Sao Paulo's Water System: A Megacity's efforts to fight water scarcity

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ABSTRACT

The Metropolitan area of Sao Paulo is in the southeastern part of Brazil, located at the headwaters of the Alto Tiete River Basin. Water is supplied to the metropolitan region through three significant systems: The Cantareira, Guarapiranga and Billion systems, all facing harsh conditions, such as decreased quality of water, high rates of pollution and the divided opinion of stakeholders about the destination of their waters. The roots of Sao Paulo's water crisis are many, deriving in part from the city's location on a plateau where rain falls but then quickly flows away. Besides, regular and increasing drought, environmental degradation, pollution of drinking water, Poverty and illegal settling around the river basins, lack of water treatment, and conflicts in water consumption serve to exacerbate the crisis. Amidst this challenge, Sao Paulo needs to provide water security for almost 20 million inhabitants after experiencing the most severe water crisis in the record during 2014-2015. The paper describes the challenges faced by the city as policymakers consider the ways and means of achieving water security. The State Government of Sao Paulo and SABESP developed a strategic plan to address urgently the possible catastrophes that could be faced under these conditions, e.g., infrastructure development, encouraging conscious consumption and improvising national regulatory framework. The paper concludes that Sao Paulo must make better use of the water that it does have. There is a lack of coordination among the water authorities, which otherwise can be worked together with the principles of IWRM to achieve water security despite the climate conditions.

Key Words: Cantareira system, Climate change, Demand management, Drought, Infrastructure, Resilience, Water Accounting, Hydrological Cycle, São Paulo Metropolitan Region, Water Consumption Distribution, Water crisis, Water security.

I. Introduction

The latest United Nations report on cities around the world highlights Sao Paulo (Brazil) as the fourth megacity in the world, with more than 22 million inhabitants living in its metropolitan region (UN, 2018). The rapidly augmenting size of Sao Paulo has created many challenges for both the city itself and its citizens, as they have to deal with rapid urbanization, water management and disposal of residues (including water disposal), among others (Varis, 2006; Braga, 2006). Sao Paulo struggles with similar situations as other megacities in the Global South: Poverty, violence, crowding and one of the foremost complicated challenges, water scarcity, which can be challenging to understand due to the unique conditions of the region. Located in the highlands of the State, the Metropolitan Region of Sao Paulo enjoys 1,317 millimetres (51.9 in) of rain during the raining season (World Bank, 2018), its southern part of the region is covered by rainforest and

northwest by araucaria forest (Zambrano, 2016; Varis, 2006). Sao Paulo obtains its water from three river basins (The Cantareira basin, the Guarapiranga basin and the Billings System (World Bank, 2018) and requires that it is transported by large-scale interbasin water transfer (Varis, 2006).

In 2015, São Paulo faced a severe water crisis. The water level of the Cantareira reservoir was severely low, exposing its "dead volume" (Empinotti, Budds, & Aversa, 2019). Facing this crisis, the governor of São Paulo State and the CEO of the São Paulo State Water and Sanitation Company (SABESP), assured citizens that the city would not run out of water. However, despite the government's assurances, the citizens and businesses became habituated to water shortages from 2014 onwards. It is no surprise that all the promises were said amidst his re-election campaign (Empinotti, Budds, & Aversa, 2019). These plans reflect conventional 'water security' interventions: maintaining sufficient water of appropriate quality over the long term to reduce shortages and risks relative to human needs across a range of uses (domestic, industrial, agricultural) (Empinotti, Budds, & Aversa, 2019).

When considering human-water social relations, the hydro social cycle can be derived from the hydrological cycle and can be defined 'as a socio-natural process by which water and society make and remake each other over space and time.' This concept explores the idea that the need to manage water has an essential effect on the organization of society, which in turn, affects the disposition of water, which gives rise to new forms of social organization and so on in a cyclical process. Secondly, the idea that water and society have an internal relation, which means that particular kinds of social relations produce different kinds of water, and vice versa. Furthermore, the physical properties of water play an imperative role in the hydro social process, sometimes constructing and rupturing social relations (Linton & Budds, 2014), e.g. hurricanes, flood, etc. In line with the notion of the hydro social cycle, the definition of water security is more holistic now. For example, UN-Water has shifted the focus from the water itself to human capacity and its interaction with water, which had already been reflected in the definition of hydro social process. From UN-Water, water security is 'the capacity of the population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human wellbeing, and socioeconomic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability' (Water, 2013).

Answering to water's scarcity, in political terms, water flows increasingly in accordance with flows of capital and political interests (Linton & Budds, 2014). In 2014 and 2015, political obstinacy along with a severe drought pushed São Paulo, Brazil to the edge of a severe water insecurity (Millington, 2018). Despite the state government declared that only a minority was suffering without water, the reality was that the shortfall of water waved throughout the city and residents of the urban periphery were being disproportionately impacted. People of Sao Paulo had different experiences of water scarcity which were produced by the combination of existing inequities in city's water infrastructure and the differentiated abilities of residents to store water in small-scale reservoirs (Millington, 2018). Water is not just a resource to drive economies or a commodity to sell, but a necessary element of social sustainability. In the case of water security for Sao Paulo, it is

important to see how water is used, who has it, who does not, how decisions are made, and to revisit this entire hydro social system rather than just seek new sources of water.

Toward this end, the paper proceeds as follows: in the next section we present a background of Sao Paulo, followed by the key challenges faced by the city which policymakers consider the ways and means of achieving water security; the next section then describes Sao Paulo's current action plans, and finally, the paper concludes with discussion and recommendations in achieving water security.

