HYDRAULIC SIMULATION OF EXISTING WATER SUPPLY AND DISTRIBUTION NETWORK IN MINNA USING WaterGEMs MODEL

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ABSTRACT

A steady state simulation for the hydraulic parameters of existing Minna Water supply and distribution Network was carried out using water GEMs Model. With a total nodes of 459, 530 pipes and a length of 188 km after skelelotonization and accumulated fluid volume of 7,067m^3 which represent 67% of total pipe network used for the simulation. The results revealed 4 pressure zones throughout the existing network, with single zone occupying 99.3% of the entire Network, with maximum pressure head of 588m, which causes more than 90% of the network to have a very low velocities of 0 -1.5m/s and as high as 6m/s. Suction pressure were detected at PAIDA and SHIRORO tanks as a result of higher pressure from direct line. Pressure head of over 50m were detected at Dutsen Kura Hausa, Government House and F-layout Areas. Poor networking, lack of proper urban planning and hydraulic design, unauthorized connection to the transmission lines, was identified as factors responsible for the existing poor distribution system. The water balance Method was used to estimates the NRW of 84% of Water loss. The study concluded by recommending zoning the system in to 5 Hydraulic DMAs (District metered areas), and Installation of Valves. Findings revealed that water GEMs Modelling approach is a promising alternative for the prediction of hydraulic parameters and optimal design of water distribution system. The study also recommend disconnection of all pipes on transmission lines, and to provide proper hydraulic design for newly developed areas to be served and Restrenghtening of the existing network.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The need for a portable drinking water for any community cannot be overemphasized. It is an essential resource for human life. A large population around the world does not have a reliable uncontaminated piped water supply.

A good treated water must be transported or conveyed through pipes for human consumption. This processes begin some 3,500 years ago, when for the first time pipes were used on the Island of crete. Jasperson (2001) has provided a brief history of public water supply system tracking back to 700 BC. When sloped hillside tunnel were built to transport water to Persia. Ramalingam *et al.* (2002) refer to the earlier pipes made by drilling stones, wood, clay and lead. Cast iron pipes replaced the early pipes in the 18^{th} century and significant developing in making pipes joint were witnessed in the 19^{th} century. Use of different material for pipe manufacturing increased in the 20^{th} century.

A safe supply of potable water is the basic necessity of mankind in the industrialized society, therefore, water supply system are the most public utility. A huge amount of money is spent every year around the world for providing or upgrading water facilities. Nearly 80% – 85% of the cost of water supply project is used in the distribution system (Swamee, 2008). Therefore, using the best and rational methods for designing water distribution system will result in considerable savings. The aim and objective of all water supply system are to supply water for the cheapest cost.

The distribution system configuration consist of four main component; (1) the water sources and intake works, (2) the treatment works and storage, (3) Transmission mains, and (4) the distribution network.

Water is carried over a long distance through transmission. If the flow of water in a transmission main is maintain by creating a pressure head by pumping, is called a pumping main; on the other hand, if the flow in a transmission main is maintain by gravitational potential available an account of elevation difference is called Gravity main. Similarly the flow in distribution network is maintained either by pumping or by gravity.

A distribution network delivers water to consumers through service connection and may have different configuration depending upon the layout of the area. The distribution network may have a looped and branched configuration of pipeline, but sometimes either looped or branched are also provided depending of upon the general layout plan of the city road and streets. Urban network have mostly looped configuration whereas rural networks has branched configuration on accuracy high-reliability requirement of water service, looped configuration are preferred over branched configuration.

The operation of a municipal water system involves dynamic interactions between various water system components, including source, storage, transmission, and distribution system facilities. These interactions and their effect on the level of service provided to District customers are dependent on the distribution and magnitude of water demands within the system and the performance characteristics of the water system facilities.

1.2 Statement of the Research Problem

Minna, the Niger state capital has over the years experienced and still experiencing water scarcity primarily due to rapid increase in population and urbanization. Mohammed (2014a), conducted performance enhancement of water supply distribution in Minna metropolis and an appropriate pumping schedule for efficient water supply. He stressed that, with a combine pumping from the three pumping stations at 558 m^3/h (2 numbers), and 350m^3/h, it is possible to supply water for twelve hours daily. However, the author's on-site investigation revealed that due to epileptic power supply, only two out of three pumps are pumping for only four hours a day. This records a slight improvement when compare to years back, when the supply was only for four hours a day and to specific area on rationing basis (Muhammad, 2014b).

Available data (maps) obtained from the Niger State Water board Headquarters revealed that a total of 70 km pipeline are of transmission main and 210km pipeline are distribution. The source of Minna water supply are Chanchaga water works and Bosso treatment plant with a capacity of 77,000 m^3/day and 1200 m^3/day respectively. However, as at today these design capacity were under- utilized due to inefficiency of pumps which operates at about 20% over the years. Recently, the Government has replaced the aging pumps, but yet the water supply is still inadequate to even the areas that are connected to the system. Vandalizing of mains contributed to the overall failure of pumps to supply water to the storage tanks as designed, thereby creating a 'NO PRESSURE 'zones in the distribution system.

Most of the supplies from Chanchaga and Bosso treatment plant are by gravity with little having direct pumping. There is only one boaster station at Dutsen- kura tank (Mohammed, 2014b). Another problem of inadequate supply is lack of metering. Currently the board is operating Manual billing of customers every month, ranging from N1000 to N2000 per resident in Minna metropolis. There are about 12,245 residents being supplied by the board and about 359 commercial and industries(which includes, schools and institutions, hotels, car wash, pharmacies, package water and block industries), charging them N200/m^3. Others, are water tankers of 9000litrs, 7000litrs and 6000litrs and water vendors.

The distribution network of Minna water supply is divided into 5 commercial zones. Zone A runs from Chanchaga town, Tungan goro, up to city gate with 2,446 households and commercials of 72. Zone B comprises of Kpakungu to tipper garage having 1620 and 40 commercials respectively .Zone C consist of Tunga with 3,846 and 118.Zone D, runs from Maitumbi down to F/layout having a total of 2,820 and 61 commercials. The last zone is Bosso to Tudun Fulani with 1, 513 and 68 commercials (Niger state Water Board). Nasir, and Busari, (2019) conducted an Evaluation of quantity of water supply in Minna metropolis and found out that the supply is not proportional to the quantity demanded. Even at design capacity of 88 Mlpd the demand is 209 Mlpd. The problem of Minna WDS is as a result of the followings:

(1) Intermittent supply due to epileptic power supply.

(2) Transmission pipes are being tampered with.

(3) The Existing Network is Branched configuration in some areas.

(4) Inadequate Pressures and velocities in most Areas.

(5) The Branched Network produces dead End.

1.3 Aim and Objectives of the Study

The aim of this work is to simulate the hydraulic parameters of the existing Minna water supply and distribution network, using WaterGEMS software, through the following objectives;

1. To determine and use Shapefiles of the existing Minna network.
2. To determine total demand of the study area.
3. To identify pressure zones of the existing Network.
4. To calibrate the simulated results

1.4 Scope of the Study

This work is limited to only simulation of existing water supply and distribution network in Minna using average daily demand. The author could not perform field calibration and measurement considering the size of the network and instruments involved.

1.5 Purpose of the Study

The purpose is to group the Existing pressure zones in to District metered Areas (DMAs) for optimal performance, each zone to have about 100 nodes.

1.6 Justification for the use of WaterGEMs

WaterGEMs and WaterCAD are hydraulic Modelling software developed by Bentley system to design and simulate water distribution network through a pressurised pipe. Several scholars and researchers had been using Softwares that run on personal computers to optimized water distribution system by modified pipe diameter, energy consumption of pumps and location of reservoirs in the network. Many of these software are complex and difficult to use for technical application in the real networks of developing countries like Nigeria. For this reason, WaterGEMs (water geospatial Engineering modelling system) has been chosen to solve these complex situations. The popular WDS software, EPANET, has the disadvantage of its inability to work within the ArcGIS environment. Not until recently when it can import from QGIS (which is a free GIS software).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1.1 Theory of water distribution network analysis

One of the earliest theories into finding solution to water flow and pressure in water distribution network includes the popular Hardy Cross method which is an iterative method for determining the flow in pipe network systems where the inputs and outputs are known, but the flow inside the network is unknown. Adeleke and Olawale (2013) developed a computer program of pipe network analysis using Java programming language for the Hardy Cross method to study some existing pipe network in Osun State to evaluate their suitability towards sustainable resource planning. The Hardy Cross method is an adaptation of the Moment distribution method, which was also developed by Hardy Cross as a way to determine the moments in indeterminate structures.

The introduction of the Hardy Cross method for analysing pipe flow networks revolutionized municipal water supply design. Before the method was introduced, solving complex pipe systems for distribution was extremely difficult due to the nonlinear relationship between head loss and flow. The method was later made obsolete by computer solving algorithms employing Newton-Raphson method or other solution methods that removed the need to solve nonlinear systems of equations by hand. Pipe network analysis of water distribution systems has evolved from a time consuming process done infrequently to a quick and easy process done regularly on systems of all sizes.

The cost of a water distribution network depends upon proper selection of the geometry of the network. The selection of street layout adopted in the planning of a city is important to provide a minimum-cost water supply system. The two most common water supply configurations of looped water supply systems are the gridiron pattern and the ring and radial pattern; however, it is not possible to find an optimal geometric pattern that minimizes the cost.

2.1.2 Flow hydraulics and network analysis

The flow hydraulics covers the basic principles of flow such as continuity equation, equations of motion, and Bernoulli's equation for close conduit. Another important area of pipe flows is to understand and calculate resistance losses and form losses due to pipe fittings (i.e., bends, elbows, valves, enlargers and reducers), which are the essential parts of a pipe network. Suitable equations for form-losses calculations are required for total head-loss computation as fittings can contribute significant head loss to the system.

The flow hydraulics of fluid transporting sediments in suspension and of capsule Transport through a pipeline is complex in nature and needs specific consideration in head-loss computation. Such an area of fluid flow is of special interest to industrial engineers/designers engaged in such fluid transportation projects.

Analysis of a pipe network is essential to understand or evaluate a physical system, thus making it an integral part of the synthesis process of a network. In case of a single input system, the input discharge is equal to the sum of withdrawals. The known parameters in a system are the pipe sizes and the nodal withdrawals. The system has to be analysed to obtain input point discharges, pipe discharges, and nodal pressure heads. In case of a branched system, starting from a dead-end node and successively applying the node flow continuity relationship, all pipe discharges can be easily estimated.

Once the pipe discharges are known, the nodal pressure heads can be calculated by applying the pipe head-loss relationship starting from an input source node with Known input head. In a looped network, the pipe discharges are derived using loop Head-loss relationship for known pipe sizes and nodal continuity equations for known nodal withdrawals.

