Cape Town Water Crisis 2017
Analysis from International Experience

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Executive Summary

This report summarizes the results, conclusions and recommendations[1] of an assignment by the World Bank as part of the World Bank program of support to the South African National Treasury. The objective of the assignment was to provide advice to the National Treasury and the City officials of Cape Town on: (i) the short term augmentation and demand management plans; and (ii) options and key decisions that could be useful to maximize the continuity of approach and goals between short term emergency measures and the necessary medium and longer term measures of the city's water resilience plan.

***Background**. Cape Town's water scarcity situation is the result of three years of severe droughts, according to some estimates the worst suffered by the city since recorded data exists, and to an almost complete reliance for its supply on surface water stored in dams used by both the city and agriculture, under a multipurpose operation managed by the national agency in charge of water resources.*

Cape Town's water scarcity is in line with what is being experienced in many other cities around the world. Current situation is the result of the steady decline the region has seen in the amount of water feeding its dams, and the large influx of additional population to the city, but this in by no means an extreme case when compared to the challenges experienced by other cities. However, with the information available early 2017, according to reliable models, the dams that supply the city were predicted to be below the levels that allow water extraction by early 2018 and the city would loose its only source of supply if consumption patterns from previous years did not change and no new supplies were made available. Such a situation is indeed a crisis comparable to the extremes of what other cities have faced.

***Results until Now**. The city has done an excellent job to respond to the emergency, adapting the resilience plan recently adopted to work on three main lines of action aimed at maintaining the supply of water despite the drought: (i) developed an emergency program of investments to augment supplies in record time; (ii) introduced an aggressive demand management program; and (iii) established relations with other water users in the region to increase the availability of bulk water to supply the city. This response has all the elements of comparable programs in other cities and initial result indicate that Cape Town would be able to maintain adequate water services in the coming summer season and avert the worst part of the crisis.*

Although the augmentation plan is generally technically sound, several changes were recommended to the original investment program. These recommendations include: (i) give the highest priority to the development of groundwater sources, particularly in the shallow Cape Flats aquifer (together with serving as a rapid response to the crisis, groundwater and aquifer recharge and management should be one of the pillars for long-term water resilience for the city); and (ii) reformulate the proposed plan to build emergency desalinization plants to reduce the number of small container type plants originally proposed (in the order of 7-10 Ml/d) and replace these by a limited number of smaller plants for specific sites and one larger in the harbor (120-150 Ml/d). Additional desalinization plants should be considered as part of the longer-term resilience plan since desalinization needs to be another of the pillars of a diversified supply for Cape Town.

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[1] The conclusions and recommendations expressed in this report are the sole responsibility of the author and do not necessarily represent the position of the World Bank group or the National Treasury. The author wants to express its appreciation to the rest of the team that accompanied him in the visit to Cape Town from November 1 to 14, David Savage, Nishendra Moodley, Chris Heymans and, specially, Rolfe Eberhard, whose comments and contributions have helped enormously in the completion of this assignment. The author also wants to thank the City Executive Mayor and her team, as well as the water department and emergency response teams for their support during the visit

The battery of demand management actions which has been implemented by the Water Department has all the elements of best-practices. These include an extensive communication campaign, replacement of meters with cut-off devices, pressure management of the network and flow reducers. Additionally, the city has increased tariffs for highest users, introducing an aggressive economic incentive to reduce consumption. System input at the end of the visit was in the range of 600 Ml/d, still short of the target of 500 Ml/day.

The agreement the city has initiated with other users in the basin (primarily the agriculture sector) can increase the allocation from multipurpose dams to Cape Town by about 40 Ml/d during the coming six months, if completed with sufficient guarantees. There is significant potential to trade, transfer or purchase large amounts of water during the crisis, at significantly lower cost than other options being considered.

***Challenges**. To make effective the emergency program, the city needs to ensure that there is strong coordination among the different lines of action and between the different units involved. To achieve such coordination it is recommended that the city adopts a matrix management structure for the resilience program and institute three points of focal responsibility for (i) demand management; (ii) investments in augmentation; and (iii) interbasin relations and water trading, which should report directly to the Resilience and Services leaders on these three lines of response to the emergency.*

Aggressive demand management actions like the ones being implemented in Cape Town do have an impact on water consumption during the emergency, but also in the longer term. Of special importance is the impact of demand management on the highest consumption block: eliminating band 6 consumption would result in a reduction of water use of only 10 Ml/d, but would reduce the department's revenues by about 40%, putting at risk its financial viability. It is urgent: (i) a decision on how to finance emergency investments (it is suggested that these should be financed separately from longer-term actions, through instruments different from volumetric tariffs, a levy calculated on the basis of property values was discussed); and (ii) initiate the reform of the water sector delivery model and revenue generating mechanisms and tariffs structure to adapt them to the new situation that water scarcity represents.

Agreement with other users to increase the amounts of water available to supply the city is probably the initiative with the highest potential yield at lower costs. Since South African framework for managing water resources keeps the responsibility for managing water resources (and guaranteeing the availability of supplies) in a national agency, the issue of conflicting responsibilities needs to be addressed if the investments and initiatives foreseen in the response to the emergency are to be carried out efficiently and with proper legal support, but also to establish the framework to be able to respond to future emergency situations and for long-term resilience. International experience has many good examples of water trading schemes, water banks and user associations water markets, that could be adapted to the specific conditions of South Africa and Cape Town particularly, making sure that those instruments are not applied for the benefit of a few only, and that no one involved in the water cycle (one example are farm workers) is not better off after their application.