II. Background

Sao Paulo is the capital of Brazil, and in 2019 ranked 10th in the Megacities Index (UN,2019).It is located in the southwest of Brazil, 30 miles away from the Atlantic Ocean as can be located in figure 2. It is home to 22,043,028 of inhabitants, of which about 11 million people live in slum-like conditions in the Municipal Region of Sao Paulo (MRSP). In 1950, the population of Sao Paulo was 2,334,038. Sao Paulo has grown by 1,159,982 since 2015, which represents a 1.09% annual change which indicates that the population will reach around 23 million by 2050 (Review, 2020). Once the principal industrial city in the country, Sao Paulo has also developed a strong services and other business market that draw to the city the most important companies around the world.

Fig.2 Sao Paulo's location in Brazil (Britannica, 2020)

The average per capita water use in Sao Paulo was about 180 liters per day as of 2011 (Bank W. , 2017). The amount of groundwater recharge and extraction is estimated at 15m3/s and 10m3/s respectively, and the latter is expected to increase (Bank T. W., 2012); nonetheless the region need to prepare for the demand forecast that provides 25 million of inhabitants. The city source its water from three principal water systems, the Cantareira, Guarapiranga and Billings systems which together provide the water consumed by 70% of the population (Document, 2009) and from the inter-basin transfers to the Alto Tietê come from the Capivari and Guaratuba rivers. In total there are eight production systems that supply drinking water to the 22 million citizens of São Paulo Metropolitan Area. Problems resulting from sewage pollution,

deforestation and uncontrolled urban expansion in watershed areas make the citizens suffer (Document, 2009). It also tackles extreme challenges of pollution of drinking water reservoirs that are surrounded by slums, water scarcity (leading to conflicts with the Campinas Metropolitan area in the north), inefficient water use, and flooding.

The main stakeholders in water management in MRSP are the State's government, the State's water and sanitation utility SABESP and 39 other municipal governments. A basin committee for the Alto Tietê Basin, which covers the entire area of the MRSP and supplies half of its water, brings together all stakeholders (Porto, 2009). Brazil has three administrative levels, and they are local (city councils), State and federal. In each level, there is a sectoral structure of secretariats (in states and local) and ministries (in federal) who are responsible for different issues, for instance, energy, water, agriculture and tourism (Braga, Flecha, Pena, & Kelman, 2008). Only the state and national levels own constitutional rights for water resource management. The local authorities entirely control the water supply and sanitation companies (Barbosa, Mushtaq, & Alam, 2016). The National Water Resources Management System is a political and institutional mechanism that defines the form of participation of stakeholders in water policy implementation. Representation is among national, State and local governments (these three categories cover up to 50% of representation) and civil society entities that act in the basin and users of the water (these two categories cover at least 50%) (Porto & Porto, 2008). The river basin committees set concentration on water management, facilitate conflict resolution, approve the river basin plans and design and implement charging systems. These committees have periodical meetings with local authorities and SABESP, to analyze the what is happening with the project and initiatives of the basin, the projects development and the needs for the future. Additionally, water agencies manage the funds from charging systems and provide technical and administrative support to the decision-making process (Barbosa, Mushtaq, & Alam, 2016). Figure3, illustrates the different levels of the National System for Water management in Brazil, with the participation from river-basin communities, the MRSP, and the public and private authorities from State, region and national level.

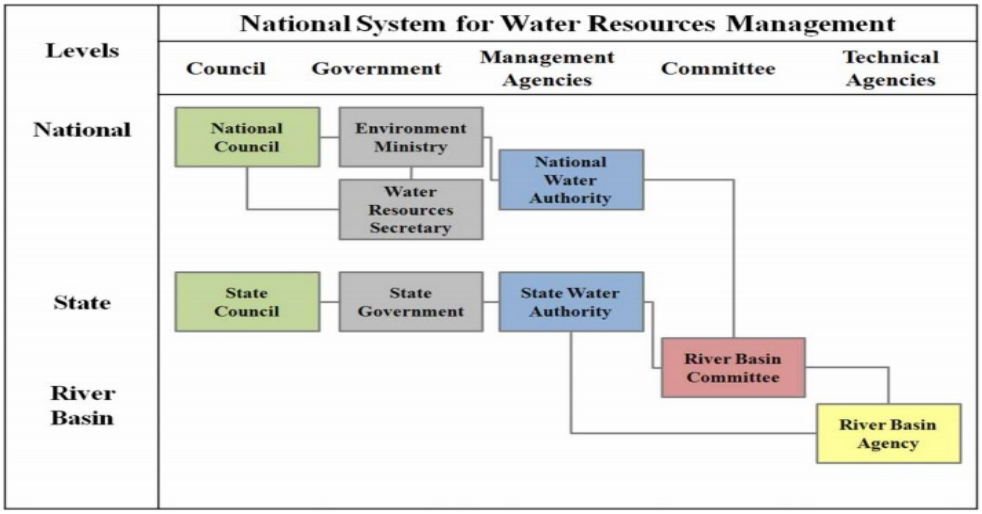

Fig.3. National System for Water Resource Management in Sao Paulo State. (Barbosa, Mushtaq, & Alam, 2016).

The state-level comprises of two major agencies: Water and Energy Agency (DAEE) and Environmental Agency (Cetesb). DAEE is currently linked to the Sanitation and Water Resources Secretary, which is responsible for quantitative water aspects, especially the issuance of water use permits. Cetesb is associated with the Environment Secretary and is responsible for qualitative aspects of water-related, specifically to protection and conservation (Barbosa, Mushtaq, & Alam, 2016). The organization that provides the services to the different communities is SABESP[1] in 93% of the municipalities including Sao Paulo city, the other 7% are attended by municipal companies in each locality.

