Desalination and the disarticulation of water resources: Stabilising the neoliberal model in Chile

1. INTRODUCTION

> Securing water for Chile is securing its future. […] We must see the supply and use of water as a state policy and a national objective.[1]
>
> - Michelle Bachelet, President of Chile, 24 March 2015.[2]

On 24 March 2015, during the sixth and most acute year of a major drought affecting Chile, the country's President, Michelle Bachelet (2014-18), launched the National Drought Management Plan (Gobierno de Chile, 2015b). With a budget of USD 152 million for its first year, the Plan entailed immediate and short-term drought alleviation responses as well as medium and long-term measures to increase the availability of water, primarily through the construction of small and large-scale infrastructure, following the country's tradition of "technocratic approaches to water management and governance" (Budds, 2013: 313). A distinguishing feature of the Plan is that it scaled up an incipient infrastructural solution to both address existing and projected water scarcity, and to respond to future water demand: seawater desalination. The Plan included a proposal to construct five new desalination plants along the coast of northern and central Chile – the regions worst affected by the drought – primarily to produce drinking water.[3]

These proposals reflect a growing global trend to introduce desalination to both complement and diversify freshwater sources, particularly in arid coastal areas. Of the three dominant techniques to increase water supply without exploiting natural freshwater reservoirs - rainwater harvesting, wastewater recycling, and desalination (of seawater or brackish groundwater) – the latter is an increasingly common option, and is widely recommended as a climate change adaptation measure (e.g. Bates et al., 2008). A technique with origins dating back to 3000 BC

(Al-Sofi, 2001), seawater desalination (hereafter desalination) has evolved to become a “mature techno-economic application” (Delyannis and Belessiotis, 2010: 206), as major technological advances have significantly reduced the costs of the technology and process (Bernat et al., 2010; Khawaji et al., 2008), and energy demand (March, 2015), thereby rendering it increasingly viable.

Much existing academic and institutional literature on desalination examines the nature of desalination technologies, their economic profiles, and their environmental impacts, predominantly concentrating on the scale of the desalination plant (NRC, 2008). The environmental impacts of desalination, comprising the effects of concentrated brine discharge on marine ecosystems, energy consumption and CO_2 emissions, and the disposal of solid waste pollutants, have been well documented (Cooley et al., 2006; Mezher et al., 2011; Roberts et al., 2010). An emerging body of scholarship within social science of the environment has started to scrutinise the wider social and political implications of desalination, both conceptually and empirically. Studies have examined the development of the desalination industry, including its material and discursive drivers, financing strategies, and governance dimensions (Loftus and March, 2016; Swyngedouw, 2015; Swyngedouw and Williams, 2016), as well as the social and environmental consequences and implications of the availability and use of desalinated water (Feitelson and Rosenthal, 2012; McDonnell, 2014; McEvoy, 2014; McEvoy and Wilder, 2012; Meerganz von Medeazza, 2005).

These studies focus on the production of desalinated water as an *additional* source of water, which complements and augments existing sources, whether to fulfil social needs (e.g. McEvoy, 2014; McEvoy and Wilder, 2012) or to foster capital accumulation (e.g. Loftus and March, 2016; McDonnell, 2014). In this paper, we extend these analyses by examining how desalinated water *integrates with*, and *reconfigures*, existing sources, and its wider social and political implications. We use the framework of the hydrosocial cycle to approach desalinated water as materially, economically, and symbolically distinct from freshwater, and to examine how its production disarticulates water resources and uses, and reworks hydrosocial relations. To ground our analysis, we use two cases from Chile, Antofagasta in the far north and Petorca in the central-northern region, where freshwater resources are pressured by intensive and high-value export industries: copper mining and fruit cultivation, respectively. While desalination has been developed in Antofagasta, where a large desalination plant has supplied drinking water to much of the region's coastal urban population since 2003, Petorca is destined to receive two plants for drinking water and irrigation as a long-term drought mitigation measure under the aforementioned Plan, given that it has been one of the most severely affected regions. Our analysis is informed primarily by interviews and analysis of documentation, conducted between 2015 and 2017.[4]

Our analysis reveals how desalination disarticulates drinking water from freshwater, with problematic implications. First, the desalination plants are dedicated primarily to domestic drinking water, yet do not serve to extend provision per se, but rather to substitute existing freshwater sources with desalinated water. This replacement, we assert, reconfigures the social relations of control over water, and generates new risks by rendering households dependent upon the conditions of production of desalinated water, such as centralised control and dependence on cost-effective energy. Second, in this way, desalinated water does not simply create additional water, but liberates existing freshwater sources for economic activities. We contend that desalination thus serves as a supply-led solution to fuel the same industries whose growth has depleted drinking water sources that are now being replaced with desalinated water. Moreover, this dynamic serves to create new opportunities for capital accumulation via the production of desalinated water on the one hand, and the expansion of these industries on the other. Third, Chile operates a system of water rights markets under the 1981 Water Code that is designed to manage demand, but which has been largely ineffective in curbing overexploitation of water (Budds, 2004, 2008). This, in turn, has subjected it to increased public scrutiny and pressure for reform (Budds, in press). We suggest that desalination serves as a supply-led solution that, by increasing water supply in times of crisis, serves to shore up the Water Code by alleviating the water problems that could be attributed to it. Paradoxically, the desalinated water that is stabilising the Water Code, and by extension Chile's neoliberal economic and political model (Budds, 2013), is not regulated by this legal framework.

Following this introduction, in the next section we examine how desalination has been approached within the geography and political ecology literature, and consider how the hydrosocial cycle can frame an analysis of desalination and generate new insights. In section 3, we introduce Chile's water markets model and present the two case studies of the introduction of desalination in Antofagasta and Petorca. In section 4, we discuss our results, before concluding in the final section.

