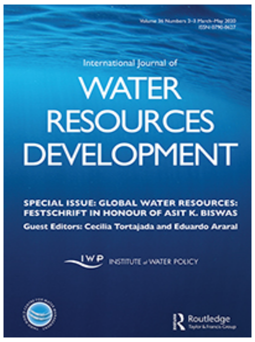

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VIEWPOINT

Facing the challenge of extreme climate: the case of Metropolitan Sao Paulo

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ABSTRACT
This article describes the hydrologic conditions that resulted in the most severe drought ever experienced in Metropolitan São Paulo (2014–2015). The dramatic situation was tackled by structural and non-structural initiatives by water authorities to avoid social chaos in a region home to more than 21 million people. The article also considers the post-crisis scenario when, in 2018, the metropolis was hit by another serious drought. Due to more rational consumption, a better prepared water system and the start-up of two major water transfer structures, which added new contributions from nearby basins, the critical situation was not perceived by the population.

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Introduction

Water availability, in both quantitative and qualitative terms, is one of the major concerns of both the business community and government authorities worldwide. Water is a fundamental element of food, energy and health security. Water is also the engine for socio-economic development. In September 2015 the United Nations General Assembly passed Resolution 70/1, 'Transforming Our World: The 2030 Agenda for Sustainable Development', in which a standalone target for water was approved. A 2012 report by the US National Intelligence Council claimed that 'water may become a more significant source of contention than energy or minerals out to 2030 at both the intrastate and interstate levels'.

Given the importance of water in the global scene and understanding that peoples' concerns about climate are not climate per se but the consequences of too much or too little water due to climate change, we must increase our resilience to climate variability. By and large, all the impacts of climate variability are manifested through, by and with water, whether it is impacts on ecosystems or hydrological extremes.

Hydrologic extremes have recently manifested themselves in different parts of the planet. It is salient the states of California, Texas and Arizona in the United States since 2013; Australia went through the Millennium Drought in 2000–2010; and in South Africa in 2017, the government announced the possibility of the Day Zero, when dam levels would not be able to supply Cape Town. Fortunately, this did not occur. Some years

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Supplementary data can be accessed here.

earlier, in 2013, Singapore faced unexpected climate challenges, just to name some of many situations around the world. In all these cases, we note the importance of water infrastructure and demand management to face the challenge.

In 2014 and 2015, the state of São Paulo, in South-East Brazil, had the most severe water crisis in its 125-year hydrologic record. Was this extreme drought as an outlier, or must we consider it in planning, as an event that will recur in the coming years?

This article describes the hydrologic conditions in the most severe drought experienced by the state and the structural and non-structural initiatives by water authorities to avoid social chaos in the São Paulo Metropolitan Region (SPMR).

The physical and hydrologic context

Figure A1 shows the 12 hydrographic regions of Brazil and their correspondent freshwater availability, in terms of average annual yield. (Figures A1–A26 are in the online supplementary data, at https://doi.org/10.1080/07900627.2019.1698412). Brazil has 12% of the world's freshwater resources, but most (70%) of this water is concentrated in the Amazon basin, which hosts only 7% of the Brazilian population. South-East Brazil, which is the focus of this article, is in the Paraná basin, which has the third-largest average availability (361 km^3/y).

There are three states in South-East Brazil: São Paulo, Minas Gerais and Rio de Janeiro. The population of São Paulo is 43 million, which corresponds to 21% of the Brazilian population (Brazilian Institute of Geography and Statistics, 2019), and 32% of GDP (Investment Promotion Agency, 2019).

A 2015 report from the National Water Agency (ANA) indicated that in 2014 South-East Brazil experienced anomalous precipitation patterns. Figure A2 shows the rainfall amounts and the return periods during the rainy season (January to March) in 2012–2014. Warmer colours represent drier climate (red means a return interval longer than 100 years). The exceptionality of the 2014 drought can be appreciated for a large extent in central and eastern São Paulo State. Figure A3 shows the average annual rainfall distribution in the state for 1979–2013, and Figure A4 shows the contrast with what happened in 2014.