Fig.4. Part of the Cantareira reservoir, in São Paulo state, in late January 2015. Source: Roosevelt Cassio, Reuters. 2015

III. Key Issues/Challenges

The rapidly augmenting size of Sao Paulo has created many challenges for both the city and its citizens as they have to deal with rapid urbanization, water management and disposal of residues (including water disposal), among others (Varis, 2006) (Braga, 2006). The challenges faced are not small, pollution of the clean water reservoirs, illegal settlements growing at the sides of the water

[1] Companhia de Saneamento Básico do Estado de São Paulo *(São Paulo, Brazil water and sanitation utility)*

bodies, which affect water supply and creates water conflicts. The battle here is cruel and unswerving (World Bank, 2018).

The most critical challenges to overcome are five: pollution of drinking water; poverty and informal settlements; state of calamity (drought and flood); conflicts of consumption; and lack of water treatment. We discuss each of these in turn.

Pollution of Drinking Water

When water starts going downstream Sao Paulo, in the highlands of the State, it begins a treacherous journey. At this stage, the condition of the water begins to be severely compromised, its qualities decrease, and when they arrive in the city, they are completely polluted.

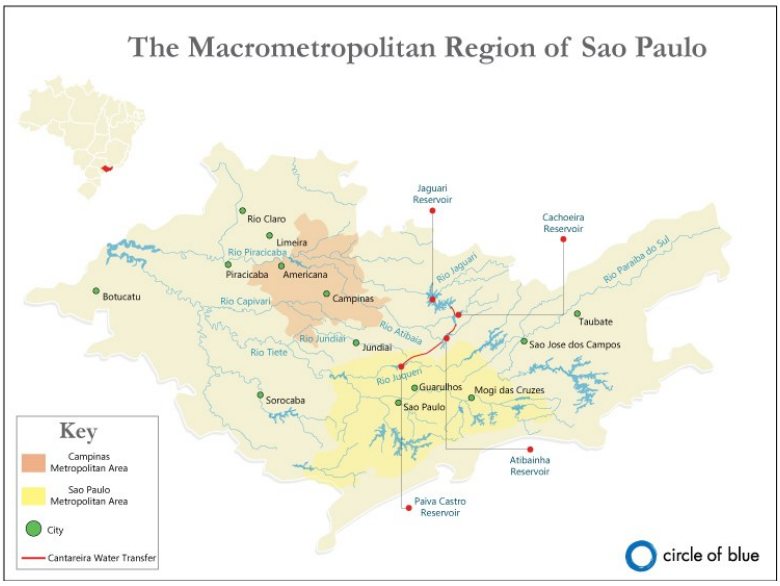

Fig.7. Water basins in Metropolitan Region of Sao Paulo. Source: Codi Kozacek Circle of Water, 2014.

As it is represented in Figure 7. the Metropolitan Region of Sao Paulo has different basins to source water from and shows (in red) the location of the principal basins that supply water to the area and the megacity. The water runs downstream from The Jaguar Basin until the lowest point at Paiva Castro Basin, where it is directed to Sao Paulo through tubes and channels, as depicted in Figure 8.

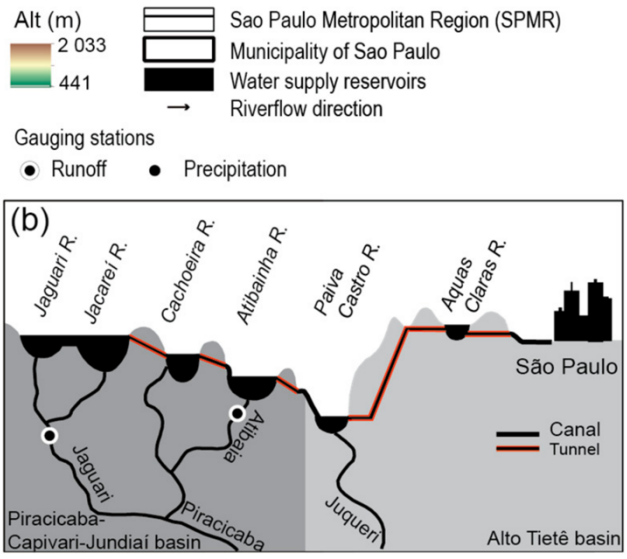

Fig. 8. Simplified representation of the Cantareira system (R: Reservoir). Source: (Milano, Reynald, Muniz-Miranda, & Guerrin, 2018)

All around, people have been constructing illegal settlements that surround the rivers basins (World Bank, 2018). People arriving at the Metropolitan Area of Sao Paulo are often under extreme poverty conditions, and their house structures lack sanitary systems to dispose of residues, affecting the area. The residues in the water generate sewage that produces hypertrophication, which is the growth of excessive quantities of algae and the excessive level of sediment in the water (World Bank, 2018).

The river basins also have another threat of pollution as they face industrial spillover, illegal dumping of industrial residues, agricultural pesticides and other pollutants that contaminate water and affect their condition for human use and consumption. (Braga, 2006, WSP, 2012)

Poverty and illegal settling around the river basins

The industrial wastage levels are also the result of the rapid and unplanned urbanization that the city has experienced in the last century. Sao Paulo does not have the appropriate infrastructure to cope with the millions of inhabitants that are living in all the metropolitan region while urban sprawl continues to grow as low-income citizens are continuously made to live in the city's periphery (Johnsson, R. M. F., & Kemper, K. E., 2005). According to the study of the World Bank, this is far more evident in the Alto Tiete basin; in this area, investments have been scarce, only 47 % of the water receives treatment and the rest polluted water continues its travel towards the rivers ahead and into Sao Paulo's system. (Martins, 2014, Braga, 2006, World Bank, 2018). The Alto-Tiesto basin is composed of a complex hydraulic and hydrological system. Though the basin has an extensive network of dams and pipes, the water availability of the region is still deficient (201 m3 /hab/an). The total demand for water consumption in the Alto-Tietê river basin exceeds the basin water supply: current public urban system supply is 63 m3 /s (serving 99% of the basin's population), irrigation consumes 2.6 m3 /s of the water supply, while industrial demand is met by both the public system (9.5 m3 /s) and by independent withdrawals and extraction of groundwater

(Johnsson, R. M. F., & Kemper, K. E., 2005). Groundwater is being extracted at an alarming rate where industrial wells take 35% of the share, household (private homes and apartment buildings) take 25%, and other services take 24%. The rate of extraction is considered 'alarming' because of a lack of motoring and control of groundwater use (Johnsson, R. M. F., & Kemper, K. E., 2005).