***Options for Long-Term**. Cape Town is not an exception, new challenges complicate "Business as Usual" for water services and cities are being forced to look beyond their traditional practices and sources for supply. To respond to these challenges cities in the world have already adopted a change in their Paradigm and implemented new principles for their operation and service delivery criteria, which could be applicable to Cape Town. These include: (i) diversifying water sources and improving the reliability and independence of their supply; (ii) becoming active beyond the city limits through institutional arrangement that allow them to operate at different geographical scales; (iii) seeing droughts as a reality to be considered in any plan and for which*

agreed and clearly established protocols for gradual response are prepared and adopted by wide consensus, which cover from which sources to use according to their different cost, to triggering mechanisms for the reallocation of resources among different users in the basin; and (iv) finally, but probably the most important element of the response to droughts, in most of these cities demand management, understood in its broad sense of efficiency in the network and reduction of excessive consumption, has become the cornerstone of any resilience plan.

Although much has been achieved already with the demand management program lowering consumption to about 150 lpcd, additional reductions are possible without diminishing quality of life or putting at risk the health of the population. The decision on which targets to achieve must take into consideration the marginal cost of saved water. The objective should be to reach a sustainable situation where efficiency in the network, incentives and communication should form the core of the demand management program, rather than physical limitation to consumption.

Financial sustainability of the water department needs to be part of the equation too. However, it should not be pursued by transferring inefficiencies to consumers through higher water tariffs, but through improved efficiencies in operation, better collections and a reform of the service delivery model and tariff structures. Crisis are perfect occasions for sector reform.

Background. Framing the WS&S Situation in Cape Town

Cape Town's water scarcity situation is the result of three years of severe droughts, according to some estimates the worst suffered by the city since recorded data exists[2], and to an almost complete reliance on surface water stored at three large dams (130-480 Hm^3) and three medium size ones (30-50 Hm^3) for its supply. The larger dams are used by both the city and agriculture, under a multipurpose operation managed by the national agency in charge of water resources. All the dams are part of an integrated system. Figure 1 illustrates the evolution of dam stored volumes (as percentage of total capacity) for the last four years.

The city has been able to keep a 24/7 continuous water supply service until now despite these extreme challenges thanks to significant work undertaken in recent years and in the months since the beginning of 2017. Water consumption has been decreasing in the last few years and, after the drought became apparent and demand management strengthened, it is now half of what it was just few years ago (300 to 150 lpcd). Although water supply services do not reach all Cape Town population with in-house piped connections because of informal settlement (8% of water delivered is not metered, 4% to informal settlements) and significant work is still needed to reach full in-house supply coverage, physical losses are low, estimated at about 9.5% of water produced[3]. On the other hand, 100% of wastewater collected is treated, of which 9% is reused for non-potable uses with a network of over 200 km length. Despite some deficiencies it might be argued that Cape Town's water services are managed within most normal standards[4].

Under the current administration the city adopted a Resilience Plan for medium-term that includes a vision for the water sector taking into consideration potential changes to its supply because of climate change. Coherent with this Plan the city declared the Emergency Situation in May with targets for reduction in consumption and additional bulk production (500/500 Ml/d), which were aimed at preventing water levels at the dams from falling below the usable limits (estimated at 10% of total capacity, without any additional action on the intakes or dams).

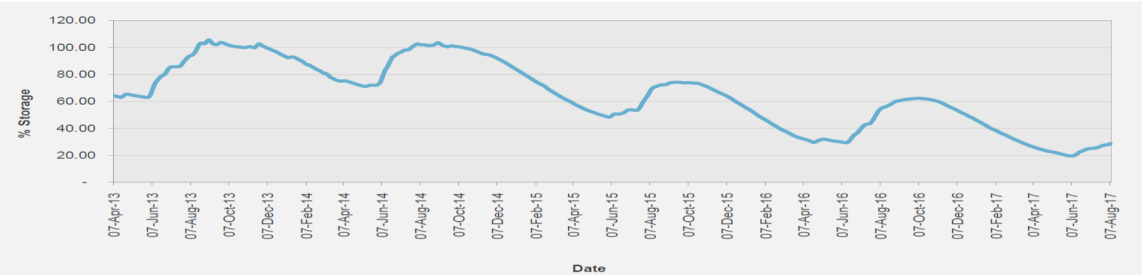

Figure 1. Total Stored Capacity in the Dams supplying Cape Town

Cape Town's water scarcity is in line with what is being experienced in many other cities around the world. Current situation is the result of the steady decline the region has seen in the amount of water feeding its dams in the last three years, and the large influx of additional population to the city, but this in by no means extreme when compared to the decline experienced by cities like Perth (see figure 2 below which shows the evolution of inflows into the system of reservoirs supplying Perth) or Amman (which has seen a sharp influx of close to 40% of its pre-conflict population after the war in Syria), and can be managed with a combination of actions available to

[2] Without incorporating recent years in the historical hydrological data, the drought from this year corresponds to a 200 year drought

[3] According to data in the 2016 annual report

[4] It is not the objective of this report to make an assessment of the current functioning and operations of the Water Department, but some minimal considerations were required to frame the situation. Making such assessment is strongly advised

the city and regional institutions and the resilience plan launched by the city. It is important to point out that, according to South African water sector framework, the responsibility for water resources management and for guaranteeing the availability of water resources to urban centers and metropolitan areas is not part of the cities' mandate, but resides with the national agency.