During the drought, most of the northern and eastern parts of the state had less than 900 mm of annual rainfall, though the average is more than 1200 mm. This situation led the Water Resources Department of the State of São Paulo (DAEE) to issue new water permits exclusively for the water supply of the population.

Many municipalities in these areas passed municipal decrees of state of public calamity, giving them access to state and federal funds and expedited bidding processes for emergency civil works. Figure A5 shows the water resources management regions affected and the respective municipalities.

SPMR

SPMR is in the upstream reach of the Tiete River, a tributary of the Parana River (Figure A6). It is the most active economic region of Brazil (18% of Brazilian GDP and 54% of São Paulo state GDP), and its 21 million people (São Paulo Company for Metropolitan Planning, 2019), makes it one of the world's most densely populated. The combination of its dense urban concentration and its location at the furthest edge of the Alto Tietê basin makes it a region of very low per capita water availability, even under normal climate conditions. The situation is similar to that experienced in semi-arid regions.

Eight water treatment plants (Figure A6) operated by Sabesp (Water and Sanitation Company of the State of São Paulo) provide all the potable water for SPMR (São Lourenço, the ninth metropolitan water production system, started operation in April 2018, after the water crisis). In 2014, their joint maximum production capability was almost 73 m^3/s. Based solely on the hydrologic record available before the 2014–2015 drought, the firm yield from the rivers and reservoirs feeding these water treatment plants would roughly match the maximum production capability. However, if the full hydrologic record is used, including 2014–2015, the firm water yield shrinks to less than 52 m^3/s. This 31% drop is the most vivid expression of the severity of the drought.

SPMR draws most of its water from the neighbouring Piracicaba River basin, through the Cantareira system (Figure A6). Water travels 80 km through a set of interconnected reservoirs, tunnels, channels and pumping stations (Figure A7), comprising one of the largest water supply schemes in the world, with a nominal capacity of 33 m^3/s (Barros and Netto, 2010). Figure A8 shows the monthly inflows to the Cantareira system. The magnitude of the drought experienced by this system, which provides almost 50% of the supply, is such that the 2014 inflow to Cantareira was roughly 50% of the all-time low discharge in 83 years of records, which had occurred in 1953.

As a result, in January 2015, the Cantareira system storage was less than 5% of maximum, including dead storage (technical reserve), and the water level was several metres below the intake elevation. Since May 2014, water had been pumped out of the dead storage.

Table 1 compares the potable water production in February 2014, just before the adoption of anti-crisis measures (described later), with production in April 2015, when these measures were in place.

The water supply system operated by Sabesp serves practically the entire population of the formally urbanized area of SPMR, where one can find meters in virtually all households. But this is not the case in many of the informal settlements, where roughly 10% of the metropolitan population lives (Brazilian Institute of Geography and Statistics, 2013). Most people living in the informal settlements have illegal and unpaid access to potable water through precarious and wasteful distribution systems formed by a bundle of small-diameter plastic tubes connected to the mains (Figure A9).

Several barriers impede the water utility from entering these irregular settlements to provide regular services. Some relate to judicial disputes over land ownership (people

Table 1. Potable water production before and during the water crisis (m^3/s).

System	February 2014	April 2015	Difference
Cantareira	31.77	13.48	−18.29
Guarapiranga	13.77	15.05	+1.28
Alto Tietê	14.97	12.25	−2.72
Rio Grande	4.94	5.09	+0.15
Rio Claro	3.83	3.87	+0.04
Alto Cotia	1.16	0.76	−0.40
Baixo Cotia	0.88	1.01	+0.13
Ribeirão da Estiva	0.096	0.086	−0.01
São Paulo Metropolitan Area total	**71.42**	**51.60**	**−19.82**

have invaded private property), others to environmental restrictions (people have invaded protected areas), and still others – most of them – to the impossibility of installing water supply and sewage collection systems in neighbourhoods where there are no streets to bury the pipes under. This unorganized urbanization process began in the 1950s, when only 30% of the Brazilian population lived in the cities, and has grown worse, especially in the early 1970s, with the intensification of the industrialization process.