State of calamity (Flooding and drought)

Fig. 9. The Upper Tiete River Basin and Its Surroundings. Source: (Braga, B., & Silva, R. T., 2006)

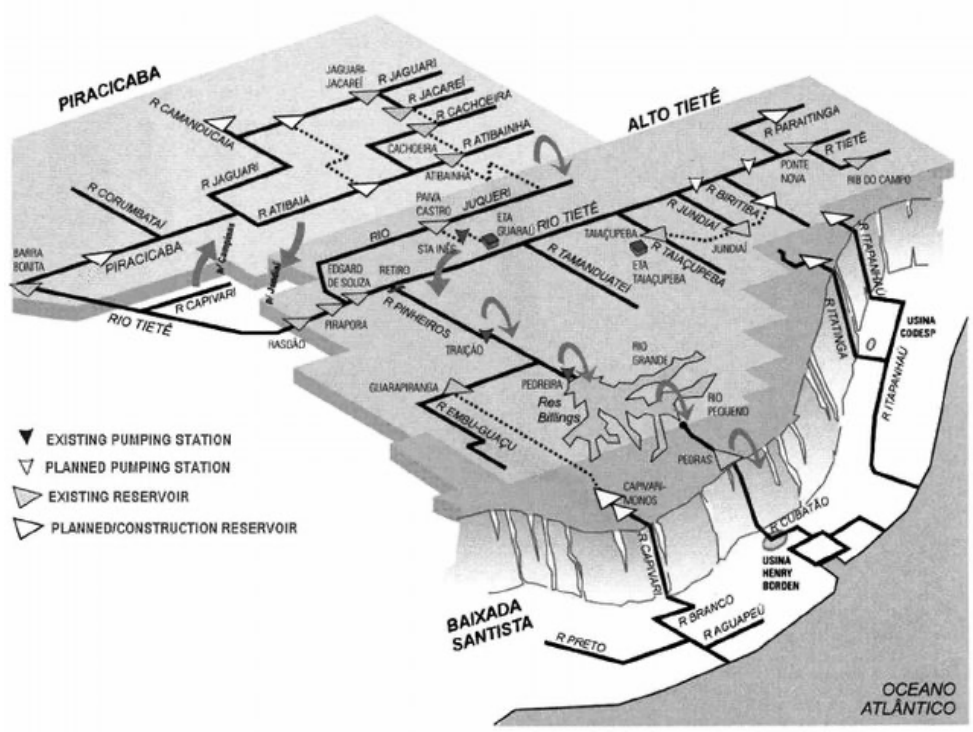

Figure 9 shows the integrated water management in the Upper Tietê River basin in the Metropolitan Region of São Paulo (MRSP). As seen in the figure, the objective was to transfer water from the dams (Edgard de Souza, Pirapora, Billings and Guarapiranga) towards the Billings reservoir by reversing its natural flow with the help of pumping stations (Braga, B., & Silva, R. T., 2006). Further, water was transferred to the Pedras reservoir while generating hydroelectricity at the Henry Borden hydropower plant using a 750 m hydraulic head. This innovative system increased the supply of hydroelectricity to more than 600 MW, which boosted industrialization, development, and urbanization of the region (Braga, B., & Silva, R. T., 2006). The rapid industrialization of the region and an inadequate plan of treating the water produced a deficient quality of the water in the upper Tietê River basin. These problems included the low Tietê river flow (average 17 cm/km), which made flooding a significant issue in the basin (Braga, B., & Silva, R. T., 2006). Floods in this basin bear a public health threat because of the poor water quality in the rivers.

From 2013-2015, Brazil suffered from a severe dry climate, which in turn severely affected the Metropolitan Region of Sao Paulo. Instead of the usual one or two weeks of drought, the region

had an extremely dry and hot climate in summer 2014 (Milano, 2018). This calamity was also seen in 1962 (with only 830 mm of rainfall than the average calculations of 1981-2018 of 1681 mm) (Coelho, 2015). As a result, there was a significant reduction in water-flows from 70% to 35% in the reservoirs, according to SABESP records, which adversely affected the water supply to the Metropolitan region. Eight water treatment plants operated by SABESP (Water and Sanitation Company of the State of São Paulo), supply all the potable water for SPMR (refer to Figure 10 circled areas). Their joint Maximum Production Capability (MPC) is approximately 73 m3 /s (Braga, B., & Kelman, J., 2016). The hydrologic record available before the 2014–2015 drought alone indicates that the firm yield from the rivers and reservoirs feeding these water treatment plants would hardly match the MPC (Braga, B., & Kelman, J., 2016). Nonetheless, if the hydrologic record is utilized to its full potential, including the years 2014–2015, the firm water yield reduces to less than 52 m3 /s. This 31% drop gives the most precise picture of the extent of the drought (Braga, B., & Kelman, J., 2016).

