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Analyzing and Optimization of Performance of Pipe Configuration of Hostels at The Rivers State University in Nigeria

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ABSTRACT

Simulations allow engineers to explore different pipe configuration, materials and flow parameters to optimize system efficiency, minimize pressure losses and enhance good performance of hydraulic systems. The aim of study is to numerically simulate water distribution network in Rivers State University in order to know at what point does a transition occurs in pipes. In light of the findings from this research, it is recommended that a new submersible water well be drilled and installed. This well will serve as a reliable source of water, ensuring a consistent and sufficient supply to the F and G hostels. Additionally, a new overhead tank with a larger capacity should be constructed and designed to store the water efficiently. This tank will play a crucial role in maintaining a steady water supply, even during periods of high demand. The installation of the submersible well will significantly improve the water supply system for the F and G hostels, as well as for the F extension, Post Graduate, PG 1, 2, 3, and 4. This new water source will help reduce the pressure on the existing water infrastructure, which has been strained due to the ongoing water crisis.

KEYWORDS: *Mathematical modelling, Hydraulic systems, Performance, submersible water well, Overhead tank*

INTRODUCTION

Numerical simulation of water distribution networks are efficient decision support tools for development of various management scenarios to improve efficiency and reliability of existing network and to design new ones. In hydraulic models, well known hydraulic equations are involved to calculate main hydraulic parameters; such as flow rate, velocity, water pressure etc. at different points for the described water distribution network and the results are obtained and displayed tabular and graphical form to be evaluated by the users. The success of hydraulic models' predictions depends on accurate determination/estimation of input parameters and model calibration and verification studies (Egop & Echikwa, 2025). Currently many waters distribution network are equipped and controlled with supervisory control and data acquisition system to improve network efficiencies. Moreover, supervisor control and data acquisition system could be integrated with well calibrated and verified hydraulic models to provide useful inputs data sets for model set up and comparison with model predictions. In routine monitoring and control studies of water distribution networks, only limited number of monitoring and control points are selected on water distribution network to collect hydraulic data. However, an accurate calibration and verification study of hydraulic models requires simultaneous and precise estimation of many hydraulic parameters. In literature, many successful hydraulic modelling applications are presented for different operational purposes such as extension of water distribution network by adding new pipe, dividing the water distribution network system into several sections.

Determination of critical areas of rehabilitation, determination of optimum network pressure and evaluation of different water losses reduction techniques to predict water saving amounts. Network hydraulic characteristic usually demonstrate wide temporal and spatial variations. The main reasons for these variations are the different water users are spatially distributed along the water distribution network and these users have different consumption rates and profiles. Both physical configuration of the water distribution network and the spatial and temporal variations of water consumption rates needs to be transferred correctly to hydraulic models to obtain accurate predictions from the modelling study. Physical configuration of water distribution networks such as coordinates, length, diameter and materials of pipes, junctions, connections, elevations etc., can be obtained from the geographical information systems (George *et al*., 2013). However, it is usually difficult to have information about temporal and spatial variations of water consumption rates and other hydraulic parameters. In general, there are two main challenges to be addressed in hydraulic modelling applications. The first one is that the exact location of service pipe connections is not known for all water users/subscribers.

The frequency of water meter readings is not enough to prepare accurate water demand profiles for hydraulic simulation of water distribution networks with short time steps. Moreover, water losses need to be taken into account in hydraulic modelling applications as it could be one of the biggest water users in poorly managed water distribution networks where losses are reported as high as 50% or even more of system input volume. Usually the exact amount and spatial/temporal variations of water loses are not known and it is difficult to decide about the location and amount of water loses as an input to hydraulic models. Real water loses, a component of total water loses, may be distributed equally or in proportion to all nodes in water distribution network to overcome this uncertainty. Contrarily, spatial and temporal allocation of water loses are less than 15% of system input volume. The prescribed challenges could be defined as the main cause of potential model errors in hydraulic modelling applications but still different engineering approaches are used to overcome these difficulties. In addition to these problems, the users of hydraulic models face with another difficulty, which is the lack of reliable data sets, and usually the required data sets need to be supplied by the water utilities. Periodic reading of water subscribers' water is performed by water utilities for billing in long time intervals such as monthly, bimonthly, quarterly, 6 month or yearly. Laminar flow is also known as streamline flow is a type of fluid flow where the fluid moves in smooth parallel layers without mixing or fluctuating in this type of flow, fluid particles move along well-defined paths without crossing or disrupting each other's trajectories. In other words, the velocity of the fluid at a given point remains constant over time (Chevrin *et al.*, 1992).

LITERATURE REVIEW

Egop and Echikwa (2025) developed an empirical mathematical model for the simulation of flows over V-notches with the application of density, gravity, head of flow and notch angle using Buckingham's $\pi -$method of dimensional analysis. The model performance was evaluated using statistical indices. The coefficient of determination (r^2=0.9992) indicated near-perfect agreement between observed and predicated values, while the Nash-Sutcliffe efficiency (NSE = 0.88) and Relative BAIS (rBAIS = 0.15) confirmed very good predictive

ability with minimal systematic error. The study concludes that the triangular notch is a reliable, cost-effective, and accurate device for measuring low discharges in open channels.
Chevrin *et al.* (1992) investigated Reynold's stress in the near-wall region of fully developed turbulent pipe flow using glycerin as the working fluid. Two laser Doppler velocimeter (LDV) systems were employed to measure the two-point spatial correlation (R12) between streamwise and radial velocities in the radial plane of the pipe.

