Golden Sun-Rise
International Journal of Multidisciplinary on Science and Management
ISSN: 3048-5037/ Volume 2 Issue 3 Jul-Sep 2025/ Page No: 75-91
Paper Id: IJMSM-V2I3P109/ Doi:10.71141/30485037/V2I3P109

Research Article

Tool for Modelling and Sizing Drinking Water Distribution Networks Using the Rough Model Method (RMM) - Application to a Numerical Mesh Model

Ludovic Ivan Ntom Nkotto[1,2], Joberthe Vanny Meno Tegue[2], Blanche Marcelline Manjia[1], Alpha Ali Mohamadou[2,3], Jordan Valdès Sontia Metekong[2]

[1]*Civil and Mechanical Engineering Laboratory, National Polytechnic School of Yaoundé, BP 8390, Yaoundé, University of Yaoundé 1, Cameroon.*

[2]*Materials Analysis Laboratory, Mission for the Promotion of Local Materials (MIPROMALO), BP 2393, Yaoundé, Cameroon.*

[3]*Hydraulic Engineering Laboratory, National Polytechnic School of Maroua, University of Maroua, Cameroon.*

Received: 09 July 2025 Revised: 13 July 2025 Accepted: 15 July 2025 Published: 19 July 2025

Abstract - *In Cameroon, the growing demand for drinking water requires optimum planning of distribution networks. The availability of an adequate supply of drinking water is crucial to the health of the population. At present, sizing methods are based on rules of thumb, without taking account of local constraints such as topographical variations and hydrological conditions. This study proposes a tool for sizing drinking water networks using the Rough Model Method (RMM). It applies to all relative roughness ranges between 0 and 5x10^-2 and for all Reynolds number values above 2300. This is the only analytical method allowing the calculation of the normal depth in free-surface channels. The tool has been codified using the MATLAB programming language. RMM is based on the principles of hydraulics, and is used to calculate flow rates, pressures and heights of water in pipes. Unlike hydraulic simulation software such as WaterCAD, Epanet, GHydraulique, ProNET Water Network Analysis and Porteau, which are based on the Hardy-Cross method, this tool uses a four-dimensional hydraulic model ((x, y), (y, z), (x, z) and (x, y, z)) and calculates network parameters (rather than simulating them), taking into account the contextual parameters of the site (topographical and hydraulic parameters) and without the use of abacuses. The tool takes various parameters into account to generate optimum configurations, minimising pressure losses and optimising construction and maintenance costs. In this work, the hydraulic network previously studied by B. Achour (2014) was simulated using the EPANET application in order to confirm the functionality of the network. Then, the said network was dimensioned by the implemented tool. The results showed that the graphic modelling was accurate in terms of the direction of water flow. Standard diameters, which are essential for network design, were calculated and rounded off precisely, in line with industry standards. The pressures assumed at the theoretical diameters showed values similar to the work of B. Achour (2014), attesting to the reliability of the tool implemented. However, discrepancies were observed in the pressures assumed at commercial diameters, particularly in some meshes, due to the sensitivity of the roundings.*

Keywords - *Distribution networks, Drinking water, Rough Model Method, Modelling and sizing drinking water.*

I. INTRODUCTION

The availability of an adequate supply of drinking water is essential to ensure the well-being and health of the population (Zilin Li et al., 2024) . In Cameroon, as in many developing countries, the growing demand for drinking water due to demographics and multiple needs requires optimal planning and design of water distribution networks (Lefkir A., 2000; Conde, A.et al.,2024). Currently, most methods for sizing drinking water networks are based on rules-of-thumb approaches. Several methods for sizing drinking water networks have been developed and have made remarkable progress. It all began with the Hardy-cross method of 1936, based on the law of nodes and the law of equilibrium of head losses in a network mesh.

This method presents difficulties in determining the network sizing parameters, as the simulation of the equations derived from these two laws leads to an iterative system of equations that can be solved using several approaches. Newton Raphson's approach (1671), develops the non-linear terms in Taylor series, neglecting the residuals beyond the second terms and thus considering only the linear terms.

The linearisation approach to pressure losses by Wood and Charles (1972), taken up again by Leujene and his colleagues in the same year, which makes it possible to solve, by an iterative process, a system of linear equations composed of continuity equations at the nodes on the one hand and linearised mesh equations on the other, the approach using deterministic methods through the approach by Lansey and Mays (1989), the approach by Monbaliu et al. (1990) and heuristic methods such as the simulated annealing method (1983), the equivalent pipes method (1971), the Tabou method (1997), the genetic algorithms method (1981) and the Featherstone and El Djumaily method (1968).

However, these methods do not take full account of the specific constraints of the local context, such as topographical variations, soil characteristics and local hydrological conditions (Diouf P.M. and Diouf O., 2005; Ntom et al., 2023). To date, there is a mathematical and graphical approach to solving this drinking water network optimisation problem, it emphasises the specific constraints of the network's local context.

This is the Rough Model Method (RMM). It is based on the universally accepted Darcy-Weisbach and Colebrook-White relationships, and on a reference rough model. It applies to all relative roughness ranges between 0 and 5x10^-2 and for all Reynolds number values above 2300. This is the only analytical method allowing the calculation of the normal depth in free-surface channels.

In this study, we propose the development of a sizing tool for drinking water networks specifically, using the optimisation approach offered by the Rough Model Method (RMM). RMM, based on the fundamental principles of hydraulics, provides an analytical solution for calculating flows, pressures and water heads in pipes (Bedjaoui A. and Achour B., 2014). The proposed sizing tool will take into account various parameters, such as consumption flows, the geometric characteristics of the network and the hydraulic constraints specific to each study area in Cameroon. Using advanced optimisation techniques, the tool will be able to generate optimal network configurations, minimising head losses, guaranteeing adequate pressures and optimising construction and maintenance costs.

The combined approach of RMM and optimisation will enable an optimal design of drinking water distribution networks in Cameroon, in response to the growing demand for water. Such a design will take into account the country's specific geographical, hydrological and socio-economic features, thus ensuring efficient management of water resources and improved access to drinking water for the population. Smart water systems offer a way to incentivise the utility sector to drive implementation. They can offer a bottom-up approach where the utility sector can see benefits, as opposed to a top-down approach where they are expected to adopt an. (Grigg, N.S., 2024). The tool will be codified using the MATLAB programming language, which offers a multitude of functionalities. The functionalities of this tool will be verified by comparing the results of the work of B. Achour, 2014 and those generated by the tool.

Thus, the development of a sizing tool for drinking water networks based on the Rough Model Method (RMM) and using optimisation techniques represents a significant step forward in meeting the growing need for drinking water in Cameroon. This approach will enable optimum planning and design of water networks, thereby helping to improve people's quality of life and ensure sustainable management of the country's water resources.

Ludovic Ivan Ntom Nkotto et al. 2(3), 75-91, 2025

II. DESIGN AND SIZING PARAMETERS FOR DRINKING WATER DISTRIBUTION NETWORKS

Designing and sizing a drinking water distribution network is a complex process involving a multitude of parameters. The aim of this article is to present these parameters, from the preliminary studies to the determination of route flows, which are essential for hydraulic engineers when sizing a network.