Ramalingam *et al.* (2002) published a brief history of water distribution network Analysis over 100 years and also included the chronology of pipe network analysis Methods. A number of methods have been used to compute the flow in pipe networks ranging from graphical methods to the use of physical analogies and finally the use of mathematical/numerical methods.

Based on the application of an analysis method for water distribution system analysis, the information about pipes forming primary loops can be an essential part of the data. The loop data do not constitute information independent of the link-node information, and theoretically it is possible to generate loop data from this information.

The information about the loop-forming pipes can be developed by combining flow paths. These pipe flow paths, which are the set of pipes connecting a demand (withdrawals) node to the supply (input) node, can be identified by moving opposite to the direction of flow in pipes (Sharma & Swamee, 2005). Unlike branched systems, the flow directions in looped networks are not unique and depend upon a number of factors, mainly topography, nodal demand, layout, and location and number of input (supply) points. The pipe flow patterns will vary based on these factors. Hence, combining flow paths, the flow pattern map of a water distribution network can also be generated, which is important information for an operator/manager of a water system for its efficient operation and maintenance.

The analysis of a network is also important to make decisions about the network Augmentation requirements due to increase in water demand or expansion of a water servicing area. The understanding of pipe network flows and pressures is important for making such decisions for a water supply system.

Generally, the water service connections (withdrawals) are made at an arbitrary Spacing from a pipeline of a water supply network. Such a network is difficult to analyse until simplified assumptions are made regarding the withdrawal spacing. The current practice is to lump the withdrawals at the nodal points; however, a distributed approach for withdrawals can also be considered. A methodology is required to calculate flow and head losses in the pipeline due to lumped and distributed withdrawals.

The distribution network may have a looped and branched configuration of pipeline, but sometimes either looped or branched are also provided depending of upon the general layout plan of the city road and streets. Urban network have mostly looped configuration whereas rural networks has branched configuration on accuracy high-reliability requirement of water service, looped configuration are preferred over branched configuration.

The operation of a municipal water system involves dynamic interactions between various water system components, including source, storage, transmission, and distribution system facilities. These interactions and their effect on the level of service provided to District customers are dependent on the distribution and magnitude of water demands within the system and the performance characteristics of the water system facilities.

In addition to normal diurnal demands, infrequent and unanticipated demand events, such as fires and other emergencies, can significantly stress a municipal water system and its components. Water distribution systems (WDSs) are vital infrastructure for supplying water from the source to the end users. It has been designed commonly to provide an adequate amount of potable water with sufficient pressure at the consumer, where the water demand is required namely the residential, industrial, institutional, and commercial (Elsheikh *et al.,* 2013) .

2.1.3 Cost considerations

To carry out the synthesis of a water supply system, one cannot overlook cost considerations that are absent during the analysis of an existing system. Sizing of the water distribution network to satisfy the functional requirements is not enough as the solution should also be based on the least-cost considerations. Pumping systems have a large number of feasible solutions due to the trade-off between pumping head and pipe sizes. Thus, it is important to consider the cost parameters in order to synthesize a pumping system. In a water distribution system, the components sharing capital costs are pumps and pumping stations; pipes of various commercially available sizes and materials; storage reservoir; residential connections and recurring costs such as energy usage; and operation and maintenance of the system components. As the capital and recurring costs cannot be simply added to find the overall cost (life-cycle cost) of the system over its life span, a number of methods are available to combine these two costs. Fixed costs associated with source development and treatment works for water demand are not included in the optimal design of the water supply system.

2.1.4 Design considerations

The design considerations involve topographic features of terrain, economic parameters, and fluid properties. The essential parameters for network sizing are the projection of residential, commercial, and industrial water demand; per capita water consumption; peak flow factors; minimum and maximum pipe sizes; pipe material; and reliability consideration.

Another important design parameter is the selection of an optimal design period of a water distribution system. The water systems are designed for a predecided time horizon generally called design period. For a static population, the system can be designed either for a design period equal to the life of the pipes sharing the maximum cost of the system or for the perpetual existence of the water supply system. On the other hand, for a growing population or water demand, it is always economic to design the system in stages and restrengthen the system after the end of every staging period. The design period should be based on the useful life of the component sharing maximum cost, pattern of the population growth or increase in water demand, and discount rate. The reliability considerations are also important for the design of a water distribution system as there is a trade-off between cost of the system and system reliability.

2.1.5 Choice between pumping and gravity systems

The choice between a pumping and a gravity system on a topography having mild to medium slope is difficult without an analytical methodology. The pumping system can be designed for any topographic configuration. On the other hand, a gravity system is feasible if the input point is at a higher elevation than all the withdrawal points. Large pipe diameters will be required if the elevation difference between input point and withdrawals is very small, and the design may not be economic in comparison with a pumping system. Thus, it is essential to calculate the critical elevation difference at which both pumping and gravity systems will have the same cost.

2.1.6 Network synthesis

With the advent of fast digital computers, conventional methods of water distribution network design have been discarded. The conventional design practice in vogue is to analyze the water distribution system assuming the pipe diameters and the input heads and obtain the nodal pressure heads and the pipe link discharges and average velocities.

The nodal pressure heads are checked against the maximum and minimum allowable pressure heads. The average pipe link velocities are checked against maximum allowable average velocity. The pipe diameters and the input heads are revised several times to ensure that the nodal pressure heads and the average pipe velocities do not cross the allowable limits. Such a design is a feasible design satisfying the functional and safety requirements. Providing a solution merely satisfying the functional and safety requirements is not enough. The cost has to be reduced to a minimum consistent with functional and safety requirements and also reliability considerations. The main objective of the synthesis of a pipe network is to estimate design variables like pipe diameters and pumping heads by minimizing total system cost subject to a number of constraints. These constraints can be divided into safety and system constraints. The safety constraints include criteria about minimum pipe size, minimum and maximum terminal pressure heads, and maximum allowable velocity. The system constraints include criteria for nodal discharge summation and loop headloss summation in the entire distribution system. In a water distribution network synthesis problem, the cost function is the objective function of the system. The objective function and the constraints constitute a nonlinear programming problem. Such a problem can only be solved numerically and not mathematically. A number of numerical methods are available to solve such problems. Successive application of linear programming (LP) and geometric programming (GP) methods for network synthesis are discussed in Swamee & Sharma, 2008.

2.1.7 Designing a piecemeal subsystem

A subsystem can be designed piecemeal if it has a weak interaction with the remaining system. Being simplest, there is alertness in this aspect. Choosing an economic type (material) of pipes, adopting an economic size of gravity or pumping mains, adopting a minimum storage capacity of service reservoirs, and adopting the least-cost alternative of various available sources of supply are some examples that can be quoted to highlight this aspect. The design of water transmission mains and water distribution mains can be covered in this category. The water transmission main transports water from one location to another without any intermediate withdrawals. On the other hand, water distribution mains have a supply (input) point at one end and withdrawals at intermediate and end points.

2.1.8 Designing the system as a whole

Most of the research work has been aimed at the optimization of a water supply system as a whole. The majority of the components of a water supply system have strong interaction. It is therefore not possible to consider them piecemeal. The design problem of looped network is one of the difficult problems of optimization, and a satisfactory solution methodology is in an evolving phase.

2.1.9 Dividing the area into a number of optimal zones for design

For this aspect, convenience alone has been the criterion to decompose a large network into subsystems. Of the practical considerations, certain guidelines exist to divide the network into a number of sub networks. These guidelines are not based on any comprehensive analysis. The current practice of designing such systems is by decomposing or splitting a system into a number of subsystems. Each subsystem is separately designed and finally interconnected at the ends for reliability considerations. The decision regarding the area to be covered by each such system depends upon the designer’s reasoning. On the other hand, to design a large water distribution system as a single entity may have computational difficulty in terms of computer time and storage. Such a system can also be efficiently designed if it is optimally split into small subsystems (Swamee and Sharma, 1990a).

2.2 Reorganization or Restrengthening of Existing Water Supply Systems

Another important aspect of water distribution system design is strengthening or reorganization of existing systems once the water demand exceeds the design capacity. Water distribution systems are designed initially for a predecided design period, and at the end of the design period, the water demand exceeds the design capacity of the existing system on account of increase in population density or extension of services to new growth areas. To handle the increase in demand, it is required either to design an entirely new system or to reorganize the existing system. As it is expensive to replace the existing system with a new system after its design life is over, the attempt should be made to improve the carrying capacity of the existing system. Moreover, if the increase in demand is marginal, then merely increasing the pumping capacity and pumping head may suffice.

2.3 The Use of Computer Programme

The WDS infrastructure has been constructed and developed for hundreds of years across in the world on the population growth and urbanization (Ramos *et al.,* 2018). As a result of this, an optimized WDS should be implemented to minimize the total cost of the project and also satisfies required water flow velocities and pressure on the nodal.

The numerous optimization methods are studies in the worldwide such as GA (genetic algorithm), linear programming (Samani and Zanganeh, 2010; Bello *et al.,* 2015) nonlinear programming and dynamic programming (Keles, 2005; Akdogan, 2005) talk too much time for computations and need more powerful computer (Guc, 2006). The development of a computer hydraulic models, (like LOOPS, EPANET, waterCAD, HAMMER, infoWATER and waterGEMS) which can accurately and realistically simulate the response of a water system under a variety of conditions and scenarios, has become an increasingly important element in the planning, design, and analysis of municipal water systems.

However, many of these software's are complex and difficult for technical application in the real networks of developing countries, where few number of skill manpower's. Recently, it is easier to model and optimization theories with the help of WaterGEMS (Water Geospatial Engineering Modeling System) software. This software is suitably used in hydraulic model to optimize the WDS in worldwide using the Darwin Designer and Darwin Scheduler tools based on the Genetic Algorithm (GA) (Switnicka *et al.,* 2017). It deals with the extended period simulation and linked with optimization software.

Adeniran & Oyelowo (2013) conducted an analysis of water distribution network of university of Lagos using EPANET software. The study found out that due to increase in population which give rise to increase in demand, from 2.48 mlpd to 3.75 mlpd in 2012, the supply has declined. The study concluded that the performance of the existing distribution network under current water demand is inefficient and recommended appropriate improvement.

Similar study was also conducted in Alnavar of dharwad district in karnataak state of India by Ramesh, (2012) for simulations of hydraulic parameters using EPANET 2.0 and GIS. The study concludes by recommending the reliability of EPANET in analysis and simulation of hydraulic parameters since it was compared with manual equations and found satisfactorily. The methods used in the project are mentioned below.

(1)Arithmetic Increase Method; Pn=$\lfloor po + n.x^{*} \rfloor$…………………………… (2.1.1)

(2) Geometric Increase Method: $Pn = PO \left\lfloor \frac{1+r}{100} \right\rfloor n$…………………………… (2.1.2)

(3)Incremental Increase Method: $\boldsymbol{P}$n =$\left\lfloor po + n.x^{*} \; + \{\frac{n(n+1)}{2}\} \right\rfloor y^{*}$…………… (2.1.3)

Where Pn = Prospective or forecasted population; n = Number of decades; r = Assumed growth rate in %; x^* = Average increase of population of known decades; y^* = Average of incremental increase of the population of known decades.