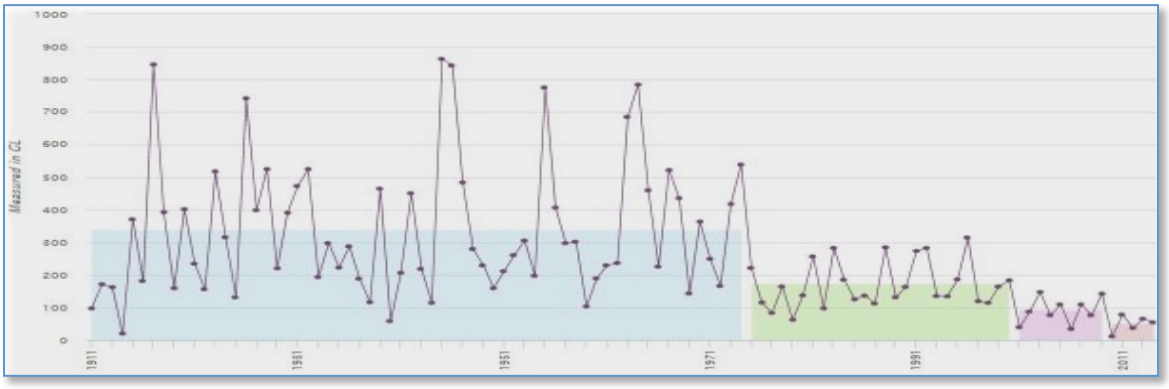

Figure 2. Inflows to Perth's Reservoires

To better understand how stressful the water scarcity situation in Cape Town is, the following box summarizes data from several other cities in the world to compare, grouping these cities in three types or scenarios that could be associated to Cape Town: (i) cities where external transfers from another basin is not possible (or lack security) and total conventional available resources are thus physically limited; (ii) extreme scarcity environments; and (iii) basins with limited resources:[5]

Box 1. Representative figures from Water Scarce Cities

a. Singapore or Malta, "island" water scarce cities?
- *Singapore*: 2300 mm/y; 150 lpcd; 45% ExtIBTr; 24/7
- *Malta*: 530 mm/y; 135 lpcd; 0% ExtIBTr; 24/7

b. Las Vegas, Windhoek and Amman, "desert" water scarce cities?
- *Las Vegas*: 106 mm/y; 1000-600 lpcd; 94% ExtIBTr; 24/7
- *Windhoek*: 340 mm/y; 290 lpcd; 60% ExtIBTr
- *Amman*: 270 mm/y; 125 lpcd; 0% ExtIBTr (74% GW); IS

c. Murcia, Perth and Jaipur, "basin water scarce" cities?
- *Murcia*: 360 mm/y; 155 lpcd; 39% ExtIBTr (32% desal); 24/7
- *Perth*: 670 mm/y; 390 lpcd; 0% ExtIBTr (73% GW); 24/7
- *Jaipur*: 490 mm/y; 155 lpcd; 83% ExtIBTr; IS

Cape Town: 500 mm/y; 150 lpcd; 95% ExtIBTr; 24/7

From these figures it can be said with confidence that Cape Town is within average water stressed cities, but definitely not one of the extreme cases. However, with the information available early 2017, according to reliable models, the dams that supply the city were predicted to be below the levels that allow water abstractions by early 2018 and the city would loose its only source of supply, *IF consumption patterns from previous years did not change and no new supplies were made available*. Such a situation is indeed a crisis comparable to the extremes of what other cities have faced, say Malta in the early 90s, Barcelona or Cyprus in early 2000s, to mention

[5] Figures include the average rainfall in mm/y; consumption in lpcd; percentage of supply from external interbasin transfers (ExtIBTr), and Intermittent Supply (IS) or 24/7 continuous supply

some other cities that exhausted their traditional supplies. As such, the situation in Cape Town fully justified the actions and response by the city, but also opens opportunities to undertake a complete assessment of potential reforms and changes the sector might require, particularly with regard to service delivery criteria and tariff structure. *A crisis should not be wasted without being used to undertake needed reforms.*

Actions and Results until Now

The city has done an excellent job in three main lines of response to maintain the supply of water despite the drought: (i) developed an emergency program of investments to augment supplies; (ii) introduced an aggressive demand management; and (iii) established relations with other water users in the region to increase the availability of bulk water. This response has all the elements of comparable programs in other cities of the world that face similar problems (Singapore, Malta, Murcia, Perth, …) and initial result indicate that, as long as efforts are not weakened in coming months, Cape Town would be able to maintain adequate water services during next summer season and avert the worst part of the crisis.

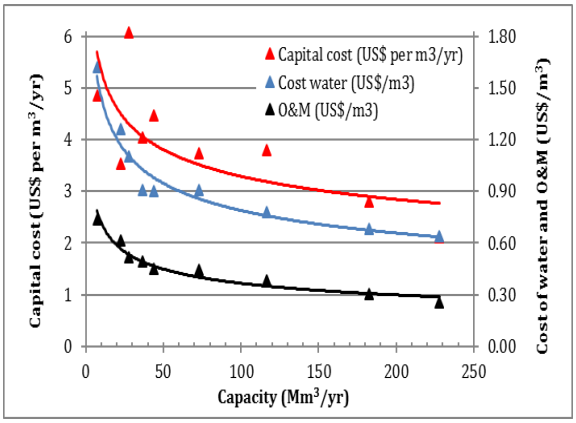

Figure 3. Desalinization costs (2016)

Supply Augmentation. In record time the city has designed a technically sound emergency package of investments to diversify and augment the amount of water it can supply from other sources, additional to the amount available from the dams. During the visit carried out for the preparation of this report the complete program was discussed in detail with the unit in charge of its preparation and implementation and several changes were recommended to the original investment program, these recommendations include:

(i) Give the highest priority to the development of groundwater sources, particularly in the shallow Cape Flats aquifer located south of the city. Wells in this area would allow a quick emergency response that would be compatible with the plans for groundwater management and aquifer recharge foreseen in the resilience plan. Similarly, production at the Atlantis-Silwestroom aquifer located north of the city should be increased to the full capacity of what the existing main trunk line can carry, plus local consumption. Together with serving as a rapid response to the crisis, groundwater and aquifer recharge and management should be one of the pillars for long-term water resilience for the city.

