Table 1). These two case studies correspond to larger river basins, comprising respectively 186 and 229 municipalities. The geology is highly varied within these territories: in alluvial valleys, groundwater can easily be reached at depths of 5–10 m, while in karstified limestone areas, households may need to sink wells to depths of up to 150 m.

	Hérault	**Pyrénées–Orientales**	**Vaucluse**
Groundwater geology	Limestone, alluvial deposits, sands	Quaternary alluvial deposit, Eocene sedimentary aquifer	Limestone, alluvial deposits,
Depth of bore-wells	5 to 175 m	5 to 150 m	5 to 150 m
Water price (€/m^3)			

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Avg / min / max	**2.60** / 0.53 / 4.23	**2.60** / 0.24 / 3.71	**3.32** / 0.80 / 4.50

Table 1: Characteristics of the three case studies selected in Southern France.

The results shown in Table 2 suggest that bore-wells are less common in these two other case studies. In Pyrénées–Orientales and Hérault, there are far fewer situations which combine high scheme-water price and easily accessible groundwater. Consequently, the number of municipalities where bore-well density exceeds 25% remains low (14% in Hérault, 4% in Pyrénées–Orientales).

Table 2: Estimated bore-well density in the three Southern France case studies.

County	No. munici-palities	Estim. no. of bore-wells	Number of municipalities per class of bore-well density (density in % of municipal housing stock)				
			< 1%	1–10%	10–25%	25–50%	> 50%
Hérault	186	8,800	108 (58%)	47 (15%)	24 (13%)	18 (10%)	7 (4%)
Pyrénées–Orientales	229	16,400 to 22,000	135 (59%)	39 (17%)	46 (20%)	7 (3%)	2 (1%)
Vaucluse	66	14,000 to 21,000	5 (8%)	7 (10%)	9 (14%)	26 (39%)	19 (29%)

Source: Montginoul (2008) ; Montginoul & Rinaudo (2011); Desprats et al, 2012.

These three case studies conducted at the county level were supplemented by local investigations conducted in the Perpignan Méditerranée Urban Community, the metropolitan area of the Pyrénées–Orientales county. Our investigations relied on the use of various sources of information including: i) the municipal register of bore-well declarations; ii) an internet survey conducted on a sample of 204 households occupying single-family houses[4]; and iii) an analysis of water-billing records over a 5-year period.

According to municipal records, there were only 351 domestic bore-wells officially registered in the community, which comprises more than 52,000 single family dwellings. This very low rate of bore-well ownership (0.6%) was not consistent with the results of the study presented in Table 3, which estimated the total number of bore-wells in the Perpignan metropolitan area as 17,400, i.e., a 34% rate of ownership (households living in single family units only). The internet survey conducted with 200 households confirmed a higher value, with 24% of respondents declaring using a private bore-well.[5]

Table 3: Estimated rate of bore-well ownership from three distinct sources (the Perpignan Méditerranée Urban Community).

Estimation method	Estimated rate of bore-well ownership (in % of single family houses)

[4] The survey targeted a sample of 2,778 households living in detached houses. They were selected in 100 neighborhoods representative of the diversity of the metropolitan area in terms of income, housing characteristics, groundwater characteristics, and water tariffs. The response rate was just below 10% (227 answers with 200 fully exploitable).

[5] The estimated rate of bore-well ownership in this metropolitan area is high compared to what has been found in other cities. In the nearby Montpellier area for instance, a similar internet survey conducted with 347 households showed a borehole equipment rate of 9%. The difference is mainly explained by geological conditions.

Official bore-well declaration registers	0.6%
Economic modeling (all municipalities)	34%
Internet survey (*N* = 200)	24%

How do households use their bore-wells?

Previous studies suggested that most households only use bore-well water for irrigating gardens and filling swimming pools, and only a minority use it indoors for washing machines, toilet flushes, and sometimes personal hygiene (showers and baths) or even cooking and drinking (Montginoul et al. 2005). In the Perpignan Méditerranée Urban Community, we found that half the households equipped with a declared bore-well almost totally substituted untreated groundwater for municipal supply (Table 4). These households use less than 5 m^3 per year of scheme water, mainly for drinking and cooking. A second group of bore-well owners had drinking-water consumption ranging from 5 to 60 m^3 per year (average 32 m^3), indicating that they use scheme water for drinking, cooking, and showers but use bore-well water for washing machines and toilet flushes. The third group consumes more than 60 m^3 per year (average 124 m^3) which corresponds to the average water use in Perpignan, implying that the bore-well only supplies outdoor uses.