Selami *et al.* (2016), presents an EPANET hydraulic model application at Old Town DMA (District Metered Area), a well-known tourism area in Antalya City, Turkey. Old Town DMA has highly variable WDN characteristics and it contains about 1400 active and inactive water subscribers, mostly related to tourism facilities. Daily and hourly water consumption profiles and water consumption rates by different subscribers in the DMA exhibit wide variations. The temporal and spatial variations of water consumptions and highly varying topographic levels of the DMA are taken into account to allocate nodal water demand in hydraulic modelling. Water pressure and flow rates are continuously monitored online at the SCADA station located at the entrance of the DMA. Additionally, continuous water pressure measurements are performed via portable pressure loggers at 4 different points located at different elevations of the DMA. The monthly water consumption of each water subscriber is recorded. Moreover, the daily and hourly water consumption rates of 13 different water subscribers were monitored for 5 days. The obtained data sets were used to prepare water consumption patterns for different water subscribers and to estimate nodal demands. The hydraulic model was calibrated for Hazen - Williams's pipe roughness coefficient and the predicted pressure values were in good agreement with field measurements.

Izinyon & Anyata, (2011), conducted a study of a network model which was constructed for the hydraulic analysis and design of a small community (Sakwa) water distribution network in North Eastern geopolitical region of Nigeria using WaterCAD simulator. The analysis included a review of pressures, velocities and head loss gradients under steady state average day demand, maximum day demand conditions, and fire flow under maximum day demand using average day demand of 60 lpcd(litres per capita per day).

The results indicate: that the tower height of the existing storage tank is inadequate and should be increased from 10m to 15m to provide satisfactory service, and that there are no areas of concern with respect to pressure or available fire flow for the proposed service area and also that flow velocities are not excessive while head loss gradients in the network are within acceptable limits. Pipes P-6, P-12, P-15 and P-19 expectedly have relatively low flow velocities due to the low average day demands in small communities and the constraint of minimum commercially available pipe sizes makes design of self-cleansing networks in such communities not easily realizable.

Tewelde & Tamru (2020), carried out an optimization of water distribution system using waterGEMS, a case study of Wukro town Ethiopia. The WaterGEMS model was implemented in water distribution networks which include 117 pipes (40.67km), 99 demand nodes (equivalent to 50480 end users) that are spread across a hilly area over a 1989m to 2046m elevation gradient. The model was calibrated at the selected nodes with a very good performance. The results have shown that the maximum pressure before optimization is 31.1m and after optimization increased to 38.1m, the minimum pressure on the former is 7.9m and 16m later during peak hour demand. The finding of this study indicated that the WaterGEMS model is a promising approach for optimal sizing of pipes in design water distribution networks and pumping operational schedules.

A technical report on hydraulic modelling of pipe network was carried in Jalingo Taraba State for E-WASH programme, where areas with high pressures of more than 10m was proportionally distributed to 14 District metered areas (pressure zones) as a proposed solution to the pipe network using waterGEMS software (Fig. 2.1). This software, unlike EPANET operates on an AutoCAD platform and also work within ArcGIS, thereby avoiding manual inputs mistakes, and speedy-up the load building process.

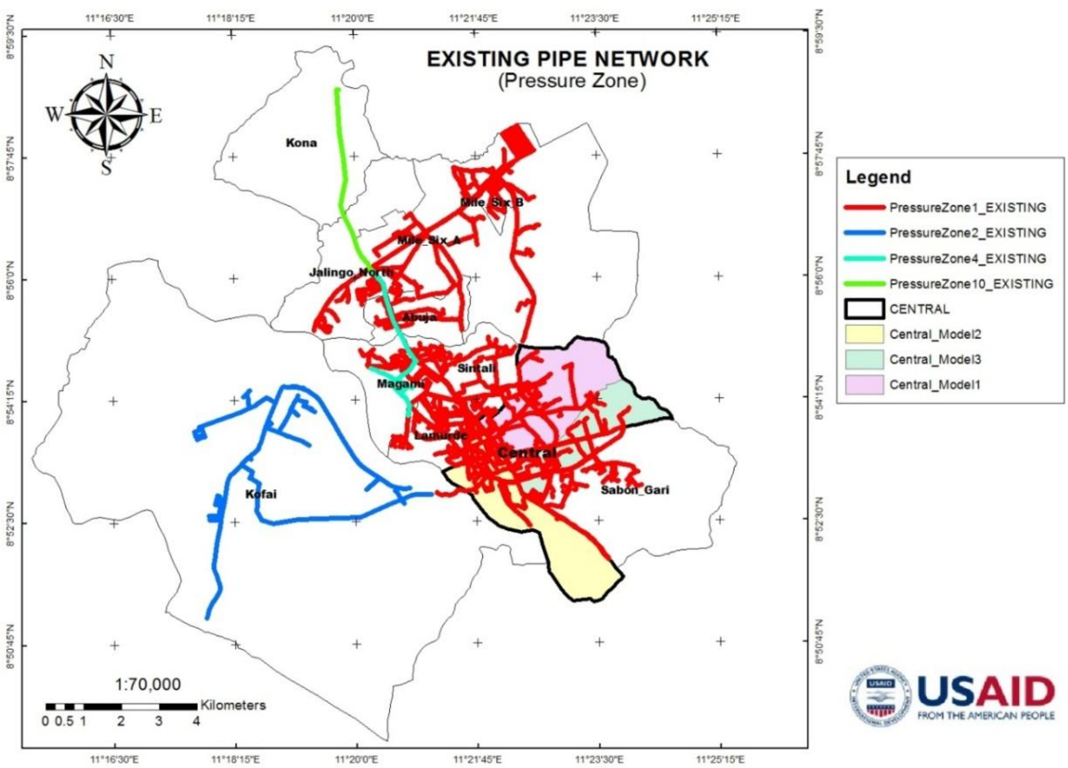

Figure 2.1: Existing Pressure zones of Taraba. (Sources: IDL Consult)

Table 2.1: Attributes of existing pressure of Taraba

Pressure Zone	Nodes <Count>	Isolation Elements <Count>	Pipes <Count>	Length (km)	Fluid Volume (m^3)
Pressure Zone - 1	762	20	850	223	3,840.80
Pressure Zone - 2	51	1	53	29	653.5
Pressure Zone - 4	8	4	11	7	378.7
Pressure Zone - 10	2	1	2	5	40.6

(Sources: IDL Consult, 2020)

2.4 Hydraulic Equations used by the Software under Steady State

2.4.1 Continuity equation or law of conservation of mass

Which states that matter cannot be created or destroy. In hydraulics and considering Hardy Cross method of analysis used by the software, it implies that the total flow entering a loop must be equal to the total flow leaving it.

Thus; Q_1=Q_2……………………………………………… (2.1.4)

Which gives, $A_1 V_1 = A_2 V_2$…………………………...... (2.1.5)

And $\sum Q_{in} - \sum Q_{OUT} = C_J$……………………………….. (2.1.6)

Where $\boldsymbol{Q_{in}}$ and $\boldsymbol{Q_{out}}$ are flow rates into and out of a junction or node respectively.

$\boldsymbol{C_j}$ Represent external consumption or input flow rates at the junction or nodes.

Steady-state models, such as WaterCAD or WaterGEMS, are capable of two modes of analysis: steady state and extended period simulation (EPS). EPS solves a series of consecutive steady states using a gradient algorithm and accounting for mass in reservoirs and tanks (e.g., net inflows and storage). Both methods assume the system contains an incompressible fluid, so the total volumetric or mass inflows at any node must equal the outflows, less the change in storage. In addition to pressure head, elevation head, and velocity head, there may also be head friction. These changes in head are referred to as head gains and head losses, respectively. Balancing the energy across two points in the system yields the energy or Bernoulli equation for steady-state flow: $\frac{P_1}{\gamma} + \frac{V_1}{2g} + Z_1 + h_p = \frac{P_2}{\gamma} + \frac{V_2}{2g} + Z_2 + h_l$……………………… (2.1.7)

The components of the energy equation can be combined to express two useful quantities, the hydraulic grade and the energy grade.

Hydraulic grade—The hydraulic grade is the sum of the pressure head (*p/γ*) and elevation head (Z). The hydraulic head represents the height to which a water column would rise in a piezometer. The plot of the hydraulic grade in a profile is often referred to as the hydraulic grade line or HGL.

Energy grade—the energy grade is the sum of the hydraulic grade and the velocity head ($^{V2}/_{2g}$). This is the height to which a column of water would rise in a pitot tube. The plot of the hydraulic grade in a profile is often referred to as the energy grade line or EGL. At a lake or reservoir, where the velocity is essentially zero, the EGL is equal to the HGL.

2.4.2 Head loss formula

Additionally, the head loss is given $h_l = KQ^X$ …………………. (2.1.8)

for Hazen- Williams, X=1.85……………………………………(2.1.9)

Where $K = \frac{8fl}{\pi^2 g d^5}$, ………………………………………(2.2.0)

That is from Darcy –weisbach equation, $h_l = \frac{flv^2}{2gd}$ ………….. (2.2.1)

Mean Velocity = $0.85C_H R^{0.63} S^{0.54}$ …………………………… (2.2.2)

2.4.3 Pressure along the pipe length

$P = \rho g h$……………………………………………………….. (2.2.3)

Pressure at the node (pressure head) = $\frac{p}{\rho}$ = gh…………….(2.2.4)

HGL elevation at the end of pipe = HGL at the beginning - head loss…. (2.2.5).