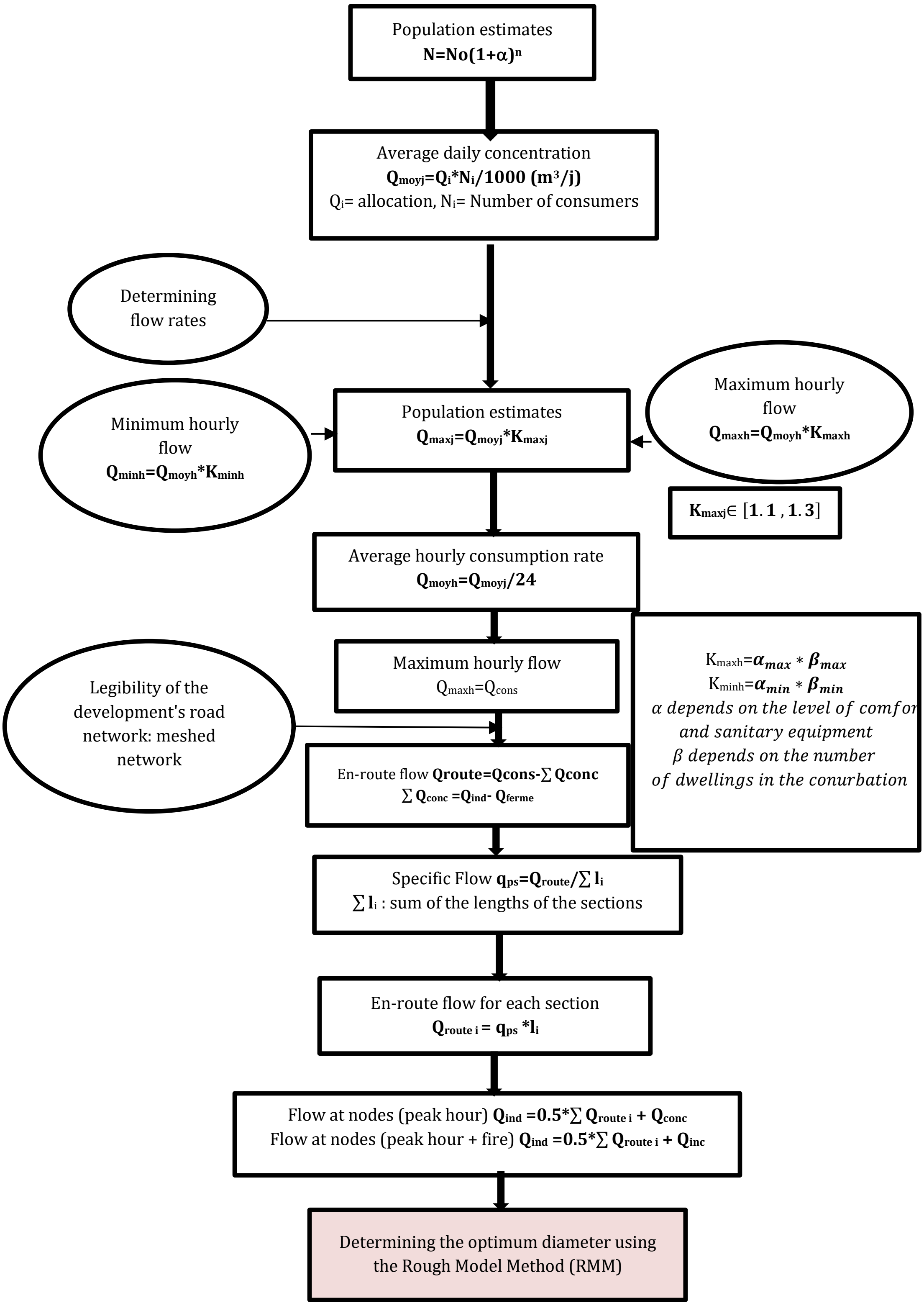


Figure 1: Flow Chart for Sizing a Drinking Water Distribution Network in Urban and Peri-Urban Housing Estates

A. Design Parameters for a Drinking Water Distribution Network

The design of networks in both developing and developed countries generally follows the existing road infrastructure and adopts a mesh configuration. This configuration provides a redundant supply, where each point of the network can be supplied from several sides, offering increased safety and a uniform distribution of pressures and flows. The implementation of this design requires various preliminary studies, which are:

- **Site Topology**: The schematic representation of network nodes and their physical links is influenced by the location of subscribers, the presence of roads, natural obstacles and other networks. Hydrogeological, topographical, geological and geotechnical studies provide crucial information for this representation.
- **Network Layout Principle**: The identification of major consumers, the direction of water flow, and the distinction between main and secondary pipes are key elements of the layout.
- **Adequacy of Resources and Needs**: The works must be sized to meet the current and future needs of the population, taking into account the available water resources.
- **Economic Function**: In mathematical optimisation, this function is used as a criterion to determine the best solution to an optimisation problem, often solved by methods such as the simplex algorithm.

B. Sizing Parameters for a Drinking Water Distribution Network

Sizing is based on determining the optimum pipe diameter and corrected road flows. This involves hydraulic calculations to meet the estimated water needs of the population. Key steps include:

- **Estimation of Water Needs**: A complete assessment of domestic, industrial, community and tourist needs is necessary for an adequate response.
- **Flow Assessment**: Once the water requirements have been estimated, the associated flows are determined, including
  - Qmax,j, is the maximum daily flow rate
  - Qmoy,h, the average hourly flow rate
  - Qmin,h is the minimum hourly flow rate
- **Hydraulic Calculation**: En-route and node flows during peak hours and peak hours plus fire are estimated to size the network according to two scenarios: peak case and peak case plus fire. Figure 1 (not shown here) illustrates the sizing flowchart for a drinking water distribution network, highlighting the interdependence of the various parameters and stages in the process.

The determination and evaluation of all these design parameters are summarised in Figure 1 above.

III. APPLICATION OF THE ROUGH MODEL METHOD (RMM) IN THE DESIGN OF TOOLS FOR DRINKING WATER DISTRIBUTION

The Rough Model Method (RMM) is an innovative approach to the design of drinking water distribution networks. It is based on a rough reference model that simulates the hydraulic behaviour of pipes. This article describes the geometric and hydraulic parameters, the principle of the method, the calculation process and the verification of the method.

A. Presentation of the RMM (Bedjaoui A. and Achour B., 2014)

This method, based on a reference roughness model, makes it possible to determine the pipe diameter of each section of the network and the normal depth in free-surface channels. Determining the diameter involves collecting flow and pressure data, applying the appropriate hydraulic equation, such as those of Darcy-Weisbach, and taking into account the parameters of the rough reference model. The various calculation steps are as follows:

Step 1: Propose pressures at the network nodes (except at the reservoir node) of between 10 and 40 m.c.e, ensuring that the sum of the natural ground level and the pressure remains below the piezometric level of the reservoir.

Step 2: Determine the hydraulic gradient J for each section according to the equation

$$J = \frac{\Delta H}{L} = \frac{CP_{am} - CP_{av}}{L} \quad (1)$$

in m

with : $$CPi = CTNi + PSi \quad (2)$$

CPam: Piezometric head upstream of the section (m) ;
CPav: Piezometric height downstream of the section (m);
CTNi: Natural ground elevation at node i (m);
Psi : Assumed pressure at node i (m.c.e.);
L: Length of the section (m).

Step 3*:* Distribution of road flows for each section calculated (case of meshed networks),
Step 4: Determine the geometric diameter D for each section as a function of the flow rates in the sections and the gradients J using equation (6) or (7) or (10). This assessment is based on the calculation of the parameters $\overline{D}$, $\overline{R}$,ψ with R* of the reference rough model according to equation (3), the diameter $\overline{D}$ is :

$$\overline{D} = (2\pi^2)^{-1/5}\left(\frac{Q^2}{gJ}\right)^{1/5} \quad (3)$$

Reynolds number $\overline{R}$ is by virtue of equation (10) for $\overline{Q} = Q$: (4)

$$\overline{R} = \frac{4Q}{\pi \overline{D} \nu} \quad (4)$$

The parameters $\overline{D}$ and $\overline{R}$ are used to assess the ψ according to equation (5), i.e.:

$$\psi \cong 1.35\left[-\log\left(\frac{\varepsilon/\overline{D}}{4.75} + \frac{8.5}{\overline{R}}\right)\right]^{-2/5} \quad (5)$$

The diameter D is calculated using the equation: $D = \psi \overline{D}$ (6)

The Reynolds number is given by R* : $R^* = \psi^{3/2}\overline{R}$

Step 5: This stage consists of choosing the standard diameter or the commercial diameter. D_n=f(D) which depends on several parameters:

- The standard diameter chosen must be as close as possible to the nominal diameter chosen and must not be less than 150 mm in order to ensure fire protection;
- Where sections of 150 mm diameter pipe are more than 180 m long, the intersecting pipes (i.e. those to which they are attached) must be at least 200 mm in diameter, to avoid excessive pressure losses;
- In cul-de-sacs or where networks are only partially meshed, it is recommended that pipes with a diameter greater than 150 mm be used.

The results must be checked and adjusted by iterations to guarantee the performance and safety of the network.

To determine the corrected route flow, the corrected assumed pressure and the corrected piezometric level in each section, these parameters must be calculated, taking into account variations in flow and specific hydraulic conditions. These steps ensure optimum distribution of flows and pressures in the pipe network.

Step 1: The gradient of the head loss J is checked according to Darcy's equation

$$J = \frac{8f}{g\pi^2}\frac{Q^2}{D^5} \quad (11)$$

The coefficient of friction is determined by:

$$f = \left[-2\log\left(\frac{\varepsilon}{3,7D} + \frac{10,04}{\overline{R}}\right)\right]^{-2} \quad (12)$$

Where the Reynolds number $\overline{R}$ will be evaluated using the equation (13):

$$\overline{R} = 2R\left[-\log(\frac{\varepsilon}{3,7D} + \frac{5,5}{R^{0,9}})\right]^{-1} \quad (13)$$

The Reynold's number is obtained by:

$$R = \frac{4Q}{\pi R \upsilon} \quad (14)$$

The total head loss for each section is given by:

$$\Delta H = J.L \quad (15)$$

Step 2: Determination of the corrected flow rate
Step 3:
It entails:

Main Mesh Correction CMP:

$$CMP = -\frac{\sum \Delta H}{2\sum \frac{\Delta H}{Q}} \quad (16)$$

Adjacent Mesh Correction (AMC)

$$CMA = \frac{\pm CMP}{0} \quad (17)$$

In the existing case (depending on the direction of water flow in the network) if the section is not adiacent to the main mesh

Flow correction

$$Qcor = Q + CMP + CMA \quad (18)$$

Step 4: Determination of corrected piezometric levels and corrected assumed pressures.
The corrected piezometric level:

$$CPcor = CP - \Delta H \quad (19)$$

Assumed corrected pressure :

$$PScor = CPcor - CTN \quad (20)$$

The process of determining the corrected flows, pressures and piezometric levels is repeated iteratively until the Hardy-Cross conditions are verified for all the grid cells in the network.