Type of bore-well water use	Average scheme water use (m^3/year/household)	Sample % (*N*=351)
Type 1: full indoor and outdoor substitution	Range = [<5] Average = 0	49%
Type 2: partial indoor and full outdoor substitution	Range = [5, 60] Average = 32	27%
Type 3: no indoor and full outdoor substitution	Range = [>60] Average = 124	24%

Table 4: Scheme-water consumption for three types of bore-well owners in Perpignan Méditerranée Urban Community.

Issues for water utilities

The development of groundwater self-supply by households is generally perceived as a threat by water utilities, who cite three types of negative impacts (Montginoul et al. 2005). The first impact is on groundwater resources. The risk of groundwater contamination is increased in areas characterised by high bore-well density. Because they are often poorly constructed, private bore-wells often connect previously distinct hydrogeological layers and become multiple contamination vectors for groundwater resources. The development of bore-wells also increases total water abstraction, as households having free access to cheap groundwater will use more than when they fully rely on municipal supply. This is more of a problem when private bore-wells and public supplies tap the same aquifer.

The second impact is on public health. Untreated bore-well water is sometimes used indoors for personal hygiene, cooking, and even drinking without ensuring that its chemical and bacteriological quality complies with drinking water standards. Montginoul et al. (2005) also report cases where, due to improper construction of the dual-pipe system inside the house, high-pressure contaminated bore-well water flows back from a private bore-well into the municipal drinking water network.

The third impact is financial. The development of private bore-wells may reduce water sales and generate cost-recovery problems for public water suppliers. Moreover, where sanitation and waste-water treatment are charged proportionally to drinking water use (as is the case in France), the development of groundwater self-supply generates additional financial problems for utilities in charge of waste-water treatment and sanitation. This is particularly a problem where water demand is already in decline for demographic or economic reasons.

Legislative authorities recently reacted to these problems by allowing water utility staff to enter private properties in order to record the existence of bore-wells and to control the bore-well itself as well as the water pipe network inside the house[6]. Utilities are authorised to cut off the connection to scheme water if the installation does not comply with regulatory requirements. Domestic bore-well owners are also under the legal obligation to install a meter which can be used by utilities to charge sanitation and waste-water treatment services.[7]

However, enforcement of this new legislation remains highly problematic in France. Despite information campaigns, households rarely declare their bore-wells to the municipality for fear of being charged for groundwater abstraction in the future (currently exempt for less than 1,000 m^3 per year) or for sanitation and waste-water treatment by the utility in charge of the service. Municipal water utilities are often unable to identify bore-well owners, for utilities frequently lack the technical capability to analyse water consumption data and cross-check it with other sources of information such as aerial photographs and household demographic data. The situation is exacerbated by a lack of political will: the mayor generally tends to refrain from sending staff to conduct property inspections lest he or she loses support for the next election.

3. Western Australia

By contrast with the French situation, the development of private bore-wells in Perth, Western Australia, was considered by water authorities as one way to reduce the growing pressure on drinking water supplies. Groundwater self-supply reduces the demand on scheme-water supplies, delaying the time when new resources (dams and well fields) will be needed.

With a population of 1.5 million (2006), Perth is the fourth largest Australian city. For the last 30 years, rapid population growth and economic development have been accompanied by an impressive urban sprawl. The urban landscape is characterised by very low-density suburban estates with detached housing (Kennewell & Shaw, 2008). More than 75% of the population lives in single-family detached dwellings. The fondness of Perth households for their garden (Syme et al. 2004) and the desire to replicate the English country garden in a semi-arid climate (Kennewell & Shaw 2008), has resulted in very high water use. Average water consumption was around 500 m^3 per household in 1975–76. It has remained relatively high over time, as shown by Loh & Coghlan (2003), who estimate single residential use at 460 m^3 per year, with 56% of that volume being used outdoors.[8]

[6] The 2006 water law, modifying article L 2224-12 of the Code Général des Collectivités Territoriales (CGCT) and application decrees of 2/07/2008, 17/12/2008.
[7] Article 2224-12-5 of CGCT.
[8] Based on a sample of 720 households living in detached houses and monitored during 1998–2000.