2.5 Comparison between EPANET and waterGEMs/waterCAD

Table 2.2 gives the differences between EPANET (which is an open source developed by Army Corps Engineers of the United State Environmental Agency), and Bentley's Softwares in terms of the following; Ease of Use, Hydraulic elements, CAD,GIS compatibility, Model building tools, Advanced hydraulic features and Technical support and Training

Table 2.2: Comparison between WaterGEMS, waterCAD and EPANET

S/N	FEATURES	EPANET	WaterCAD	WaterGEM
1.	**Ease of Use**			
	• Model Layout/Data Entry	Limited	Available	Available
	• Graphs	Limited	Available	Available

	• Tabular Report	Limited	Available	Available
	• Profiles	Limited	Available	Available
	• Contours	Limited	Available	Available
	• Export to Google Earth	Not Available	Limited	Available
	• Pressure Zone manager	Not Available	Available	Available
	• Network Navigators	Not Available	Available	Available
2	**Hydraulic Modelling element**			
	• Reservoir	Available	Available	Available
	• Tank	Available	Available	Available
	• Junction	Available	Available	Available
	• Pipe	Available	Available	Available
	• Air valves at high point	Not Available	Available	Available
	• Variable speed pump	Limited	Available	Available
	• Hydrants	Not Available	Available	Available
	• Hydro pneumatic pump	Not Available	Available	Available
3	**CAD, GIS Interoperability**			
	• Database import/Export	Not Available	Available	Available
	• Convert CAD to pipes	Not Available	Available	Available
	• Runs inside of Arc GIS	Not Available	Not Available	Available
	• Runs inside of Auto CAD	Not Available	Available	Available
	• Runs inside of Micro station	Not Available	Available	Available
	• Excel import/Export	Not Available	Available	Available
	• Background CAD, Shape files, JPG	Not Available	Available	Available
	• Import/ Export EPANET Files	Available	Available	Available
4	**Model Building Tools**			
	• Demand Allocation using meter Data	Not Available	Available	Available
	• Demand Allocation using population	Not Available	Available	Available
	• Demand Allocation by land use or area	Not Available	Available	Available
	• Include Average demand library	Not Available	Available	Available
	• Network skeletonization	Not Available	Available	Available
	• User-defined attributes	Not Available	Available	Available
	• Associate external files (photo video)	Not Available	Available	Available
5	**Advanced Hydraulic Features**	Not Available	Available	Available
	• Scenario management	Not Available	Available	Available
	• Automated fire flow analysis	Not Available	Available	Available
	• Model calibration	Not Available	Available	Available
	• Pumps scheduling	Not Available	Available	Available
	• Automated design and rehabilitation	Not Available	Available	Available
	• Criticality Analysis and flushing	Not Available	Available	Available
	• Source tracking	Not Available	Available	Available
	• Leakage defection	Not Available	Available	Available
	• Pressure dependent demands	Not Available	Available	Available
	• Water modelling	Not Available	Available	Available
6	**Training And Training Support**			
	• 24/7 technical support	Not Available	Available	Available
	• Virtual instructor-led training	Not Available	Available	Available
	• Virtual on-demand training	Not Available	Available	Available
	• Local class room training	Not Available	Available	Available
	• Internal forums	Limited	Available	Available
	• Online knowledgebase	Not Available	Available	Available
	• Modelling books and textbooks	Not Available	Available	Available

Source: https://communities.bentley.com/products/hydraulics.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 The Study Area

Minna city is the capital of Niger State of Nigeria located at9^0 36'46''.00, N and 9^0 42'49'' Latitude and 6^0 33'18.56''E and $6^0$40'48''. Longitude, with annual rainfall of about 1200m, with developed area of 125km^2. Though, Muhammad (2014b) opined 324km^2, it is pertinent to note that Minna is the capital of Chanchaga local government area, but its area of water supply extended to cover some part of Bosso local government area including the Chanchaga town where the water work is located. However as at today, the total developed land area is beyond even 125km^2(Fig. 3.1). In fact, a declaration was made by previous and present government that Minna metropolis should stretch 20km from the centre of the city (Mobil Roundabout).

Figure 3.1: The Boundary of Study Area (Retrieve: 21/04/2021. 11:04am)

Figure 3.2: The Neighbourhoods of Minna city

3.1.1 Tanks and their capacities

Table 3.1 display the tanks and their capacities with areas they are expected to serve, while their attributes are shown in appendix E. The attributes includes, the elevations at base, initial elevation, minimum and maximum elevations.

Table 3.1: Service Tanks with equivalent pipe length and diameter

Diameter (mm)	Length (m)	Types	Tank	Capacity (m^3)	Area served
300	9624	DI	Dutsen Kura	10,000	Dutsen Hausa Dutsen Kura Gwari, Bosso Loc-Cost, Bosso Estate Shanu village Police London street
300	5665	DI	Biwater	4,500	Shango, Army barrack, new seet gidan madara kuna
700	7451	DI	Shiroro	2,000	Tunga, Tunga Low-Cost, Shiroro Road, Niteco Road
	9617	DI	IBB tank	7000	Minna central, Maitumbi Bosso road 123 quarters old airport road okada road commission quarters
600 &450	1407 &11024 &9617	DI	Paida tank	4000	Unguwan daji unguwan sarki, F-layout, zarumai, abayi close.
450	7925	DI	INEC	1000	Police barrack, bay Clinic road, tunga sabon titi, tunga dan boyi & railway quarters
300	7125	DI	Tunga top medical	2000	Tunga, top medical road& sabon gari
300& 400	1648 &889	DI	Bahago underground.	1000	Bosso A, Goggo mai lalle, old ATC, old Abbatoir and MTP 59

(Sources: Niger State Water Board)

3.1.2 The use of ArcGIS software

ArcGIS is a geographic information system used for working with maps and topographical maps developed by esri. It is used for creating and analyzing mapped information in a range of applications. It can also be used in creating shapefiles (geospatial data; such as DEM'S utilities and other physical features). The Minna shapefiles is obtained from the Niger state water board, (now water and sewage corporation) which include pipelines, reservoirs, tanks and other geographical features of the study area. If the shapefiles is not available, these can be prepared easily by exploring the Google Earth and or using survey data.

The hydraulic model is then created by importing the shapefiles from ArcGIS in to the waterGEMS or work within the ArcGIS environment.

3.1.3 Hydraulic modelling software

Minna water system is analysed using Bentley WaterGEMS hydraulic modelling software, which operates in an AutoCAD computer aided design and drafting environment. The software can carry out water quality modelling for some chemicals like Chlorine residual, Aluminum residual, Sulphate residual, automatic demand allocation etc. It can also handle all network control elements like check valves, shutoff valves, pressure release valves, pressure sustaining valves, different shapes of storage tanks (circular, rectangular,…), elevated and ground reservoirs; elements like fixed and variable speed pumps, ability to calculate energy consumption, color coding of the network based on available pressures and flow velocity.

Each water system element, including pipes, valves, and reservoirs, is assigned a unique graphical representation within the model. Each element is assigned a number of attributes specific to its function in the actual water system. Typical element attributes include spatial coordinates, elevation, water demand, pipe lengths and diameters, and critical water levels for reservoirs.

3.1.4 The population of Minna metropolis

The Existing Minna Water Distribution Network covers the entire Minna city as it is the Headquarter of Chanchaga local government area. Chanchaga town, where the water works is located is in Bosso local government, of which the pipelines covers some part. Therefore, Minna Metropolis includes about 30 neighbourhood (Fig. 3.2). The data was obtained from National Population Commission, Minna Area Office and is presented in Table 3.1 at growth rate of 2.67 as at 2018 projections.

Table 3.2: Projected Population of Study area

Neighbourhood	2006 Census	2018 Projected population	Water demand	WD 2018 L/S	WD 2050 L/S
Chanchanga	21236	29,136	8124044	40.5	94.0
Shango	4494	6,166	1719225	8.6	19.9
Tundun Wada North	10028	13,758	3836312	19.1	44.4
Tundun Wada South	10274	14,096	3930421	19.6	45.5
Sauka Kahuta	6774	9,294	2591461	12.9	30.0
Barikin Sale	9362	12,845	3581527	17.8	41.5
Kpakungu	20775	28,503	7947684	39.6	92.0
Makera	13104	17,979	5013066	25.0	58.0
Sabon Gari	12104	16,607	4630506	23.1	53.6
Nasarawa	8774	12,038	3356581	16.7	38.8
Minna Central	19496	26,749	7458390	37.2	86.3
Limawa	7774	10,666	2974021	14.8	34.4
Anguwan Daji	6811	9,345	2605616	13.0	30.2
F-Layout	4112	5,642	1573087	7.8	18.2
Maitumbi	18775	25,759	7182564	35.8	83.1
Tayi Village	2417	3,316	924648	4.6	10.7
GRA	5074	6,962	1941109	9.7	22.5
Fadikpe	10274	14,096	3930421	19.6	45.5
Dutsen Kuran Gwari	7802	10,704	2984733	14.9	34.5
Dutsen Kuran Hausa	8302	11,390	3176013	15.8	36.8
Jikpan	6604	9,061	2526426	12.6	29.2
Bosso Estate	4083	5,602	1561992	7.8	18.1
Bosso Town	34856	47,822	13334511	66.4	154.3
Tudun Fulani	1983	2,721	758616	3.8	8.8
	255288	**350,256**	**97662977**		

Source: National Population Commission, 2006

3.1.5 The system demand

The maximum daily water consumption occurs before 8:00am to 2:00pm. Therefore, the average domestic needs for the three categories as listed above i.e. high living standard, medium and low living is 200 litres per capital for high, 120 litres per capita for medium and 80 litres per capita for low. Therefore average per capita demand = **133**litres/capital/day. Hence other demands can be taken as 50% of domestic demand. Therefore per capita demand can be taken as 200 Litres and total Demand can be calculated as 88,040,413 litres/day or 88m^3/day.

3.1.6 Non-revenue water

The water balance method (under **Steady State**) in the WaterGEMs Model was used to estimate the water loss in the distribution system determined by Eq.3 1. This method calculates the total water loss in the distribution system from total flows of water (Al-Bulushi *et al.,* 2018; Gisha *et al.,* 2016). This describes the difference between inflows to the distribution system and all types of water consumption.

$$NRW = \frac{Wtot.\ prod - Wtot.\ cons}{Wtot.\ Prod} \quad (3.1)$$

Where NRW is Non-revenue water (%); Wtot.prod is total water produced (m^3 /year); and Wtot. cons is total water consumed (m^3 /year).

3.1.7 System network analysis

The software uses Hardy Cross method of Analysis which is an adaptation to Moment distribution method for indeterminate structures. Two conditions must be satisfied (1) The Algebraic sum of the pressure drops around any closed loop must be zero (2) The flow entering a junction must equal the flow leaving it. It is based on the theories of continuity equation and Energy equation.

3.1.8 Method of demand allocation

Demand allocation using load builder tools. There are 3 ways of assigning demand under two headings namely; external data and internal data. External Data; (1)Point load data method; billing meter aggregation, Nearest node, Nearest pipe (2) Area load data; Equal flow distribution, proportional distribution by area, unit line (3)population/land use data; load estimation by land use, load estimation by population. Internal Data; customer load data.

However, in this research work, proportional distribution by area method was used (as seen in the Flow chart of Figure 3.1). The software distribute the total demand base on the area covered by nodal withdrawal.

3.1.9 Model skeletonization

The model skeletonization process was done in WaterGEMS using the skelebrator skeletonizer tool. According to USEPA (2005) the skeletonization of pipes are study adopted by conditions as follows: at least 50% of total pipe length of the distribution, at least 75% of the pipe volume in the distribution system and all Diameter 200mm, 300mm and larger pipes that connect pressure zones, influence zones from different sources, storage facilities, major demand areas, pumps, and control valves to be significant transport of water. In this study a total of 280km length of pipes was used .The requirement was performed to skeleton the pipes based on length and volume of pipes in the WaterGEMS model before and after Skeletonization. Skeletonized from the diameter 75mm to the larger pipes diameter 100mm diameter, and the process result to 188km length, which represent 67% of the total length of pipe in the network.