Habib *et al*. (1999) analyzed heat transfer characteristics of pulsated turbulent pipe flow under different pulsation frequencies, amplitudes, and Reynolds numbers, with uniform heat flux at the pipe wall. They revealed that pulsation had little effect on the mean Nusselt numbers at low Reynolds numbers.

Pavelyev *et al*. (2003) conducted experiments to evaluate resistance coefficients at critical Reynolds numbers using Blasius and Prandtl formulas for laminar and turbulent flow, respectively, and also studied the effect of inserts. Their findings concluded that inserting a rod led to a decrease in the critical Reynolds number. In 2005, Galinat et al. analyzed drop fragmentation caused by a cross-sectional restriction in a pipe, studying drop breakup downstream of the restriction and finding that the mean drop diameter increased linearly with the inverse square root of the pressure drop.

Katsuhide *et al*. (2011) investigated the effect of pipe diameter on pressure drop and heat transfer of cryogenic slush fluids, observing that larger pipe diameters resulted in higher onset velocities for reducing pressure drop, while also worsening heat transfer characteristics.
Kang and Yang (2012) studied flow instability in the presence of baffles in heat exchanger channels, observing that time-periodic two-dimensional flow bifurcated into three-dimensional flow.

George *et al*. (2013) performed numerical simulations for turbulent flow in smooth circular pipes at high Reynolds numbers, presenting a comprehensive dataset compared to other simulation results from pipes, channels, and boundary layers.

Wenbin *et al*. (2014) analyzed the influence of small pipe inserts on heat transfer performance and pressure drop in a circular tube. Their study showed that pipe inserts resulted in a relatively low flow resistance and high heat transfer coefficient, with the Nusselt number and friction factor increasing as spacer length and arc radius decreased.

Shinji *et al*. (2015) explored drag reduction and degradation in nonionic surfactant (Aromox) solutions by computing the pressure drop and flow rate in a circuit pipe flow system using a pump. They found that the addition of organic acids to the solution significantly reduced drag.

Farmani *et al*. (2016) provided comprehensive guidelines for designing water distribution networks in any town. The study incorporates pipe rehabilitation, tank sizing, siting, and pump operation schedules as key design variables. The authors utilize multi-objective evolutionary algorithms to balance total cost, reliability, and water quality, aiming to reduce costs through methods such as minimizing pipe diameter and storage facility residence time.

MATERIALS AND METHODS

Frictional Head Loss in Pipes

The frictional loss (hf) for incompressible flow in pipe depends on the fluid properties such as density (p), the viscosity of fluid (v), length of the pipe (L), internal diameter (D), pipe wall roughness (e), using diameter analysis, it has been that the head loss (hf) can be written as:

$$hf = \frac{fL}{D} \times \frac{V^2}{2g} \qquad \text{……..(1)}$$

Equation 1 is known as Darcy-weisbach formula.

If the velocity (v) is replaced by $^{Q}/_{A}$ and the area of flow by A = $^{\pi D^2}/_{4}$ for circular pipes, equation 1 becomes:

$$hf = \frac{16fLQ^2}{\pi^2 \times 2gD^5} = \frac{8fL}{\pi^2 \times 2gD^5} \times Q^2 = KQ^2 \qquad \text{……..(2)}$$

The coefficient of surface resistance for turbulent flow depends on the average height of roughness projection, ε of the pipe wall. The average roughness of pipe wall for commercial pipes is listed in Table 1

Table 1: Average Roughness Height

Pipe Material	**Roughness Height (mm)**
Wrought Iron	0.04
Asbestos Cement	0.05
Poly Vinyl Chloride (PVC)	0.05
Steel	0.05
Asphalted cast iron	0.13
Galvanized Iron	0.15
Cast/ductile Iron	0.25
Concrete	0.3-3.0
Riveted Steel	0.9-9.0

The coefficient of surface resistance also depends on the Reynolds number Re of the flow defined as:

$$Re = \frac{inertial\ forces}{viscous\ forces} = \frac{\rho v D}{\mu} \qquad (3)$$

Where p is density of the fluid, V is the velocity of the fluid flow; D is the diameter of the pipe and μ is the dynamic viscosity. Equation (3) can be in terms of kinematic viscosity (V) as:

$$Re = \frac{VD}{V_k} \qquad (4)$$

Where the ratio of the dynamic viscosity μ to density e is the kinematic viscosity

$$V_k = {}^{\mu}/_{\rho} \qquad (5)$$

The kinematic viscosity of fluid can be obtained using the equation given by Swamee and Sharma (2008). -1

$V_k = 1.792 \times 10^{-6} \left[1 + (\frac{T}{25})^{1.165}\right]$ (6)

Where T is the water temperature in $^\circ{}_C$. Pipe flow is the most commonly used mode of carrying fluid for small to moderately large discharges in a pipe flow, fluid fills the entire cross section and no free surface is formed. The fluid pressure is generally greater than the atmosphere pressure but in certain reaches it may be less than the atmosphere pressure, allowing free flow to continue through siphon action. However; is the pressure is much less than atmospheric pressure; the dissolved gases in the fluid come out and the continuity of the fluid in the pipeline will be hampered and flow will stop. The pipe flow is analyzed by using the continuity equation and the equation of motion. The continuity equation for steady flow in a circular pipe of diameter D is given as

$$Q = \frac{\bar{\wedge}}{4} D^2 V \quad (7)$$

The following equation can be obtained by substituting equation (6) into (7)

