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Optimization of the Drinking Water Supply System From the Supply Pipes of Lac De Guiers to Thies (Senegal)

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***Abstract*:- In an era of unprecedented urbanization, population pressure and industrial growth are now serious threats to water management in Senegal. Human health faces serious problems due to the deterioration of the quality of drinking water. The diagnostic mission, the subject of this article, consists in conducting a documentary study of the various recent reports on the subject, as well as a complete examination of the Lake Guiers Feeding System (ALG), to identify the hotspots of fragility and the investments necessary to ensure the continuity of Dakar's drinking water supply. This mission is complemented by a hydraulic modeling of the ALG system and the study of different operating scenarios, to identify the hydraulic and operating constraints that do not currently allow to make the most of the installations. The results of the simulation showed high pressures in the pipes that are higher than the standards set by the factory, and this will cause leaks and water shortages.**

Keywords:- Optimization, diagnosis, drinking water, water, Lake Guiers, Senegal

1. INTRODUCTION

Water not only serves as a means of hydration, whether for humans, animals, or vegetables, it also serves to clean and maintain good hygiene, to provide energy, to regulate the climate or to welcome life, that is, it performs key and essential functions for our planet to remain as it is [1-5].

In Senegal, the potential in water resources (surface water and groundwater) is important, the availability of renewable water resources is now estimated equal to 4747 m3 / inhabitant / year, well above the reference value of water scarcity equal to 1000 m3 / inhabitant / year. [6-10].

Despite this significant water potential, the water sector in Senegal is threatened by several natural and anthropogenic constraints [11-15].

The availability of water remains uncertain for areas facing problems of quality, quantity, but also access because of the high costs of mobilizing the resource. Climate change is likely to impose additional constraints on water availability (drought) and accessibility (salinization and water pollution) [16-20].

Improving the quality of life of the population through accessible basic social services is undoubtedly one of the major objectives of the Government of Senegal. Thanks to the many efforts noted in the water sector and attributable to the efforts made in terms of resource mobilization for the development of access to water, the rate of access to drinking water in Senegal is increasing drastically [21].

While various programmers implemented within the framework of the Drinking Water and Sanitation Programmed for the Millennium (PEPAM) have enabled Senegal to achieve the Millennium Development Goals (MDGs) in the drinking water sector, the fact remains that significant efforts to improve water quality and reduce deficits in major urban centers are needed, particularly in the Dakar region [22].

Despite the constant efforts of the National Water Company of Senegal (SONES) in improving the public water service, the water deficit in Dakar continues to increase with a galloping increase in the population [23].

Thus, the establishment of water purification plants namely Ngnith, Keur Momar Sarr and the reinforcement projects for the water supply of certain localities have really relieved a large part of the population.

In this study, we plan to make a diagnosis to provide technical solutions to propose a new mechanism of water transfer much more optimal by making a documentary study of the various recent reports on the subject, as well as a complete examination of the ALG system in situ, to identify the nerve points of fragility and the investments necessary to ensure the continuity of the drinking water supply of Dakar in the ideal conditions.

2. MATERIALS AND METHODS

2.1. Description of the study area

Lake Guiers is the only major freshwater reserve in Senegal. It is located at latitude 14°09' N and longitude 16°08' W. It supplies drinking water to the population of Dakar and its surroundings from the supply pipes of Lake Guiers (ALG) [24,25].

The ALG 1 is the pipe that leaves the Ngnith station towards Thiès and the ALG 2 the one that leaves the Keur Momar SARR factory towards Thiès.

Figure 1 below shows the route of the network from the source to the Thiès reservoirs.

Figure 1: Route of the ALG network to Thiès

After describing the mode of operation of the water transfer system, we made the diagnosis of the network with the Epanet software. This diagnosis aims to make improvements for a better optimization of the flow management.

A flow measurement campaign at the level of the boreholes that inject into the network was made to have visibility on the flow inputs.

Table 1 contains the drill flow measurement results that support ALG 1 and 2.

Table 1. Production Meter Flow Rates

Sites	Throughput output drilling (m^3/h)
FLN 1	137
FLN 2	0
FLN 4	121
FLN 5	113
FLN 7	124
FLN 8	164
FLN 9	44,8
FLN 10	242
FLN 11	Blocked
Kelle 1	175
Kelle 2	391
Kelle 3	264
Kelle 4	251
Kelle 5	112
Kelle 6	308
Kelle 7	81
Kelle Village F2	301
F1 Gueoul	80

Table 2 shows the characteristics of the discharge pumps at the Nginth and Keur Momar SARR drinking water treatment plants. The Nginth drinking water treatment plant which operates with 3 diesel pump units in parallel and 2 in backup with an outlet pressure of 25 bar.