3.1.10 Model calibration and simulation

Geospatial Maps were produced and data were calibrated. Spot heights at critical nodes were extracted from the Topographic map. Demand of 88m^3/day were assigned to nodes with the help of Thiessen polygon tool in the Software at steady state. The update of the calibration of the hydraulic model provides a measure of assurance that the model is an accurate and realistic representation of the actual system.

Model output for static pressure is generated by running the model at average system demands. The system pressures and pipe flow rates determined in the hydraulic analysis are highly dependent on the friction loss characteristics established for each pipe. Hazen-Williams C-factor 130 are used throughout the system. However, the friction factors for the pipe also compensates for system losses through valves and pipe fittings.

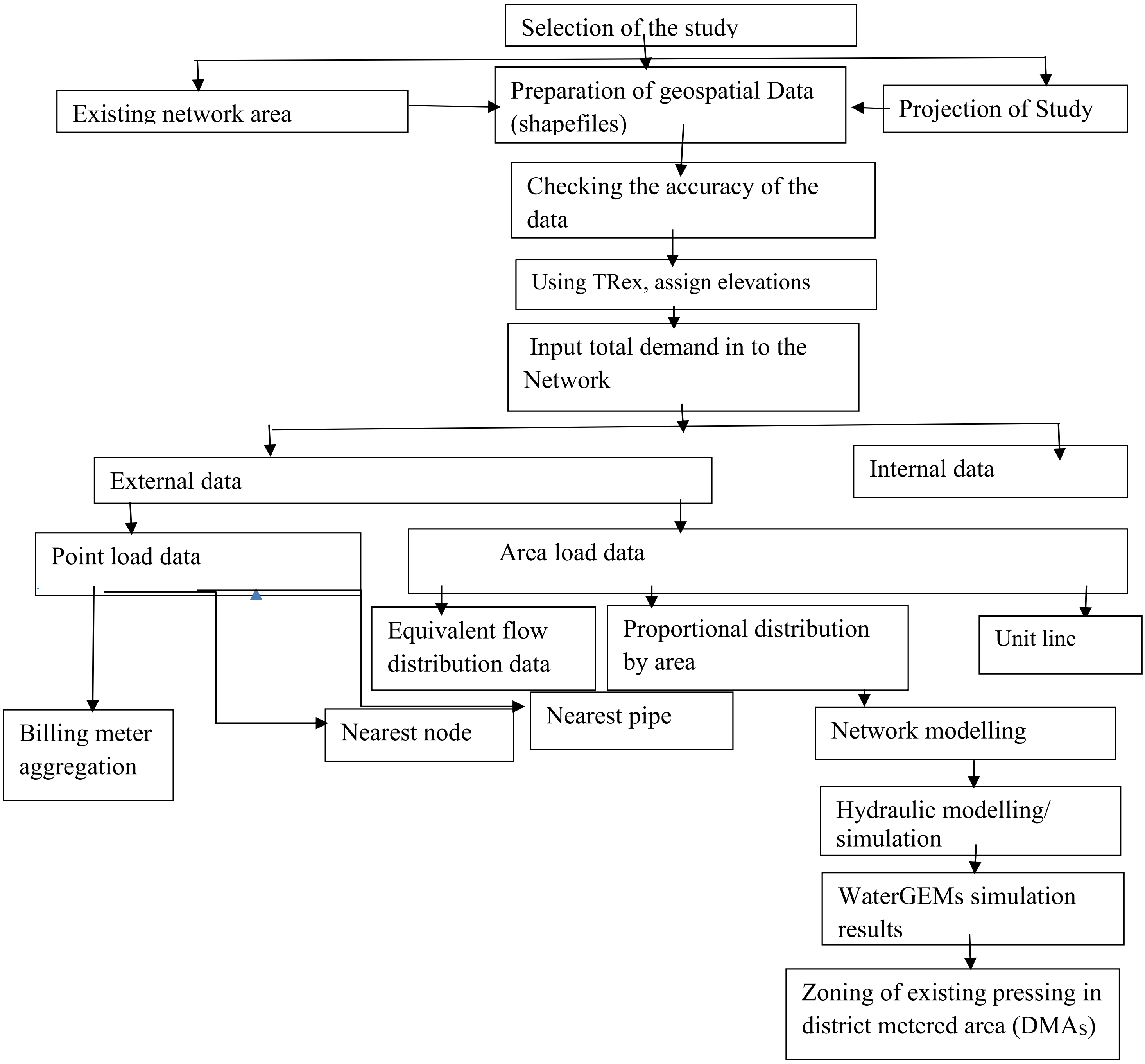

Figure 3.3: Flow Chart of Methodology

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Boundary of the Network

The boundary of the network was carved out of the shapefiles using the ArcGIS software, indicating the pipelines. The WaterGEMs Model work within the ArcGIS platform, this eliminates the possibility of Manual inputs error. The network covered about 125km^2 as shown in Figure 4.1.

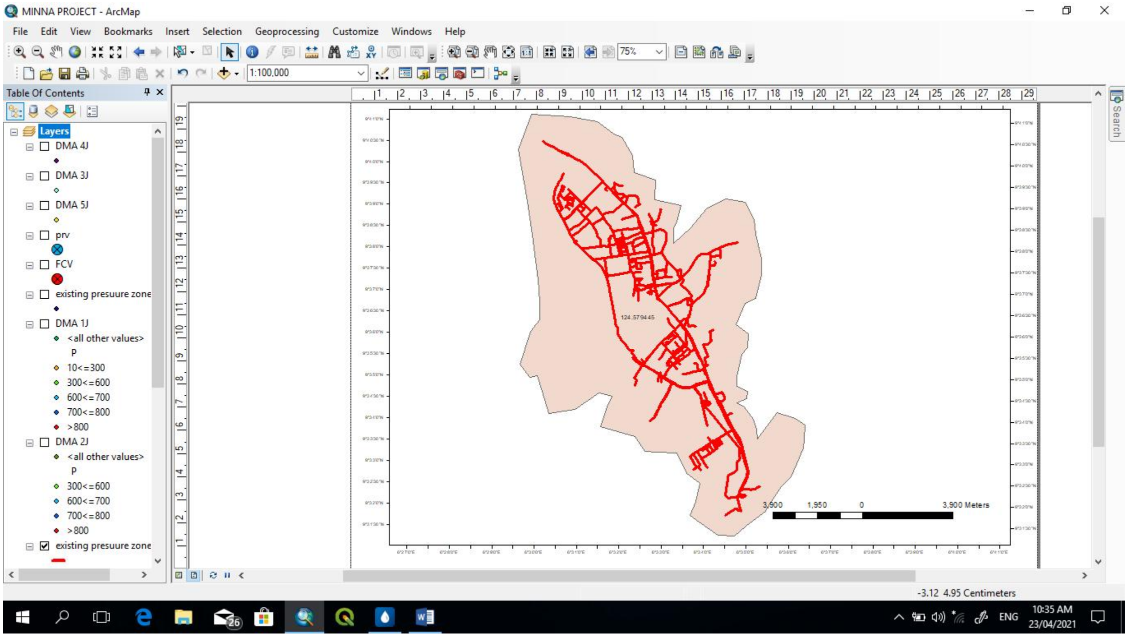

Figure 4.1: Showing the boundary of the study Area

4.2 Results of the Thiessen Polygon Development

Figure 4.2 shows how the demand was distributed proportionally based on area load method adopted for this work using the Thiessen polygon tool in the WaterGEMs Model.

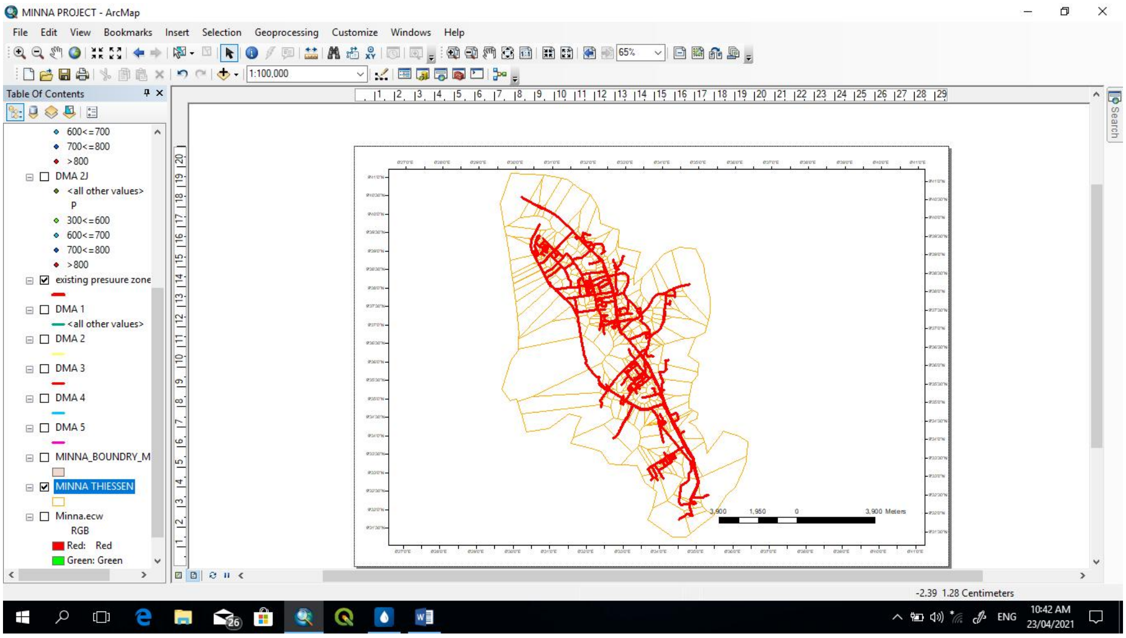

Figure 4.2: Thiessen polygon development of the study Area

4.3 Existing Pipe Network of Minna WDS after Skeletonization

The Figure 4.1, above shows the pipe network system as at the time of this work. The Bi- water transmission lines and Imperesit line all have diameter ranging from 600mm, 450mm and 300mm. The pipelines are designed to fill the Elevated Tanks at scheduled time. There are also direct supply to institutions and Army Barrack. The total length of both transmission and distribution pipes was 280 km before Skeletonization and simulation, from 600mm transmission to 75mm distribution.