(ii) Reformulate the proposed plan to build emergency desalinization plants and reduce the number of small container type plants originally proposed (in the order of 7-10 Ml/d), replacing these by a limited number of smaller plants for specific sites[6] (ie. the Waterfront

[6] One option to consider is to seek financing by the private sector for the purchase of these plants, but keep operation and quality control by the Water Department, under an agreement that would secure the

complex) and one larger one located in the harbor, increasing its capacity to 120-150 Ml/d so that it is in the cost-efficient range, is part of the long-term resilience plan, and uses the full capacity of nearby trunk lines to incorporate the plant's yield to the distribution system. Additional desalinization plants should be considered as part of the longer-term resilience plan since desalinization needs to be one of the pillars of a diversified supply for Cape Town. See in figure 3 current costs of desalinization, from World Bank data (2016).

At the end of the visit seven investments (first phase of resilience plan) have been procured, or were under advance procurement/implementation, focused on groundwater development, wastewater reuse and desalinization in the cost-effective ranges (yields between 100~200 Ml/d).

Demand Management. A battery of best-practice demand management actions has been implemented by the water department and additional ones are being prepared. These include an extensive communication campaign, replacement of meters by systems that shut-off supply once the maximum allowed consumption is reached and pressure management of the network, and is now considering to roll out flow reducers to further limit consumption in those areas of highest water use and where network pressure management is not technically feasible (euphemistically called "equalizers"). Additionally, the city has changed its tariffs with steep increases in the blocks of highest users, particularly for block 6 (consumptions over 50 m^3 per month), introducing an aggressive economic incentive to reduce consumption by those largest consumers. As a result, consumption at the end of the visit was in the range of 600 Ml/d, including the supply to other cities, but not yet within the objectives originally established.

Additional Allocations. The city has initiated contacts with other users from the basin to develop agreements with the agriculture sector to augment the amounts available for Cape Town from the multipurpose dams (~40 Ml/d during the coming six months). There may be potential for additional similar agreements to transfer or purchase large amounts of water from agriculture during the crisis (agriculture use is of the same order or slightly higher than that of the city during the summer season) at significantly lower cost than other options being considered.

At the time of the visit it was mentioned that transfers between sectors is one option worth considering given its significant potential for high yields at low cost, and in very short time, but that such transfers need to be done with proper coordination among different levels of government to guarantee their legality and defense of all involved or affected parties. One possibility for such transfers could be the delivery of treated wastewater to agriculture users that draw from the Berg dam regulated volumes (normally from water releases into the river), exchanging those volumes for comparable volumes that would not be released from the dam and thus become available for the supply of the city. Although at the time of the visit sufficient information was not available to properly assess this possibility, data produced recently indicates that resources that could become available by delivering treated wastewater to farmers by trucks and reducing equivalent releases from the dams could have costs in the order of efficient desalinization, and definitely lower than several of the options being considered.[7]

Main Challenges

As indicated before, the city responded to the crisis with an aggressive demand management and an emergency program for the augmentation of supply using alternative sources (groundwater, desalinization, reuse of used water, reallocation of sources among users). According to reliable

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functioning of these strategically important economic activities they would supply. The city could also agree that excess production would be purchased as part of this agreement to make then viable

[7] Using 20 m^3 tank trucks, 40 Ml/d could be made available to supply the city by a fleet of 250 trucks at a cost of less than 20 Rand/m^3, for delivery distances of up to 60 km. The cost would be slightly higher, 23.4 Rand/m^3, for 30 m^3 trucks and same distance (170 trucks in this case)

hydrological modeling consulted during the visit, it is possible to predict that the combination of these augmentation investments, agreements for the transfer of additional resources and reduced consumptions will allow the city to keep minimum dam levels that secure the supply through the next summer season. Only in worst-case scenarios, supply might be at risk during the following summer season (2018-19) if demand management actions are not sustained beyond the summer and additional resources do not become available.

However, the current program is not exempt from important challenges since these efforts are complex, involve different institutions at the city, province and national levels, and need to be maintained against a potential scarcity fatigue among the population and financial constrains that might limit the investments required. Similar to what has happened in other cities faced with equivalent crisis, once the crisis is over public and political support for these efforts can easily diminish, leaving the city again at risk for similar droughts that, according to all available information, would become more recurrent in the future. Some of the challenges faced by the city under the emergency program are:

Strong Coordination and clear Responsibility/Accountability. To be effective, the emergency program needs to ensure that there is strong coordination among the different lines of action and between the different units involved. To maintain such coordination it is recommended that the city adopts a matrix management structure for the resilience program and institute three points of focal responsibility for (i) *demand management*; (ii) *investments in augmentation;* and (iii) *interbasin relations and water trading*, to report directly to the "Resilience" and "Services" leaders on these lines of response to the emergency.

The city has already instituted a single unit for communication with the public that is also in charge of public opinion relations. To avoid different opinions among units involved in the emergency response and provide uniform information to the communication unit, the city should decide on one hydrological model to be used to predict dam levels and on the scenarios to use for decision making, which is technically reliable and independent. One option is to locate this model outside the city's administration and departments, for example in the university, to avoid any dispute about its credibility and independence, as well as to make its results available equally to all units involved in the emergency and to the public in general.