As for the Keur Momar SARR drinking water treatment plant, it operates with 4 electric pumps in parallel and 1 in backup operating at fixed speed with an outlet pressure that varies between 19 and 25 bars.

The nominal flow rate of the treated water pumping station is 2,700 m^3/h, which corresponds to 64,000 m^3/j.

Table 2. Characteristic of the Ngnith and Keur Momar SARR (KMS) plant discharge pumps

Identity		Power (kW)		Debit (m^3/h)		HMT (m)	
Ngnith	K M S	Ngnith	K M S	Ngnith	K M S	Ngnith	K M S
GMP1	A	1 340	1 300	970	1 440	250	190
GMP2	B	1 340	1 300	900	1 440	250	239
GMP3	C	1 200	1 300	970	1 440	250	239
GMP4	D	1 320	1 300	900	1 440	250	239
GMP5	E	1 340	1 300	900	1 440	250	239

The Keur Momar SARR plant was commissioned in 2004 (KMS1) + and in 2006 (KMS2). The nominal production capacity is approximately 65,000 and 65,000 m^3/j respectively for the two stations, for a total of approximately 130,000 m^3/j. However, the average actual capacity is 121,000 m^3/j.

2.2. Presentation of the EPANET and PICCOLO software

EPANET is a simulation software for the hydraulic and qualitative behavior of water over long periods of time in pressurized networks. [26].

EPANET calculates the flow rate in each pipe, the pressure of each node, the water level in the tanks, and the concentration of chemical substances in the different parts of the network, during a simulation time divided into several steps. The software is also able to calculate residence times and track its evolution. [27,28].

The PICCOLO software is a general tool for simulating loaded flow problems in mesh networks. Hydraulic simulation makes it possible to reproduce the flow of liquid subjected to obstacles [29].

Figure 2 shows the backbone of the network in EPANET.

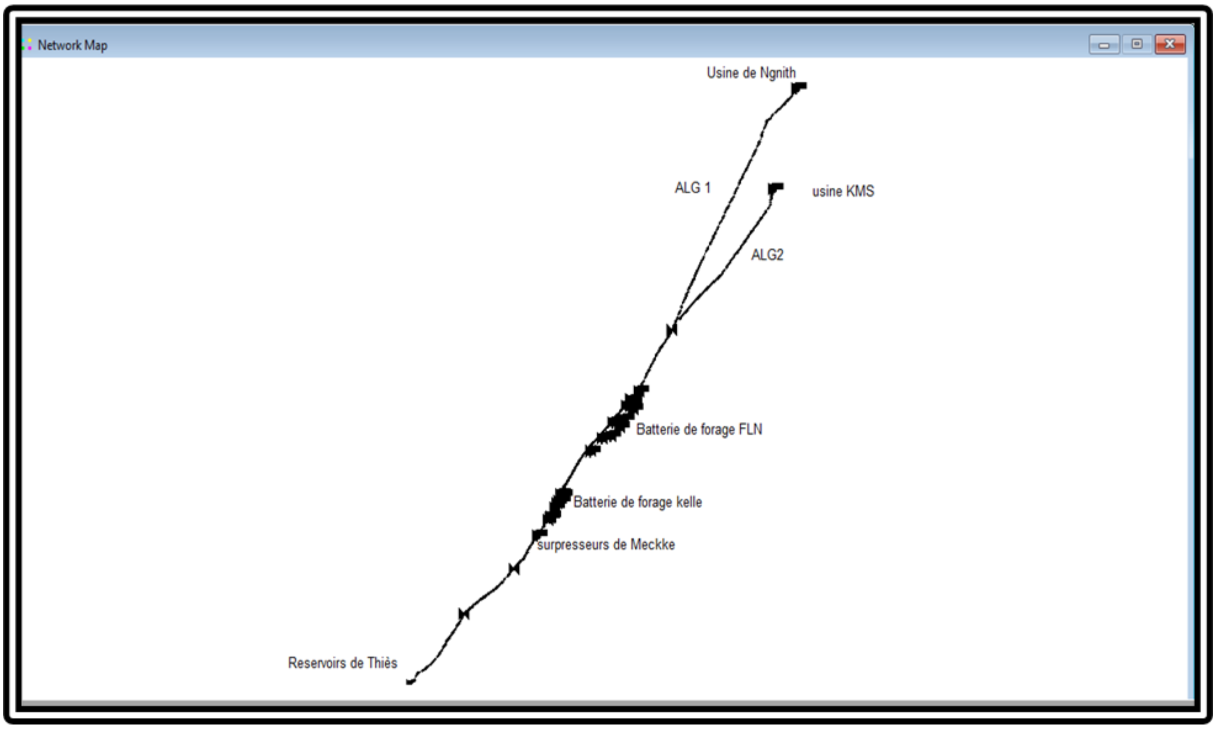


Figure 2. Network backbone in EPANET

3. RESULTS AND DISCUSSIONS

The results of the simulation in EPANET have Showed high pressures that exceed even the limit value of 25 bar or 250 meters of water column (mCE) at the adductors.