In a few years, the urban population swelled to 70% of the national population, but the infrastructure growth was much slower, resulting in several problems. For one, a large quantity of untreated sewage is dumped into the local water bodies, impelling the search for new water supply sources far away from the demand centre (Braga, Porto, & Silva, 2006). But in spite of difficulties, practically everyone living in SPMR has access to potable water in their household, through either formal or informal connections.

Facing the challenge of the 2014–2015 drought

The strategy adopted by the state government and Sabesp to face a potential social disaster included the implementation of structural measures (emergency construction works that were implemented from the very first signs of the crisis, which reinforced the infrastructure and gave the different supply systems more resilience) and non-structural measures (demand management via economic instruments and raising public awareness) (Figure A10).

Infrastructure development

Emergency civil works

When the water level was approaching the minimum elevation necessary for the free flow through the intake of the upstream Jaguari Reservoir (Figure A11), Sabesp installed a set of floating pumps and built channels and coffer dams to pump water from the dead storage to a provisional upper pond built adjacent to the intake (Figure A12).

This simple engineering solution stirred a public debate, fuelled by the media, about alleged health hazards for the people that would drink water from the 'dead' storage. It was a false problem, because for many years a bottom gate had been continuously releasing water from the reservoir to the downstream to ensure the minimum environmental flow along the natural waterway. Nevertheless, a serious media campaign was set up to explain that there was no risk to health, using the term 'technical reserve' instead of 'dead storage'.

Interbasin transfers and interconnection of production systems

Many construction works were performed in the distribution network in 2014 and 2015 to increase the operational flexibility of the eight producing systems of SPMR. Structural integration, extending the system to sectors belonging to other water sources, was made possible by a series of operations, mainly refurbishing water mains and pumping stations and also replacing or adapting boosters.

In this way, sectors that before the crisis were only supplied with water from the Cantareira system began to receive water from other, better-stocked producing systems. Some 3.5 million people stopped consuming water from Cantareira, and instead received water from the Guarapiranga, Alto Tiete and Rio Grande systems (Figure A13).

Since April 2015, the Rio Grande system has also been a new source for 250,000 people who were previously served by the Guarapiranga system. This was achieved by installing 2.1 km of water mains to carry the water to the southern part of the city. The surplus water from Guarapiranga was redirected to areas previously served by the Cantareira system. At the end of May 2015, it was the Claro River system's turn to boost its contribution to the area previously attended by the Cantareira, with the construction of a new link between two water mains in the eastern part of São Paulo.

Pumping stations and mains that had been decommissioned due to excessive leakage were refurbished. For the Franca Pinto pumping station and main, this required the injection of high-density polyethylene piping into 550 m of the 6600 m water main. This allowed an additional supply from Guarapiranga to help the sector served by the Cantareira system.

The steps taken in 2014 and 2015 to increase the operational flexibility of water production and distribution relieved the water sources most affected by the drought. The swap of the source of supply of the Paulista Avenue region, located at one of the highest spots of São Paulo City (at an altitude of about 830 m), is an example of this flexibility increment. Previously supplied by the Cantareira system, because of its favourable topography for water distribution, the region was now also supplied by the Guarapiranga system, which is in the southern part of the city at a lower altitude.

The overall result was an increase in the capacity to transfer flows between the production systems by 6.6 m^3/s. This meant that 3.5 million people that previously received water exclusively from the Cantareira could also receive water from other systems (Figure 1).

An important initiative undertaken in 2015 was the constructions of the pipelines to interlink different bulk water sources. First, 9 km of water mains and a pumping station were installed to transfer water from the Guaió River, in Suzano Municipality, to the Taiaçupeba