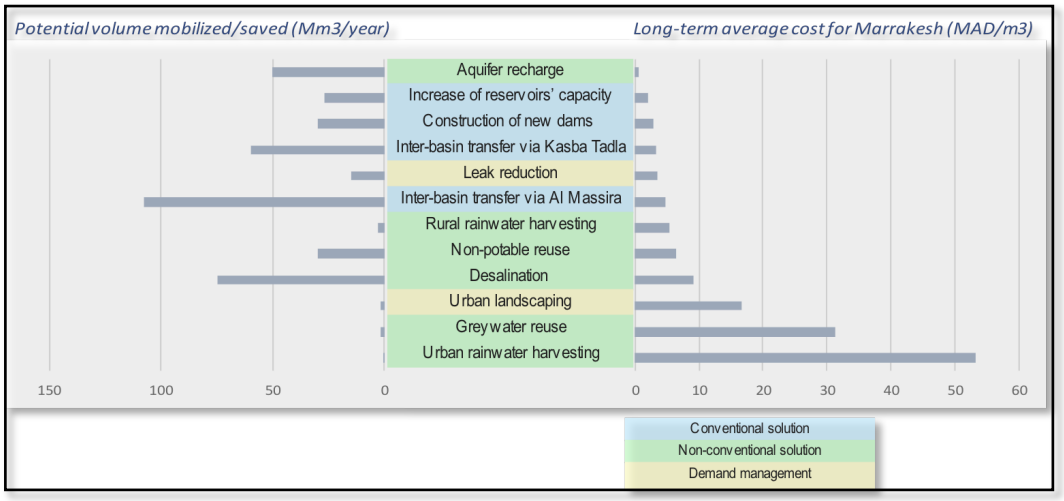

Figure 4. Comparison of Options for Augmenting Supply. Marrakesh

Disconnection of Emergency Investments and Actions from the Longer-Term Resilience Plan. The complexity of the program and the need to be efficient in the use of the large financial resources that will be needed to implement it require that any action taken as part of the

emergency response is compatible with the long-term resilience plan and contributes to its objectives. Therefore, the units involved in the emergency response should elect, phase and scale investments on the basis of yield-effectiveness, cost-efficiency and relative impact on the emergency and longer-term resilience situations. For this purpose, it would be useful to develop a model similar to the one developed in Marrakesh, Morocco, where potential volumes of water and long-term average costs are compared, but also including an additional dimension on when such resources might become available to respond to the emergency (see figure 4). Such model would be very useful for city officials to make informed decisions on which actions should receive priority, and when impact of investments could be expected, but also for communicating to the public.

Financial Sustainability of the Sector. Aggressive demand management actions like the ones being implemented in Cape Town do have an impact on water consumption during the emergency, but also in the longer term. These actions tend to induce changes in the way the population see the water resource, introduce important physical and financial incentives to reduce consumption and result in decisions at the individual level that change consumption patterns permanently. One example of these is the decision to invest on rain harvesting systems and tanks or boreholes by those that have the financial capacity to do so and which, in most cases, were among the highest consumers before the crisis and thus the main revenue generators for the water department, and will not be so anymore now.

The city's administration strong response to the crisis has achieved, according to all information available, an important public support to the importance of using less water, but also an understanding that the emergency requires expenses and that the burden of financing the additional investments also needed for the resilience plan has to be shared. This strong public support should however no be seen as a blank check to pass to consumers the costs of the response, but also the inefficiencies of the service, through higher tariffs that could be justified from a simple financial model. Indeed, a city can not afford to do so from a financial and social point of view if 23% of internal consumers metered consumption was provided as "free basic" service, 22% of all water produced is labeled as non-revenue-water, but specially one where the percentage on water delivered that does not generate revenues reaches 42% when considering internal consumers and water delivered as free basic service[8].

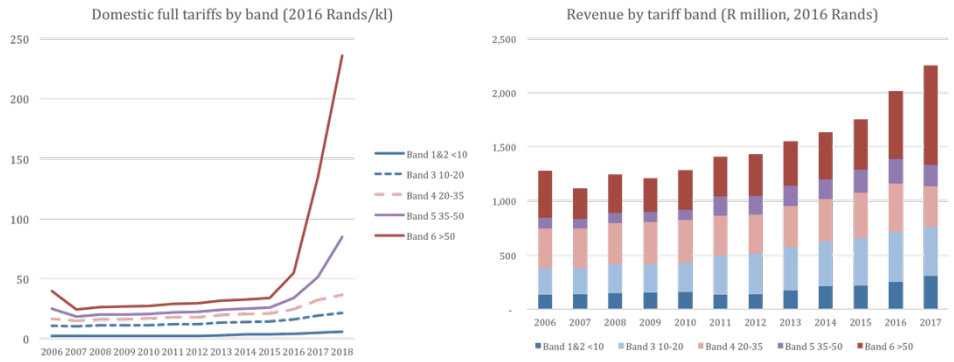

Figure 5. Block Tariffs and Revenues by Tariff Band[9]

Of special importance is the impact of demand management on the highest consumption block. Figure 5 illustrate this impact on the finances of the utility: eliminating band 6 consumption would result in a reduction of water use of only 10 Ml/d, but would also reduce the department's

[8] Data from 2016 report
[9] From Rolfe Eberhard presentation on the subject, 2017

revenues by about 40%!