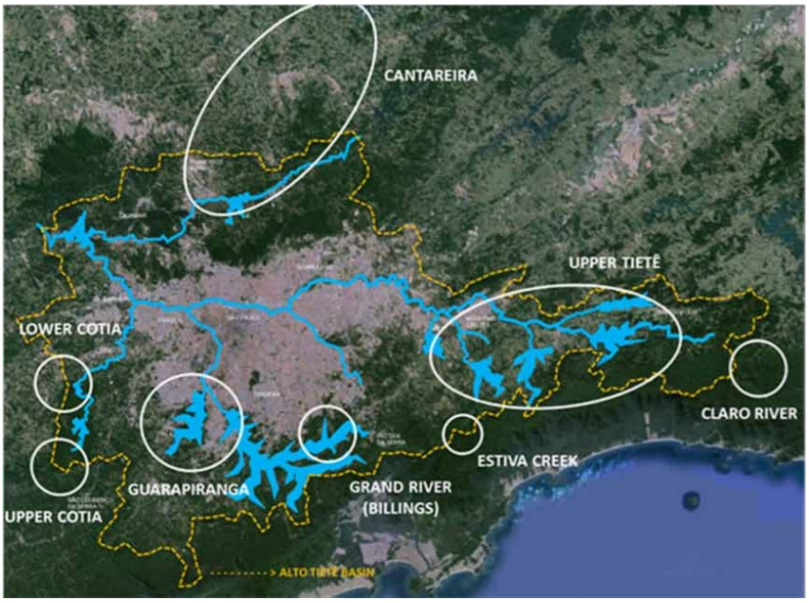

Figure 10. Water Sources in the Metropolitan Region of Sao Paulo. Source: (Braga, B., & Kelman, J., 2016)

Conflicts in Water Consumption

The water supply problem also possesses a conflict between two principal regions: the MRSP and the Piracicaba River basin (Figure 9). A water supply inter-basin transfer scheme was implemented to transfer water from the Piracicaba River basin to the MRSP in the 1970s. This system transferred water naturally to the downward stream, from the Jaguari, Cachoeira, and Atibainha Rivers (Figure 9) into the Paiva Castro reservoir, where water is then pumped to a treatment station 120 m uphill. This inter-basin transfer is named the "Cantareira system," facilitating a continuous transfer of 33 m3/s of water to the MRSP (Braga & Silva, 2006).The Cantareira system has been a significant source of water supply for the MRSP, and its establishment was made in the timeline when the industrial development of São Paulo State was not high when compared with the MRSP (Braga & Silva, 2006). Hence, at the beginning of the 1970s, water taken from the Piracicaba River basin had a small impact on the local communities. However, in the 1980s and 1990s, this region experienced an accelerated growth with high demands for domestic and industrial water supply,

irrigation, and wastewater dilution (Braga & Silva, 2006). Water demands are growing in these basins, and conflicting situations have become critical consequently.

On the other hand, the struggle for drinking water in Greater São Paulo also came into conflict with the influential hydropower sector (Johnsson, 2005). Section 21-XII of the Brazilian Federal Constitution gives the federation authorization to explore the hydroelectric potential of the water resources (Braga & Silva, 2006). As mentioned earlier, the Guarapiranga and Billings reservoirs were built for hydropower generation purposes in the 1920s and 1930s, respectively. Nevertheless, water treatment infrastructure in São Paulo failed to enhance at the same rate as the population, resulting in severe pollution of these rivers and, consequently, of the Billings reservoir (Johnsson, 2005). Even though politicians and engineers have known the importance of drinking water for decades, the priority had always been placed on hydropower generation, as was backed by the constitution.

Lack of Water Treatment

Investments in water treatment and collection network expansion commenced in the Alto-Tietê basin in the 1970s and increased significantly in the 1990s (Johnsson, 2005). Nevertheless, the scenario remains project deficient in coverage and substantial increases in water quality, e.g. only 65% of wastewater is collected, and of that portion, only 32% is treated (Johnsson, 2005). Many major municipalities have their sanitation systems, and these are exclusively underserved as SABESP is the only water company in the basin that treats sewage. SABESP's most recent forecasted figures indicate a significant increase in sewage collection, reducing the deficit in coverage from 17% in 2005 to 7% in 2020, but no figures for increases in wastewater treatment has been estimated by SABESP (Johnsson, 2005).

IV Efforts to Achieve Water Security

After the 2014-2015 drought it was clear for Brazilian authorities that the situation needed to be handled in order to prevent the even from happening again. Different measures were taken by Central and State government and by the SABESP and NGOs in the State of Sao Paulo.

State Government and SABESP developed a strategic plan to address urgently the possible catastrophes that could be faced under these conditions (Braga, 2016). The plan contained the following specifics issues: Institutional strengthening at all levels toward sustainability and water protection. Development of institutional tools and technical instruments that support the measurement of all the dimensions involved in water security; development of instruments for community and public participation; community mobilization and environmental education and finally rehabilitation of basin in terms of ecological recovery including natural infrastructure, residue and waste management (Tundisi, 2016). These measures will increase the water security for the region, the city and their inhabitants.

Let us briefly look at 5 key issues: infrastructure development; conscious consumption; regulatory frameworks and practices; the re-agua project; and the communications campaign.

Infrastructure Development

At micro level, one example of how SABESP intervene the reservoirs to make sure the flows continue to run toward the city, was the installation of floating pumps and the building of channels and cofferdams, through which water was pulled upstream avoiding dead storage and contamination, especially at the Jaguari point, as pictured in Fig.9.