2. DESALINATION THROUGH THE HYDROSOCIAL CYCLE

In this section, we review existing literature on the social and political dimensions of desalination in order to identify key issues, perspectives, and gaps. We then proceed to mobilise the framework of the hydrosocial cycle to analyse desalinated water as a form of manufactured water, whose conditions of production matter for its social relations of control.

2.1 Social and political dimensions of desalination

Desalination is, by definition, a supply-led approach to water, because it constitutes a new water source that complements or increases existing supply - often in response to shortages or uncertainties - rather than manages demand. However, geographers and political ecologists have highlighted that desalination has important material differences with other water supply strategies. First, it can be operated independently of hydrological conditions, potentially providing continuity of supply even in arid areas (Feitelson and Rosenthal, 2012; Swyngedouw and Williams, 2016). Second, due to its few productive uses and perceived abundance, unlike freshwater, seawater is usually not subject to water allocation and access norms, leading to its characterisation as an "unlimited" and "uncontested" resource (March et al., 2013; Swyngedouw, 2013, 2015;

Swyngedouw and Williams, 2016). Third, despite some resistance to accept desalinated water for drinking (Budds and Hinojosa, 2012; McEvoy and Wilder, 2012), it is still often culturally preferred over recycled wastewater (Rygaard et al., 2011; McDonnell, 2014). These characteristics have influenced the impacts and dynamics of desalination, and thus are important to consider in analyses.

Previous work examining desalination as a supply-led strategy has characterised it as a non-flexible, growth-oriented, and path-dependent solution to water scarcity (McEvoy and Wilder, 2012). While there exists a narrative that the production of desalinated water for drinking water can be environmentally beneficial by reducing pressure on existing freshwater that could be dedicated to other priority uses (e.g. ecological flows, food production) (McEvoy and Wilder, 2012), others contend that it could equally foster unsustainable water use, in particular by promoting non-essential water uses and discouraging water storage and conservation (arguably promoting maladaptation to climate change) (Feitelson and Rosenthal, 2012; McDonnell, 2014; McEvoy and Wilder, 2012; Meerganz von Medeazza, 2005). For example, McDonnell (2014) described how the production of desalinated water in Abu Dhabi, United Arab Emirates, led to the transformation of a desert landscape into a cityscape replete with green vegetation and water features, and transformed cultural practices based on sparing water use into ones accustomed to exorbitance. The framing of desalination as a solution to water scarcity – ecological modernisation – is thus problematic given its potential to reproduce that same scarcity that it was designed to address.

Other work has examined the introduction of desalinated water into drinking water supply, noting issues of differential vulnerability and environmental security (Agudelo-Vera et al., 2012; Kallis, 2008; Ludwig et al., 2011). Some studies have demonstrated that lower-income groups are negatively impacted by the introduction of desalinated water into the water supply network as higher and lower income households have differentiated capacities to respond to price increases (March and Saurí, 2009; McEvoy and Wilder, 2012; Renwick and Archibald, 1998). Others have shown that consumers of desalinated water do not use tap water for drinking due to quality concerns, demonstrating that, although desalination may overcome physical water scarcity, it can reproduce water insecurity at the household level (Fragkou and McEvoy, 2016; McEvoy, 2014).

Attention to the wider political economy of desalination demonstrates how it goes beyond a technical solution to water scarcity, to present new opportunities for economic growth and capital accumulation, by both producing water for economic activities, as well as becoming a site for private investment itself (Loftus and March, 2016; Swyngedouw and Williams, 2016). Swyngedouw (2015) and Feitelson and Rosenthal (2012) argue that desalination provided a fix to the uneven geographies of water in Spain and Israel, respectively, and enabled those countries to continue water-intensive economic growth. Loftus and March (2016) show how desalination forms part of the commercial strategy of companies adopting it, through the case of the water utility in London, which maximised returns for shareholders by passing the cost of a large - and arguably unnecessary - desalination plant onto households' future water bills. Budds and Hinojosa (2012) demonstrate a different strategy, whereby mining companies in Peru reduced energy costs by switching drinking water supply in coastal cities from mountain water to desalinated water, in order to be able to use mountain water for highland mining, rather than transport desalinated water. These studies of different dimensions of desalination as a supply-led strategy to water security help to show how desalination does not simply produce water, but also changes relations at the level of the household, city or industry.

These analyses of how desalination reshapes political economies and water geographies are complemented by attention to how it affects water governance. Two studies of the effects of desalination on municipal drinking water provision in Mexican tourist resorts suggest conflicting results. McEvoy (2014) argued that, in Baja California Sur, it did not address the inadequacies of the existing water service, and alleviated pressure for institutional reform of water utilities, while Domínguez Aguilar and García de Fuentes (2007) observed that major hotels in Cancún adopted private desalination plants to avoid the problems (quality, continuity, cost) of the public water supply, a shift that could further destabilise that public service, as well as increasingly transfer water provision from the public to the private domain. Authors writing about the desalination industry in general echo the latter point, contending that it reinforces the role of the private sector in decision-making, and reconfigures the roles and power of water institutions (Feitelson and Rosenthal, 2012; McDonnell, 2014; Swyngedouw, 2015; Swyngedouw and Williams, 2016). Writing on Spain, Swyngedouw (2015) and Swyngedouw and Williams (2016: 56) go further, by positing that desalination leads to a "consensual, politically uncontested form of governance", whereby the creation of a new, separate and uncontested source of water served to forge consensus among disparate stakeholder groups that desalination formed an unproblematic and modern solution to the country's water demands. These studies, however, have tended to focus on the governance of the plant or the industry, with less attention to the desalinated water produced.