Re = $\frac{4Q}{\bar{\wedge} V D}$ (8)

For turbulent flow (Re = >4000) Colebrook (1938) found the following implicit equation for

F = 1.325 $\left[in \left(\frac{\varepsilon}{3.7D} + \frac{2.51}{Re\sqrt{f}}\right)\right]^{-2}$ (9)

Using equation (9) moody (1944) constructed a family of curves between f and Re for various values of relative roughness $\varepsilon/_D$

For laminar flow (Re ≤ 2000), f depends on *Re* only and is given by Hagen-Poiseuille equation

$f = {}^{64}/_{Re}$ (10)

For Re lying in the range between 2000 and 4000 (called transition range) no information is available about estimating *f*, Swamee (1993) gave the following equation for *f* valid in the laminar flow, turbulent flow and the transition in between them

$$f = \left\{\left(\frac{64}{Re}\right)^8 + 9.5\left[in\ \left(\frac{\varepsilon}{3.7D} + \frac{5.74}{Re^{0.9}}\right) - \left(\frac{2500}{Re}\right)^6\right]^{-16}\right\}^{0.125} \quad (10a)$$

Equation (10a) predicts f within 1% of the value obtained by equation (9). For turbulent flow equation (10a) simplifies to

$$f = 1.325\left[in\ \left(\frac{\varepsilon}{3.7D} + \frac{5.74}{Re^{0.9}}\right)\right]^{-2} \quad (10b)$$

Combining equation (8) and (10a) can be written as

$$f = 1.325\left\{in\left[\frac{\varepsilon}{3.7D} + 4.618\left(\frac{VD}{Q}\right)^{0.9}\right]\right\}^{-2} \quad (10c)$$

A more recent formulation is given by Barr (1985)

$$\frac{1}{\sqrt{f}} = -2.02log\left[\frac{ks}{3.7D} + \frac{5.1286}{Re^{0.89}}\right] \quad (11)$$

Pipes in Series

In case of a pipeline made up of different lengths of different diameters as the following head loss and flow conditions should be satisfied:

$$h_L = h_{L1} + h_{L2} + h_{L3} + \cdots$$

$$Q = Q_1 = Q_2 = Q_3 \cdots$$

Using the Darcy-Weisbach equation with constant friction factor f, and neglecting minor losses, the head loss in N pipes in series can be calculated as:

$$h_L = \sum_{i=I}^{N} \frac{8fL_iQ^2}{\pi^2\ gD_i^5} \quad (12)$$

Denoting equivalent pipe diameter as D_e the head loss can be rewritten as:

$$h_L = \frac{8fQ^2}{\pi^2\ gD_e^5}\sum_{i=I}^{N} L_i \quad (13)$$

Equating these two equations of head loss, one gets

$$D_e = \left(\frac{\sum_{i=1}^{N} L_i}{\sum_{i=1}^{N}\frac{L_i}{D_i^5}}\right)^{0.2} \quad (14)$$

Pipe in parallel

If the pipes are arranged in parallel, the following head loss and flow condition should be satisfied:

$h_L = h_{L1} = h_{L2} = h_{L3} = \cdots$

$Q = Q_1 + Q_2 + Q_3 + \cdots$

The pressure head at nodes A and B remains constant, meaning thereby that head loss in all the parallel pipes will be same.

Using the Darcy-Weisbach equation and neglecting minor losses, the discharge Q_i in pipe i can be calculated as

$$Q_i = \pi D_i^2 \left(\frac{gD_i h_L}{8fL_i}\right)^{0.5} \qquad (15)$$

Thus for N pipes in parallel,

$$Q = \pi \sum_{i=1}^{N} D_i^2 \left(\frac{gD_i h_L}{8fL_i}\right)^{0.5} \qquad (16)$$

The discharge Q flowing in the equivalent pipe is

$$Q = \pi D_e^2 \left(\frac{gD_e h_L}{8fL}\right)^{0.5} \qquad (17)$$

Where L is the length of the equivalent pipe. This length may be pipe length L_1, L_2, L_3, and so forth. Equating these two equations of discharge

$$D_e = \left[\sum_{i=1}^{N} \left(\frac{L}{L_i}\right)^{0.5} D_i^{2.5}\right]^{0.4} \qquad (18)$$

Newton-Raphson method

The pipe network can also be analyzed using the Newton-Raphson method, where unlike the Hardy Cross method, the entire network is analyzed altogether. The Newton-Raphson method is a powerful numerical method for solving system of non-linear equations. Suppose that there are three nonlinear equation $F_1(Q_1, Q_2, Q_3) = 0$, $F_2(Q_1, Q_2, Q_3) = 0$, and $F_3(Q_1, Q_2, Q_3) = 0$ to be solved for Q_1, Q_2, and Q_3. Adopt a starting solution (Q_1, Q_2, Q_3). Also consider that $Q_1 + \Delta Q_1, Q_2 + \Delta Q_2, Q_3 + \Delta Q_3$ is the solution of the equations. That is,