The reference Rough Model Method is used until the meshes are in equilibrium and the two Hardy-Cross laws are respected. The number of iterations decreases as the diameters approach the standards.

B. Design and Operation of the Tool

The tool developed is based on RMM and aims at optimising the management of drinking water networks. It has been designed using MATLAB software to manage calculations and graphics, while Excel and Word are used to display the results.

The calculation process for determining corrected route flows, corrected assumed pressures, and corrected piezometric heads is iterative, following the steps described above, until the Hardy-Cross conditions are verified for all network meshes. In conclusion, RMM is an iterative process that aims to balance the meshes and ensure compliance with the Hardy-Cross laws. The resulting Intelligent Decision Support Tool (IDST) offers methodological solutions for optimal management of drinking water networks.

IV. APPLICATION

In this study, we propose to study a numerical model which is the subject of previous work by B. Achour, initiator of the RMM, in the context of drinking water distribution in the housing estate.

A. Presentation of the Achour B. Digital Model and its Results

The network examined in this study is made up of 3 meshes and 09 nodes with natural terrain dimensions (NTC) of between 56.8 and 99.3 m, as shown in Figure 2. From the start node 'R: Reservoir' this network runs between nodes '1, 5, 6, 2, 4, 7, 3' to end at the finish node '8'. The direction of water flow is indicated by arrows on each section, and the data relating to this network is given in Table 1.

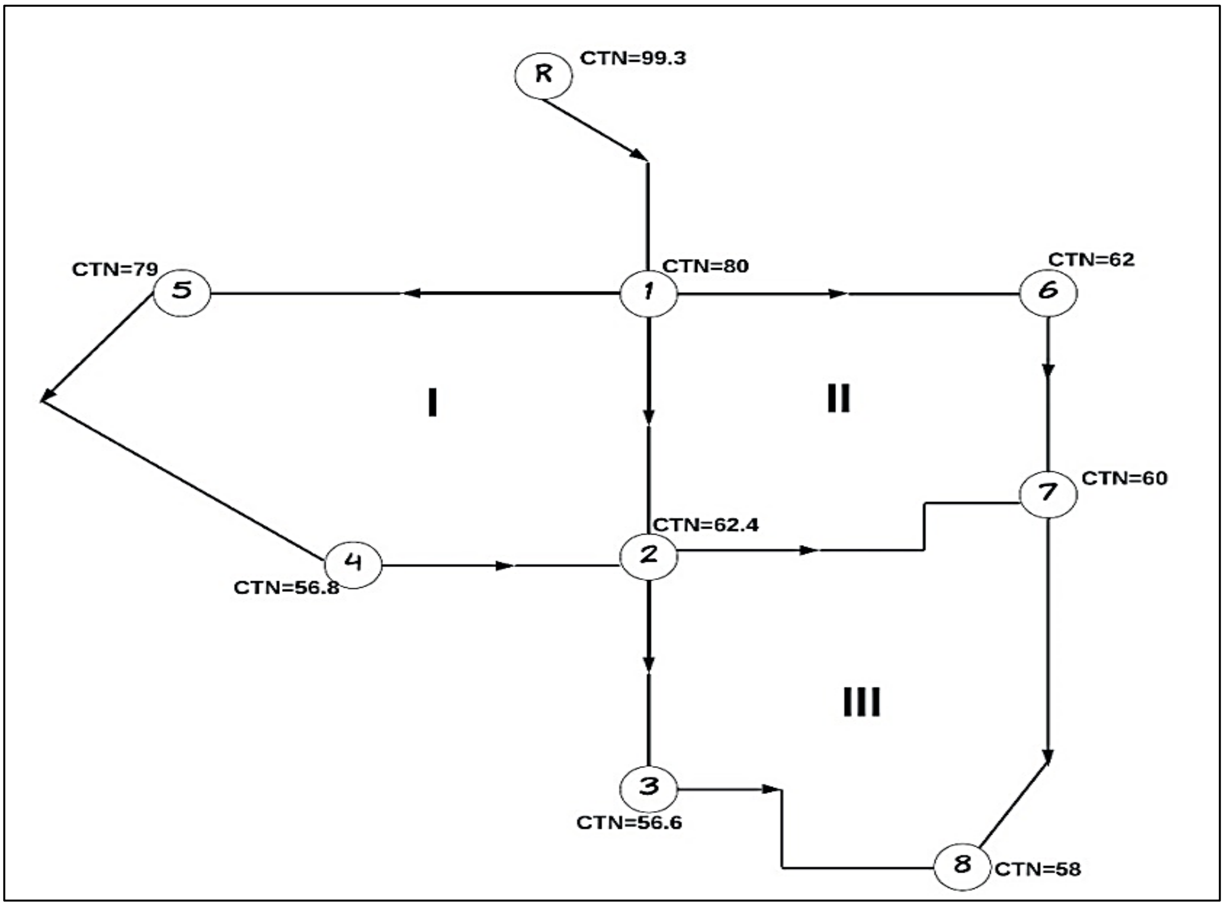


Figure 2: Diagram of the Mesh Network Studied

Table 1. Geometric and Hydraulic Parameters of the Network Studied (Bedjaoui A. et Achour B., 2014)

Mesh	Sections	Length (m)	Flow Rates (m3/s)	ε (m)	CTN	
I	1-2	186	0.171	0.0001	80	62.4
	5-1	170	0.04833	0.0001	79	80
	5-4	355	0.04833	0.0001	79	56.8
	4-2	25	0.03333	0.0001	56.8	62.4
II	1-6	300	0.04833	0.0001	80	62
	6-7	125	0.03133	0.0001	62	60
	7-2	357	0.02033	0.0001	60	62.4
	2-1	186	0.04833	0.0001	62.4	80
III	7-8	270	0.021	0.0001	60	48.5
	7-2	357	0.02033	0.0001	60	62.4
	2-3	107	0.02033	0.0001	62.4	56.6
	3-8	242.5	0.00533	0.0001	56.6	48.5

The results of the work carried out by this author are summarised in the tables below:

- Table 2 shows the steps involved in calculating the theoretical pipe diameter of each section in the network and the standard (commercial) diameter chosen by the author;
- Table 3 is a procedure for determining the corrected road flow rate and the corrected piezometric levels from the theoretical diameter;
- Table 4 represents the first iteration in the search for corrected flow rates, corrected piezometer heights and corrected assumed pressures for the network sections and nodes;
- Table 5 represents the last iteration (iteration 3) verifying the Hardy-cross condition allowing us, for the pipe diameters chosen (marketed), to determine our corrected flow rates, corrected piezometric levels and corrected assumed pressures.

Table 2. Calculation of the Mesh Network Using the New Method STEP: Determination of Pipe Diameters (Bedjaoui A. et Achour B., 2014)

MP	MA	Ss		Q (m3/s)	Assumed Pressures		CP		ΔHt (m)	J	$\overline{D}$ (m)	$\overline{R}$	ψ	D thé (m)	D Norm (m)
		Start	Finish		PS Start	PS Finish	CP Start	CP Finish							
1		0	1	0.171	0	19	99.3	99	0.3	0.0027	0.562	3.88E+05	0.83	0.4646	0.500
	2	1	2	0.04833	19	30	99	92.4	6.6	0.0355	0.202	3.04E+05	0.78	0.1589	0.150
		1	5	-0.04833	19	19	99	98	1	0.0059	0.290	2.12E+05	0.78	0.2260	0.250
		5	4	-0.03333	19	36	98	92.8	5.2	0.0146	0.208	2.04E+05	0.79	0.1640	0.150
		4	2	-0.01833	36	30	92.8	92.4	0.4	0.016	0.161	1.45E+05	0.80	0.1285	0.150
2		1	6	0.04833	19	35	99	97	2	0.0067	0.283	2.18E+05	0.78	0.2205	0.200
		6	7	0.03133	35	35	97	95	2	0.016	0.200	2.00E+05	0.79	0.1575	0.150
	3	7	2	-0.02033	35	30	95	92.4	2.6	0.0073	0.197	1.32E+05	0.791	0.1561	0.150
	1	1	2	-0.04833	19	30	99	92.4	6.6	0.0355	0.202	3.04E+05	0.78	0.1589	0.150
3		7	8	0.021	35	34	95	92	3	0.0111	0.183	1.46E+05	0.79	0.1454	0.150
	2	7	2	0.02033	35	30	95	92.4	2.6	0.0073	0.197	1.32E+05	0.79	0.1561	0.150
		2	3	-0.02033	30	35.6	92.4	92.2	0.2	0.0019	0.258	1.00E+05	0.79	0.2046	0.200
		3	8	-0.00533	35.6	34	92.2	92	0.2	0.0008	0.178	3.82E+05	0.82	0.1460	0.150

Table 3. Calculation of the Meshed Network by Applying the Reference Rough Model Method for the Case where the Calculation Diameter is taken to be Equal to the Theoretical Diameter. (Bedjaoui A. et Achour B., 2014)