Our review thus far suggests that much of the existing scholarship on the social and political dimensions of desalination is concentrated on two themes: first, the effects and implications of desalination as a supply-led solution to address water shortages; and, second, the role of the desalination industry in fostering capital accumulation and influencing governance practices. While some attention is given to the social and cultural dynamics of desalinated water - social acceptability, affordability, cultural practices – as distinct from other sources of water, what is less explored is how desalinated water relates to other sources within the water mix and to what effect. Almost all existing literature treats desalinated water as an artificial and necessarily additional source that *augments* existing supplies to fulfil unmet demand – whether due to natural or produced scarcity – and overlooks the way in which it *interacts* with these existing sources and potentially reconfigures them within wider resource, economic, institutional and social assemblages. In this way, the existing literature links desalinated water with capital accumulation in two main ways: through the production of additional water for economic activities, and through investment opportunities in the industry itself. What merits attention, in addition, is how the reconfiguration of the water mix resulting from desalination could contribute to economic and political objectives, and transform access to water among different social actors. It is thus to the hydrosocial relations of desalinated water that we now turn.

2.2 Desalination and hydrosocial relations

As desalination manufactures freshwater from seawater, it constitutes a process through which water is made. This, we contend, renders it amenable to analysis within the framework of the hydrosocial cycle. The hydrosocial cycle is an approach to conceptualising and analysing society-water relations that goes beyond the recognition of the social relations and politics that exist around water, and instead emphasises the processes through which water is socially constructed and produced, in different contexts and under different configurations of power (Budds et al., 2014; Linton and Budds, 2014). Within the hydrosocial cycle, therefore, "water" is never seen as simply material or universal H_2O, but as a socio-nature that becomes produced through socio-ecological processes, and which, in turn, reconfigures social structures, relations and subjectivities. What is important, therefore, is how water is produced, and how this process of production of water reconfigures social relations, recognising that different hydrosocial arrangements produce different waters, and that those different waters in turn produce different hydrosocial relations. Linton and Budds (2014: 170) define the hydrosocial cycle as "a socio-natural process by which water and society make and remake each other over space and time", and argue that unravelling this process of making and remaking offers analytical insights into how water is produced, framed, contested and enrolled into wider agendas of socio-ecological change. This perspective, we suggest, is useful for drawing greater attention to the implications of desalinated water as an instance of water that enters and shapes the waterscape.

So far, desalinated water has mainly been linked with the hydrosocial cycle through the nexus between water, capital, and power. The hydrosocial cycle thus draws attention to the way in which desalination reverses the hydrological cycle to make freshwater flow from the sea to the land (McDonnell 2014, Feitelson and Rosenthal 2012; Swyngedouw, 2015), reflecting the idea that power makes water flow in the direction of capital. In this way, Loftus and March (2016) explored how London's hydrosocial cycle was shaped by flows of water, finance, and energy, and how these elements converged to justify a major desalination plant. By attending to how energy, water and capital intertwined within the hydrosocial cycle, the authors identified an agenda that had less to do with the challenges of providing water to a growing city amid climate change, but was rather related to the use of large-scale infrastructural assets to maximise returns for overseas investors. McDonnell's study of Abu Dhabi coincides with this point. Her analysis through the hydrosocial cycle revealed that the transformation of the Emirate's landscape from desert to oasis based on desalinated water was inherently precarious, since it depended on cheap imported natural gas from Qatar, counted on storage facilities that could only hold three days' supply, and was subject to escalating demand as citizens became accustomed abundant water. Once again, these analyses tend to treat desalinated water as the product of the desalination industry, rather than an instance of water with particular conditions of production and hydrosocial relations.

While these studies examine the production of water through the hydrosocial cycle, we suggest that approaching desalinated water as socially produced opens up new analytical possibilities by treating it as distinct from other types of water. This enables attentiveness to a different set of relations that may come into play in both the process of production of desalinated water, as well as its integration into the water mix. Desalinated water can thus be seen as a particular instance of water that becomes characterised by, and embedded in, particular social relations, as suggested by Budds and Hinojosa (2012) in the context of Peru, where an anti-mining activist contested the potential substitution of mountain water with desalinated water as the source of drinking water as replacing 'live' water with 'dead' water. It is these analytical possibilities that we seek to develop to shed light on the processes and relations through which *desalinated water* – as distinct from *any water* – is produced and deployed. Therefore, our aim is to explore how desalinated water intersects with existing water sources and uses, and how this affects hydrosocial relations and the waterscape. For this, we turn next to our two case studies of Antofagasta and Petorca in Chile.

3. DESALINATION IN WATER-SCARCE CHILE: CASE STUDIES OF ANTOFAGASTA AND PETORCA

In this section, we analyse how desalination has emerged as a solution to water scarcity in Chile, and how the incorporation of desalinated water in regional water mixes has reconfigured water sources and social relations. Antofagasta and Petorca differ in terms of hydro-climatic conditions – arid and semi-arid - and by the type of export industry – copper mining, and fruit production, respectively. Yet, in both, intensive water use combined with water shortages has threatened the sustainability of the industries, against which the market mechanisms under the Chilean Water Code have been ineffective.

We start by introducing the framework of the 1981 Water Code in order to provide contextual detail for the governance and regulatory framework, followed by a brief overview of the development of desalination in Chile. We then proceed to present the case studies, starting with Antofagasta Region, the site of Latin America's largest desalination plant for human consumption since 2003, with well-studied impacts from the regional to the household levels (Fragkou and McEvoy, 2016; Fragkou, 2018). Antofagasta serves as an example of the use of desalinated water for drinking water as a long-term measure for mitigating water scarcity, which is advocated for replication elsewhere. We then turn to Petorca Province, where the significant expansion of fruit plantations for export since the 1990s has substantially increased legal and illegal groundwater extraction, leading to significant environmental and social impacts (Budds, 2004, 2008, 2009a; Guiloff, 2013). As a result of the 2014-15 drought, desalination plants for each of the Petorca and the La Ligua river basins have been proposed to fulfil rural water supply needs, as well as to provide some additional irrigation water.