This substantial urban growth and rising water demand has coincided with a declining trend in rainfall, which has diminished inflows to reservoirs and lowered groundwater levels, at a time when groundwater is making increasingly larger contributions to Perth's water supply. In the late 1970s, restrictions were imposed on outdoor water use due to a long spell of dry weather. Volumetric pricing was also introduced at that time, and campaigns were conducted to promote water-conservation practices. Many households did not reduce their usage of water, but responded by seeking alternative private sources of supply. Given that the Perth metropolitan area is underlain by extensive shallow aquifers, many unlicensed private bore-wells were drilled to substitute groundwater self-supply for scheme water. Since the aquifer is easily accessible and productive in most locations, private bore-wells can be constructed at reasonable cost, ranging from A$3,500 to 5,000.[9] The development of private bore-wells was facilitated by the regulatory framework, which does not require any licence for bore-wells tapping shallow groundwater and used to irrigate less than 0.2 ha. Bore-owners also do not pay any groundwater extraction fees and the amount of groundwater they use is not metered.

The development of private bore-wells was investigated in the late 1980s. A study published by the Metropolitan Water Authority (1985) found that 24% of households owned a bore-well, with a further 3% having access to one. According to Thomas et al. (1987, quoted in Thomas & Syme 1988), bore-well ownership increased from 11% of households in 1976 to 27% in 1982. More than two-thirds of the 64,000 bore-wells constructed at the end of the 1980s had been installed after the onset of drought and its consequent publicity, restrictions, and changes in price regime (Syme et al. 2000). Bore-well popularity continued to increase due to more stringent restrictions on the central water supply and mounting water prices.

The number of households that use bore-well water has risen from 64,000 in 1987; 99,600 in 1992; 135,000 in 2001; 150,900 in 2006; to 167,000 in 2010 (Department of Water 2011). The total amount of water pumped from these bore-wells is estimated at 75–120 million m^3 depending on the source, corresponding to 30–50% of the potable water supply of the metropolitan area (235 million m^3/year, 1994–2005). Since 2003, bore-well installation has been encouraged by the government, which offers a rebate[10] to people in areas where bore-wells are considered suitable according to the Perth Groundwater Atlas. About 5,000 subsidies are granted each year (Smith et al. 2005). Bore-well density varies significantly from one area to another depending on the depth of the water table (the cost can be dissuasive when the water table is more than 10 m deep), the type of aquifer (drilling in limestone is more expensive), and the chances of success (bore-wells are fewer in areas of clay where bore-well yields are generally low).

Most studies and surveys report that self-supply groundwater is only used outdoors. Estimated volumes are relatively high by international standards (see Table 5), even in view of Perth's dry climate. This suggests that Perth households are overusing water compared to what they would use if they relied solely on more expensive scheme water.

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[9] In 2013 A$, based on quotes provided by drilling contractors in the Perth metropolitan area; equivalent to €2,500–3,500.
[10] Up to A$300 (capped at 50% of the installation cost) offered by Western Australian government as part of the 'Water Wise' rebate program.

Table 5: Estimated bore-well density and use as a function on property size.

Property size (in m^2)	Indicative groundwater use (m^3/year)	Average bore-well installation rate (% of lots)
Less than 500	400	5
500–999	800	30
1000–5000	1,000	30

Source: Department of Water (2009)

Concerns over increasing bore-well water use in Perth have been raised recently in relation to its possible impact on groundwater levels and quality. The response from the authorities was to impose partial groundwater use restrictions on bore-wells: watering is banned between 9 a.m. and 6 p.m. to reduce losses by evaporation; it is only allowed three days per week; and it is banned in winter. These restrictions do not apply to highly efficient irrigation methods such as sub-surface trickle irrigation. In the future, these restrictions are likely to be increased, if future climate and rainfall patterns persist (Australian Bureau of Statistics 2007). However, enforcement problems are reported by the Department of Water.[11]

4. Understanding households' motivations to invest in private supply

Understanding households' motivations to drill is essential for predicting the future evolution of self-supply development and the resulting demands for scheme water. The analysis that follows attempts to identify these motives, based on the few studies that address this issue in France (Montginoul et al. 2005; Montginoul & Rinaudo 2011) and in Australia (Thomas et al. 1987; Thomas & Syme 1988). We also use the results of surveys of households' perception of alternative water sources (Hurlimann 2011), shortages, and conservation (Roseth 2006).