MP	MA	Sections		Q (m3/s)	D thé (m)	ΔHt (m)	ΔH/Q (m)	CMP (m3/s)	CMA (m3/s)	First correction				
		Start	Finish							Qcor (m3/s)	CP		PS	
1		0	1	0.171	0.4646	0.30	1.76	0.0000	0.0000	0.1710	99.3	99	0	19
	2	1	2	0.04833	0.1589	6.61	136,68	0.0000	0.0000	0,0483	99	92,39	19	29.99
		1	5	-0.04833	0.2260	-1.00	20,73	0.0000	0.0000	-0,0483	99	98	19	19
		5	4	-0.03333	0.1640	-5.21	156,26	0.0000	0.0000	-0,0333	98	92,79	19	35.99
		4	2	-0.01833	0.1285	-0.40	21,86	0.0000	0.0000	-0,0183	92,79	92.39	35.99	29.99
						-0.01	335,53							
2		1	6	0.04833	0.2205	2.00	41,46	0.0000	0.0000	0,0483	99	97	19	35
		6	7	0.03133	0.1575	2.00	63,94	0.0000	0.0000	0,0313	97	94,99	35	34.99
	3	7	2	-0.02033	0.1561	2.61	128,19	0.0000	0.0000	0,0203	94,99	92,39	34.99	29.99
	1	1	2	-0.04833	0.1589	-6.61	136,68	0.0000	0.0000	-0,0483	99	92,39	19	29.99
						0.01	370,26							
3		7	8	0.021	0.1454	3.01	143,15	0.0000	0.0000	0,0210	94,99	91,99	34.99	33.99
	2	7	2	0.02033	0.1561	-2.61	128,19	0.0000	0.0000	-0,0203	94,99	92,39	34.99	29.99

		2	3	-0.02033	0.2046	-0.20	9.87	0.0000	0.0000	-0,0203	92,39	92,19	29.99	35.59
		3	8	-0.00533	0.1460	-0.20	37,66	0.0000	0.0000	-0,0053	92,19	91,99	35.59	33.99
						0.00	318,88							

Table 4. Calculation of the Meshed network by Applying the Reference Rough Model Method for the Case where the Calculation Diameter is taken to be Equal to the Standard Diameter (Iteration no. 01) (Bedjaoui A. et Achour B., 2014)

MP	MA	Sections		Q (m3/s)	D Norm (m)	ΔHt (m)	ΔH/Q (m)	CMP (m3/s)	CMA (m3/s)	First correction				
		Start	Finish							Qcor (m3/s)	CP		PS	
1		0	1	0.171	0.500	0,20	1,20	0,0001	0,0002	0.1710	99.3	99,10	0,00	19,10
	2	1	2	0.04833	0.150	8,88	183,71	0,0001	0.0000	0,0486	99,10	90,22	19,10	27,82
		1	5	-0.04833	0.250	-0,60	12,46	0,0001	0.0000	-0,0482	99,10	98,48	19,10	19,49
		5	4	-0.03333	0.150	-8,22	246,65	0,0001	0.0000	-0,0332	98,49	90,27	19,49	33.47
		4	2	-0.01833	0.150	-0,18	9,99	0,0001	0.0000	-0,0182	90,27	90.09	33,47	27,69
						-0,13	452,81		0,0001					
2		1	6	0.04833	0.200	3,29	68,04	-0,0002	0.0000	0,0482	99,10	95,81	19,10	33,81
		6	7	0.03133	0.150	2,57	81,95	-0,0002	0.0000	0,0312	95,81	93,24	33,81	33,24
	3	7	2	-0.02033	0.150	3,19	156,84	-0,0002	-0,0002	0,0186	93,24	90,05	33,24	27,65
	1	1	2	-0.04833	0.150	-8,88	183,71	-0,0002	-0,0001	-0,0486	99,10	90,22	19,10	27,82
						0,17	490,55		-0,0002					
3		7	8	0.021	0.150	2,57	122,19	0,0016	0.0000	0,0226	93,24	90,67	33,24	32,67
	2	7	2	0.02033	0.150	-3,19	156,84	0,0016	0,0002	-0,0186	93,24	90,05	33.24	27,65
		2	3	-0.02033	0.200	-0,22	11,06	0,0016	0.0000	-0,0187	90,05	89,83	27,65	33,23
		3	8	-0.00533	0.150	-0,18	32,98	0,0016	0.0000	-0,0037	89,83	89,65	33,23	31,65
						-1,02	323,07		0,0016					

Table 5. Calculation of the Meshed Network by Applying the Reference Rough Model Method for the Case where the Calculation Diameter is taken to be equal to the Standard Diameter (Iteration no. 03) (Bedjaoui A. et Achour B., 2014)

MP	MA	Sections		Q (m3/s)	D Norm (m)	ΔHt (m)	ΔH/Q (m)	CMP (m3/s)	CMA (m3/s)	First correction				
		Start	Finish							Qcor (m3/s)	CP		PS	
1		0	1	0.171	0.500	0,20	1,20	0,0002	0.0000	0.1710	99.3	99,10	0,00	19,10
	2	1	2	0,0515	0.150	8,78	182,71	0,0002	0.0000	0,0483	99,10	90,32	19,10	27,92
		1	5	-0,0456	0.250	-0,60	12,44	0,0002	0.0000	-0,0480	99,10	98,50	19,10	19,50
		5	4	-0,0306	0.150	-0,60	246,11	0,0002	0.0000	-0,0330	98,50	90,31	19,50	33.51
		4	2	-0,0156	0.150	-0,18	9,96	0,0002	0.0000	-0,0180	90,31	90.13	33,51	27,73
						-0,19	451,22		0,0002					
2		1	6	0,0479	0.200	3,33	68,50	0.0000	0.0000	0,0487	99,10	95,76	19,10	33,76
		6	7	0,0309	0.150	2,62	82,82	0.0000	0.0000	0,0317	95,76	93,14	33,76	33,14
	3	7	2	0,0220	0.150	2,82	147,93	0.0000	-0,0002	0,0188	93,14	90,32	33,14	27,92
	1	1	2	-0,0515	0.150	-8,78	182,71	0.0000	-0,0002	-0,0483	99,10	90,32	19,10	27,92
						0,00	481,96		0,0000					
3		7	8	0,0189	0.150	2,96	130,79	0,0002	0.0000	0,0228	93,14	90,18	33,14	32,18
	2	7	2	-0,0220	0.150	-2,82	147,93	0,0002	0.0000	-0,0188	93,14	90,32	33,14	27,92
		2	3	-0,0224	0.200	-0,19	10,28	0,0002	0.0000	-0,0185	90,32	90,12	27,92	33,52
		3	8	-0,0074	0.150	-0,09	24,48	0,0002	0.0000	-0,0035	90,12	90,03	33,52	32,03
						-0,15	313,49		0,0002					

B. Pre-Audit of the B. Achour Network Achour

Checking the functionality of this network is a prerequisite before using the tool. To do this, the network will initially be simulated on the Epanet software to ensure its reliability. Figures 3 and 4 are the result.