3.1 The 1981 Water Code

Chile operates a system of water rights markets to manage water allocation, under the 1981 Water Code (Bauer, 1998). Formulated according to free market economics and political liberalism under the military regime (1973-90), the system designates water rights as private property to provide users with security of tenure, and enables water trading to manage demand by incentivising reallocation. Water rights are needed for all uses except rural drinking water, with surface water and groundwater designated as separate rights. Once water rights are allocated, there is no fee for water use, but there is a tax on non-use after five years (Budds, 2013). Desalinated water is considered a private good, and is not regulated by the Water Code.[5]

From 1981, water rights could be acquired in three ways: (1) existing water rights were converted into private water rights; (2) new water rights to available sources were allocated; and (3) water rights could be purchased from other owners. Once available water rights for a source were fully allocated, redistribution was expected to happen through the market according to supply and demand, although markets in water rights throughout Chile have been largely inactive (Bauer, 1998; Budds, 2004, in press; Prieto, 2016).

In 2005, minor reforms were made to the Water Code following 13 years of debate in Congress. Key concerns were the speculative accumulation of water rights, and inadequate provisions for groundwater management and environmental flows. The process was controversial and protracted because the Water Code was an emblematic free-market policy of the military regime, and was vigorously defended – irrespective of evidence - by those who had supported that regime (Budds, 2013). Yet, following a series of high profile water conflicts concerning illegal extraction and over-exploitation throughout Chile, the Water Code has attracted renewed public scrutiny, and civil society organisations have called for the privatised and marketised system to be overturned (Budds, in press; Larraín and Segura, 2017).

3.2 Development of desalination in Chile

Desalination is a relatively new industry in Chile. The first plants were constructed in northern Chile, including a private one to serve a large copper mine in response to the unavailability of new water rights, the cost of purchasing water rights, and controversy over potential infringement of indigenous customary entitlements (Budds, 2009b, 2010). The Chilean Copper Commission (COCHILCO) estimates that, by 2025, 35 per cent of water for copper mining will come from desalination plants, many of which are expected to be private (Comisión de Recursos Hídricos y Desertificación, 2016).

Under the 2015 National Drought Management Plan, desalination became a new strategy to increase water supply in response to both increased demand and growing scarcity, which impact both economic activities and drinking water provision (Gobierno de Chile, 2015b, 2017). The Ministry of Public Works (Ministerio de Obras Públicas, 2017: n/p) reflects this supply-led stance, considering seawater as "an inexhaustible source for the country" that can "guarantee the timely supply of high quality water for irrigation and drinking water". The Commission for Water Resources and Desertification of the Chamber of Deputies of the Chilean Parliament, echoes this perspective, concluding that "the solution to the excessive use of freshwater, therefore, lies in taking forward the construction and use of desalination plants" (Comisión de Recursos Hídricos y Desertificación, 2016: 3). Nevertheless, the Commission stressed that the mining industry should switch to desalination to fulfil its water needs, noting that drinking water should not be secondary to economic activities; a stance contradicted by the state Water and Sewerage Concessionary Company (ECONSSA), which stated that desalination "will enable the state to undertake commercial activities oriented towards the supply of drinking water for the population" (idem: 6).

Of the five new desalination plants proposed in 2015, four will be commissioned by the government's Directorate of Hydraulic Works, with the entire process (feasibility study, environmental impact assessment, environmental authorisations, design, construction) being tendered, while the fifth will be awarded as a concession contract to a water utility.[6]

Figure 1: Location of Antofagasta Region and Petorca Province, Chile (Source: Tamara Monsalve Tapia).

3.3 Antofagasta Region

Antofagasta Region, situated in northern Chile (see Figure 1), hosts both the world's driest desert and its largest copper reserves, with a 35 per cent share in world markets (COCHILCO, 2010). Extracting hard rock minerals under arid conditions has been a historical challenge in the Atacama Desert, reflected by the installation of the world's first solar-powered desalination plant to serve local saltpetre mines and traders in 1872 (Arellano Escudero, 2011).

Since the nineteenth century, mining, urban growth, and water supply infrastructure have been co-evolving in this region (Lagos and Blanco, 2010). Antofagasta has undergone radical socio-territorial transformations as a consequence of the copper mining boom of the 1990s, and rapid urban expansion, as a direct result of the region's economic development (Arias et al., 2014). Between 1996 and 2011, urban and industrial land uses have increased from some 3,300 to 196,000 hectares, while wetlands and agricultural land have decreased significantly (IDE, 2017). At the same time, the region's population has increased by 50 per cent since 1992, with over 97 per cent of the total population in 2016 being urban inhabitants, principally residing in the region's coastal cities and towns.

By the 1990s, the water needs of the rapidly growing mining sector generated a situation of water stress in the region (Gobierno Regional de Antofagasta, 2008). At that time, the regional water utility, ESSAN (Empresa Sanitaria de Antofagasta SA), was a state-owned company created during the government of Patricio Aylwin

(1990-94). The utility was corporatised in order to make it attractive for its future privatisation, and, as part of this plan, it was charged with developing a long-term strategy for securing water supply for the Region's socioeconomic development.

To achieve this, first, ESSAN entered into contracts with regional mining companies for the provision of raw water for industrial use (Fragkou, 2018). Second, to secure water to fulfil these contracts, in 2001, ESSAN awarded a Build-Operate-Transfer (BOT) contract to a Spanish company, INIMA, to construct the La Chimba desalination plant in the regional capital, the coastal city of Antofagasta. Using the desalinated water to supply the Region's main urban consumers in Antofagasta (approximately 400,000 inhabitants), would thus release the company's (inland) water rights for the direct sale of freshwater to the mining sector. As a result, upon its impending privatisation, the concessionaire would not only have access to ESSAN's water rights, but the water provision agreements with the mining sector, plus the complete control and management of the La Chimba desalination plant, an additional source of water that would fragment the Region's water mix between drinking water for human consumption and raw water for industrial use.