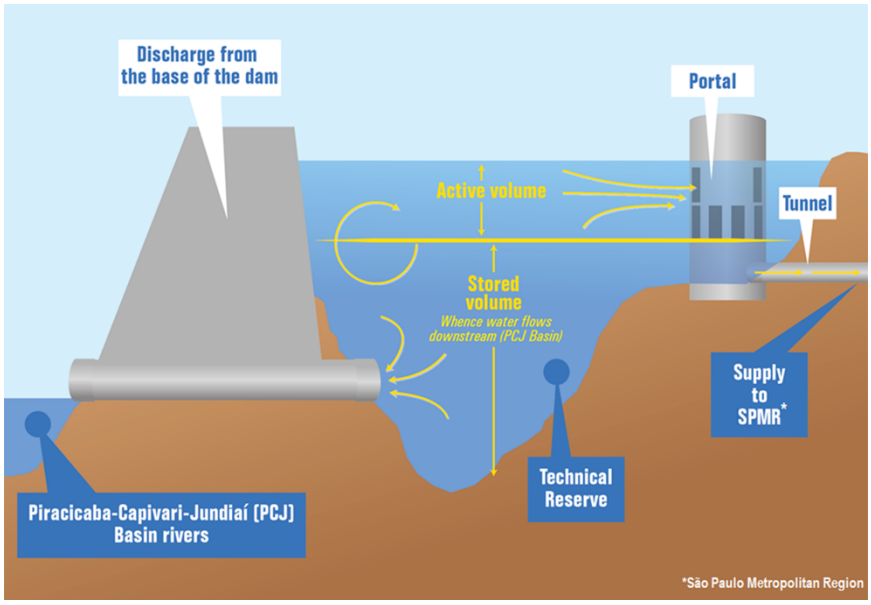

Fig.9.Tapping the dead storage of Jaguari Reservoir. Source: Braga, 2016

There were also many other efforts made as almost all 8th systems were improved in order to enhance their capacity. The result of this interventions was that areas that only provided water from the Cantareira system, were able to source from other reservoirs leveraging the demands of consumption in the region (Braga, 2016). This measure achieved that 3,5 million people start having available water from the Grande River, the Upper Tiete and Guararapiranga, instead of only Cantareira system.

Efforts to conscious consumption of water in communities

Since 2000, different efforts have been made in order to incentivize through economic instruments the protection of the water systems and ecosystems restorations (Tundisi, 2016). In 1997, the Presidency of the country regulated the Water Resources Policies and Water use regime number 9433. It contained the elements to protect the reservoirs and watershed, allowing SABESP and other governmental institutions to invest in their reforestation and restoration. Every year 1.5 million dollars have been invested in these projects and have had a positive impact on the global governance of water. These measures have also motivated economic growth and created jobs along the banks of the rivers through the actions of the environmental efforts, the reforestation and the protection of biodiversity along with supporting and enhancing environmental education

on these communities. The results of the measures can be observed in fig.10, along with the stratification of discounts offered to communities (IWA, 2016).

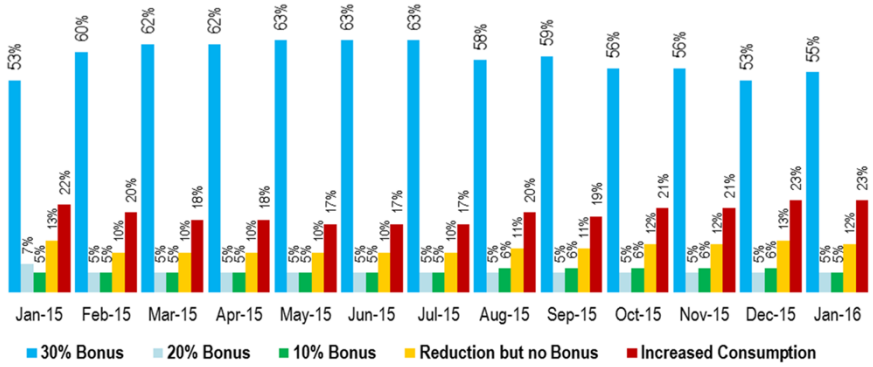

Fig.10. Impact of economic instruments on water consumption in SPMR (IWA, 2016)

National regulations and framework

In Brazil, Law 9433 of 1997 established the framework of the National Resource policy and the National Water Resource Management System (NWRMS) proposing a new strategy throughout the application of economic and planning elements. (Veiga, 2013) This framework is composed of the National Water Resources Council (NWRC),State Water Resources Councils (SWRCs), River Basin Committees (RBCs), State Water Resources Management Institutions (SWRIs) and Water Agencies(WAs). It can also be concluded from the literature reviewed, that has followed the international trends, based on the principles of decentralised hydrographic basin management, the participation of different stakeholder through the basin committees and the valuation of water as an economically and public asset (Veiga, 2013)

Sao Paulo Water Recovery Project (Re-agua)

This project supported by the World Bank, was planned to tackle the State's water shortage issue by increasing the supply of clean water in the State's five most important watersheds. Plans included (a) increasing the volume of water recovered by reducing real water losses and promoting rational water use in public schools; (b) improving water quality by improving wastewater systems; (c) enhancing water quality by improving wastewater systems. The project was directed by the Sao Paulo State Secretary for Water Resource along with other stakeholders in the region. It benefited 97.400 inhabitants of five different critical neighborhoods along the river basins. Through its activities related to reducing and controlling real water losses and promoting rational water use (World Bank, 2018).

Communication Campaigns

The government and SABESP developed different campaigns that encourage community in general to improve the consciousness of water consumption through different media. Adding to the increasing press attention, eight promotional campaigns were also carried out in 2014, with more than 3,000 TV ads and another 13,000 radio advertisements, in addition to news and magazines, predicting that every resident of São Paulo was reached at least 40 times by water-saving messages (Bragaa, 2016).