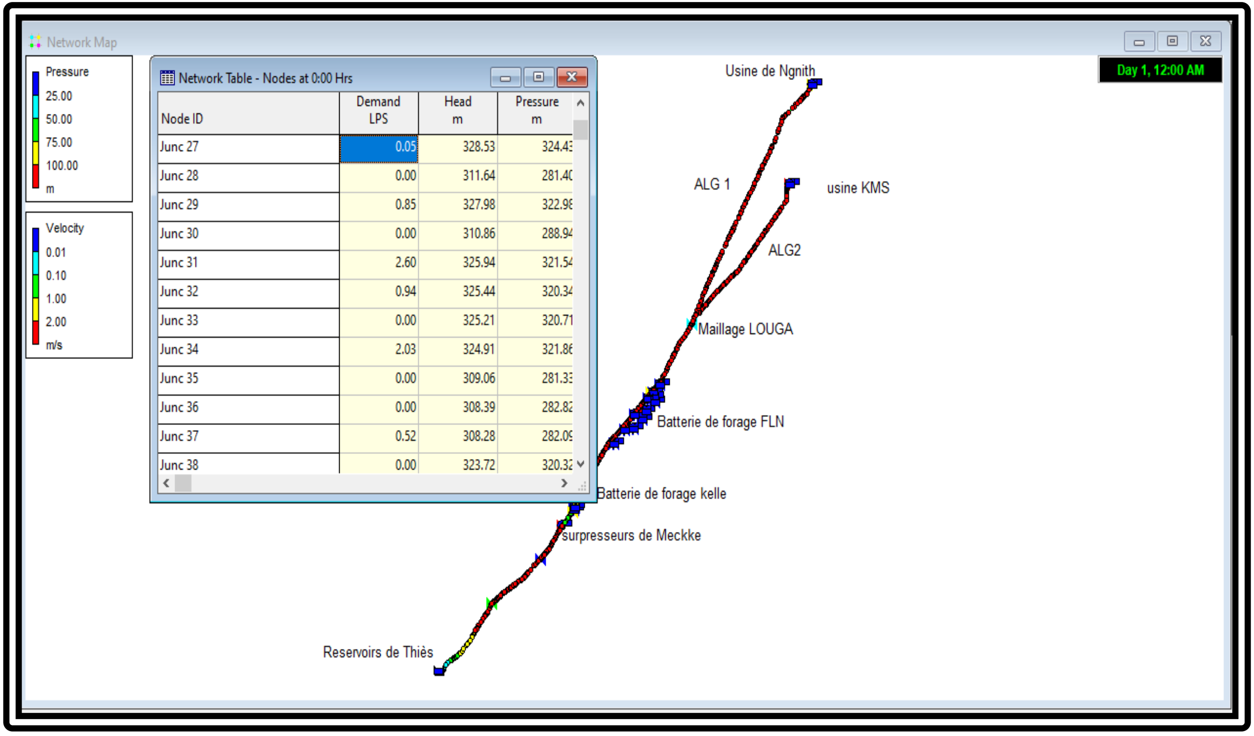
On ALG 1, the outlet pressure on the discharge line with a diameter of 1000 mm is 32.3 bar, which is well above the pressure limit value. This high-pressure value is related to the proximity of the plant with the effect of over-pumping [30].

However, we note a gradual decrease in pressure after narrowing the pipe of the ALG 1 which passes to the nominal diameter (DN) 1000 in DN 900.

The pressure at this level is equal to 23.3 bar up to the first mesh with the ALG 2 at Louga. This decrease may be related to the change in diameter and the length of the section favoring an increase in pressure losses that can lead to a pressure drop in the pipe [31].

This same situation is noted at the level of ALG 2 where we have a high pressure of 32 bar on the DN 1200 cast iron. The mesh pressure with ALG 1 is equal to 23 bar. However, these pressure values present threats to pipes that can cause severe leakage [32].