In 2003, three months after the desalination plant entered into operation, Aguas Antofagasta SA took control of the water company, through a 30-year concession contract. Aguas Antofagasta was part of Antofagasta plc, a major national conglomeration of mining and transport companies that owns two of the nine large mines in the region. Since then, desalinated water production has increased from 150 litres per second in 2003, to 850 litres per second in 2017, and has been gradually substituting freshwater as the source of Antofagasta's urban water supply. This has allowed Aguas Antofagasta to not only maintain the existing water supply contracts, but also add three new ones, including for the two mines owned by Antofagasta plc. By 2016, the total volume of water sold to the mines, according to the contracts in force, was just over 17 million cubic metres per year[7]; the La Chimba desalination plant produced 19 million cubic metres in the same year.

This implies that the gradual substitution of freshwater with desalinated water for human consumption in the region's coastal cities, which concentrate 70 per cent of its population, is part of a longer-term plan to secure water for mining in the national interest. The port town of Mejillones (10,000 inhabitants) is already being supplied exclusively with water from the La Chimba plant, which is being expanded to be able to supply all of the city of Antofagasta, and complemented by a additional project underway in the town of Tocopilla (24,000 inhabitants). Representatives of the current owners of the water utility since 2015, the Colombian company EPM (Empresas Públicas de Medellín) claims that the plant was constructed in order to supply Antofagasta's expanding population, attributed to the success of the region's mining sector. This is contradicted by a report from the Inter-American Development Bank (IDB) in 2003, which states that the water produced by the plant will gradually replace the use of freshwater for drinking water in the city of Antofagasta, and that "the substituted water will be negotiated with the mining companies that require it for their new expansion projects" (IDB, 2003: 21). Therefore, desalination has facilitated the disarticulation of the regional water mix, through the allocation of desalinated water to human consumption in the coastal cities, and freshwater for mining activities in the inland highlands.

In Antofagasta, the substitution of freshwater with desalinated water implies more than the replacement of one source of water with another. The La Chimba plant has expedited household connections to the water network and added value to neighbourhoods (Martín and Sánchez, 2002). It is also associated with urban expansion, as Antofagasta has experienced its most rapid rate of urban growth rate since the plant came into operation, as green spaces have increased, and absolute and per capita water consumption levels have also risen (Fragkou and Vásquez, 2018). Some authors thus claim that desalinated water has reduced water shortages, improved continuity of service, and greatly improved water quality, having overcome the chronic problem of the natural presence of arsenic[8] in freshwater sources (Martín and Sánchez, 2002). Yet, other studies indicate that some residents of Antofagasta avoid the direct intake of tap water – sometimes even for cooking - because of its organoleptic properties, fears over its health effects, and/or mistrust in the water company (Fragkou and McEvoy, 2016). This suggests that access to water is in practice not improved, especially for lower-income households, who resort to time-consuming and precarious methods for household water treatment, saving and storage, as well as purchase bottled water of uncertain quality (Fragkou, 2018). In this way, desalination is potentially increasing what is effectively self-disconnection from the water supply network.

Furthermore, the gradual introduction of desalinated water into the city's water mix has altered the nature of water supply for its inhabitants. Since the introduction of desalination, different parts of the city have been supplied with water that comes from three sources and is qualitatively different: freshwater, desalinated water, and a mixture of both. This is important, because the quality of desalinated water is slightly but always more negatively perceived than that of freshwater in the city, even when consumers are not aware of the source of water that they are consuming (Fragkou, 2018). The issue of perception of desalinated water in the specific context of Antofagasta is exacerbated by the sea being regarded as "dirty", since the plant is in a bay that hosts the city's industrial port and into which its wastewater is discharged.

The water supply system also has implications in terms of cost and governance. Initially, urban residents did not pay more for drinking water that derived from desalinated water, despite higher production costs, because this was offset by the profits from the sale of water to the mining sector. However, the new parent company has plans to raise future tariffs accordingly, potentially when all coastal urban water supply is transferred to desalinated water.[9] As desalination has been conducted in a top-down way in the region, most of the residents are not even aware that they are being supplied with desalinated water, and there has been no opportunity for public consultation on the gradual substitution of their water source from freshwater to desalinated water, and its implications in terms of quality, cost and continuity.

3.4 Petorca Province

Petorca Province is located in Valparaíso Region, and comprises the two small river basins of Petorca and La Ligua, which rise in the Andean foothills and so have low river flows during the summer (see Figure 1).[10] The region is characterised by a semi-arid Mediterranean climate, and its economy is based on agriculture with a small proportion of mining. Agriculture traditionally comprised a mix of annual and perennial crops, on both large commercial and small family farms. Given Chile's emphasis on developing export industries under the military regime, fruit production significantly expanded since the 1990s (Budds, 2004). Table 1 shows the development of avocado production in Petorca Province, indicating a steep increase between 1997 and 2008 as plantations expanded, followed by a similarly sharp decline by 2014, as a result of drought.

Year	Area (hectares)	Source
1997	2799	INE, 1997
2002	5659	ODEPA-CIREN, 2002
2008	8670	ODEPA-CIREN, 2008
2014	5595	ODEPA-CIREN, 2014
2017	4807	ODEPA-CIREN, 2017

Table 1: Area of land under avocado production in Petorca Province, 1997-2017.

While agriculture had traditionally been irrigated with surface water from La Ligua river, the expansion of fruit plantations, primarily on rain-fed land on the valley slopes, led to demand for groundwater, which had been hitherto underexploited (Budds, 2004). Applications for groundwater rights rose steeply, and in 2004 allocation was finalised, and the aquifer declared closed to future allocation (Budds, 2009a).

Until around 2009, the province was able to sustain the expanded agricultural production in years with normal precipitation, likely due to groundwater reserves, with scarcity only emerging in years with lower rainfall (Budds, in press). However, from the start of a prolonged period of drought in 2010, most summers became characterised by severe water scarcity, as lower rainfall was no longer sufficient to sustain the flows of Petorca and La Ligua rivers, and adequately recharge aquifer levels, and as matured fruit plantations required more water (Budds, in press). By 2016, Valparaíso Region was characterised by the greatest hydrological deficit in the country, with surface and groundwater levels at between 30 and 100 per cent below normal levels (DGA, 2016).