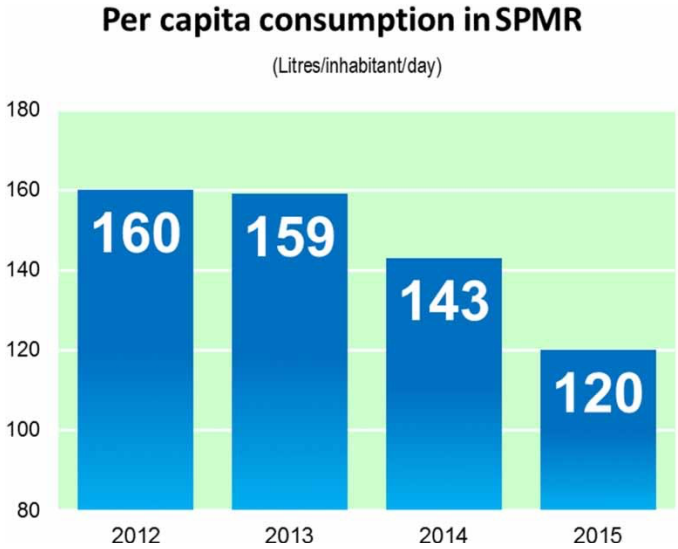

Fig.11. Impact of communications campaigns over water consumption in Sao Paulo. Source: IWA, 2016.

As shown in Figure 11, the results of the communication efforts are visible, with a reduction of 40 litres per person per day in Sao Paulo city and region. As the communications keep being part of the local government and SABESP strategy, the results are expected to last over the years to come. One of the more visible and hopeful results is the decrease in the consumption rate from the Cantareira System.

IV. DISCUSSION

After reviewing the situation in Sao Paulo Metropolitan Area and the city, it is clear that there are many challenges and efforts necessary to achieve water security for the thousands of inhabitants and industries. These challenges do not arise only from the water system but also from the socio-economic, environmental, structural and governance systems. They must be addressed to secure water service for all-region.

Located in the highlands of the State of Sao Paulo, the metropolitan area is supplied od water by different basins. The Cantareira system, the most affected by the drought during 2013-2015, is now supported by new infrastructure projects operating in the region. This action allowed more people to have available water from other sources like the Grande River, the Upper Tiete and Guararapiranga, instead of only the Cantareira system. The region's greatest threats lie in effect on climate change over the basins, that have developed in higher temperatures and longer dry seasons, resulting in severe droughts. The other major challenge result from from the contamination the basins receive from the numerous slums and illegal settlements in the area.

These aspects will affect the socio-demographic system, resulting in more people joining illegal settlements and their survival opportunities during the droughts. It also severely affects businesses and industrial activities, resulting in job losses and affecting the region's economic development. For addressing these challenges, clear governance policies and aids need to be developed before the occurrence of these events.

To limit environmental effects is necessary for water, waste management and sewage institutions to work together on new measures and campaigns at domestic and industrial levels. It should be noted that not all of them work together in the metropolitan region. To 2019, different institutions are involved in making the service different in the city than in the metropolitan area. This disconnection is notable, for example, in the sewage area, which has not covered all the metropolitan areas, especially in poor neighbourhoods that are attended differently through municipal administrations. The municipality's water supply is composed of two types of systems: Metropolitan Integrated Water System (SIM) and separate municipalities that are attended by their water management systems. The Municipality of São Paulo is served almost entirely by the Integrated System (SABESP,2019). Also, there are multiple private initiatives to maintain and improve the conservation of water basin and natural infrastructure that focus on improving conditions of the land, the jungle and natural forest in order to create positive impact in the contamination of water and air, reduce gas emissions and protect water sources all along the system.

It is also worth mentioning that the billing system does not encourage water savings and is also not fair, as consumption ranges organize it, making it the same as being in the lowest or highest range. The need here is to arrange the collection of the tariff so that, as experts have suggested, the population pays a fixed amount for the delivery of the service plus the value of the m3 consumed over the month. The plan is intended to strengthen the tariff's ability to encourage the fair use of energy while maintaining the provider's economic and financial balance. This programme must also shift to a model of different tariffs: water, sewage collection and sewage treatment. All prices will be reflected in the same account so that the consumer recognizes what service he pays for. This proposal is expected to increase service efficiency based on a more transparent and fair remuneration model.

In terms of the amount of water generated, the root of the problem is the discrepancy between the water consumption factor in São Paulo and the fact that the municipality is primarily concentrated at high quotas in Alto Tietê. This condition caused a disparity in the local water balance, increasing exposure shortages. To solve this setback and provide the whole RMSP, the system has been integrating different producer systems in the basins, each more and more distant connecting the municipalities. Other measures must be addressed to increase supply capacity like management actions on demand, education for environmental protection and loss reduction on consumption.

Concerning distribution, the current situation is approaching universal access with 96.1% coverage and 93.5% service. Service is the relationship between total active water savings and total serviced households. The regional authorities have implemented micrometres in unregulated areas through the Água Legal Program (SABESP, 2019). Although SABESP cannot formally take this action in irregular households, agreements with the municipalities have allowed the measurement of water consumed in these areas and the formalized connexion of more than 32,000 points.

Regarding water losses, two components describe them in the water-supply system: actual and estimated. Actual losses represent leaks in pipes and overflow in reservoirs and filtrations. In contrast, estimated losses can be the result of fraud, under-measurement of water metres, and flaws in the SABESP internal system. The indicators of real and total losses in the Municipality of São Paulo are 227 L / links.dia and 342 L / links.dia, respectively. In order to minimize losses, SABESP carries out numerous activities: reducing actual losses — fixing leaks, investigating non-visible leaks, handling distress, enforcing categorization works, enhancing infrastructure, and reducing leakage. Estimated-Losses measures like the calibration and adequacy of water volume measurement instruments, and optimized water metre replacement, and increasing the commercial management to increase commercial registration, consumer verification and decrease frauds.