Maximisation of utility derived from water use

Households' decision to drill can first be analysed from a utilitarian perspective, assuming they seek to maximise the benefit they derive from water use. Self-supply can be a strategy to maximise utility, in particular where the performance of public schemes is mediocre. Independent access to groundwater self-supply can help cope with limited water availability, poor water quality, low pressure, intermittent supply, and temporary restrictions. This is clearly the main motive prompting the use of wells in developing countries, as illustrated in India (Raju et al. 2008), Sri Lanka (Nauges & van den Berg 2009), Nepal (Pattanayak et al. 2005), Pakistan (Madanat & Humplick 1993) and Kenya (Mu et al. 1990), where self-supply enables a wide range of costs to be avoided, including those entailed in health, water purchase from vendors, labor for collecting water from other sources, and tank construction to cope with intermittent water supply. A similar argument also applies to developed countries, and was reported in the two case studies described above. In France, some households interviewed by Montginoul et al. (2005) say that investing in a bore-well benefits them because of the higher pressure available than with scheme water, so they can irrigate large gardens

[11] In October and November 2010, almost a thousand garden bore-well users in the Perth metropolitan area were caught breaching restrictions. News release by Department of Water, 9 December 2010. Available at http://www.water.wa.gov.au/News+and+events/News+archive/2010/1711.aspx

more rapidly. In Perth, the development of private domestic bore-wells was clearly prompted by bans on sprinklers imposed during long droughts. By drilling bore-wells, households were both securing their water supply and ensuring that their gardens would not suffer losses. Such losses would have had a financial impact (reduced property value), but also a psychological one, given the importance of home gardens for a variety of quality-of-life variables such as avoidance of stress, recreation, and personal and social identity (Syme et al. 2004). The demand for garden bore-wells is largely related to the belief that a garden must be green to be healthy (Roseth 2006).

Cost minimisation

Groundwater self-supply can also be a strategy to minimise the cost of water supply. Realising that they do not need high-quality water to irrigate lawns and fill swimming pools, some households decide to drill a bore-well in order to substitute cheap untreated groundwater for costly tap water in all outdoor uses. This strategy differs notably from the previous one in that it aims to bypass a public service that performs well simply to reduce the total cost of water. This decision is based on a simple cost–benefit analysis (CBA) of comparing investment cost with water bill savings. A majority of the French households interviewed by Montginoul et al. (2005) and Desprats et al. (2012) took the decision to drill a bore-well based on this type of CBA. The development of domestic bore-wells in France was apparently prompted by the drastic increase in scheme-water price in the 1990s and the prospect of a continuation of this trend.[12] The introduction of volumetric scheme water pricing in the late 1970s in Perth could also have played a role, albeit ranking behind sprinkler bans. This was shown by Thomas & Syme (1988), who conducted an econometric analysis to estimate a demand function for bore-wells. They identified three main significant explanatory variables: water price, household income, and the number of days of restriction. Estimated coefficients suggest that the demand for a bore-well was highly responsive to the level of restriction on water use.

Ethical and political motivations

The utilitarian framework presented above cannot fully account for the complexity of households' decisions to invest in self-supply. Utility maximisation interacts with ethical and political values and beliefs.

- *Green households*

Some households may view drilling as a commendable action from an environmental and social standpoint. A frequently cited argument is that it avoids wasting precious treated drinking water for watering lawns. A second one is that it alleviates technical and financial pressures on water utilities faced with rapid population growth and corresponding demand. Investing in groundwater self-supply is thought to be consistent with public policies which incentivise the installation of solar hot water systems or solar panels for electricity production. With this perspective, investing in a bore-well reinforces the idea of being environmentally neutral.

[12] In the medium term, and as energy prices rise, there could be cross-elasticity because of the cost of electricity or other fuel to provide energy for running the bore.

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- *Libertarian households*

A number of citizens may also consider water-use restrictions as inherently limiting personal freedom and rights. Owning a private bore-well allows this freedom to be regained and provides the moral satisfaction of being independent. In her study of community views on water shortages in six Australian metropolitan areas, Roseth (2006) finds a minority of households (7–11%) who believe it is their right to use as much water as they want when they want, given that they pay for it. However, while the majority accepts restrictions in principle, 50% wouldn't accept having their garden be impacted, insofar as they have the *right* (our emphasis) to keep their garden looking green and healthy.