- $F_1(Q_1 + \Delta Q_1, Q_2 + \Delta Q_2, Q_3 + \Delta Q_3) = 0$
- $F_2(Q_1 + \Delta Q_1, Q_2 + \Delta Q_2, Q_3 + \Delta Q_3) = 0$ (19a)
- $F_3(Q_1 + \Delta Q_1, Q_2 + \Delta Q_2, Q_3 + \Delta Q_3) = 0$

Expanding the above equation as Taylor's series,

- $F_1 + [\partial F_1/\partial Q_1]\Delta Q_1 + [\partial F_1/\partial Q_2]\Delta Q_2 + [\partial F_1/Q_3]\Delta Q_3 = 0$
- $F_2 + [\partial F_2/\partial Q_I]\Delta Q_1 + [\partial F_2/Q_2]\Delta Q_2 + [\partial F_2/\partial Q_3]\Delta Q_3 = 0$ (19b)
- $F_3 + [\partial F_3/\partial Q_1]\Delta Q_1 + [\partial F_3/\partial Q_2]\Delta Q_2 + [\partial F_3/\partial Q_3]\Delta Q_3 = 0$

Arranging the above set of equation in matrix form

$$\begin{bmatrix} \partial F_1/\partial Q_1 & \partial F_1/\partial Q_2 & \partial F_1/Q_3 \\ \partial F_2/\partial Q_I & \partial F_2/Q_2 & \partial F_2/\partial Q_3 \\ \partial F_3/\partial Q_1 & \partial F_3/\partial Q_2 & \partial F_3/\partial Q_3 \end{bmatrix} \begin{bmatrix} \Delta Q_1 \\ \Delta Q_2 \\ \Delta Q_3 \end{bmatrix} = - \begin{bmatrix} F_1 \\ F_2 \\ F_3 \end{bmatrix} \tag{19c}$$

$$\begin{bmatrix} \Delta Q_1 \\ \Delta Q_2 \\ \Delta Q_3 \end{bmatrix} = - \begin{bmatrix} \partial F_1/\partial Q_1 & \partial F_1/\partial Q_2 & \partial F_1/Q_3 \\ \partial F_2/\partial Q_I & \partial F_2/Q_2 & \partial F_2/\partial Q_3 \\ \partial F_3/\partial Q_1 & \partial F_3/\partial Q_2 & \partial F_3/\partial Q_3 \end{bmatrix}^{-1} \begin{bmatrix} F_1 \\ F_2 \\ F_3 \end{bmatrix} \tag{20}$$

Knowing the corrections, the discharges are improved as

$$\begin{bmatrix} Q_1 \\ Q_2 \\ Q_3 \end{bmatrix} = \begin{bmatrix} Q_1 \\ Q_2 \\ Q_3 \end{bmatrix} + \begin{bmatrix} \Delta Q_1 \\ \Delta Q_2 \\ \Delta Q_3 \end{bmatrix} \tag{21}$$

Discharge problem

For a long pipeline, form losses can be neglected. Thus, in this case the known quantities are $L, D, h_f, g, and\ v$. Swamee and Sharma (2008) gave the following solution for turbulent flow through such a pipeline:

$$Q = -0.965D^2\sqrt{gDh_f/L}\ \text{in}\left(\frac{\varepsilon}{3.7D} + \frac{1.78v}{D\sqrt{gDh_f/L}}\right)$$ ……(22a)

Equation (22a) is exact. For laminar flow, the Hagen-Poiseuille equation gives the discharge as $Q = \frac{\pi g D^4 h_f}{128 v L}$ ....(22b)

Swamee and Sharma (2008) gave the following equation for pipe discharge that is valid under laminar, transition, and turbulent flow condition:

$$Q = D^2 \sqrt{\frac{gDh_f}{L}} \left\{ \left(\frac{128v}{\pi D \sqrt{\frac{gDh_f}{L}}} \right)^4 + 1.153 \left[\left(\frac{415v}{D \sqrt{\frac{gDh_f}{L}}} \right)^8 - ln \left(\frac{\varepsilon}{3.7D} + \frac{1.775v}{D \sqrt{\frac{gDh_f}{L}}} \right) \right]^{-4} \right\} \ldots \ldots ..(22c)$$

Equation (22c) is almost exact as the maximum error in the equation is 0.1%

Diameter problem

In this problem, the known quantities are $l., h_f, \varepsilon, Q, and\ v$. For a pumping main, head loss is not known, and one has to select the optimal value of head loss by minimizing the cost. However, for turbulent flow in a long gravity main, Swamee and Sharma (2008) obtained the following solution for the pipe diameter:

$$D = 0.66 \left[\varepsilon^{1.25} \left(\frac{LQ^2}{gh_f} \right)^{4.75} + vQ^{9.4} \left(\frac{L}{gh_f} \right)^{5.2} \right]^{0.04} \quad \ldots\ldots (23a)$$

In general, the errors involved in eq. (2.22a) are less than 1.5%. However, the maximum error occurring near transition range is about 3%. For laminar flow, the Hagen-Poiseuille equation gives the diameter as

$$D = \left(\frac{128vQL}{\pi g h_f} \right)^{5.2} \quad \ldots\ldots (23b)$$

Swamee and Swamee (2008) gave following equation for pipe diameter that is valid under laminar, transition, and turbulent flow conditions

$$D = 0.66 \left[\left(214.75 \frac{vLQ}{gh_f} \right)^{6.25} + \varepsilon^{1.25} \left(\frac{LQ^2}{gh_f} \right)^{4.75} + vQ^{9.4} \left(\frac{L}{gh_f} \right)^{5.2} \right]^{0.04} \quad (23c)$$