Figure 3 below shows the evolution of the pressure in the network.



Network Table - Nodes at 0:00 Hrs

Node ID	Demand LPS	Head m	Pressure m
Junc 27	0.05	328.53	324.43
Junc 28	0.00	311.64	281.40
Junc 29	0.85	327.98	322.98
Junc 30	0.00	310.86	288.94
Junc 31	2.60	325.94	321.54
Junc 32	0.94	325.44	320.34
Junc 33	0.00	325.21	320.71
Junc 34	2.03	324.91	321.86
Junc 35	0.00	309.06	281.33
Junc 36	0.00	308.39	282.82
Junc 37	0.52	308.28	282.09
Junc 38	0.00	323.72	320.32

Figure 3. Evolution of the pressure before Louga mesh

Flow velocity is an important parameter because a low velocity value has a negative impact on water quality and can lead to deposits in pipes [33].

The results of the simulation showed that the speed is acceptable and belongs to the permissible interval of [0.3-3] m/s meeting the self-cleaning conditions [34].

Thus, the results of the pressure drop gradient that reflects energy losses per kilometer have very low values of 1.33 m/km. In other words, over each kilometer we lose a pressure of 0.1 bar [35].

The description and diagnosis of the ALG network made it possible to identify the functioning of the ALG system. We note very high pressures that even exceed the limit values on several sections. We also noticed a saturation of the pipes at the downstream part of the boreholes. Thus, these saturated pipes have negative impacts on the operation of the pumps at the stations.

Faced with this situation, it is desirable to set up a new mechanism for operating the network to optimize the ALG transfer system. In this part, we have tried to provide technical solutions to propose a new water transfer mechanism much more optimal with the use of piccolo software.

Figure 4 shows the network backbone in the PICCOLO software

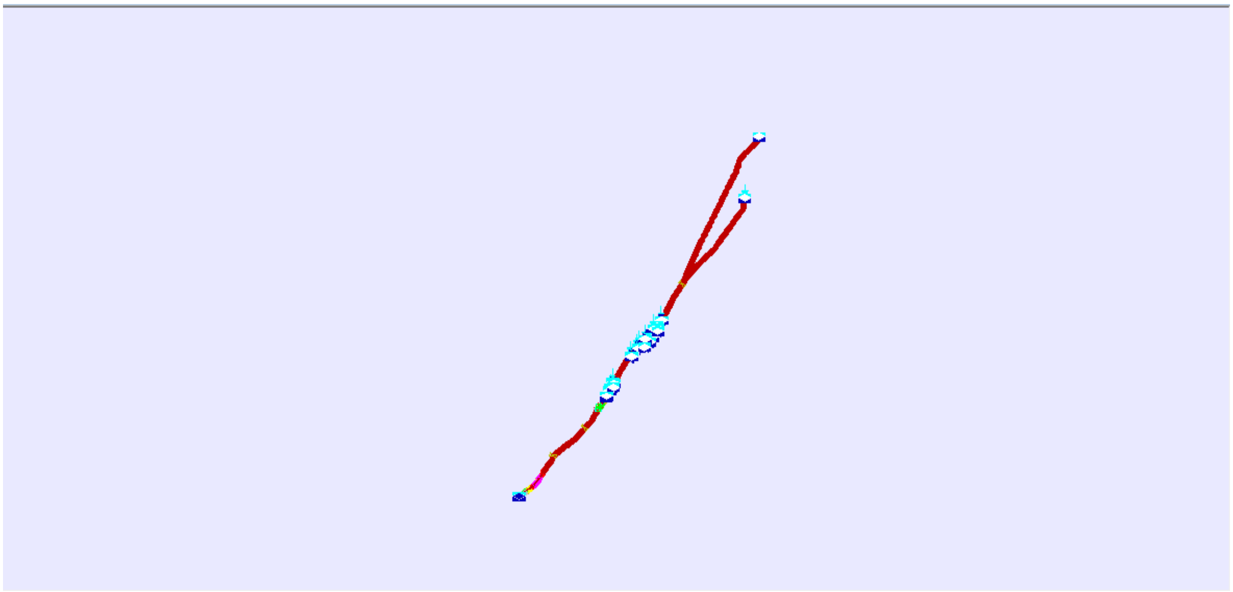


Figure 4. Importing the network into PICCOLO.

The results of the simulation in EPANET showed very high-pressure values at the ALG level. These values have also exceeded the maximum value of 25 bars upstream and downstream of the Mbekké station and the instructions for the proper functioning of the latter seems not to be respected.