To address this important challenge short-term and long-term changes on how the water department is financed should be considered (as well as improving the efficiency of the department's operations), among which two seem urgent: (i) a decision on how to finance emergency investments (it has been suggested to finance these separately from longer-term actions, through instruments different from volumetric tariffs; a levy calculated on the basis of property values was discussed); and (ii) initiate the reform of the water sector delivery model and revenue generating mechanisms and tariffs structure to address the impact of lower consumption and additional investments of the resilience plan, but also the backlog of maintenance for the long-term and to increase collection in the short-term.

Distribution of Responsibilities for Bulk Water. It has been mentioned the important effort and initiatives the city has undertaken to augment the water available from the system of dams and how this includes the development of well fields, desalinization, advance treatment of treated wastewater through reverse osmosis, and agreement with other users to increase the amounts of water available to supply the city, probably the initiative with the highest potential yield at lower costs. It has also been mentioned that South African framework for managing water resources keeps the responsibility for guaranteeing the availability of supplies in the national agency responsible for water resources management[10]. It could be argued therefore that the city has overstepped its responsibilities with these initiatives, or that the national agency responsible for water resources management did not react to the emergency with the speed and resolution that would be needed, but this would not add to the solution. Looking forward it is important though to raise this issue of conflicting responsibilities if the investments foreseen in the response to the emergency are to be carried out efficiently and with proper legal support, but also to establish the framework to be able to respond to future emergency situations and for long-term resilience.

International experience has many examples of water trading schemes, water banks and user associations water markets that could be adapted to the specific conditions of South Africa and Cape Town particularly, to make sure that those instruments are not applied for the benefit of a few only and that no one involved in the water cycle (one example are farm workers) is not better off after their application. Similarly, the initiatives currently under way (water transfers among users and groundwater development, particularly) should be reviewed at the regional level, with all relevant parties (city government, provincial government, industry and consumer associations and national agency for water resources) so that all required permits and authorizations are obtained with proper protection for all those involved or potentially affected.

Long-Term Vision. Averting the crisis and waiting for rains to fill the dams in coming winters is not enough. As important as increasing and diversifying sources, the city should strengthen its demand management actions with the objective of reducing consumption to what other cities have achieved in comparable situations without loss of service quality or well-being of their citizens (i.e. Zaragoza, Singapore). The city should strengthen and pursue its medium-term resilience plan by focusing on the most effective new supplies, both in terms of potential additional yield, security and cost, to develop a diversified portfolio of sources that complement each other.

Main among these are desalinization from larger plants, in the order of 100-200 Ml/d rather than smaller ones (except for individual areas under self-supply indicated above), groundwater recharge and management, RO for reuse of treated used water, and working with the National Agency and other users in the region (primarily agriculture) to develop and adopt the mechanisms

[10] Other work carried out before identified important hidden subsidies in this system that not necessarily contribute to the efficient functioning and managing of water resources, but this issue is outside the scope and objectives of the current analysis

and rules for water resources management and allocation/trading at the river basin level, potentially the largest and most efficient source in the short term. Last, but critical, the city must look into option for the reform of the water supply and sanitation sector to clarify responsibilities (i.e. on storm water and aquifers management or rainwater harvesting) and to guarantee the financial viability of the service through more efficient tariff structures and equitable service delivery standards.

Which reforms are needed: "Business as Usual" is not longer Possible

In previous paragraphs the main information obtained during the mission, main conclusion and important challenges the city faces have been summarized. This section will review the key elements that international experience indicates should be considered when undertaking a program like the city of Cape Town has launched, both to respond to the emergency, but also to increase its resilience against water scarcity.

The common practice among managers of water utilities and water departments has traditionally been to focus on three main objectives:

- Secure that water is available in terms of quality and reliability. If resources diminish, work with regional or national authorities to launch a solution for the transfer of additional resources or build additional storage has been the norm (the "*Big Pipe*" option), a solution in which everyone normally benefits/wins and for which economic/political pressures generally unblock funding, particularly in the case of larger urban areas
- Produce and distribute safe drinking water to all, at lowest cost
- Collect wastewater and treat it before discharging, at lowest cost (there is a changing trend in this respect worth mentioning: the urban water cycle now includes stormwater management, thus water utilities are increasingly being involved in this area)

However, new challenges complicate "Business as Usual" and cities are being forced to look beyond their traditional practices and sources for supply, particularly in water scarce situations, diminishing resources, quality deterioration or when overexploitation of available resources occurs. Most common among these challenges that can be mentioned are the following:

- Information and financial pressures limit "Big Pipe" solutions, which become more expensive or not viable for social or environmental constrains
- Climate change and increased variability
- Competing users for same resources at the source (a growing trend for many cities that depend for a large part of their supply from interbasin external transfers, such as *Murcia, Jaipur*, *Singapore* …)

To respond to these challenges and new situation many cities in the world have already adopted a change in their *Paradigm* and implemented new principles for their operation and service delivery criteria, becoming active beyond the city limits through institutional arrangement that allow them to operate at different geographical scales, as needed.

Diversifying sources and improving the reliability and independence of their supply is another common pattern observed in most cities facing scarcity. Such a move does indeed provide additional resilience, specially when some of these new sources are independent from external influences and controlled only by the city (the best example is provided by desalinization, but this could also be said of wastewater reuse or storm water management, as long as the city is entitled to their use and these resources are not considered as "belonging" to the basin as return flows).

Additionally, cities are seeing droughts as a reality to be considered in any plan and for which agreed and clearly established protocols for gradual response are prepared and adopted by wide consensus. These protocols cover from which sources to use according to their different cost, to triggering mechanisms for the reallocation of resources among different users in the basin.