The drought had severe impacts on agriculture and drinking water. With irrigation canals diminished or empty, and many wells dry as water tables fell to depths of around 80 metres or more, much agricultural land could no longer be irrigated. Many areas planted with fruit trees were cropped in an effort to save them, in effect becoming unproductive for that and the two subsequent seasons needed for regrowth. Areas planted with annual crops were either temporarily abandoned, or converted to low density livestock rearing. Small and family farmers, with the fewest resources to be able to invest in the most common responses – deepening existing wells, drilling new wells, constructing storage ponds or purchasing water from other farmers - were the most affected by the drought (Budds, in press).

Rural drinking water supply systems were also severely affected, as the majority relied on wells as their water source, most of which were no longer deep enough to yield water.[11] As a result, the municipal governments of the province,[12] which were legally obliged to provide drinking water, contracted emergency water tankers to fill village water cisterns.[13] The tankers were run by private licensed operators, and supplied approximately a third of the rural population from 2011 onwards (Budds, in press), at a cost of approximately USD 10 million between 2014 and 2016 for Petorca Province (CIPER, 2017).

The Chilean government announced a range of emergency measures in response to the drought, which were financed by the central government, and coordinated by the Provincial Government of Petorca. In 2014, a supreme decree[14] announced a feasibility study for a desalination plant for the province, to provide rural drinking water to replace the water tankers, and the 2015 National Drought Management Plan subsequently defined plants for each of Petorca and La Ligua river basins. The Ministry of Public Works (2017) set out plans for two reverse osmosis plants to supply village water systems that were no longer self-sufficient, and additional irrigation water, to be maintained as separate supplies. The projects included pumping stations and transmission pipelines to village systems throughout the basins, to supply 48 and 67 litres per second of drinking water in Petorca and La Ligua, respectively. Each plant will cost USD 38 million (excluding land aquisition), commissioned by the Directorate of Hydraulic Works, producing a running cost (excluding capital costs) of USD 0.40/m^3 and 0.34/m^3 for Petorca[15] and La Ligua, respectively. Each plant will also produce 1000 litres per second to irrigate 3750 hectares of mainly export fruit (avocado, citrus, table grape, nuts, tomato), with beneficiaries expected to make a 93 per cent contribution to the cost, thus apparently subsidising the construction of the plants for rural drinking water. The tenders were due to be published in 2016.

The proposal to introduce desalination to address deficiencies in rural water supply in Petorca Province ignores that water scarcity is caused by a combination of reduced precipitation and the overexploitation of water for commercial fruit plantations. Increasing water through desalination therefore serves to sustain and, moreover, legitimise, an arguably unsustainable level of agriculture (see Budds in press). Desalination is therefore not simply a means to ensure rural drinking water needs, but also a means of, in principle, liberating the groundwater that they relied upon and essentially transferring it to the agricultural sector. While wells for rural drinking water systems are exempt from water rights, they still constitute a historic entitlement for this use.[16]

In this way, desalination would disarticulate rural drinking water from the water resources of the province, also reflected in the production of separate flows for rural drinking water and irrigation by the desalination plant. On the one hand, this enables drinking water – which is guaranteed by the state – to be divorced from agricultural water use so that it no longer depends on the behaviour of farmers. On the other hand, it forms new opportunities for capital accumulation, through the construction and operation of the desalination plant, and the provision of desalinated water to an existing and dependent customer base. That said, it is the sale of water to irrigators that would seem to render the desalination plant financially viable for rural water supply.

The cost implications of replacing rural drinking water from village wells[17] with desalinated water are likely to be significant due to its production costs, even if the plant were subsidised by the state and/or irrigators. Rural drinking water systems are organised as village-based autonomous committees or cooperatives, for which the initial infrastructure and training is provided by the state, and which then continue operation and maintenance with user fees.[18] Replacing well water with desalinated water is not a simple fix to the problem of scarcity, because even if the cost is subsidised in the short term, it is not guaranteed over the medium or long terms.

Moreover, replacing well water with desalinated water implies a shift of control over water from the villages – who have both legal rights to and autonomous control over their water[19] – to arrangements that are as yet uncertain. Desalinated water could render village systems susceptible not only to cost increases but other future changes in water supply, such as quality or continuity, which they may not be able to influence. Again, a switch to desalinated water is more than the simple substitution of one source of water with another: it is a fundamental change in the institutional arrangements around rural water supply, whereby the rural population would potentially lose their autonomy over their water provision.

4. DESALINATION AND THE DISARTICULATION OF WATER RESOURCES

From a water management perspective, the two case studies could easily be interpreted as a 'win-win' situation, whereby desalination provided a secure water supply in the face of extreme water shortages and competition between uses. In this way, desalinated water could be seen to solve the problems of water continuity and quality that were affecting households, while simultaneously enabling the prioritisation of freshwater allocation to key economic sectors. A simple cost-benefit analysis of this water management arrangement would support its environmental, social, and economic efficiency. However, this assessment is predicated upon a view of water as homogenous, which privileges the supply of water and disregards the social relations of control over water. Employing the hydrosocial cycle to examine the social construction and production of water frames desalinated water as materially, economically, and symbolically distinct from freshwater, and exploring the dynamics of its integration into the water mix enables us to identify a series of direct and more implicit implications.

In the two Chilean cases, the desalination plants are promoted and initially developed by the state primarily for human consumption rather than for productive activities. This contrasts with other contexts, where desalinated water is mainly used for large-scale irrigation (e.g. Feitelson and Rosenthal, 2012). Yet, our cases demonstrate that the replacement of existing freshwater sources used for drinking water with desalinated water serves to create a freshwater surplus that can be diverted to dominant local industries. Furthermore, that the surplus comprises freshwater is also important, because this entails extraction (mainly groundwater pumping) costs, as opposed to production costs in the case of desalinated water, and is thus cheaper. Therefore, in Antofagasta, the liberated freshwater is convenient for its geographical proximity to the mining industry, whereas desalinated water would have to be produced and then transported inland. In Petorca, it is beneficial by protecting drinking water from the potential overexploitation of groundwater by farmers, and, at least in principle, some or all of the production cost can relatively easily be passed to households, who are already used to paying for water supply.