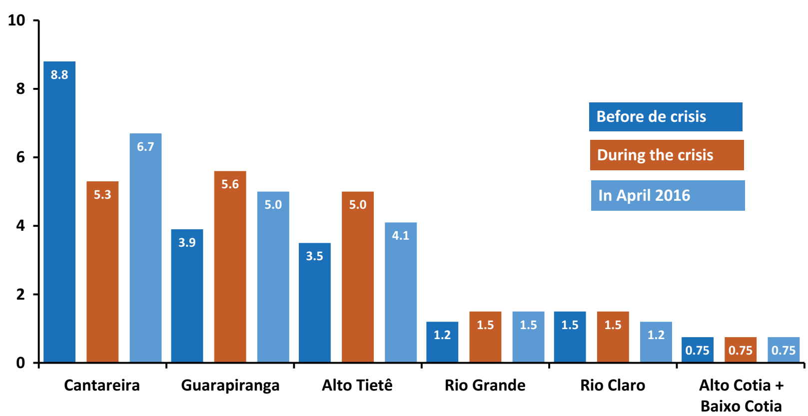

Figure 1. Interconnection of sources and population served (in millions).

reservoir in the Alto Tietê system. This took four months to be built and added 1 m^3/s of water to the SPMR integrated supply system. Next, the Rio Grande and the Alto Tiete systems were interconnected by two parallel water mains made of high-density polyethylene, with a flow capacity of 4 m^3/s over a distance of 10.5 km (Figure A14). This construction work also stirred much public debate, mostly fuelled by the press, and litigation in the judiciary. Some feared that this arrangement would jeopardize the quality of the drinking water. Others were concerned about impacts on the environment. Still others used the debate as a political weapon to blame the government for poor planning. It was necessary to launch a difficult battle at the public opinion front.

Once the links were in place for redistributing areas of the city from one production system to another, the next step was to increase the water treatment capacity and to build new water storage within the distribution system.

These were made possible by the technological advantages of ultrafiltration membranes: quicker filtration, less space needed for the equipment, fully automatic functioning and fewer chemicals. Two modules of ultrafiltration membranes (1 m^3/s each) were installed in the Guarapiranga system, increasing its production capacity from 14 m^3/s to 16 m^3/s.

Twenty-two steel storage reservoirs, with a storage capacity of 147,000 m^3, were installed in different sectors of the city. They provide a reserve of treated water and uninterrupted supply to districts far from the principal water mains. This was an efficient option for making the distribution system more secure and flexible. Besides expanding storage capacity and using strategic locations, closer to the region served, some reservoirs can receive water from more than one production system.

Demand management

Pressure relief valves and water loss reduction

SPMR's distribution system is divided into sectors for better management. Boosters pump the water to serve regions at a higher altitude, and pressure relief valves (PRVs) at lower levels alleviate leaks and eventual damage to the pipes and other structures. PRV technology is used in the best systems worldwide and has been used in SPMR since the 1990s. PRVs are also used for remote control of pressure at times of low demand, such as the early hours of the morning, when there is more pressure in the networks. Starting in October 2014, with the worsening of the drought, the water loss due to leakages decreased 7.6 m^3/s, which corresponds to around 42% of the total water savings during the crisis, thanks to the pressure reduction in the distribution system, which was extended to time intervals beyond the early hours of the morning. This policy proved more effective than the traditional method of rotating shutdowns among sectors.

At the start of 2016, the periods of pressure reduction returned to normal, that is, were restricted to night-time. Currently there are 1303 PRVs operating in SPMR. During the crisis, many were installed, today representing coverage of 55% of the distribution network, which consists of 33,000 km of secondary pipes and 1200 km of water mains.

Reducing water losses has been a priority of the water supply sector in the state of São Paulo for more than two decades. In 2009, Sabesp introduced the Corporate Loss Reduction Programme, in technical partnership with the Japan International Cooperation Agency, with forecasted investment cash flow until 2020 of R$ 5.5 billion. The objective is to reduce unaccounted-for water to 18%. In 2015 it was 27%, including 18% due to leakage (Figure A15).

Reducing leakage requires the installation of PRVs, substitution of mains, acoustic sweeps to locate leaks (so far, more than 87,000 repairs) and substitution of connection pipes to households (so far, more than 280,000 branches). Limiting non-physical losses due to illegal connections or fraud, as well as inaccurate metering, demand anti-fraud patrols and the replacement of meters, respectively. In 2015 alone, 3.7 billion litres of illegal consumption was identified, and more than 255,000 water meters were replaced.