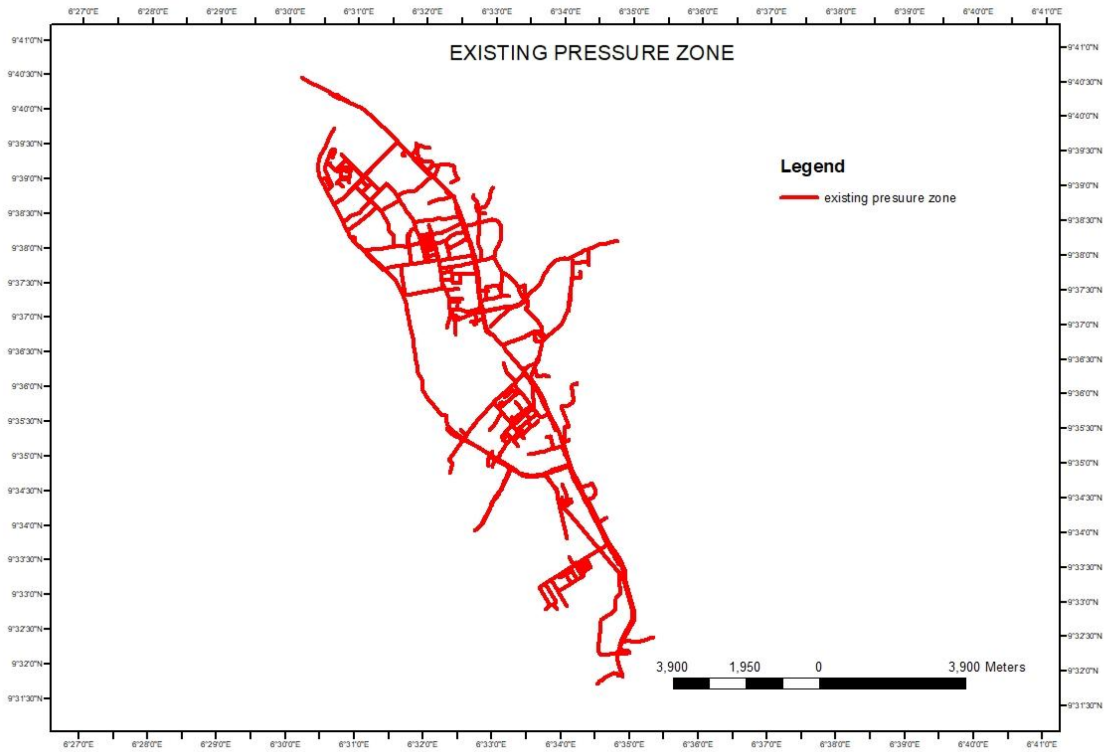

Figure 4.3: Results of Simulation after Skeletonization

Table 4.1: Attributes of Existing pressure zones

Pressure Zone					
Pressure Zone	**Nodes <Count>**	**Isolation Elements <Count>**	**Pipes <Count>**	**Length (m)**	**Fluid Volume (L)**
Pressure Zone – 1	456	5	528	188,119	7,067,145.20
Pressure Zone – 2	1	1	1	4	283.3
Pressure Zone – 3	1	0	0	0	0
Pressure Zone – 4	1	2	2	7	668.2

Table 4.1 above and Figure 4.3 shows that Minna WDS is currently operating on one pressure zone type. Pressure zone 1 occupy almost all the network with total length of 188km (after Skeletonization) and total fluid volume of over 7,000m^{3}.

Table 4.2: Results of the Water Balance (Steady State)

Flow Supplied L/S)	Flow Demanded (L/S)	Flow Stored (L/S)
809.129	131.914	677.21
Time stamp	03/09/2021 3:36 PM	
Time to load	00:00:00.67	
Time to run	00:00:00.08	
Time step count	1	
Link count	535	
Node count	468	

Table 4.2, is the run statistics from the Model. It takes 67 seconds to load and 8 seconds to run, with total pipes count of 535 and 468 junctions. The NRW of the system is 677.21 litres/second which amount to 83.7% loss for each production.

4.4 Discussion on Existing Pressure Zones

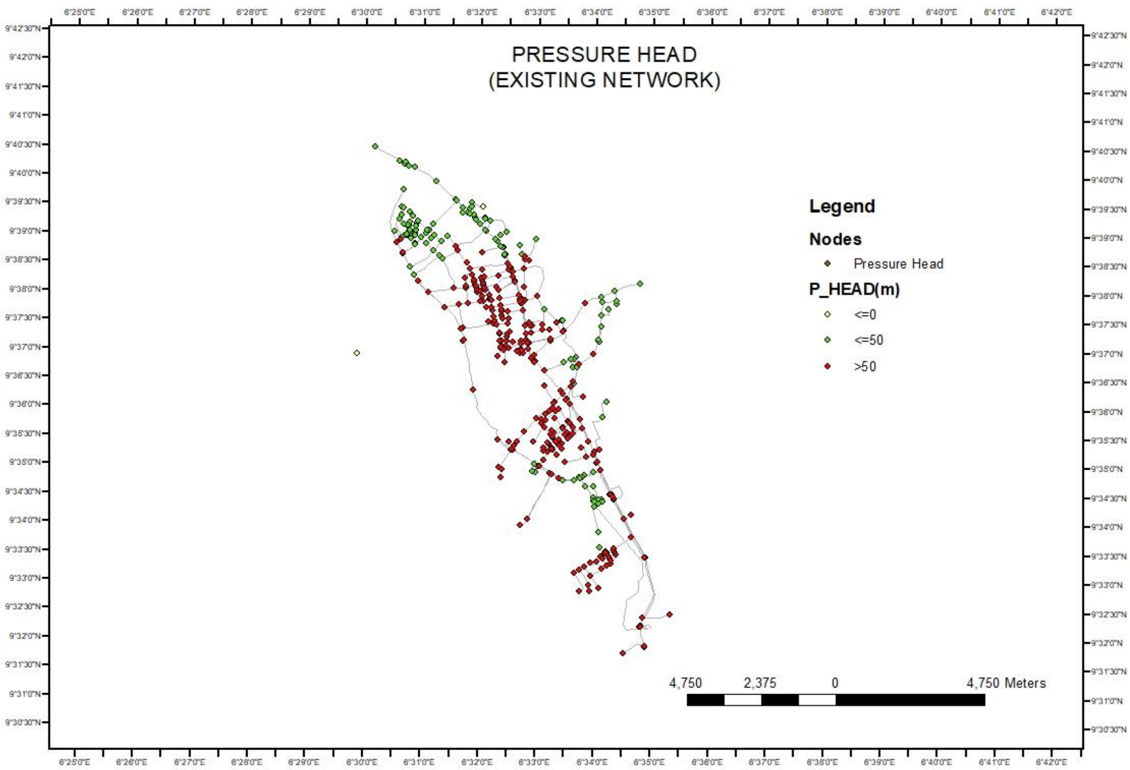

Figure 4.4: Existing Nodal Pressure head

Figure 4.4, shows the range values of pressure head distribution. Areas of behind trade fair complex, Gidan Madara, Dogon koli Hotel, Water Board headquarters Building, Gidan taya along bye pass road near Garima fillin station, INEC office ,Top medical road and Aloe Vera Hotel all have pressure head ranges from 1 to 50m head. Others in these ranges are Bosso Estate up to tudun Fulani Areas.

Chanchaga water works, Army Barrack, Farm centre, tunga Low cost, Niteco, sabon Titi, Limawa, unguwar daji, Paida, Commissioners quarters, Bosso low cost, F-layout London street and some part of Bosso estate, has a pressure head of 50m and above.

Also from the analysis result, it can be seen that, areas of Morris, Deeper life, barkin sale, Soje A, and Railway Station area has no proper network and therefore the software skeletonized the pipes to the most influence zones. Meanwhile the areas was captured in the demand analysis.

It is important to note that more than 98% of the nodal and pipe pressure has exceeded the minimum acceptable pressure of 241kpa or 24m or 2.4bar and more than 50%has reach maximum standard pressure of 650kpa (though not strict). For a city like Minna, 10m head is acceptable under normal condition and during fire or emergency. So there is need to balance the system.

4.5 Pumping Station

There are three reservoirs that store clear water, two for BI-WATER (with 2 pumps each has 805KW) and one for IMPRESIT (with 1245KW pump). These are used to pump water at snap shot for the simulation process. The attributes of these pumps are shown in appendix G.

Table 4.3: Hydraulic results: pressure

Label	Elevation (m)	Demand (L/s)	Pressure Head (m)	Hydraulic Grade (m)	Pressure (kPa)
J-1	256.32	0.264	31.65	287.97	310
J-2	245.04	0.215	42.99	288.02	421
J-4	236.07	0.299	51.94	288.01	508
J-9	276.88	0.165	40.15	317.03	393
J-10	275.43	0.264	41.57	317	407

Table 4.3, is a hydraulic result of pressures of one loop in the network. Full results Could be access in the appendix B.

4.6 Discussion on District Metered Areas (DMAs)

WaterGEMs software has automatically divide the existing pressure zones in five district metered areas by selecting 100 nodes or less per DMA. DMA1 has a total number of pipes 154, and 138 nodes, it has elevation difference of 64.79m and it covers, paida, unguwar daji, F-layout, IBB Uphill. It jump to Bosso Estate and some part of Bosso low cost up to Tudun Fulani and River Basin. DMA 2 has a head of 59,54m and covers Abdulsalam Garage, all of eastern bye pass, Medium prison, Top medical, tunga market and ends at David mark road. Some part of Bosso town also inclusive. It has 84 pipes and 78 nodes, with flow control valve (FCV) and Pressure Reducing valve (PRV).

DMA 3 takes 70.26m head with total pipes of 87 and 73 nodes, covering Bosso low cost, FUT Minna Bosso campus, Tudun Fulani, Hajj camp and some part of Bosso town.

DMA 4, takes effect from Farm centre, school of midwives, peter sarki road, shiroro tank area and the whole of Tunga Low cost, with a head of 31.73m.

The largest, DMA5 has an elevation difference of 230.59m with 115 pipes and 106 nodes. All the way from Chanchaga Water works up to city gate, state assembly, state secretariat and Water board head office (Table 4.4 and figure 4.7).