Equation (23c) yield *D* within 2.75%. However, close to transition range, the error is around 4%

RESULTS AND DISCUSSION

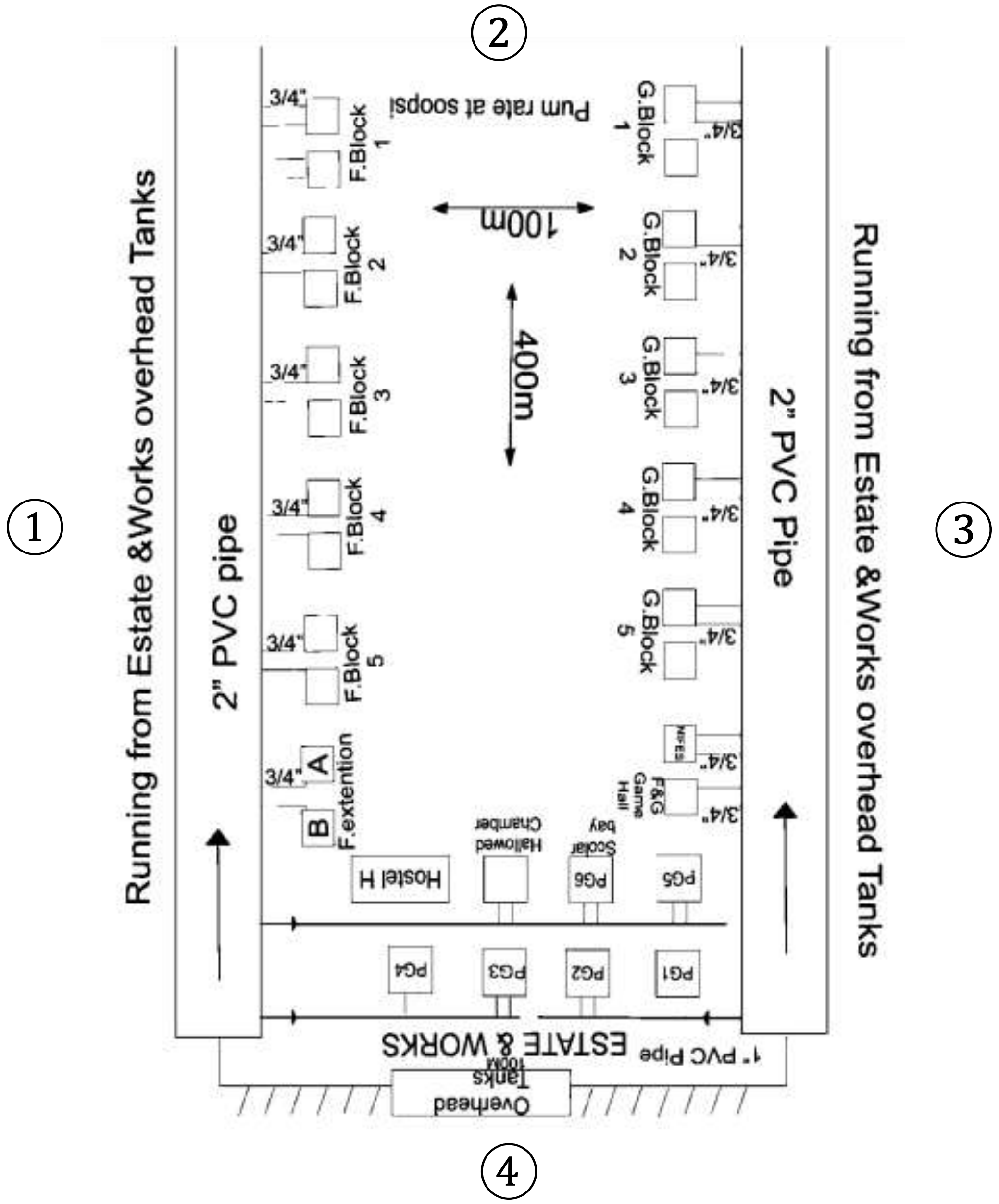

Figure 1: Pipe network system of Fand G hostel

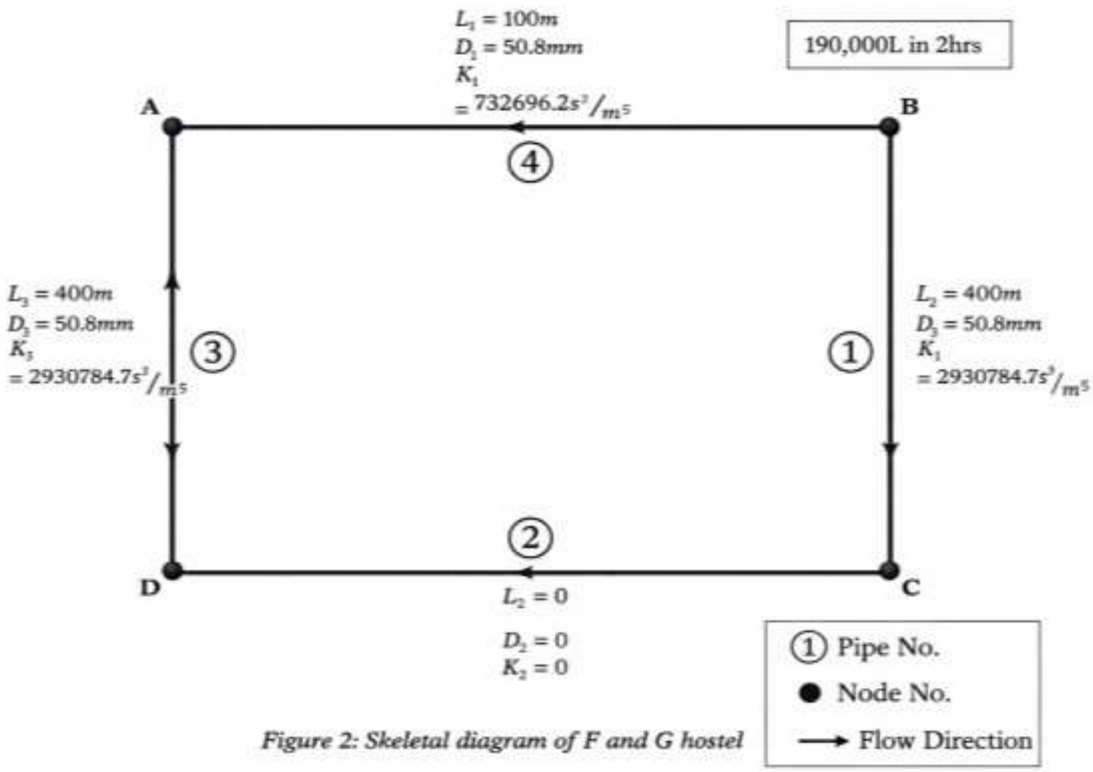

Figure 2: Skeletal diagram of F and G hostel

$Q_1 = Q_3 = Q_4 = {}^{0.026m^3}/_{s}, \qquad Q_2 = 0$

The nodal discharge function f are:

$f_1 = Q_1 + Q_4 - 0.026 = 0$

$f_2 = Q_1 + Q_2 = 0$

$f_3 = Q_2 + Q_3 = 0$

And loop head loss function

$f_4 = 2930784.7|Q_1|\, Q_1 + 732696.21|Q_4|\, Q_4 - 2930784.7|Q_3|Q_3 = 0$

The partial derivatives are

$\frac{\partial F_1}{\partial Q_1} = 1, \frac{\partial F_1}{\partial Q_2} = 0, \frac{\partial F_1}{\partial Q_3} = 0, \frac{\partial F_1}{\partial Q_4} = 1$

$\frac{\partial F_2}{\partial Q_1} = -1, \frac{\partial F_2}{\partial Q_2} = 1, \frac{\partial F_2}{\partial Q_3} = 0, \frac{\partial F_2}{\partial Q_4} = 0$

$\frac{\partial F_3}{\partial Q_1} = 0, \frac{\partial F_3}{\partial Q_2} = 0, \frac{\partial F_3}{\partial Q_3} = 1, \frac{\partial F_3}{\partial Q_4} = 0$