Finally, but probably the most important element of the response to droughts, in most of these cities demand management*, understood in its broad sense of efficiency in the network and reduction of excessive consumption,* has become the cornerstone of any resilience plan. The example of Malta illustrates this trend: Malta's losses reduction program resulted in a decrease of networks leakages from 3,900 m^3/h (ILI of 20) in 1995 to 395 m^3/h (ILI of 1.9) in 2015. Urban water demand today is <60% of what it was in 1994, without any decrease in quality of live.

Three examples illustrate this change with experiences that could be applicable to Cape Town: Windhoek, Singapore and Murcia, where these four tools: *regional approach; diversification of resources; protocols for gradual response to droughts; and demand management*, have been efficiently implemented.

Windhoek offers a good example of a regional approach and mix of different sources, making use of its traditional source, aquifers, to increase storage in a situation of potentially extreme losses by evaporation. Its experience in wastewater reclamation is also worth considering for Cape Town. See in box 2 below a summary of the different sources Windhoek is supplied from today, with the average cost of production, as well as additional new sources under consideration.

Box 2. Windhoek Alternative Sources and Average Cost

Existing supplies:	
Windhoek aquifer ground water	N$ 4.80/m^3
NamWater Supply	N$ 9.00/m^3
Reclaimed wastewater	N$ 9.00/m^3
Reused wastewater (for irrigation)	N$ 6.30/m^3
Additional supplies:	
Okavango pipeline	N$ 45/m^3
Tsumeb aquifer	N$ 30/m^3
Aquifer Recharge	N$ 16/m^3
New Reclaimed wastewater plant	N$ 17/m^3
Desalination and pumping	N$ 40/m^3

1 USD = 13.29 N$ Namibia's GDP per capita: 4,140 USD (2016)

Singapore presents another example of diversification of sources, combining desalinization, storm water management and wastewater reclamation ("NEWater") with interbasin transfers to achieve a reliable and increasingly independent mix of alternatives to supply the city/state. Figure 6 below summarizes the system and sources supplying Singapore. For comparison purposes, the energy required for the production of each of these pillars of supply is[11]: (i) local catchment from stormwater runoff (10-15%) 0.2 kW/h/m^3; (ii) imported water through an inter basin transfer from Johdor, Malaysia (40-50%) 0.2 kWh/m^3; (iii) reclaimed treated wastewater (now 20%, expected to increase to 55%) 1.0 kWh/m^3; and (iv) desalination (now 25%, expected to increase to 30%) 3.6 kWh/m^3. Could this be a mix for Cape Town?

Murcia water system includes several elements that could be identified in Cape Town: a regional

[11] The percentage they represent today of the supply to Singapore and the planned increases are included in parenthesis for each of these "pillars"

agency in charge of treated bulk supply, similarly to how the water department does now with other municipalities in the area; inter-basin transfers from a series of dams managed by the regional agency and extra-basin transfers of water managed by a national agency; multiple users, requiring coordination and agreements between agriculture, industry and urban users; and a framework for water resources management that resembles (and apparently has been used in part for its design) the South African model.

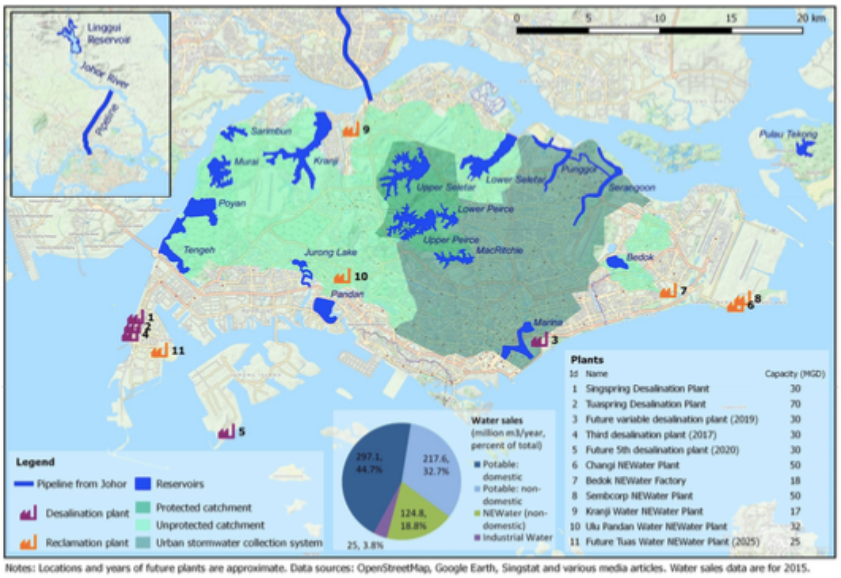

Figure 6. Singapore's System of alternative Sources of Supply

It also includes solutions and procedures that could be applied efficiently in Cape Town: diversification of resources that allows using those that result most efficient and economic in each situation; clear rules for water allocation, trading and use among different users, with a mechanism to resolve disputes; and a plan for drought management. To illustrate how this system functions, in figures 7 and 8 the schematic diagram of involved infrastructure and the evolution of use of different resources are summarized.