Economic instruments: bonuses and fines

Bonuses for those who reduce water consumption, and a contingency tariff for those who waste water, were strategic measures to restrain demand. Starting in February 2014, at the beginning of the crisis, a discount on the water bill (bonus) was granted to water savers – those who reduced their water consumption by at least 20%, compared to their own average. This programme had the support of most families. More than 80% of consumers reduced their consumption, and 49% received discounts in 2014 and 70% in 2015.

The net effect was a lumped reduction of 3.5 m^3/s in potable water production, or around 19% of the total water savings during the crisis (Figure A16). Starting in January 2015, a penalty was imposed on those who did not understand the severity of the crisis and increased their consumption. Some 19% of consumers were in this situation, but 8% were exempt from the charge because they did not use more than 10 m^3 per month.

Communication campaigns

The government of the state of São Paulo and Sabesp encouraged conscientious use of water through visits, lectures and the distribution of posters and leaflets at condominiums, schools, commercial establishments and homes, making people aware of the importance of economizing water. Concurrently with the growing press coverage, widespread advertising/awareness campaigns were carried out in 2014, with over 3000 TV insertions and 13,000 radio insertions, besides publications in newspapers and magazines; it is estimated that each citizen was reached at least 40 times by water-saving messages.

In February 2015, the state government began another campaign called Every Drop Counts, promoting the importance of water rational use. More than 20 million printed materials were distributed by the Water Guardian team. Campaign teams made almost 74,000 visits in 2015. Two million people were approached directly, and almost 20 million indirectly. It was also necessary to launch a publicity campaign of print, radio and television advertisements.

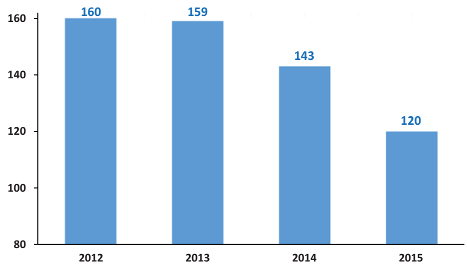

Figure 2. Impact of non-structural measures on per capita consumption (household clients, litres per person per day) in the São Paulo Metropolitan Area, 2012–2015.

Figure 2 shows the combined effect of economic incentives and communication campaigns on the water consumption of SPMR. Prevailing per capita household water consumption was reduced by 20%.

Reduction in water supply production of the Cantareira system

Figure A17 synthesizes the overall result of all these actions: it was possible to reduce potable water production in the Cantareira system from approximately 32 m^3/s to 13 m^3/s. The breakdown of different actions shows that this enormous saving was due to PRV/leakage reductions (7.7 m^3/s), interconnection of systems (6.6 m^3/s), economic incentives (3.4 m^3/s), and reduced supply to partner utilities in SPMR (0.8 m^3/s). This reduction of almost 60% was essential to keep the Cantareira storage from running out, which would have brought a major collapse in the water supply system of SPMR (Figure 3).

Figure 3. Depletion of storage in the Cantareira system during the 2014–2015 crisis (% of operational volume, including technical reserve).

Post-crisis scenario

SPMR faces a new challenge in 2018

After the driest period (2014–2015), the next two years (2016–2017) saw the recovery of the main systems that supply SPMR. But in 2018, there was another very dry period. The Cantareira system did not record significant rainfall (over 10 mm) for 71 days. The Guarapiranga system faced the same situation for 117 days, and the Alto Tietê system had six months of almost no rain. Together, these three metropolitan reservoirs supply about 16 million people. This situation adversely affected the metropolitan system as a whole (Figure A18), with natural contributions well below the historical average (Figure A19). The Cantareira system was also severely impacted (Figure 4).

Nonetheless, in 31 December 2018, the cumulative overall volume of the water sources was 916.8 million m^3. This is slightly more than the amount registered on the same date in 2017, but 7% more than the total in December 2013, just before the water crisis (Figure 5).

Though the Cantareira water level has dropped in 2018 (in September 2018 the system registered only 33% of storage, against the post-crisis peak of 68%, reached 14 months earlier, in July 2018), a range of factors has helped keep the total water storage at comfortable levels.