Table 4.4: Attributes of DMAs

DMA Label	Total Pipe Length (m)	Elevation (Max) (m)	Elevation (Min) (m)	Elevation (Diff) (m)	Number of Pipes	Number of Nodes	Number of Boundary Pipes
DMA 1	48635	303.52	238.72	64.79	154	138	11
DMA 2	28185	295	235.46	59.54	84	78	8
DMA 3	26223	313.74	243.47	70.26	87	73	4
DMA 4	21445	264.94	233.22	31.73	78	68	1
DMA 5	60315	293.37	62.78	230.59	115	106	2

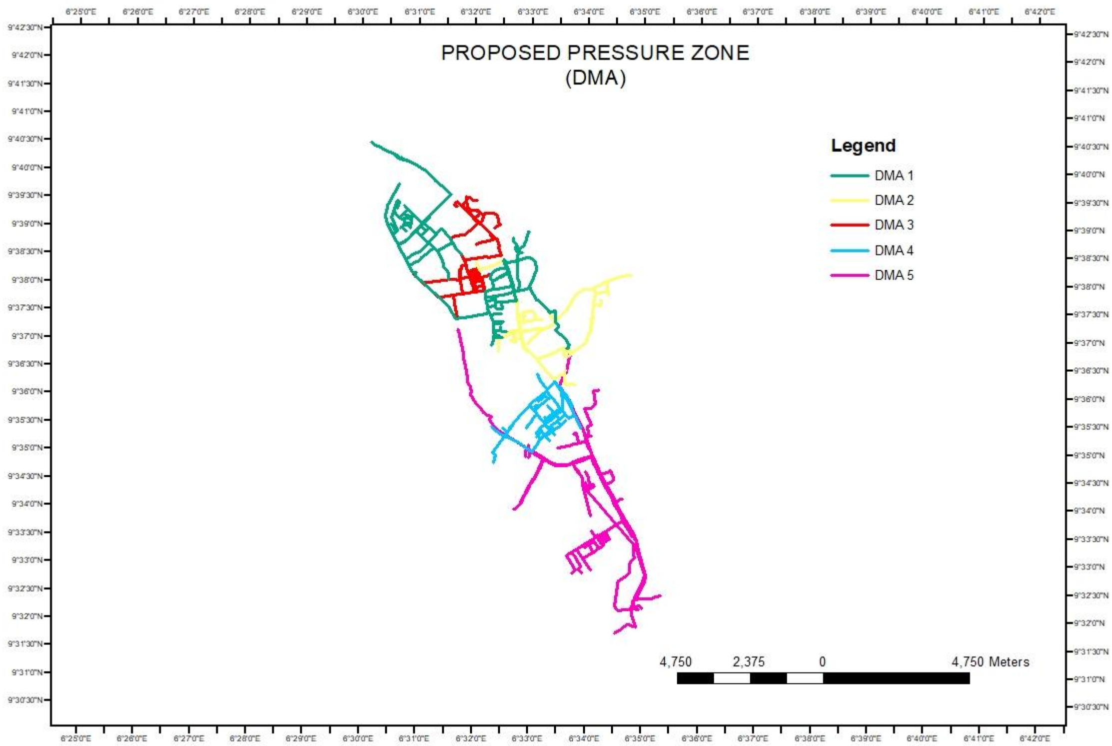

Figure 4.5: Proposed Zoning of pressure zones in to District metered Areas (DMA)

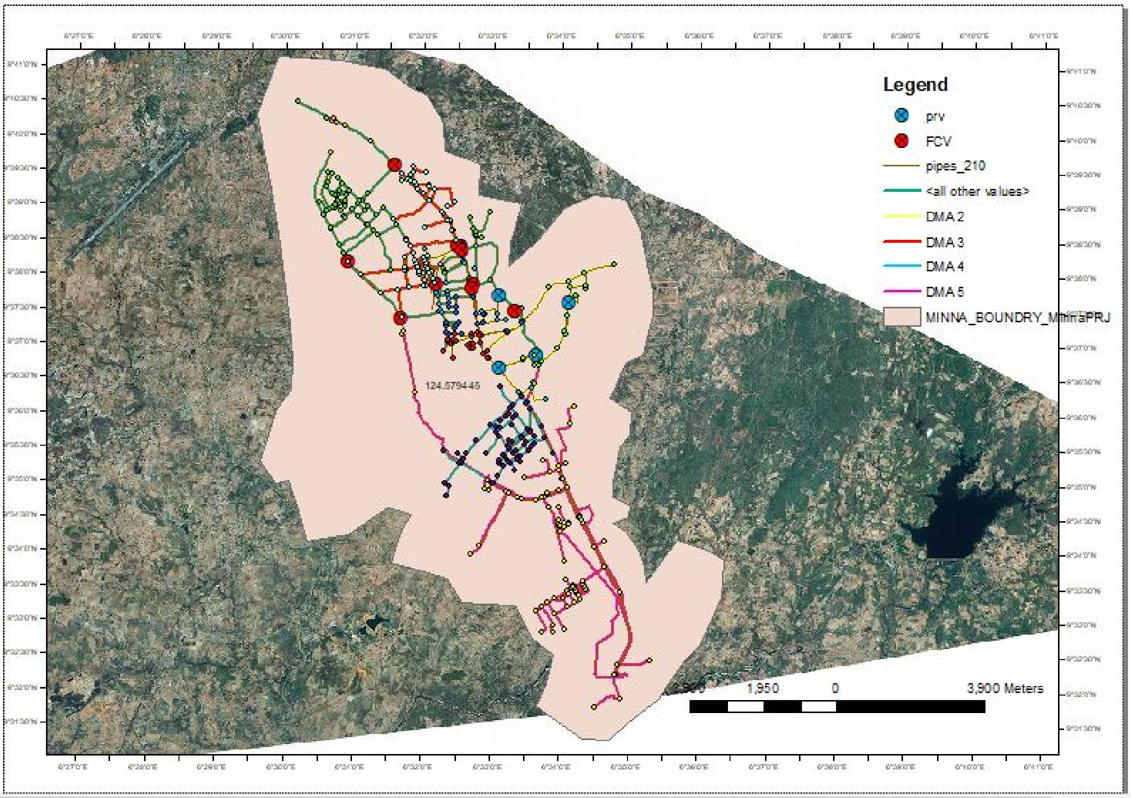

Figure 4.6: The positions of PRVs and FCVs ON DMAs

4.7 Discussion on Mean Velocity

Another important parameter of hydraulics of flow is the velocity, it should be at acceptable range for effective performance of the system. The model results displayed below in Figure 4.7, indicates that, about 38% of the total pipes, are below the minimum velocity standard and therefore may cause poor water quality due to increase in the age of the water in the pipelines. Areas covered in this values include Army barrack, city gate, some part of Tunga low cost, Farm centre, Sabon titi, Keteren Gwari, Kwangila, F-layout, old ATC, Okada road, Bosso low cost, Bosso Estate. Practically, the deterioration of pipe links has been experienced in these Areas which causes insufficient flow (0-0.5m/s). High velocity on the other hand causes wearing of pipes.

However, more than 90% of Minna WDS has not meet minimum velocity standards of 1-3m/s. WaterGEMS results revealed that the designed pressure and velocity did not meet the required standard at some part of network of the existing WDS in the study area. As a result of this, the required water demand did not deliver to the end users of the affected areas as mentioned above. The flow in the pipe has experienced inadequacy of flow and the problem throughout the link depend on low velocity. This will also exacerbated the pipe to overstated leakage value and pipe burst which in turn bring a shortage of delivered water, which is the reason for lack of water supply in the city. Those problems leads to balancing the flow and optimize the pressure zones Table 4.5 and Appendix C).

Table 4.5: Hydraulic result: velocity

Label	Length m	Diameter Mm	Velocity m/s	Head loss m/km
J1	458	152.4	2.223	32.710
J2	357	450	0.083	0.021
J4	250	450	0.078	0.019
J9	775	300	1.350	5.985
J10	1408	152.1	1.244	11.162

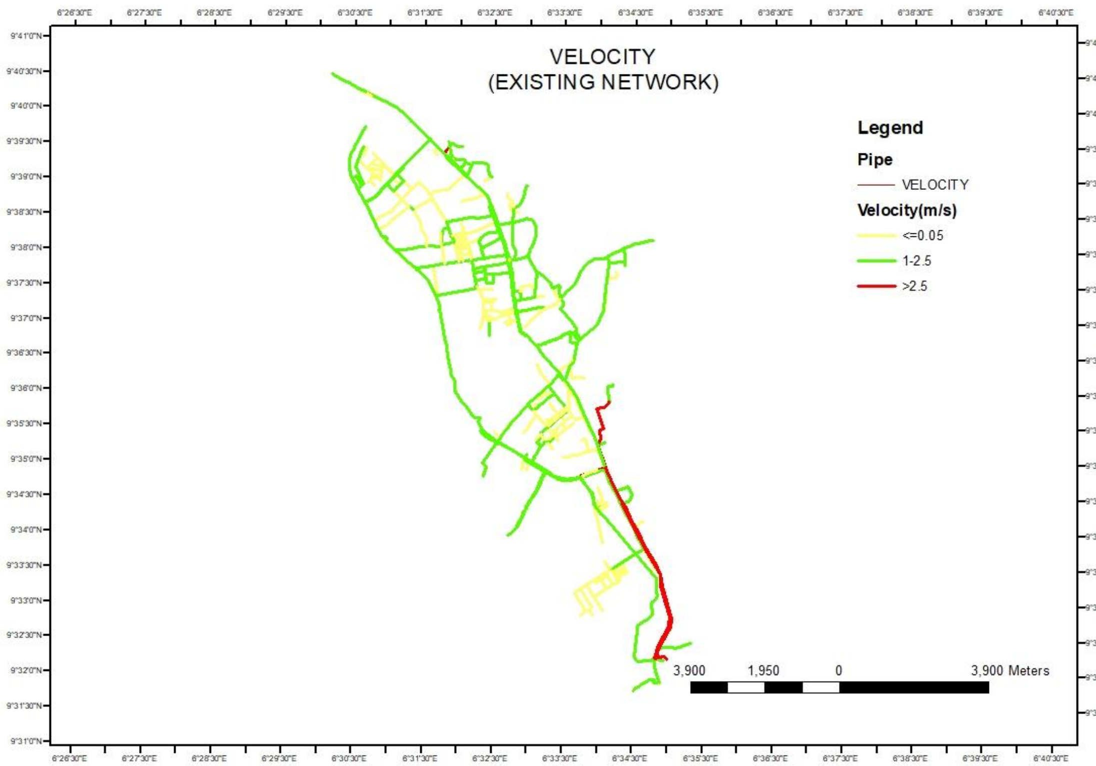

Figure 4.7: Existing Mean velocities

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this study, waterGEMs was used to carry out the simulation of hydraulic parameters of Minna water supply and distribution network. The findings of this study shows that the shapefiles obtained in the Arcmap of the ArcGIS contain the geospatial data (attributes) of Minna WDS and were used in the simulation process of the entire network of about 125km^2.

The total demand of the study area is 88,000 m^3/day and was assigned to the network by Thiessen polygon tool in the WaterGEMS software (figure4.4) which was proportionally distributed on the nodes, using AREA LOAD METHOD in the software Five (5) Pressure zones were identified on the existing network, with zone 1 dominating the network (table 4.1). The result shows that Minna water network operates on single pressure pattern despite higher elevation differences with accumulated fluid volume of 7000 m^3.

Majority of Nodal pressure were above international standard and norms for a city like Minna (Appendix D). The maximum pressure for Minna is 10m, equivalent to four storey. The results shows significant difference of pre-optimization(pressure head of 1m, minimum and 588m maximum), and post-optimization (31.75m minimum and 230.59m), which in turn normalises the velocity of flow to record about 60% with ranges from 1-2.5m/s.

The findings of this study can be concluded that WaterGEMS modelling approach, which is based on genetic algorithm is a promising alternative for the optimal design of water distribution systems, as demonstrated in this case study in terms of hydraulic pressure and computational efficiency.