$\frac{\partial F_4}{\partial Q_1} = 2930784.7Q_1, \frac{\partial F_4}{\partial Q_4} = 732696.2Q_4$

$$\frac{\partial F_4}{\partial Q_3} = -2930784.7Q_3, \frac{\partial F_4}{\partial Q_2} = 0$$

Substituting the derivatives into the matrix form we get

$$\begin{bmatrix} \Delta Q_1 \\ \Delta Q_2 \\ \Delta Q_3 \\ \Delta Q_4 \end{bmatrix} = -\begin{bmatrix} \frac{\partial F_1}{\partial Q_1} & \frac{\partial F_1}{\partial Q_2} & \frac{\partial F_1}{\partial Q_3} & \frac{\partial F_1}{\partial Q_4} \\ \frac{\partial F_2}{\partial Q_1} & \frac{\partial F_2}{\partial Q_2} & \frac{\partial F_2}{\partial Q_3} & \frac{\partial F_2}{\partial Q_4} \\ \frac{\partial F_3}{\partial Q_1} & \frac{\partial F_3}{\partial Q_2} & \frac{\partial F_3}{\partial Q_3} & \frac{\partial F_3}{\partial Q_4} \\ \frac{\partial F_4}{\partial Q_1} & \frac{\partial F_4}{\partial Q_2} & \frac{\partial F_4}{\partial Q_3} & \frac{\partial F_4}{\partial Q_4} \end{bmatrix}^{-1} \times \begin{bmatrix} F_1 \\ F_2 \\ F_3 \\ F_4 \end{bmatrix}$$