Based on SABESP studies, the Metropolitan Region São Paulo has a potential of 1.2 million/ m^3 / year of reusable water for non-potable uses. The advance on this project depends on demand non-potable water in the region by industries, agricultural practices and maintenance public. With the region's critical water availability situation given the size of the consumption, these practices are increasingly important. Today, according to SABESP, advances in progress refer to improving the treatment process for reuse. However, the challenge also lies in incentivize the businesses to use reused water instead of sourcing from the watershed and the water management system.

V. Conclusion and Recommendations

After researching about Sao Paulo's water management system, it was found that Sao Paulo was hit by drought in the most adverse manner, and the recent Brazilian climate projections indicate a significant decrease in rainfall in the southeast, central and northeast region, coupled by a temperature increase. The rainfall decrease could reach 20% below the historical average by 2040, and to an impressive 40% of the average by 2100 (Júnior et al., 2016). These trends should logically drive nations to a more flexible approach to water use and management, as espoused by the concept of Integrated Water Resources Management (IWRM). The issue of deforestation and its adverse effects on retention and pollution of water should not be taken lightly. However, we have seen a lack of coordination among the water authorities, which otherwise can be worked together with principles of IWRM and achieve water security despite the climate conditions. Keeping these points in mind, our recommendations are as follows:

- In the case of Metropolitan Regions, low water security is attributable, in addition to poor water quality, to the demands of large urban agglomerations, which are mainly polluted without proper treatment by domestic sewage. The problem of providing water in these areas, with greater economic and industrial dynamism, is connected to the regular use of interdependent water supplies, many of which are marked by water transfers between basins and collapsing into disputes over water use. Furthermore, the utilisation of these outlets is typically achieved by distributed networks, which support many overlapping and interconnected municipal offices, involving an operationally complex water network. That was also the remedy used in the semiarid area to feed the people.

- Among the critical issues to answer are the degree of effect population and/or delay of new requests in assembly. Predicting strategies and systems that represent the most disadvantaged communities and strengthening systemic control of urban sanitation are key concerns that arise on many of the identified topics about the different components.
- Increasing understanding of the different contexts of the municipality and the conditions of the main sanitation components, especially in areas that are still lacking infrastructure; Instead, the information is collected and compiled so that it is used efficiently for decision-making, response collection and the involvement of multiple actors in surveillance and social regulation.
- Advance in active transparency, with regular dissemination of data and assessments regarding municipal contexts related to sanitation components to be used in the development of new project and frameworks for future developments in infrastructure, policy and billing initiatives.
- There is urgent need of efficient institutional structuring for integrated sanitation planning and management, with strategic distribution of functions for each activity and needs to address.
- Integration of the information systems of the City and the Metropolitan Area and other bodies involved in the services sanitation, bringing greater efficiency to tasks and carrying out municipal processes. And to foster the integration of services in such a way that it can cover the whole metropolitan region with the appropriate services to protect from water pollution and scarcity at the same time.
- For maintaining an active civil society, the city requires new models for more efficient participating initiatives, that can enable and consolidate the assimilation of proposals or issues brought by different actors to decision makers. It is also interesting to promote Incentive to initiatives that raise awareness about sanitation, accelerate and improve the quality of care, control of services, among others.
- Establish integrated solutions adapted to local conditions for structures and service provision for environmental efficiency of systems, with goals that combine in relation to energy efficiency, resource recovery and reduction of negative impacts generated. From this point new service delivery models can be developed, allowing the care of more vulnerable populations vulnerable in time appropriate to criticism identified issues.
- Restore potable water quality in water sources like reservoirs for Guarapiranga and Billings, via the administrative articulation of the three Government spheres (State, municipal and national).
- Pursuing green water to preserve blue water can carry a potential opportunity to achieve water security. Restoring nearly 10,000 acres of the forests in the Cantareira Water Supply System's watershed could reduce sediment pollution by 36 percent within 30 years, which will further reduce turbidity by almost half and potentially boosting water supply when it is most scarce. If establishing a natural infrastructure plan gets federal approval, then all it will need is planting trees in the right places (Ozment & Feltran-Barbaeri, 2018). The strategy proposes to partner with farmers, rural landowners, and other surrounding stakeholders to implement for constructing the natural infrastructure. Fortunately, the water-dependent companies will not have to build relationships from scratch because

several non-profit and government-led programs already studied and invested in natural infrastructure for water in the Cantareira (Braga, 2018).

- Even though the current water policy is based on principles of decentralization, integration and participation, the situation in practice is rather opposite. A gap between policy and practice is observed in the Sao Paulo State, which limits the accomplishments of water policy objectives and policy implementation. The water policy in the State of Sao Paulo can be considered to align with international approaches for water resources management. In our study, it was found that the policy principles are not sufficient to guarantee good practices. In order to shift from principles to practice in Sao Paulo, several issues need to be addressed, which includes constructing the decision-making authority of river basin committees, clarifying the roles and responsibilities of agencies, and reducing fragmentation, by facilitating integration between organizations at different government levels and sectors (Júnior et al., 2016). For decentralization to be effective in Sao Paulo, there must be coordination between organizations and a balance of power between upper and lower levels of the governance arrangement; lower levels must be empowered to make decisions; however, upper levels must still hold the authority to drive the decision-making process. Water managers should prioritize the useful application of the three principles of IWRM: integration, decentralization, and public participation (Barbosa, 2016).

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