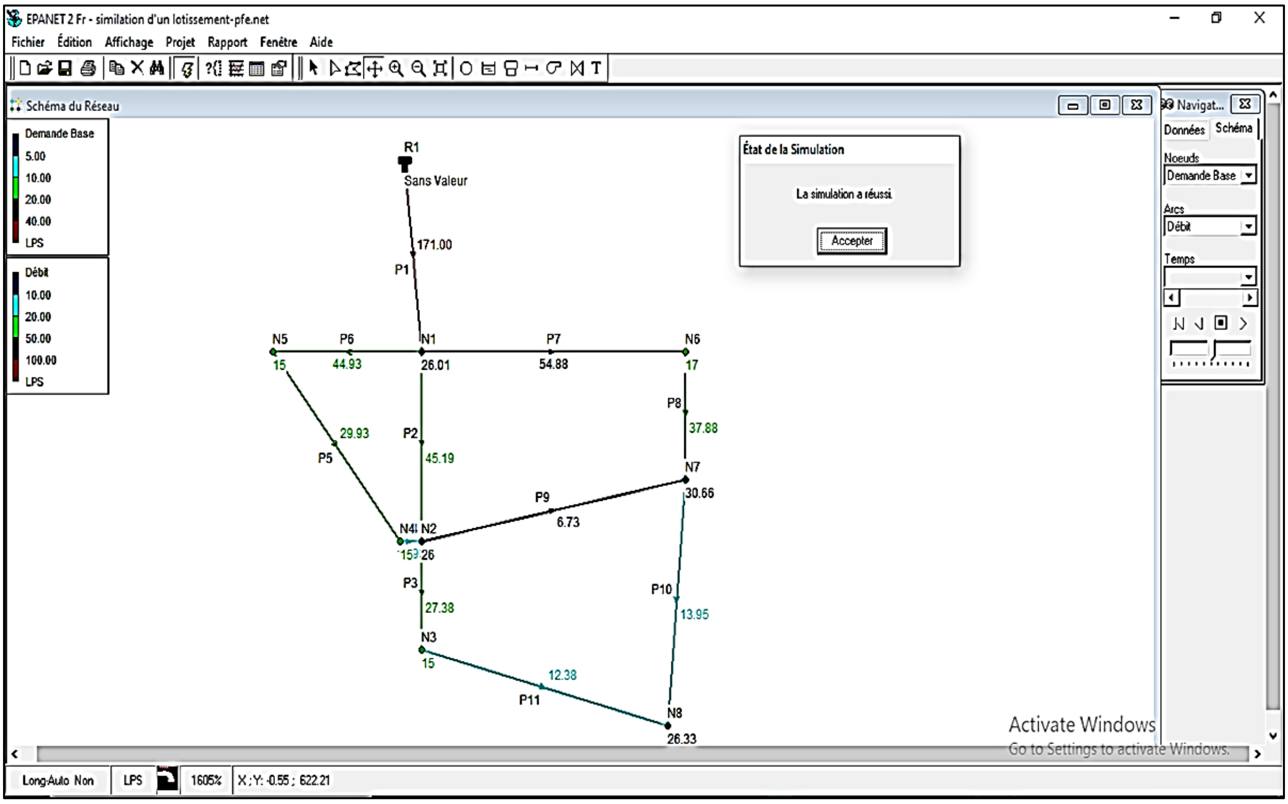


Figure 3. Flow Diagram for Nodes and Routes on the Network Simulated on EPANET

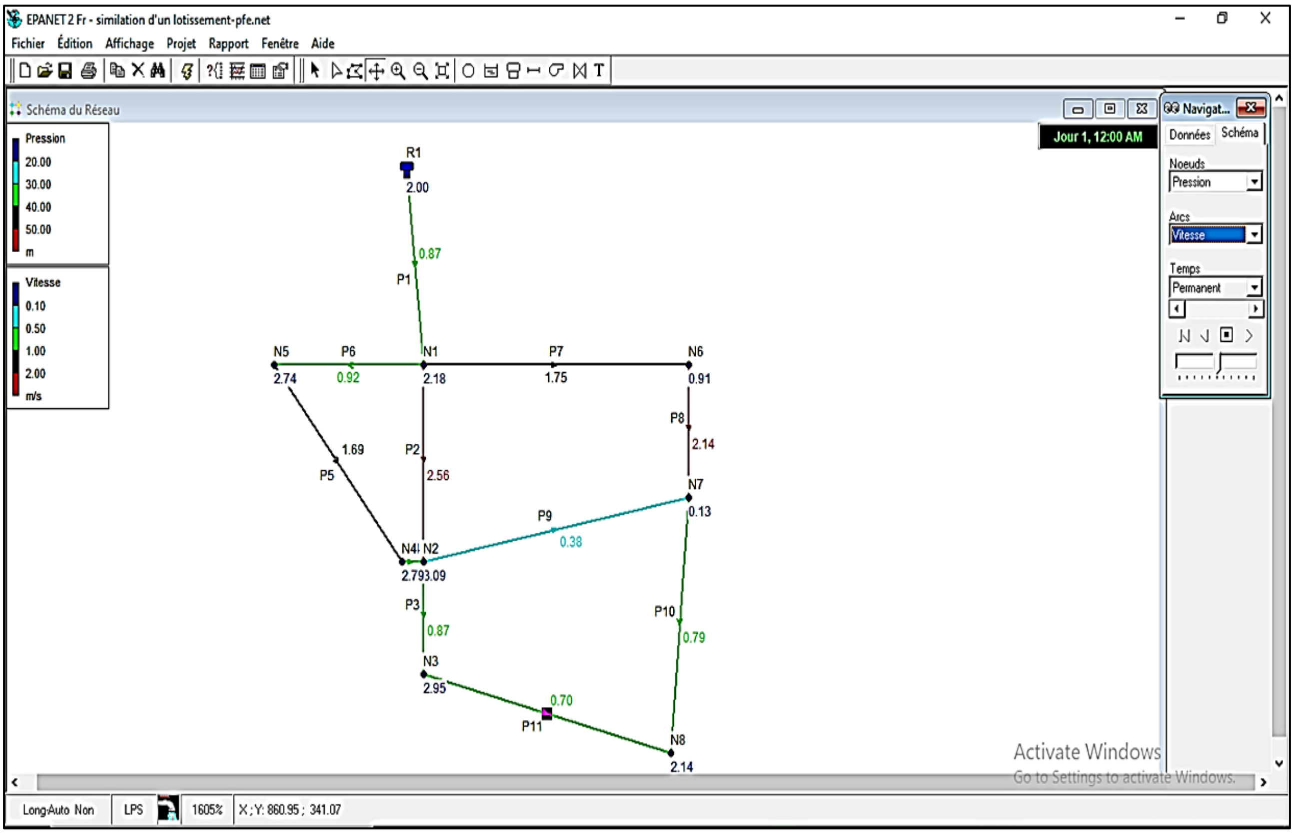


Figure 4. Diagram of Pressures at Nodes and Flow Speeds in the Network Simulated on EPANET

It should be noted that these results were taken from the simulated network up to the coordinates of each node, in order to identically reproduce the drinking water network that is the subject of this study. The simulation was successful in this network, thus marking the functional network.

C. Application of the Tool and Results

The network previously included in the work will be dimensioned using the application that has been set up. To do this, we will first need to have the coordinates of each node, and the lengths of each section will be calculated automatically, along with results such as the theoretical diameter, corrected route flows, corrected piezometric levels and corrected assumed pressures. However, the user will have to enter the data relating to the network as well as the commercial diameter of his locality. Both graphical and numerical results will be generated in Excel. Once installed, the user must have the minimum characteristics listed in the installation panel below:

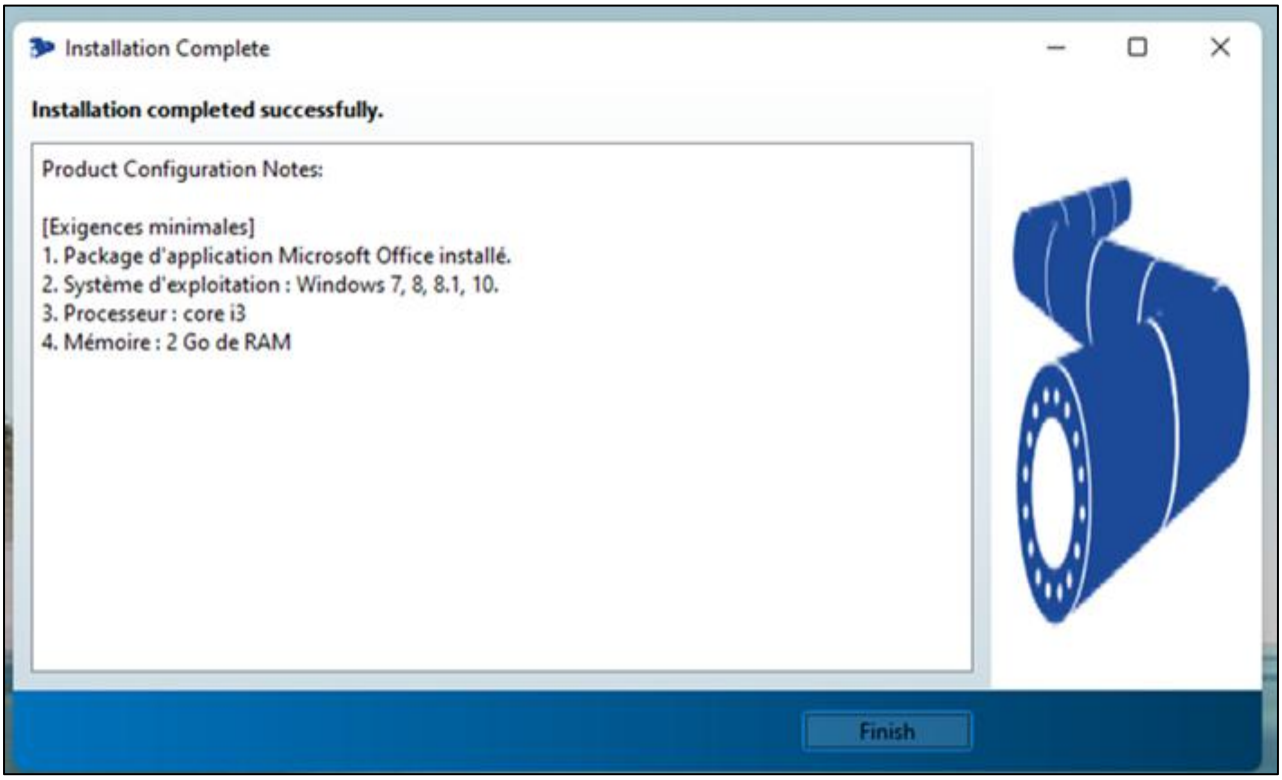


Figure 5. Application Installation Panel

Taking into account the piezometric levels at each node and the lengths of each section, the following planimetric coordinates are simulated:

Table 6 : Simulated Planimetric Coordinates of the Mesh Network of Bedjaoui A. et Achour B., 2014

Nœuds	Piezometric Levels CPM (m)	Planimetric Coordinates (x, y)	
Reservoir	99.3	180	577.9
Nodes 1	99	200	393
Nodes 2	92.4	200	207
Nodes 3	92.2	200	100
Nodes 4	92.8	175	207
Nodes 5	98	30	393
Nodes 6	97	500	393
Nodes 7	95	500	268
Nodes 8	92	480	26.3

These coordinates entered into the application led to the production of several results on the Excel spreadsheet named ‘Note de calcul’ presenting several sheets.