First iteration:

$$\begin{bmatrix} \Delta Q_1 \\ \Delta Q_2 \\ \Delta Q_3 \\ \Delta Q_4 \end{bmatrix} = -\begin{bmatrix} 1 & 0 & 0 & 1 \\ -1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 \\ 76200 & 0 & -76200 & 19050 \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 19050 \end{bmatrix}$$

$$= \begin{bmatrix} 0 \\ -0.25 \\ 0.25 \\ 0 \end{bmatrix}$$

Then: $Q_1 = Q_1 + \Delta Q_1 = 0.026 + 0 = {}^{0.026m^3}/_s$

$Q_2 = Q_2 + \Delta Q_2 = 0 - 0.25 = {}^{-0.25m^3}/_s$

$Q_3 = Q_3 + \Delta Q_3 = 0.026 + 0.25 = {}^{0.276m^3}/_s$

$Q_4 = Q_4 + \Delta Q_4 = 0.026 + 0 = {}^{0.026m^3}/_s$

Second iteration:

$$\begin{bmatrix} \Delta Q_1 \\ \Delta Q_2 \\ \Delta Q_3 \\ \Delta Q_4 \end{bmatrix} = -\begin{bmatrix} 1 & 0 & 0 & 1 \\ -1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 \\ 76200 & 0 & -808897 & 19050 \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 19050 \end{bmatrix}$$

$$= \begin{bmatrix} 0 \\ -0.0236 \\ 0.0236 \\ 0 \end{bmatrix}$$

Then $Q_1 = Q_1 + \Delta Q_1 = 0.026 + 0 = {}^{0.026m^3}/_{s}$

$Q_2 = Q_2 + \Delta Q_2 = -0.25 - 0.0236 = {}^{-0.2736m^3}/_{s}$

$Q_3 = Q_3 + \Delta Q_3 = 0.0276 + 0.0236 = {}^{0.2784m^3}/_{s}$

$Q_4 = Q_4 + \Delta Q_4 = 0.026 + 0 = {}^{0.026m^3}/_{s}$

Third iteration:

$$\begin{bmatrix} \Delta Q_1 \\ \Delta Q_2 \\ \Delta Q_3 \\ \Delta Q_4 \end{bmatrix} = -\begin{bmatrix} 1 & 0 & 0 & 1 \\ -1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 \\ 76200 & 0 & -815930 & 19050 \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 19050 \end{bmatrix}$$
$$= \begin{bmatrix} 0 \\ -0.0233 \\ 0.0233 \\ 0 \end{bmatrix}$$

Then $Q_1 = Q_1 + \Delta Q_1 = 0.026 + 0 = {}^{0.026m^3}/_{s}$

$Q_2 = Q_2 + \Delta Q_2 = -0.2736 - 0.0233 = {}^{-0.2969m^3}/_{s}$

$Q_3 = Q_3 + \Delta Q_3 = 0.02784 + 0.0233 = {}^{0.3017m^3}/_{s}$

$Q_4 = Q_4 + \Delta Q_4 = 0.026 + 0 = {}^{0.026m^3}/_{s}$

Fourth iteration:

$$\begin{bmatrix} \Delta Q_1 \\ \Delta Q_2 \\ \Delta Q_3 \\ \Delta Q_4 \end{bmatrix} = -\begin{bmatrix} 1 & 0 & 0 & 1 \\ -1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 \\ 76200 & 0 & -884218 & 19050 \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 19050 \end{bmatrix}$$
$$= \begin{bmatrix} 0 \\ -0.0215 \\ 0.0215 \\ 0 \end{bmatrix}$$

Then $Q_1 = Q_1 + \Delta Q_1 = 0.026 + 0 = {}^{0.026m^3}/_{s}$

$Q_2 = Q_2 + \Delta Q_2 = 0 - 0.2969 - 0.0215 = {}^{-0.3184m^3}/_{s}$

$Q_3 = Q_3 + \Delta Q_3 = 0.3017 + 0.0215 = {}^{0.3232m^3}/_{s}$

$Q_4 = Q_4 + \Delta Q_4 = 0.026 + 0 = {}^{0.026m^3}/_{s}$

Fifth iteration:

$$\begin{bmatrix}\Delta Q_1\\ \Delta Q_2\\ \Delta Q_3\\ \Delta Q_4\end{bmatrix} = -\begin{bmatrix}1 & 0 & 0 & 1\\ -1 & 0 & 0 & 0\\ 0 & 1 & 1 & 0\\ 76200 & 0 & -947230 & 19050\end{bmatrix}^{-1}\begin{bmatrix}0\\ 0\\ 0\\ 19050\end{bmatrix}$$

$$= \begin{bmatrix}0\\ -0.020\\ 0.020\\ 0\end{bmatrix}$$

Then $Q_1 = Q_1 + \Delta Q_1 = 0.026 + 0 = {}^{0.026m^3}/_{S}$

$Q_2 = Q_2 + \Delta Q_2 = 0 - 0.3184 - 0.020 = {}^{-0.3384m^3}/_{S}$

$Q_3 = Q_3 + \Delta Q_3 = 0.3232 + 0.020 = {}^{0.3017m^3}/_{S}$

$Q_4 = Q_4 + \Delta Q_4 = 0.026 + 0 = {}^{0.026m^3}/_{S}$

Sixth iteration:

$$\begin{bmatrix}\Delta Q_1\\ \Delta Q_2\\ \Delta Q_3\\ \Delta Q_4\end{bmatrix} = -\begin{bmatrix}1 & 0 & 0 & 1\\ -1 & 0 & 0 & 0\\ 0 & 1 & 1 & 0\\ 76200 & 0 & -1005845 & 19050\end{bmatrix}^{-1}\begin{bmatrix}0\\ 0\\ 0\\ 19050\end{bmatrix}$$