The adoption and incorporation of rational consumption habits acquired during the water crisis, in particular by domestic consumers, who use more than 80% of the water (Figure A20), contributed significantly. Thus, water production in 2018 maintained an average of 60.9 m^3/s to supply SPMR, 15% less than the 69.1 m^3/s average production in 2013, before the water crisis (Figure A21).

Average per capita domestic consumption in these three post-crisis years was 129 litres per day, 24% less than the 169 litres per day in 2013, before the crisis. In 2014–2015, it was even lower: 123 litres per day (Figure A22).

Combined with rational water consumption, the higher transfer capacity between water systems, higher water treatment capacity, new water sources and the lowered pressure in the distribution system (retained after crisis in the night-time) enabled Sabesp to maintain the reduced use of the Cantareira system. In February 2016, the better conditions of the water sources also resulted in an expansion in the authorization for

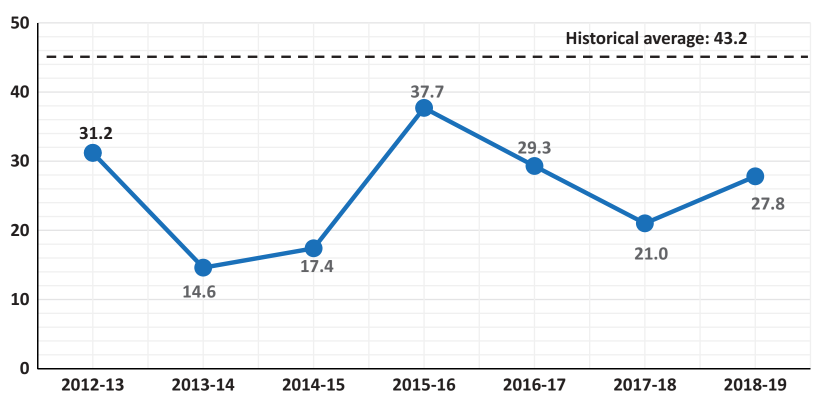

Figure 4. Natural inflow (m^3/s) in the Cantareira system per hydrological year (October–September), 2012–2019. In the 2017–2018 hydrological year, the inflow was again far below the historical average.

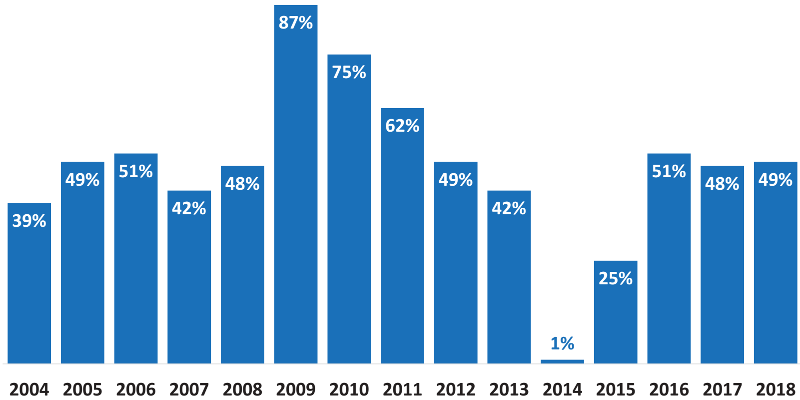

Figure 5. Total water storage in São Paulo Metropolitan Area reservoirs, 2004–2018 (%).

Sabesp to withdraw water from the Cantareira system, which had been granted by ANA and DAEE starting in 2013.

Based on the behaviour of the rainfall, water inflows and the level of the water sources, Sabesp was authorized to extract up to 23 m^3/s, a significant increase over the 13.5 m^3/s authorized in 2015. Later in 2016 (September–November), withdrawal of up to 25 m^3/s was authorized. In December 2016, uptake of up to 31 m^3/s was granted – still less than the 33 m^3/s permitted before the crisis.

In July 2018, as the level of reservoir water fell to less than 40%, the maximum allowed withdrawal from the Cantareira was reduced from 31 m^3/s to 27 m^3/s. But most of the time since the outbreak of the crisis, withdrawal has remained below the granted volume (Sabesp, 2019) (Figure A23). The Cantareira system reached the end of 2018 on an upward trend (Figure A24).