Ludovic Ivan Ntom Nkotto et al. 2(3), 75-91, 2025

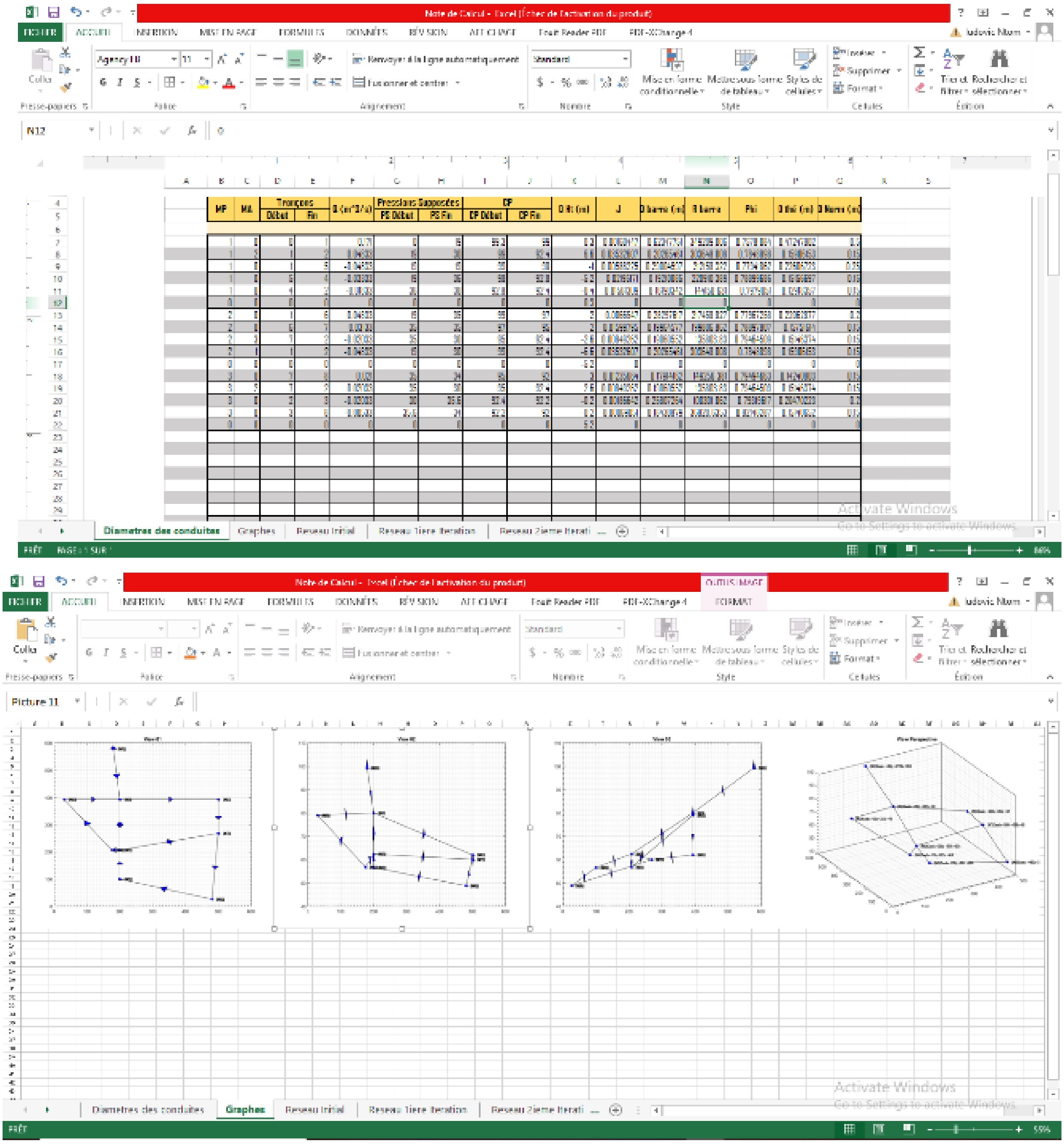


Figure 6 Presentation of the Different sheets of the Excel file 'Note de Calcul' (1-Diameter of the Pipes, 2-Graphs (x, y); (y, z); (z, x); (x, y, z), 3-Initial Network (All the Information Relating to the Initial Network), 4-1st Iteration (Start of Correction of CP, PS and Q)

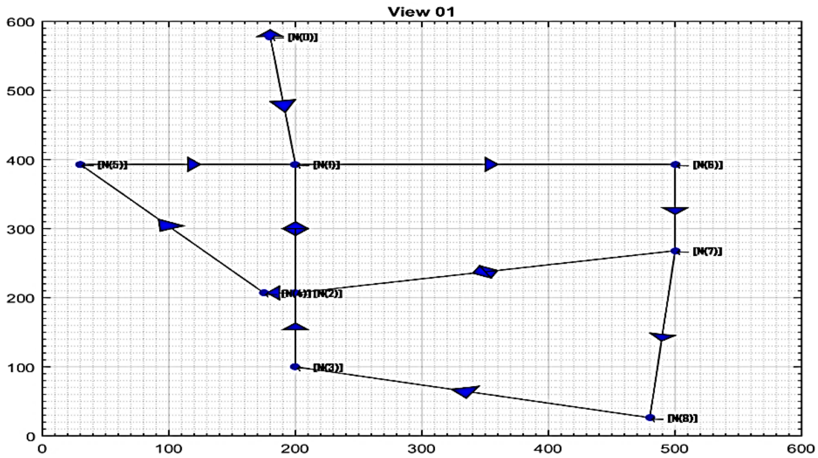
The first sheet of the spreadsheet is entitled 'Pipe diameters'. This sheet shows the theoretical diameters calculated and the nominal diameters entered by the user.

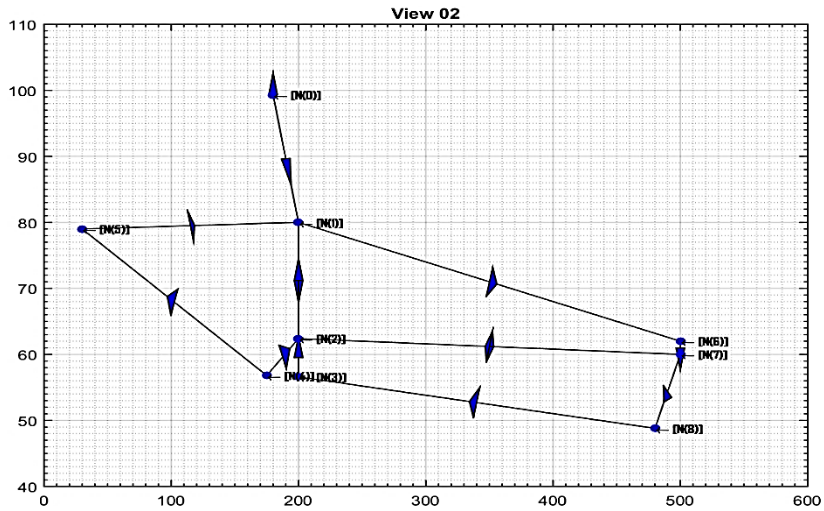
Table 7: Simulated Planimetric Coordinates of the Mesh Network of Bedjaoui A. et Achour B., 2014

MP	MA	Sections		Q (m^3/s)	Assumed Pressures		CP		D Ht (m)	J	D barre (m)	R barre	Phi	D thé (m)	D Norm (m)
		Start	Finish		PS Start	PS Finish	CP Start	CP Finish							
1	0	0	1	0.171	0	19	99.3	99	0.3	0.0016045	0.6234775	349209.01	0.7578108	0.472478	0.5
1	2	1	2	0.04833	19	30	99	92.4	6.6	0.0353261	0.2026546	303648.01	0.7848898	0.1590615	0.15

1	0	1	5	-0.04833	19	19	99	98	-1	0.0058823	0.290046	212158.32	0.7794186	0.2260672	0.25
1	0	5	4	-0.03333	19	36	98	92.8	-5.2	0.0219517	0.1921009	220910.39	0.7889969	0.151567	0.15
1	0	4	2	-0.01833	36	30	92.8	92.4	-0.4	0.0156131	0.1619034	144150.63	0.7979051	0.1291836	0.15
0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0
2	0	1	6	0.04833	19	35	99	97	2	0.0066547	0.2829762	217458.83	0.7796726	0.2206288	0.2
2	0	6	7	0.03133	35	35	97	95	2	0.015998	0.1996458	199806.86	0.7889781	0.1575161	0.15
2	3	7	2	-0.02033	35	30	95	92.4	-2.6	0.0084926	0.1906055	135803.83	0.7946451	0.1514637	0.15
2	1	1	2	-0.04833	19	30	99	92.4	-6.6	0.0353261	0.2026546	303648.01	0.7848898	0.1590615	0.15
0	0	0	0	0	0	0	0	0	-5.2	0	0	0	0	0	0
3	0	7	8	0.021	35	34	95	92	3	0.0123566	0.1791416	149256.38	0.7949466	0.142408	0.15
3	2	7	2	0.02033	35	30	95	92.4	2.6	0.0084926	0.1906055	135803.83	0.7946451	0.1514637	0.15
3	0	2	3	-0.02033	30	35.6	92.4	92.2	-0.2	0.0018664	0.2580726	100301.06	0.7931962	0.2047022	0.2
3	0	3	8	-0.00533	35.6	34	92.2	92	-0.2	0.0006905	0.1843088	36820.635	0.8214829	0.1514065	0.15
0	0	0	0	0	0	0	0	0	5.2	0	0	0	0	0	0