$$= \begin{bmatrix}0\\ -0.0189\\ 0.0189\\ 0\end{bmatrix}$$

Then $Q_1 = Q_1 + \Delta Q_1 = 0.0260 + 0 = {}^{0.0260m^3}/_{S}$

$Q_2 = Q_2 + \Delta Q_2 = 0 - 0.3384 - 0.0189 = {}^{-0.3573m^3}/_{S}$

$Q_3 = Q_3 + \Delta Q_3 = 0.3432 + 0.0189 = {}^{0.3621m^3}/_{S}$

$Q_4 = Q_4 + \Delta Q_4 = 0.0260 + 0 = {}^{0.0260m^3}/_{S}$

Seventh iteration:

$$\begin{bmatrix}\Delta Q_1\\ \Delta Q_2\\ \Delta Q_3\\ \Delta Q_4\end{bmatrix} = -\begin{bmatrix}1 & 0 & 0 & 1\\ -1 & 0 & 0 & 0\\ 0 & 1 & 1 & 0\\ 76200 & 0 & -1061237 & 19050\end{bmatrix}^{-1}\begin{bmatrix}0\\ 0\\ 0\\ 19050\end{bmatrix}$$

$$= \begin{bmatrix} 0 \\ -0.018 \\ 0.018 \\ 0 \end{bmatrix}$$

Then $Q_1 = Q_1 + \Delta Q_1 = 0.0260 + 0 = {}^{0.0260m^3}/_{s}$

$Q_2 = Q_2 + \Delta Q_2 = 0 - 0.3573 + 0.018 = {}^{-0.3753m^3}/_{s}$

$Q_3 = Q_3 + \Delta Q_3 = 0.3621 + 0.018 = {}^{0.3801m^3}/_{s}$

$Q_4 = Q_4 + \Delta Q_4 = 0.0260 + 0 = {}^{0.0260m^3}/_{s}$

Stability can only be achieved if $\left| {}^{\partial F_4}/_{\partial Q_3} \right|$ is too large i.e.

$$\begin{bmatrix} \Delta Q_1 \\ \Delta Q_2 \\ \Delta Q_3 \\ \Delta Q_4 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} we\ get \begin{bmatrix} Q_1 \\ Q_2 \\ Q_3 \\ Q_4 \end{bmatrix} = \begin{bmatrix} 0.026 \\ -Q^* \\ +Q^* \\ 0.026 \end{bmatrix}$$

The negative at pipe (2) at the end of the node no C and D there is a leakage this shows that ΔQ_2 and ΔQ_3 will always be approximately the same in magnitude but opposite in sign. ΔQ_1And ΔQ_4does change because the diameter of the pipe and no leakage occurs during the flow between node AB and BC

Which follows the case since the pipe is laid in series $Q = Q_1 = Q_2 = Q_3 = 0.026m\ {}^3/_{s}$ then $h_L = hL_1 + hL_2 + hL_3 + hL_4$ since$h_L = h_{L_1} + h_{L_3} + h_{L_4}$, since $hL_2 = 0$

$$= \left[\frac{8fl}{\pi^2 \times gD_1^5} + \frac{8fl}{\pi^2 \times gD_3^5} + \frac{8fl}{\pi \times gD_4^5}\right] \times 0.026^2$$

$$= \left[\frac{8 \times 0.05 \times 400}{\pi^2 \times 9.81 \times 0.0508^5} + \frac{8 \times 0.05 \times 400}{\pi^2 \times 9.81 \times 0.0508^5} + \frac{8 \times 0.05 \times 100}{\pi^2 \times 9.81 \times 0.0508^5}\right] \times 0.026^2$$

$$= 7429.54m$$

CONCLUSION

The primary aim of this research is to thoroughly investigate and analyze the root causes of the water crisis affecting the F and G hostels of the Rivers State University, Nigeria. The current situation has led to significant challenges in water supply, making it necessary to identify the underlying issues that are contributing to the problem. This study seeks to understand the factors that are causing the water shortage and to evaluate the effectiveness of potential solutions. By doing so, the research aims to provide a comprehensive understanding of the problem and to recommend practical and sustainable solutions that can address the water supply issues in the area.

In light of the findings from this research, it is recommended that a new submersible water well be drilled and installed. This well will serve as a reliable source of water, ensuring a consistent and sufficient supply to the F and G hostels. Additionally, a new overhead tank with a larger capacity should be constructed and designed to store the water efficiently. This tank will play a crucial role in maintaining a steady water supply, even during periods of high demand.

The installation of the submersible well will significantly improve the water supply system for the F and G hostels, as well as for the F extension, PG 1, 2, 3, and 4. This new water source will help reduce the pressure on the existing water infrastructure, which has been strained due to the ongoing water crisis. By alleviating the burden on the current system, the new well and tank will contribute to the overall efficiency and sustainability of the water supply in the estate.

Furthermore, the new water supply system will not only address the immediate water shortage but also provide long. It will ensure that the residents of the F and G hostels have access to a reliable and sufficient water supply, which is essential for their daily needs and overall well-being. The installation of the submersible well and the construction of the overhead tank are essential steps in resolving the water crisis and improving the quality of life for the residents of the area. This research and its recommendations aim to provide a sustainable solution to the water supply problem, ensuring that the water infrastructure can meet the demands of the community in the future. I will recommend the management of Rivers state university to adopt the outcome of this research to improve the quality of water in F and G hostel.

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