- *The emergence of infrastructural consumerism*

The development of private water supplies also reflects a more profound evolution of society. Increasingly, privileged users tend to reject the redistributive role of public water infrastructure monopolies. They expect to get what they pay for rather than cross-subsidising low-income users or other territories through a set of uniform rates. By bypassing the monopolistic water-supply system, they reclaim their right to freely choose their water supplier, somehow asserting "the moral superiority of individual choices over the tyranny of collective decision-making" (Leonard 1997, 4; quoted in Graham 2000). This societal evolution is exacerbated by what Graham (2000) calls "the emergence of infrastructural consumerism", referring to the fact that every household in one street can now sign up with a different electricity, gas, internet, or telephone company. This choice, however, is restricted to certain social groups, as the ability to access alternative water supply systems is dependent on income, housing type, and location.

5. Challenges for water utilities

The development of private wells raises a number of challenges for water utilities and calls for changes in water-management practices. Utilities need to develop strategies to monitor the development of private supply. They also need to control and possibly restrict private drilling where increased bore-well density poses environmental threats on the groundwater resource and dependent ecosystems. A third challenge consists in integrating the self-supply option into water-demand models used to predict future demand or simulate the impact of evolving water rates. Last but not least, utilities need to manage the social impacts associated with the development of self-supply.

Challenge 1: monitoring the development of garden bore-wells

Obtaining accurate information on garden bore-well density is essential for operating and planning urban water management. The French and Australian examples show that very different strategies can be implemented. The first one consists in obliging bore-well owners to declare their wells. The French example shows that this strategy may not work well unless significant financial resources are put in to implement and enforce the system. In a context where the state restricts financial and human resources devoted to water and environmental protection, the spontaneous bore-well declaration rate is likely to remain very low.

An alternative approach to obtaining up-to-date information consists in conducting household surveys. The government of Western Australia has adopted this strategy, and it commissions the Australian Bureau of Statistics to conduct surveys at regular intervals (2003, 2006, 2009). This is considered to be a cost-effective approach, whereas the cost of licensing large numbers (160,000) of low-yield bore-wells is thought to be prohibitive and not an efficient use of public resources.

Surveys, however, do not always provide reliable information. In the French context, because bore-well owners fear they may incur new administrative costs and taxes if they declare their wells, non-participation or falsified response rates are high. An alternative solution, then, consists in developing an indirect bore-well detection method based on a consistency check between households and housing characteristics on the one hand and metered water consumption on the other. The objective is to identify abnormally low water consumption, revealing the likely presence of a bore-well.

Such a method was developed and tested in one of the French case studies described above, the Perpignan Mediterranée Urban Community. The method comprised five steps: 1) we first developed a geographic information system integrating a digitised cadaster, a high-resolution aerial photograph, and an address database; 2) the aerial photograph was then analysed using a supervised classification method to assess each plot according to the area coming under major land-use classes, including built areas, swimming pools, irrigated lawns, tree plantations, and other non-irrigated areas; 3) next we used a simple agro-climatic model to estimate theoretical outdoor water use corresponding to irrigation requirements for irrigated lawns and trees, and evaporation for swimming pools; 4) we then cross-checked the estimated outdoor water use against metered scheme-water consumption; 5) finally, discrepancies were identified and a physical inspection by utility staff was performed to check the existence of a bore-well.

Figure 4 illustrates the results obtained with this methodology. The house on the left has an estimated outdoor water use of 263 m^3 consistent with a metered scheme-water consumption of 290 m^3. The house in the center has a metered consumption of 93 m^3, which roughly corresponds to indoor water use, while the total water use is estimated at 370 m^3. The difference suggests the presence of a bore-well which is only used outdoors (lawn and swimming pool). The difference between metered and estimated consumption is even greater for the house on the right: use was estimated at 319 m^3 but only 16 m^3 are withdrawn from the scheme, suggesting that the bore-well is not only used in the garden but also indoors (washing machine, toilet flushes, etc.).[13]

[13] This approach might not work for second homes which are only occupied during summer months. Errors are thus expected to be greater along the coast where seasonal occupancy is more frequent.