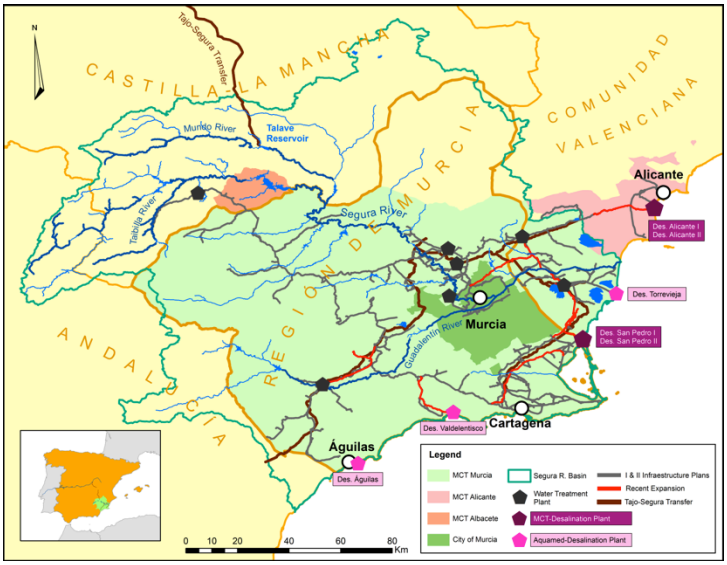

Figure 7. Murcia Water Supply System

Cape Town's Resilience Plan has to some degree all these principles already. Similarly, the plan has clearly identified the actions which are urgently needed for the emergency and can be short-term, and which are needed for long-term resilience and have requirements in terms of sustainability. If integration of short-term measures into the long-term plan is to be achieved, some basic considerations should be taken into account:

- Groundwater can be over-exploited in the short term but needs careful management in the long-term
- Similarly, groundwater quality considerations are different for short-term use and long-term supply since dilution of extracted water with water from the dams allows maintaining supply within acceptable standards
- Wells that will be drilled for the emergency response should be planned so that they can be used in the long-term solution either for abstraction or for injection into the aquifers as part of a groundwater/aquifer management plan
- Desalinization using modular systems is more expensive than plants in the cost-efficient sizing (100-200 Ml/d), but allows for shorter-term additional supply in a gradual manner. The need for this short-term supply should be modeled and compared with alternative solutions from a yield and cost point of view before making a decision

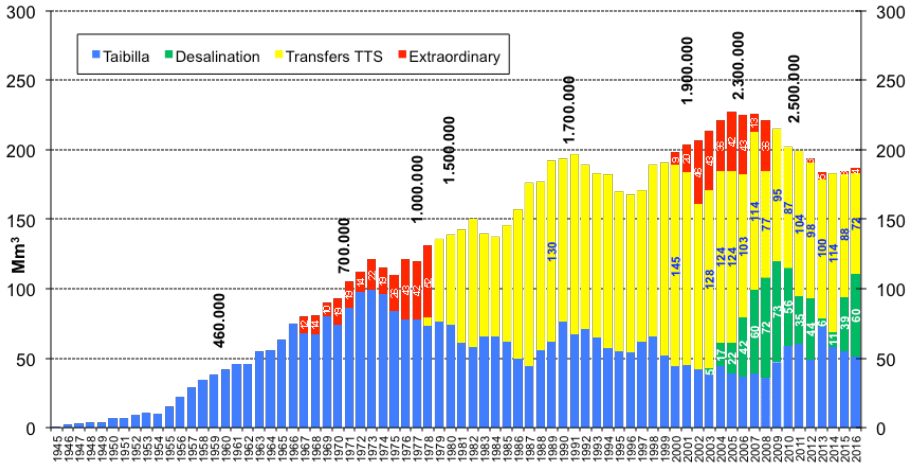

Figure 8. Evolution of Contribution by Source[12] and Population. Murcia (Spain)

Main messages for after the Crisis is over

It has been mentioned before that with the measures taken, if these are maintained, it is reasonable to expect that the city will be able to overcome the worst part of the crisis and keep an adequate supply of water throughout the coming summer season. However, it is important to not loose now the long-term perspective and keep in mind that additional efforts are needed for the following summer season, should rains do not fill the dams, and for the long term resilience. Several messages and recommendations can be extracted from the points raised in this report for that objective:

[12] "Emergency Supplies" refers to either water purchases by trading or groundwater extractions made during emergency situations. "Taibilla", or *Mancomunidad de Canales del Taibilla*, (MCT) is the regional agency in charge of supplying bulk treated water from the network of dams in the basin. "TTS" is transfer of water from an external basin (river Tajo) managed by a national agency

- Business as usual is not longer possible and inefficient. Introducing the "New Paradigm" and new criteria for service delivery and for reliability and security of sources of supply can be achieved as part of the emergency response and further expanded as part of the long-term resilience plan. *"Water Scarcity" is here to stay*
- Diversify resources for proper management. Diversification of resources should not be seen as an objective in itself to respond to the emergency, but should be considered as much as possible part of the longer-term resilience program, giving priority to "non-regret" solution first.
- Institutional setup at a proper scale is needed to apply an integrated management of resources. Use the opportunity to establish the institutional framework that allows and regulates water transfers/trading among different users in the region/basin and protects all those involved or affected by those transfers.
- Demand management must be part of the equation and a sustained effort. Although much has been achieved already lowering consumption to about 150 lpcd, additional reductions are possible without diminishing quality of life or putting at risk the health of the population. The decision on which targets to achieve must take into consideration the marginal cost of saved water. The objective should be to reach a sustainable situation where efficiency in the network, incentives and communication should form the core of the demand management program, rather than physical limitation to consumption.
- Financial sustainability of the water department needs to be part of the equation too. However, it should not be pursued by transferring inefficiencies to consumers through higher water tariffs, but through improved efficiencies in operation, better collections and a reform of the service delivery model and tariff structures. *Crisis are perfect occasions for sector reform*.