The results of the simulation in PICCOLO also justified the high pressures noted in the network and which are presented in Table 3.

Table 3. Extraction of pressure values in PICCOLO

Node number	Hydraulic head (m)	Altitude (m)	Pressure(m)
1	563.03	34	529.03
2	562.13	23.060	539.07
3	598.52	4.1000	594.42
4	560.50	30.240	530.26
5	597.81	5	592.81
6	559.76	21.920	537.84
7	595.19	4.4000	590.79
8	594.55	5.1000	586.45
9	594.25	4.5000	589.75
10	593.86	3.0500	590.81

The elevation rating of a point refers to the altitude of that point above sea level, denoted Z and expressed in meters of water column (Mce) [36.37].

The hydraulic load H is defined by the sum as shown in the table of the relative pressure P and the elevation rating at this point [38-40].

In this part we have committed to solve the problem of overpressure noted and to propose a much more economical water transfer mechanism.

We will therefore go from 4 to 2 operating pumps at the Keur Momar SARR station with a flow rate of 2,880 m^3/h without closing the mesh size of the two adductors at LOUGA.

The operation of the KMS plant with the 4 discharge pumps as shown in Table 1 show discharge pressure values above twice the limit value of 25 bar (250 Mce).

The application of this instruction has led to a decrease in the pressure values at the level of the master pipes (ALG 1 and 2) between 30 and 40 bar as shown in Table 4.

Table 4. Pressure results after simulation

Node number	Hydraulic head (m)	Altitude (m)	Pressure(m)
15	343.32	14.820	328.50
16	343.28	12	331.28
17	343.26	16.650	330.61
18	343.22	9.3200	333.90
19	343.19	10.190	333
20	343.16	9.6500	333.51
21	343.12	12.500	330.62
22	343.08	14.760	328.32
23	343.03	13.950	329.08
24	342.99	15.220	327.77

However, we found that shutting down the two KMS pumps is not enough to reduce the high pressures in the network. For this we will have to move on to the second variant.

The operation with 4 pumps including 2 at KMS and 2 at Nginth has a positive impact on the protection of ALG because the pressure values are close to the permissible value as shown in Table 5.

Table 5. Pressure results with 2 operating pumps at KMS and Nginth

Node number	Hydraulic head (m)	Altitude (m)	Pressure(m)
1	293.67	7	0.0
2	293.64	12.500	281.17
3	293.60	17	276.64
4	293.56	11.200	282.40
5	293.54	14	279.56
6	293.50	12.200	281.34
7	293.44	12.850	280.65
8	293.40	11.650	281.79
9	293.36	14.820	278.58
10	293.34	12	281.36

At the adductor discharge line, we have identified drilling batteries that inject into the network. We tried to stop a borehole to see again the evolution of the pressure. For this, the choice fell on the FLN 10 drilling which injects a flow equal to 242 m3 / h. Table 6 shows the results obtained after simulation.

Table 6. Pressure results with Géoul drilling stop and Louga mesh closure

Node number	Hydraulic head (m)	Altitude (m)	Pressure(m)
1	7	7	0.0
2	214.28	12.500	201.78
3	214.25	17	197.25
4	214.21	11.200	203.01
5	214.17	14	200.17
6	214.15	12.200	201.95
7	214.11	12.850	201.26
8	214.05	11.650	202.40
9	214.01	14.820	199.19
10	213.97	12	201.97

The stop of the FLN10 drilling resulted in pressure values (20 to 25 bar) that comply with the pressure instructions on the discharge line. However, this action is mainly noted downstream of the boreholes. Faced with this situation, it is therefore necessary to take an action that would be able to consider the upstream part.

The results of the simulations showed pressure values that rotate at the turn of 21 bars by adding to the previous actions the closure of the ALG Mesh at Louga level which we judged the best in terms of pressure.

4. CONCLUSION

This work provides an overview of the problems on the functioning of ALG in Senegal. It also attempts to highlight the challenges of enforcing water laws and policies, but also their shortcomings. It is also necessary to establish a reliable risk assessment system for water quality, human health, and ecological safety.

The ALG system ensures distribution and receives inputs from various boreholes. Previous studies have shown that the transfer capacity of the ALG system should be saturated in 2015, with a risk of salt bevel being introduced into the recharge aquifers of drilling areas in the event of overexploitation of these.

The results of our research showed some malfunctions on the water transfer system through hydraulic simulations. Thus, by applying operating laws at the level of boreholes that often lead to the saturation of pipes, we noted an improvement on the transfer system including the evolution of pressure and flow speeds in the network.

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