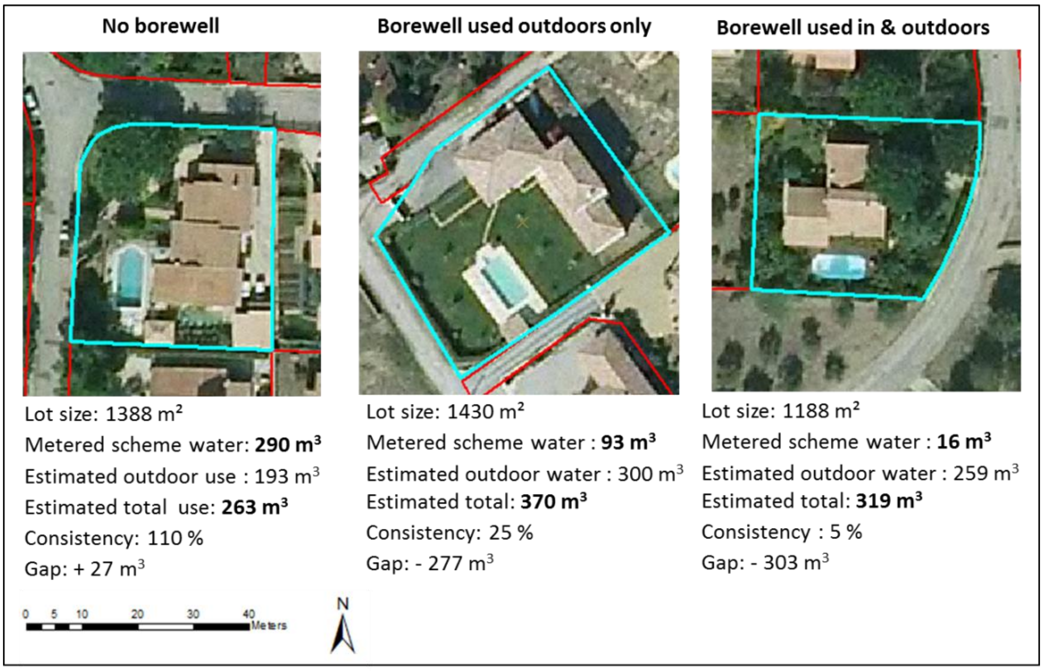

Figure 4. Comparison of estimated water use and metered scheme-water consumption for three houses of Perpignan Méditerranée urban community.

Challenge 2: controlling bore-wells in environmentally sensitive areas

The French and Australian case studies show that the continued development of groundwater self-supply could ultimately lead to environmental problems for the groundwater resource itself and for dependent ecosystems.

In Perth, bore-well development and dry climate have led to a lowered water table (1995–2004) over more than 40% of the metropolitan area (Smith et al. 2005). Assuming continuation of the climate trend over the past 10 years, additional self-supply of groundwater from the superficial aquifer can be expected to further reduce aquifer storage under parts of Perth. This will increase the general risks of seawater intrusion along the coast and loss of urban wetlands. In some parts of the metropolitan area, the water table is liable to decline to the point where substantial changes occur in the chemistry of groundwater. As acid sulfate sediments come in contact with atmospheric oxygen, acidification takes place, leading to the release of heavy metals and arsenic. These contaminants are leached into the groundwater and eventually find their way into nearby wetlands or rivers, causing environmental and economic harm (Appleyard et al. 2006; Department of Water 2009). The risk is not only environmental but also economic. If shallow aquifers deteriorated to the point where they can no longer be used for garden irrigation (for example, following sea water intrusion), the demand for public supplies would increase tremendously, imposing very high costs on water utilities to develop new resources and rebuild the distribution network, which would then be undersized to meet this increased demand.

To cope with that risk, water policy in Perth has gradually shifted from an unconditional support of bore-wells for gardens to a spatially-differentiated policy which only supports the development of groundwater self-supply in well-defined zones (Department of Water 2011). In areas deemed unsuitable, the department does not support the establishment of new domestic garden bore-wells, but existing ones can still be used. Areas are deemed unsuitable if: i) water quality is not suitable for irrigation (salinity, contaminants); ii) the area is close to the ocean and vulnerable to seawater intrusion; iii) it is near an important conservation wetland or groundwater-dependent ecosystem which could be adversely affected by bore-well use; or iv) the area is over-allocated to existing users and future development of garden bore-wells is liable to generate damage to third parties or existing users. Areas suitable and unsuitable for garden bore-wells have been defined by the Department of Environment and published in a Groundwater Atlas which is available in an interactive format on the Internet (Department of Environment 2004).