The second sheet shows the (x, y), (y, z), (z, x) and (x, y, z) diagrams generated by the software. The number of each node and its coordinates are presented in the form Ni (xi, yi, zi) in the last diagram. The direction of flow of the network is visible in each of these diagrams. In our study we have the diagrams below:





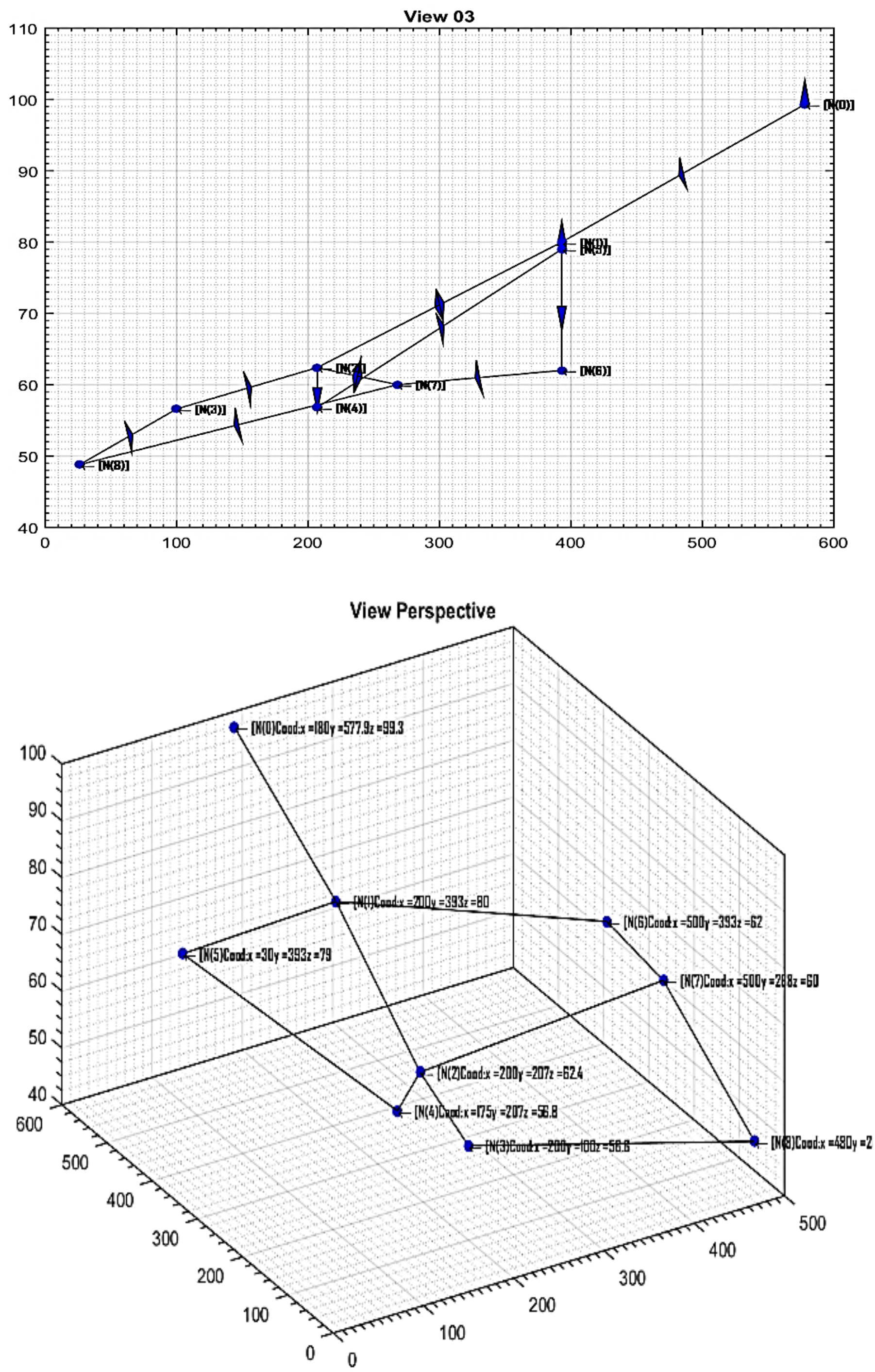


Figure 7: Diagram of the Mesh Network Studied Generated by the Software Graphs (x, y) ;(y, z) ;(z, x) ;(x, y, z)

- The third sheet recalls the initial network information before any calculation iteration;
- The fourth sheet of this file marks the start of the calculation iteration, which only ends once the flows, piezometric levels and assumed pressures have been corrected.

Table 8: Calculation of the Meshed Network by Applying the Rough Reference Model Method for the Case where the Calculation Diameter is taken to be Equal to the Theoretical Diameter

MP	MA	Sections		Q (m^3/s)	D Norm	D Ht (m)	D Ht / Q	D Q		Q cor	CP (i)		PS (i)	
		Start	Finish					C M P	C M A		CP Start	CP Finish	PS Start	PS Finish
1	0	0	1	0,171	0,5	0,3	1,754386	0,0004453	0	0,1916941	99,3	99,100271	0	19,100271
1	2	1	2	0,04833	0,15	6,6	136,56114	0,0004453	-0,0070333	0,0877877	99,100271	90,52528	19,100271	28,12528

1	0	1	5	-0,04833	0,25	-1	20,691082	0,0004453	0	-0,0276359	99,100271	98,459528	19,100271	19,459528
1	0	5	4	-0,03333	0,15	-5,2	156,0156	0,0004453	0	-0,0126359	98,459528	92,87939	19,459528	36,07939
1	0	4	2	-0,01833	0,15	-0,4	21,822149	0,0004453	0	0,0023641	92,87939	92,634438	36,07939	30,234438
0	0	0	0	0	0	0,3	336,84436	0	0	0	0	0	0	0
2	0	1	6	0,04833	0,2	2	41,382164	-0,0070333	0	0,0670936	99,100271	95,95313	19,100271	33,95313
2	0	6	7	0,03133	0,15	2	63,836578	-0,0070333	0	0,0500936	95,95313	94,600895	33,95313	34,600895
2	3	7	2	-0,02033	0,15	-2,6	127,88982	-0,0070333	0,0081733	0,0078353	94,600895	92,516519	34,600895	30,116519
2	1	1	2	-0,04833	0,15	-6,6	136,56114	-0,0070333	0,0004453	-0,0088723	99,100271	90,52528	19,100271	28,12528
0	0	0	0	0	0	-5,2	369,6697	0	0	0	0	0	0	0
3	0	7	8	0,021	0,15	3	142,85714	0,0081733	0	0,0304017	94,600895	92,901718	34,600895	44,101718
3	2	7	2	0,02033	0,15	2,6	127,88982	0,0081733	-0,0070333	0,0484953	94,600895	92,516519	34,600895	30,116519
3	0	2	3	-0,02033	0,2	-0,2	9,8376783	0,0081733	0	-0,0109283	92,516519	92,205747	30,116519	35,605747
3	0	3	8	-0,00533	0,15	-0,2	37,523452	0,0081733	0	0,0040717	92,205747	92,033627	35,605747	43,233627
0	0	0	0	0	0	5,2	318,10809	0	0	0	0	0	0	0

Table 9 : Calculation of the Meshed Network by Applying the Reference Rough Model Method for the Case where the Calculation Diameter is Taken to be Equal to the Standard Diameter (Iteration no. 01)

MP	MA	Sections		Q (m^3/s)	D Norm	D Ht (m)	D Ht / Q	D Q		Q cor	CP (i)		PS (i)	
		Start	Finish					C M P	C M A		CP Start	CP Finish	PS Start	PS Finish
1	0	0	1	0,171	0,5	0,3	1,754386	0,0004453	0	0,2293883	99,3	99,049297	0	19,049297
1	2	1	2	0,04833	0,15	6,6	136,5611	0,0004453	-0,0070333	0,1472679	99,049297	71,092983	19,049297	8,6929827
1	0	1	5	-0,04833	0,25	-1	20,69108	0,0004453	0	0,0100583	99,049297	98,821801	19,049297	19,821801
1	0	5	4	-0,03333	0,15	-5,2	156,0156	0,0004453	0	0,0250583	98,821801	97,256193	19,821801	40,456193
1	0	4	2	-0,01833	0,15	-0,4	21,82215	0,0004453	0	0,0400583	97,256193	92,797023	40,456193	30,397023
0	0	0	0	0	0	0,3	336,8444	0	0	0	0	0	0	0
2	0	1	6	0,04833	0,2	2	41,38216	-0,0070333	0	0,0888796	99,049297	93,140066	19,049297	31,140066
2	0	6	7	0,03133	0,15	2	63,83658	-0,0070333	0	0,0718796	93,140066	90,882216	31,140066	30,882216
2	3	7	2	-0,02033	0,15	-2,6	127,8898	-0,0070333	0,0081733	0,0496832	90,882216	94,624774	30,882216	32,224774
2	1	1	2	-0,04833	0,15	-6,6	136,5611	-0,0070333	0,0004453	0,0506079	99,049297	98,708665	19,049297	36,308665
0	0	0	0	0	0	-5,2	369,6697	0	0	0	0	0	0	0
3	0	7	8	0,021	0,15	3	142,8571	0,0081733	0	0,0504636	90,882216	90,616189	30,882216	41,816189
3	2	7	2	0,02033	0,15	2,6	127,8898	0,0081733	-0,0070333	0,0903432	90,882216	80,954373	30,882216	18,554373
3	0	2	3	-0,02033	0,2	-0,2	9,837678	0,0081733	0	0,0091336	80,954373	92,343002	18,554373	35,743002
3	0	3	8	-0,00533	0,15	-0,2	37,52345	0,0081733	0	0,0241336	92,343002	92,101697	35,743002	43,301697
0	0	0	0	0	0	5,2	318,1081	0	0	0	0	0	0	0