Particularly from the first half of 2018, the circumstances that enabled less dependence on the Cantareira water for SPMR supply was also made possible by two major construction projects, providing interbasin transfers from the Ribeira River basin (6.4 m^3/s) and the Paraíba do Sul River basin (8.5 m^3/s), and adding new sources of water to the SPMR integrated supply system.

The 19.6 km Jaguari–Atibainha interconnection was started in March 2018. Some 13.2 km of pipeline and 6.4 km of pipeline tunnel make it possible to transfer an average flow of 5.13 m^3/s and a maximum of 8.5 m^3/s of raw water from the Jaguari dam in the Paraíba do Sul basin to the Atibainha dam in the Cantareira system. This means that when the Paraíba River is in normal conditions, with the greater part of its waters flowing into the Atlantic in the state of Rio de Janeiro, part of this flow can be stored in the Cantareira system.

It also allows a reverse flow (Atibainha to Jaguari) of up to 12.2 m^3/s, so the Cantareira system can also serve as a water tank to supply the Paraíba do Sul basin in times of drought in that basin. It increases the water reserve and security for the population of both basins (Figure A25).

This interbasin transfer stirred a debate between the São Paulo and Rio de Janeiro metropolitan regions which ended up in the Federal Supreme Court. Eventually, an agreement made by the states involved in this issue established technical rules and priorities for the water sharing among all users. Although São Paulo and Rio de Janeiro are 400 km apart, both regions fetch water from the same river, which runs for roughly 1000 km and crosses three Brazilian states (Kelman, 2015).

In April 2018 it was the turn of the São Lourenço producer system to be put into operation. The system allows the transfer of up to 6.4 m^3/s over 82 km, from the uptake point at Cachoeira do França dam (in the Ribeira River basin) to the western part of SPMR. The water is treated at the Vargem Grande Paulista Water Treatment Plant and the system also has reservoirs capable of storing 125 million litres. The structure is ready to supply up to two million people (today's and future demands) in seven metropolitan municipalities: Barueri, Carapicuíba, Cotia, Itapevi, Jandira, Santana de Parnaíba and Vargem Grande Paulista (which were partly supplied by the Cantareira system). Since Sabesp's water supply system in SPMR is integrated, the increase in water availability indirectly benefits the entire metropolitan population (Figure A26). A third interbasin transfer, of up to 2.5 m^3/s from the Itapanhau River basin, is under environmental impact assessment.

With the operational start-up of these two major construction works, the transfer capacity of the SPMR water production systems was increased from 3 m^3/s in 2013 (before the water crisis) to 12 m^3/s in 2018. Without them, the water storage in the Cantareira system and therefore in the SPMR integrated system would be much smaller (Figure A27).

Lessons learned

The worst drought in the history of SPMR could have led to social unrest. The storage level in the most important water source system fell to less than 5%. A combination of structural and non-structural measures, including an important collaboration from the population in using water more efficiently, were essential in facing this challenge. And much emergency water infrastructure was implemented in record time, allowing more flexible use of the nine reservoir systems in the region.

Today, SPMR is far better prepared to face much worse droughts than those foreseen in the various water resources plans produced since the 1960s. Based on a long time series and assuming stationary conditions, the 2014–2015 is such a rare event that one is tempted to consider it an outlier, with little relevance to planning. However, the prudent decision maker has to consider that the stationary hypothesis may be wrong, due to climate and land use changes, and that the wise attitude is to be prepared for the recurrence of similar events (the 'firm yield' criterion). For this reason, the government of the state of São Paulo and Sabesp have decided to invest heavily in new strategic infrastructure to secure a normal water supply even if the water scarcity of 2014–2015 returns.

Facilities such as the Rio Grande– AltoTietê and Jaguari–Atibainha interconnections have brought greater water security than we had before. These works will remain on stand-by most of the time, but can be triggered at any time when necessary.

Together with the strengthening of water infrastructure, reducing waste is another fundamental task to guarantee supplies. In the last 20 years, the state government has made major efforts in this direction, building infrastructure at a cost of more than US$

2.5 billion (partly financed by the Inter-American Development Bank). But much more needs to be done.