This means that desalination, as a supply-led approach, does not challenge the unsustainable nature of water-intensive industries, and instead sustains them in the face of potentially constraining water shortages. This, in turn, suggests that the Chilean State uses desalination as a strategy for securing water for its economic sectors; yet not by using desalinated water directly for industrial use, but instead indirectly, by diverting drinking water to desalination in order to free up freshwater for industries. This strategy of securing water allows Chile to protect the production of its key exports, including copper and fresh fruit, on the one hand, and to enhance the competitiveness of these products in international markets, on the other.

The case of Antofagasta suggests that the integration of desalination also facilitates new ways of promoting capital accumulation within the water industry. When the regional water utility (ESSAN) was privatised, its water rights - used to supply drinking water to most of the region's coastal urban population, and raw water contracted by the mining sector - were included in the concession. This enabled Aguas Antofagasta to dominate the region's water resources, and therefore control their distribution to both main sectors – urban and mining - in a way that became interdependent and mutually reinforcing. Therefore, switching urban drinking water progressively to desalinated water enabled Aguas Antofagasta to maximise the value of its freshwater rights by selling volumes of raw water to the mining industry. This reorganisation of the region's water according to commercial strategy supports previous findings that desalination can bring about changes both in water allocation at the basin scale, and in underlying power structures in the water sector (Feitelson and Rosenthal, 2012).[20]

The switch of urban water supply from freshwater to desalinated water has wider ramifications, however. As noted above, as a produced (rather than extracted) source, desalinated water is more expensive, and production costs depend primarily on the costs of materials and consumables (e.g. membranes), and energy. In Chile, desalination plants are operated by energy produced using imported fossil fuels, which is subject to fluctuations in both price and supply. In Antofagasta, desalinated water is expected to increase water tariffs in the medium term. Furthermore, transferring the entire urban water supply to desalination exposes the system to power cuts, mechanical failures, algal blooms, or damage from seismic events.

The development of desalination in Chile reflects a top-down approach to water provision, that relies on large and centralised infrastructure requiring significant capital investment and operational costs, and excluding public participation in the decision-making process (McEvoy and Wilder, 2012). This approach fits Chile's technical and technocratic approach to water management (Budds, 2009a, 2013), and was exacerbated by the emergency measures legitimised by the 2015 drought (Budds, in press). In this way, desalination was introduced in Antofagasta with no participation of water consumers, even leaving them unaware of the source of water they were consuming (Fragkou, 2018). Its proposal in Petorca has entailed no consultation with village systems over how the new desalinated water supply will interface with their existing systems based on communal sources. In the case of Petorca, this is especially significant, because the introduction of desalination threatens to shift the social relations of control of water provision from village autonomy over both water sources and water systems, to ones of dependence on other providers.

The issue of governance brings us to the role of the Water Code. As a supply-led approach, desalination does not challenge the unequal distribution of water rights, but instead further reinforces the accumulation of freshwater by economic sectors under the Water Code, at the expense of lower-income and/or marginalised water users (Budds, 2004, 2009b, 2010; Prieto, 2015, 2016). In this way, desalination could be regarded as a new means of accumulation by disarticulating and reworking water resources.

Water rights markets[21] have been inactive throughout Chile (Bauer, 1998; Budds, 2004, in press; Prieto, 2016), and both Antofagasta and Petorca are clear examples of how the Water Code has failed to achieve the reallocation of water in areas characterised by both acute scarcity and high demand. In both case studies, the Chilean State has resorted to desalination to increase supply in the face of the ineffectiveness of the Water Code to manage demand, in order to sustain thirsty industries and avert crises. This supports previous findings from Chile that, in practice, demand is fulfilled by the exploitation of new sources of water (groundwater, reservoirs) rather than trading in water rights (Budds, 2004, 2009b), and that the state intervenes to address water shortages, thereby undermining the core principles of the Water Code of using markets to manage demand, and delegating water management to water rights holders (Budds, in press).

Increasing the supply of water through desalination also avoids controversial alternatives, such as compulsory repurchases or expropriation of water rights, which would entail high political, economic, and social costs, in keeping with studies that show that desalination has been used by states to avoid conflict and alleviate pressure on existing water management models (March and Saurí, 2008; McEvoy, 2014; Swyngedouw and Williams, 2016; Swyngedouw, 2015). The latter is extremely pertinent in Chile, given the ongoing debate over the effectiveness of the Water Code and increasing pressure for major reform. The Chilean state has intervened to address drought with state-led, supply-led, and top-down infrastructural solutions, in order to annihilate the circumstances that potentially challenge the Water Code (Budds, in press). Therefore, we suggest that the introduction of desalination is more than simply a means of sustaining export-led capital accumulation in the face of drought, and is simultaneously a means to shore up the Water Code against pressure for reform. Paradoxically, however, desalinated water is a non-regulated water flow in Chile, meaning that the source that is stabilising the Water Code is not actually covered by it.[22]

Nevertheless, it is institutional reform that has a crucial role in promoting water conservation measures and cultures in conjunction with the development of supply-led solutions, in order to avoid the vicious circle of increased demand leading to increased supply, as noted in multiple previous assessments. Michelle Bachelet's note of caution while launching Chile's desalination programme is thus important, if neglected:

> We also need to make cultural and institutional changes that will allow us to conserve this precious element, and use it wisely.[23]

5. CONCLUSION

In this paper, we have mobilised the framework of the hydrosocial cycle to approach desalinated water as materially, economically, and symbolically different from freshwater, in order to argue that the introduction of desalination does not merely increase available water, but also serves to disarticulate water resources and uses, and rework hydrosocial relations in potentially problematic ways. This, we suggest, contributes new insights to critical studies of desalination, which, to date, have recognised and explored the contested nature and effects of the industry, as well as the social dynamics of desalinated water, but have not examined the introduction of desalinated water into the water mix.