In France, the major problem stems from the impossibility for utilities to ensure that bore-wells are properly built and designed. As mentioned above, drilling contractors do not always install a properly cemented bore-well casing. Accordingly, each bore-well becomes a potential contamination path for groundwater, with serious consequences when the resource is exploited for municipal use. In an area of the Perpignan coast, we found a situation where the third layer of the coastal confined aquifer became brackish in the space of a few years due to the improper construction of a dozen bore-wells, so that hydraulic communication between the brackish upper layer and the confined aquifer they were exploiting was established. The challenge for water utilities is to find ways of controlling the quality of wells (through video technologies for instance) and to impose, at least in sensitive areas, credible threats of sanctions (e.g. charging owners for the cost of refilling poorly built bore-wells). However, this would presuppose that utilities already had access to reliable information on bore-well location, which is obviously not necessarily the case.

Challenge 3: including bore-well development in scheme-water demand modeling

Having access to up-to-date information on bore-well density is also a prerequisite to any accurate modeling of scheme-water demand. This is of utmost importance when forecasting long-term demand, since the unit consumption ratio differs significantly depending on the presence or absence of a bore-well on the property. An underestimation of bore-well density will lead to an overestimated demand for scheme water and consequently a costly over-sizing of storage and conveyance infrastructures. Conversely, overestimating future bore-well density might result in shortages, as infrastructure will prove to be undersized in times of peak demand.

Knowledge of bore-well density is also crucial when simulating the impact of rate changes on demand and utility revenues. Several studies have shown that price elasticity differs between households who have access to an alternative water supply and those who do not (Nauges & van den Berg 2009). In Perth, Thomas & Syme (1988) showed that bore-well owners have very low price elasticity. They also indicated that cross-elasticity of bore-well installation rates and the price of public scheme water was also significant: a 32% increase in water price would result in a doubling of the demand (+100%) for bore-wells. In France, Montginoul et al. (2011) showed that an increase in scheme-water price would significantly raise the return on investment for bore-well construction and provide incentives for households to drill. The same impact is expected from increasing block or seasonal rates. Utilities need to take into account this difference in household price sensitivity when they calculate the impact of proposed rate changes.

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Challenge 4: maintaining equity between bore-well owners and other customers

The development of bore-wells also raises an issue of consumer equity. In France for instance, it is most likely that bore-wells will be drilled by higher income households who own a detached house in a suburban estate with a garden and swimming pool. Their scheme-water consumption will decrease to a very low level, especially if they install a dual pipe system in their house to supply washing machines and toilets. Since water, and sanitation and wastewater treatment (S&WWT), are paid for on the basis of metered scheme-water use, their financial contribution to the service will decrease. To compensate for declining revenues and ensure full cost recovery, utilities will need to increase their rates. This will ultimately result in raising the bills paid by less wealthy consumers, increasing consumer inequity. In such situations, water utilities will have to develop innovative cost-recovery policies. A key issue is recovering S&WWT costs from bore-well owners who discharge wastewater into the public sewer without paying for it. This might be done by metering bore-well water entering the house, or by charging for S&WWT services using a flat rate.

The question arises differently in Perth. In 2006, a desalination plant was built to meet the demands of the growing population, and its cost will be paid for by scheme-water consumers in proportion to their level of water consumption. At the same time, authorities are contemplating a groundwater replenishment program in which the shallow aquifer is recharged with recycled waste water (Li et al. 2006). Clearly, sharing these costs on the basis of scheme-water consumption alone would be unfair from a consumer justice point of view. It would also probably be unfair in terms of social justice, as bore-well owners are probably among the better-off households. To maintain equity, utilities will have to design new cost-recovery schemes, for instance through charging bore-well owners a water abstraction fee, as practiced in Orange County, California. Such a change which would probably trigger strong political opposition, in France and Australia alike!

6. Conclusion

For decades, centralised, standardised and universal water services were developed as part of a wider elaboration of the welfare state. Technologies and centralised management allowed public or private utilities to achieve high levels of service quality and reliability. We are now starting to see users who look beyond the tap, paying attention to how the service is operated, how the infrastructure is configured, and how costs are shared among users. Some of these users have started to question the fundamental assumptions – the universality of the service, social and territorial financial solidarity – and have resorted to alternative individual water-supply systems such as rainwater harvesting, grey water recycling, and groundwater self-supply. In this chapter, we have focused on one of these strategies which consists in using a private bore-well as a partial substitute for scheme water. The development of such self-supply systems merits attention from water utilities and policy-makers alike, for a number of technical, economic, and social reasons expanded upon in this chapter. We documented two case studies in Southern France and Western Australia, but it is worth mentioning that the issue has also been reported elsewhere in the world.

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