A key initiative is being launched by the state government for demand management, to include subsidies to help the poor instal water-efficient appliances; low-interest loans to help apartment owners instal individual metering; and regulations on non-potable water reuse. Sabesp is working to eliminate the maze of pipes scattered along the alleyways of the irregular but irreversibly established settlements. This of course requires articulation with city councils and the Public Attorney's Office. The Catholic Church, which included sanitation as a theme of its 2016 Fraternity Campaign, is another important partner.

Giving priority to work to underpin water security means, inescapably, that other equally important but less urgent investments have to be postponed. But it does not change the permanent goal of providing sewage collection and treatment services for everyone.

Another important lesson learned from the water crisis is that there is an urgent need to review how water supply and sanitation tariffs are established. When customers become more parsimonious in their water use, water utilities make less money. Sabesp relies solely on revenues from consumers for operation and expansion of the system supply. No subsidies from taxpayers are provided.

Society and the courts also need to understand that the purpose of sanitation is to maximize social well-being using the resources that are available, with water treatment and distribution having first priority, followed by sewage collection, and then sewage treatment. In other words, Brazil has to follow the example of developed countries: put people's health above any other consideration. It makes little sense, therefore, to divert the scarce financial resources of the water companies to 'environmental compensation' fees, which are intended to punish companies for polluting rivers or the ocean during the period that sewage is collected but not treated. Such punitive measures eliminate resources that are necessary for the expansion and improvement of the utilities' services.

Conclusions

The water crisis SPMR suffered in 2014 and 2015 is an example of the impacts of climate variability and land use change being felt in the water sector. These impacts were magnified by the fact that the drought hit a densely populated area. The consequences could have been catastrophic if structural and non-structural measures were not timely implemented.

Tapping water from the dead volume of the largest reservoir in the Cantareira system through the construction of coffer dams and the use of floating pumps was essential in this crisis. The interlinking of storage reservoirs was fundamental to provide flexibility in the joint operation of the three major water sources in the region. Structural integration, in the form of extending the system to sectors belonging to other water sources, was made possible by a series of operations, such as refurbishing the water mains and the pumping stations, and replacing or adapting boosters. Membrane filtration technology was used to increase water treatment capacity. The stock of treated water at strategic points was increased through the construction of sector reservoirs, minimizing interruptions in supply. Large investments were necessary to reduce physical and commercial water loss by replacing networks, branch lines and water meters, and by strict measures to control fraud.

Demand management was also fundamental in facing this crisis. More than ever we all feel how important water is. The debate on the subject has taken hold of society and those who make decisions in the political-governmental sphere. The adherence of more than 80% of the population of Greater São Paulo to the water rationalization attitude, as stimulated by the educational campaigns carried out by the state government and Sabesp, represents a great success. It was also made possible by the economic incentives imposed by the water utility, which significantly reduced consumption.

The contingency tariffs, with reductions for those saving water and increases for those using too much, worked admirably. However, the extension of these incentives for more than a year depressed the income of the water utility. Sabesp had to adjust its budget to anticipate investments in water infrastructure to improve water security, at a time when revenues were very low due to less water being sold, and at a lower price. The unavoidable result was a temporary slowdown in initiatives already underway to expand sewage collection and treatment.

As the Chinese saying goes, every crisis represents an opportunity – to innovate, to change paradigms, and above all, to implement sustainable long-term solutions. After two years of intense challenges and much hard work, the population and the political class are much more aware of the importance of water security. That daily per capita consumption (household use) remains lower than it was before the crisis shows that the behavioural change is here to stay.

The lesson learned is that in the future we need to be more resilient to the vagaries of climate, as we experienced again in 2018, when the metropolitan region was hit by another serious drought, just three years after the 2014–2015 crisis. This time, though, the critical situation was not noticed by population. This experience shows that good adaptation to climate change implies more infrastructure and good governance through strong public institutions, efficient regulatory agencies, adequate legal frameworks and the understanding of the population to use water parsimoniously and efficiently.

Disclosure statement

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