IV. COMPARISON OF RESULTS AND DISCUSSION

The network simulated in this study has been previously simulated on the EPANET application (Junyu Li et al., 2022). Based on the successful simulation, we deduce that the network proposed by B. Achour is a functional network (Achour, 2019). In addition, the graphical presentation of the network shows a modelling of the hydraulic network with precision on the direction of water flow on the reference frame (x, y, z) thus noting the influence of the various parameters on the operation of the network and the analysis of its behaviour based on its structural or functional modifications. (Guide d'application de la réglementation, 2024). The hydraulic model studied was built on the basis of the physical components (nodes, pipes, cover) and the values of their properties. (A. B. KONAN-WAIDHET et al., 2023).

A. Standard Diameter

Standard diameters, which are generally selected based on calculated theoretical diameters, are of paramount importance in network design (Guide technique eau, 2009). These diameters are rounded off to the nearest centimetre depending on the dimensions available and marketed (Guide technique AEP 3M, 2014). In the current work, the standard diameters deduced in Table 7 of the tool used are identical for each section in each mesh to those presented by B. Achour in Table 2 (Achour, 2019). This correspondence attests to the reliability of the application for calculating standard diameters, guaranteeing accuracy and compliance with industry standards (Hossain, 2021).

B. Assumed Pressures at Theoretical Diameters

The assumed pressures, which depend on the piezometric levels upstream and downstream of a section, have almost similar values between those in Table 8 of the application implemented and those in Table 3 of Mr Dupont's previous study (Vali Ghorbanian, 2016). The differences, of the order of a centime, can be explained by the rounding limited to two digits after the decimal point in the studies by the authors concerned (Guide technique AEP 3M, 2014). This also establishes the reliability of the software for calculating theoretical diameters, deducting standard diameters and calculating assumed pressures (Lefèvre, 2020).

C. Assumed Pressures at Commercial Diameters

The analysis of the determination of assumed pressures at commercial diameters is of paramount importance for the functionality and reliability of a drinking water network, particularly for meshed networks (Vali Ghorbanian, 2016). The tables used in this analysis are Tables 11 and 6, representing respectively the determination of assumed pressures through standardised diameters by the application and by the study conducted by B. Achour. Contrary to the similarity observed in the case of theoretical diameters, we note a discrepancy in the results throughout mesh 3, in mesh 1 for sections 1-2 and 5-4, and in mesh 2 for sections 7-2 and 1-2 (Jim W., 2009). This discrepancy could be explained by the sensitivity of the roundings used in the studies carried out by B. Achour. Because of this discrepancy, it was not necessary to extend the calculations to the third iteration as suggested by the author, since each iteration depends on the previous one (Jim W., 2009).

V. CONCLUSION

The hydraulic simulation software proved reliable for simulating and calculating standard diameters and pressures assumed at theoretical diameters. However, adjustments are required to improve the accuracy of pressures assumed at commercial diameters, particularly in meshed networks. These results highlight the importance of rounding accuracy in hydraulic studies and the need for further validation to ensure the reliability of drinking water networks. The combined approach of the Rough Model Method (RMM) and optimisation will enable optimum design of drinking water networks in Cameroon, to meet the growing demand for water. This design will take account of the country's specific geographical, hydrological and socio-economic features, ensuring efficient management of water resources and improved access to drinking water. The applicability of this work is based on drinking water distribution networks with transient or turbulent flow for pipes with a relative roughness of between 0 and 5x10^-2. Therefore, networks with welded steel pipes that have been in service for a long time, with the bitumen partially removed, networks with welded steel pipes with no notable unevenness at the internally coated joints, networks with welded steel pipes internally coated but not free from oxidation, fouled during service with water but not corroded, networks with welded steel pipes with double transverse riveting not corroded and fouled during service with water cannot be taken into account by this tool.

VI. REFERENCES

1. Bachir, L. Zeghadnia, and J.L. Robert, "Explicit Solutions for Turbulent Flow Friction Factor: A Review, Assessment and Approaches Classification," *Ain Shams Engineering Journal*, pp. 243–252, vol. 10, no. 1, 2019. Google Scholar | Publisher Link
2. A. Bedjaoui and B. Achour, "Sizing of Drinking Water Distribution Networks Using the Reference Roughness Method (RMM)," *Underground and Surface Hydraulics Research Laboratory – LARHYSS, University of Biskra*, 2014. Google Scholar | Publisher Link
3. A. Conde, M.Á. Toledo and E. Salete, "Cracks in Arch Dams: An Overview of Documented Instances," *Applied Sciences*, pp. 7580, vol. 14, no. 17, 2024. Google Scholar | Publisher Link
4. P.M. Diouf, and O. Diouf, "Design and Sizing of a Drinking Water Supply Network and a Wastewater Evacuation System for the New Town of Diamniadio," *End of Study Dissertation, Ecole Supérieure Polytechnique, University.* Google Scholar | Publisher Link
5. *Cheikh Anta Diop de Dakar*, 128p, 2005, National Directorate of Drinking Water and Sanitation (DINEPA), "Guide to the Application of Regulations Relating to Work Near Networks," *Booklet 2, Technical Guide Version 3, National DT DICT Observatory*, 259p, 2024. Publisher Link
6. Guide technique AEP 3M, "Technical Specifications for the Design and Construction of Water Works," *Montpellier Mediterranean Metropolis*, 2014. Google Scholar | Publisher Link
7. Water Technical Guide, Veolia Environnement, 250p, 2009. Google Scholar | Publisher Link
8. N.S. Grigg, "Water Distribution Systems: Integrated Approaches for Effective Utility Management," *Water*, vol. 16, no. 4, pp. 524, 2024. Google Scholar | Publisher Link
9. A.B. Konan-Waidhet, A.B. Yao, G.B. Ouede, T.J.J. Koua and B. Dibi, "Simulation of the Operation of the Drinking Water Supply (AEP) Network of the Localities of Bébouo-Sibouo, Zaliouhan and Krébléguhé in the Sub-Prefecture of Gadouan (Central-West of Côte d'Ivoire) using the Epanet Software," *International Journal of Innovation and Applied Studies*, vol. 40, no. 3, pp. 778–791, 2023. Google Scholar | Publisher Link
10. S. Hossain, G.A. Hewa, C.W.K. Chow and D. Cook, "Modelling and Incorporating the Variable Demand Patterns to the Calibration of Water Distribution System Hydraulic Model," *Water*, vol. 13, no. 20, pp. 2890, 2021. Google Scholar | Publisher Link
11. J.W. Hall, S.A. Boyce, Y. Wang, R.J. Dawson, S. Tarantola and A. Saltelli, "Sensitivity Analysis for Hydraulic Models," *Journal of Hydraulic Engineering*, pp. 959–969, 2009. Google Scholar | Publisher Link
12. J. Li, S. Liu, F. Meng, X. Li and K. Smith, "An Efficient Constraint-Based Pruning Method to Improve Chlorine Dosage Optimization," *Journal of Water Resources Planning and Management*, vol. 148, no. 8, 04022038, 2022. Google Scholar | Publisher Link
13. A. Lefkir, "Contribution to the Optimization of Water Distribution Networks," *Doctoral Thesis, National Polytechnic School of Hydraulics*, 2000. Google Scholar | Publisher Link
14. L.I. Ntom Nkotto, B.M. Manjia, E.R. Wilson and J.V. Sontia Metekong, "Optimisation of the Choice of the Sizing Method for Drinking Water Networks in the Developing Countries: A Case of Cameroon," *International Journal of Engineering, Science and Technology*, vol. 15, no. 1, pp. 13–25, 2023. Google Scholar | Publisher Link
15. V. Ghorbanian, B. Karney and Y. Guo, "Pressure Standards in Water Distribution Systems: Reflection on Current Practice with Consideration of Some Unresolved Issues," *Journal of Water Resources Planning and Management*, 2016. Google Scholar | Publisher Link
16. Z. Li, H. Liu, C. Zhang and G. Fu, "Real-Time Water Quality Prediction in Water Distribution Networks Using Graph Neural Networks with Sparse Monitoring Data," *Water Research*, vol. 250, 121018, 2024. Google Scholar | Publisher Link