Our overarching argument is that desalination enables the reorganisation of the allocation of water sources to existing uses, according to economic and/or political agendas. This has important economic, political, and social implications that are related to the advantages of freshwater (cost, quality, location) on the one hand, and desalinated water's conditions of production (including the cost of inputs, its organisation and scale, its governance and regulation, and its exposure to risks) on the other. Importantly, this insight emerges from two particular elements of the hydrosocial cycle. The first is considering differentiating between desalinated water and freshwater, and the specific relations that their conditions and/or production entail; otherwise the substitution of "water" with "water" appears commensurate and unproblematic. The second is attending to the interests and motives that are pursued through the production, organisation, and framing of water, and which go beyond its material flows and uses.

This overarching argument comprises three more specific contentions.

First, the substitution of freshwater by desalinated water reconfigures the social relations of control over water in potentially uneven ways. Switching drinking water supply to desalinated water can generate new risks for populations, including low-income groups, by exposing them to the instabilities associated with the production of desalinated water, fostering self-disconnection from tap water where desalinated water is perceived as inferior, and undermining community water governance by replacing local water systems with centrally produced and distributed networks. This reflects a dynamic whereby less powerful groups are dispossessed of their existing, preferred, and entitled water sources as these are captured by more powerful economic and political actors, which brings us to our next argument.

Second, the disarticulation of water resources by desalination reveals an additional strategy for capital accumulation, beyond the hitherto recognised investment opportunities in the desalination industry, and the provision of additional water to key industries. The introduction of desalinated water permits the diversion of (more advantageous) freshwater to (higher value) economic uses, creating opportunities for actors that do not use desalinated water directly but which benefit from the liberated freshwater. Where this results in the diversion of water to industries that exacerbate scarcity, it potentially stabilises unequal water resources distribution and the domination of unsustainable forms of economic production, as reflected in our final argument.

Third, this dynamic can contribute to the stabilisation and legitimisation of existing water management regimes and institutions, where it conceals, or postpones, their ineffectiveness in securing water for all actors and avoiding conflicts. This is particularly important because desalinated water does not necessarily conform to, or is not always regulated by, existing water policy frameworks. We suggest that these implications can be extrapolated to other water flows that are centrally produced and are alternatives to freshwater, such as recycled wastewater. Given that these alternative technologies are heavily promoted as adaptation strategies in water stressed territories around the globe, the social, economic, and political impacts of their intertwining with freshwater flows deserve greater attention in terms of how they potentially reconfigure hydrosocial relations and rework waterscapes.

In this way, our analysis extends the analytical scope of the hydrosocial cycle by contemplating the production and intertwining of multiple instances of water that have distinct material, economic, symbolic, and regulatory characteristics, in order to shed light on the operation of economic and political agendas through water, and the production of uneven waterscapes.

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[1] All translations from Spanish are the authors'.

[2] Gobierno de Chile (2015a).

[3] Basins of Copiapó, Limarí, Choapa, Petorca, and La Ligua.

[4] Ethical clearance was obtained from our institutions.

[5] In Chile, a permit is needed to install the plant, and an authorisation is needed to extract seawater (Congreso de Chile, 2016).

[6] Commissioning is deemed to lead to considerably lower tariff increases than awarding a concession contract to a private operator (Congreso de Chile, 2016).

[7] The large mines that have contracts with Aguas Antofagasta (for the supply of raw water for industrial uses) do not include the two main companies in the Region, Minera Escondida and CODELCO (the national copper mining company), which own a significant amount of water rights and private desalination plants that secure their water supply.

[8] Given the high concentration of heavy metals in Antofagasta Region, up to the 1970s, when the first abatement plant was installed, the drinking water provided to the city had high concentrations of arsenic, exceeding by far the World Health Organization's water quality standards.

[9] Personal communication, Aguas Antofagasta, August 2017.

[10] Petorca Province comprises the municipalities of Petorca, La Ligua, Cabildo, Papudo and Zapallar.

[11] Larger urban areas, including the towns of Petorca and La Ligua, are served by the private regional water utility, ESVAL SA (Empresa Sanitaria de Valparaíso, Aconcagua y Litoral, formerly Empresa de Obras Sanitarias de Valparaíso).

[12] Mainly Petorca, La Ligua, and Cabildo, with large rural populations.

[13] Some reports indicate quality concerns with tanker water (The Guardian, 2018).

[14] Supreme Decree 1776, 28 October 2014.

[15] Due to additional costs of pumping water to higher elevations.

[16] If desalinated water were to replace existing water sources of rural drinking water systems, this could also be legally problematic since it could constitute a violation of water rights.

[17] Or from water tankers, which fill the cistern at no cost to the village system.

[18] Almost all systems are drinking water only, with households having on-site sanitation.

[19] The National Water Directorate (*Dirección de Aguas – DGA*) has started to legalise historic groundwater rights for rural drinking water systems; while these are not technically needed, they enable legal protection against any infringements by other users.

[20] In Petorca, the case is less clear, as desalination is intended for rural drinking water, which is managed by village systems rather than the regional urban water utility (ESVAL), and there is no explicit market for the water surplus, since this simply fulfils existing water rights. Furthermore, the plan for the desalination plants suggests that irrigators' financial contribution would render the projects viable for rural drinking water. It may be that ESVAL bids for the projects in the future to control urban water supply, rural water supply, and the sale of desalinated water to agriculture.

[21] As distinct from temporary sales of water volumes that derive from permanent water rights.

[22] The Water Code only regulates two sources of freshwater: surface water and groundwater; the same applies to the national guidelines for potable water quality.

[23] Gobierno de Chile (2015a).