The study shows that, Minna WDS has no proper network design that provide good looping system which is as a result of lack of proper urban planning by the authority, and there are series of unauthorized connections from the transmission and direct lines, which interrupt the gravitational flows.

5.2 Recommendations

(1) Grouping the existing pressure zones in to five (5) different pressure groups known as, District metered Areas (DMAs), with PRV (Pressure reducing valve) and FCV (Flow control valve) valves to regularize the system (Figure 4.8). This will enable detection of leakages through water balance analysis

(2) Re-organize the system by disconnecting all distribution pipes from the transmission and direct supply lines.

(3) Provide a good hydraulic design for a newly developed areas and to ensure proper urban development planning by the appropriate authorities.

(4) Train and retraining of staff especially the Hydraulics Engineers

(5) Installation of pressure gauges and Flow meters at DMAs junction.

(6) House-to-House Enumeration and subsequent installation of customer's meters.

5.3 Contribution to Knowledge

A steady state simulation for the hydraulic parameters of existing Minna Water supply and distribution Network was carried out using waterGEMs Model. With a total nodes of 459, 530 pipes and a length of 188 km after skelelotonization and accumulated fluid volume of 7,067m^3 which represent 67% of total pipe network used for the simulation. The results revealed the existing network is currently operating on a single pressure zone occupying 99.3% of the entire Network, with maximum pressure head of 588m, which causes more than 90% of the network to have a very low velocities of 0 -1.5m/s and as high as 6m/s. Suction pressure were detected at PAIDA and SHIRORO tanks as a result of higher pressure from direct line. Pressure head of over 50m were detected at Dutsen Kura Hausa, Government House and F-layout Areas. The water balance Method was used to estimates the NRW of 84% of Water loss. The study concluded by recommending zoning the system in to 5 Hydraulic DMAs (District metered areas) .Findings revealed that waterGEMs Modelling approach is a promising alternative for the prediction of hydraulic parameters and optimal design of water distribution system. A long time problem wter supply shortage of Minna has been identified with recommendations.

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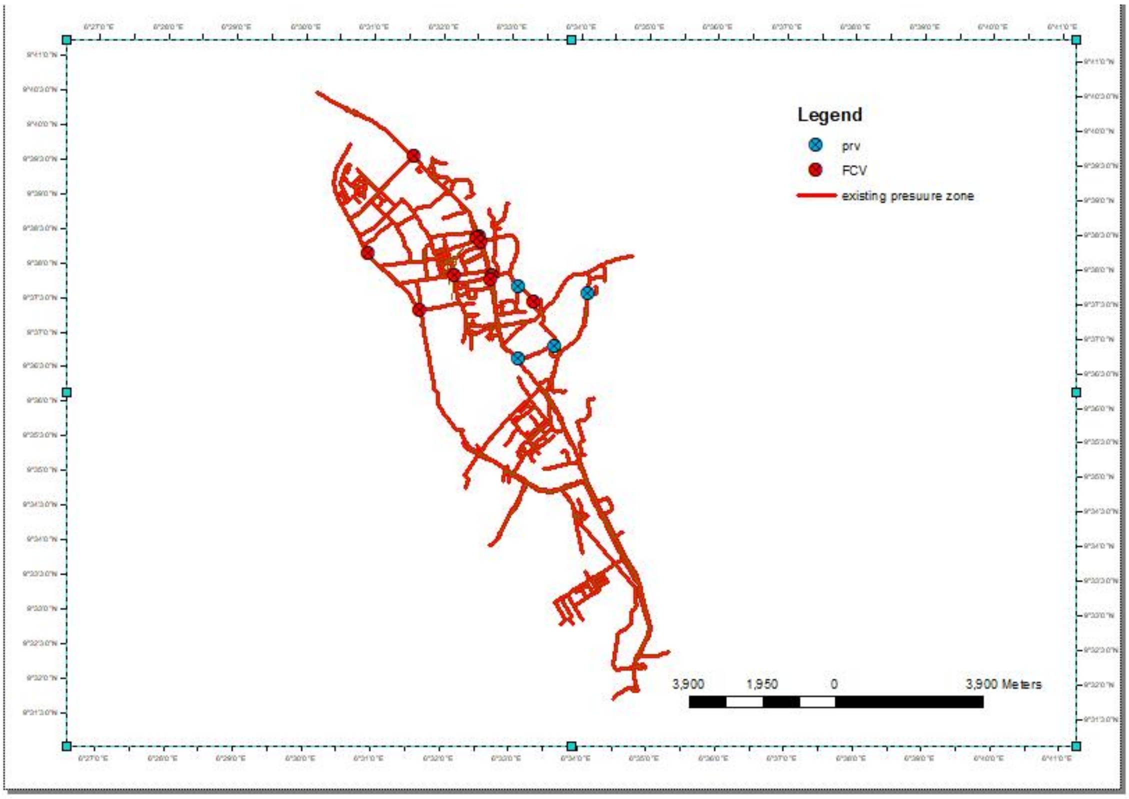
APPENDIX A
PRESSURE ZONE AND VALVES



APPENDIX B. PRESSURE PIPES INVENTORY0

Pipes

	Length (DI) (m)	Length (GI) (m)	Length (G I) (m)	Length (D I) (m)	Length (G. I) (m)	Length (D. I) (m)	Length (Ductile Iron) (m)	Length (PVC/AC) (m)	Length (AC/PVC) (m)	Length (A.C) (m)	Length (D.I) (m)	Length (All Materials) (m)	Volume (ML)
100.0 (mm)	0	2,032	0	10	43	0	0	1,221	0	0	0	56,147	0.44
150.0 (mm)	496	964	1,161	0	0	0	0	0	3,489	0	0	57,205	1.01
152.4 (mm)	0	0	0	0	0	0	2,588	0	0	0	0	2,588	0.05
200.0 (mm)	1,129	0	0	0	0	0	0	0	0	0	0	11,765	0.37
225.0 (mm)	0	0	0	0	0	0	0	0	0	0	0	3,023	0.12
250.0 (mm)	0	0	0	0	0	0	0	0	0	0	0	3,230	0.16
300.0 (mm)	0	0	0	0	0	492	21,725	0	0	1,374	0	41,692	2.95
400.0 (mm)	0	0	0	1,219	0	0	20	0	0	0	0	1,239	0.16
450.0 (mm)	0	0	0	0	731	0	7,888	0	0	0	63	8,682	1.38
500.0 (mm)	1,123	374	0	0	0	0	0	0	0	0	0	1,496	0.29
600.0 (mm)	0	0	0	437	0	0	16	0	0	0	0	453	0.13
900.0 (mm)	17	0	0	0	0	0	0	0	0	0	0	17	0.01
All Diameters	2,764	3,369	1,161	1,666	774	492	32,238	1,221	3,489	1,374	63	187,538	7.06

APPENDIX C: PIPES FLOW AND VELOCITY

	ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
30: P-159	30	P-159	273	J-365	J-366	150.0	AC	130.0	☐	0.000	0.176	0.010	0.001
37: P-160	37	P-160	239	J-314	J-315	150.0	AC	130.0	☐	0.000	0.038	0.002	0.000
40: P-161	40	P-161	719	J-579	J-580	150.0	AC	130.0	☐	0.000	0.293	0.017	0.004
42: P-162	42	P-162	229	J-299	J-300	150.0	AC	130.0	☐	0.000	0.221	0.013	0.002
44: P-163	44	P-163	241	J-322	J-323	150.0	AC	130.0	☐	0.000	0.021	0.001	0.000
46: P-164	46	P-164	560	J-486	J-487	150.0	AC	130.0	☐	0.000	1.067	0.060	0.042
79: P-2	79	P-2	16	J-10	PAIDA	600.0	Ductile Iron	130.0	☐	0.000	22.428	0.079	0.014
80: P-31	80	P-31	20	J-9	PAIDA	400.0	Ductile Iron	130.0	☐	0.000	-95.226	0.758	1.446
89: P-165	89	P-165	104	J-11	J-17	150.0	AC	130.0	☐	0.000	-22.907	1.296	12.273
91: P-12	91	P-12	25	J-16	IBB TANK	450.0	Ductile Iron	130.0	☐	0.000	-34.388	0.216	0.124
92: P-13	92	P-13	25	J-17	IBB TANK	450.0	Ductile Iron	130.0	☐	0.000	-22.915	0.144	0.059
95: P-33	95	P-33	23	J-18	BAHAGO UN...	300.0	Ductile Iron	130.0	☐	0.000	-130.282	1.843	10.489
97: P-166	97	P-166	845	J-16	J-20	150.0	AC	130.0	☐	0.000	34.374	1.945	26.024
99: P-14	99	P-14	48	J-20	INEC TANK	450.0	Ductile Iron	130.0	☐	0.000	53.056	0.334	0.276
109: P-156	109	P-156	722	J-21	J-22	152.4	Ductile Iron	130.0	☐	0.000	79.627	4.365	114.145
113: P-34	113	P-34	813	J-22	BI WATER T...	300.0	Ductile Iron	130.0	☐	0.000	150.657	2.131	13.727
120: P-352	120	P-352	8	J-28	J-29	100.0	PVC	130.0	☐	0.000	-14.952	1.904	40.137
129: P-353	129	P-353	7	J-34	J-35	100.0	PVC	130.0	☐	0.000	-0.008	0.001	0.000
132: P-354	132	P-354	10	J-36	J-37	100.0	D I	130.0	☐	0.000	0.087	0.011	0.002
135: P-35	135	P-35	11	J-38	J-39	300.0	AC	130.0	☐	0.000	63.174	0.894	2.743
144: P-15	144	P-15	16	J-44	J-45	450.0	G. I	130.0	☐	0.000	13.132	0.083	0.021
148: P-1	148	P-1	17	J-46	J-47	900.0	DI	130.0	☐	0.000	4.340	0.007	0.000
155: P-36	155	P-36	23	J-50	J-51	300.0	AC	130.0	☐	0.000	-0.142	0.002	0.000
158: P-37	158	P-37	24	BAHAGO UN...	J-38	300.0	AC	130.0	☐	0.000	63.176	0.894	2.746
159: P-355	159	P-355	24	J-28	J-52	100.0	PVC	130.0	☐	0.000	0.100	0.013	0.003
164: P-38	164	P-38	26	J-55	J-56	300.0	AC	130.0	☐	0.000	3.369	0.048	0.013
167: P-39	167	P-39	27	J-57	BAHAGO UN...	300.0	AC	130.0	☐	0.000	-79.835	1.129	4.234
169: P-40	169	P-40	27	J-58	J-59	300.0	AC	130.0	☐	0.000	-2.876	0.041	0.010
172: P-140	172	P-140	28	J-60	J-61	200.0	DI	130.0	☐	0.000	9.441	0.301	0.586
177: P-41	177	P-41	30	J-63	J-64	300.0	AC	130.0	☐	0.000	2.108	0.030	0.005
180: P-167	180	P-167	30	J-65	J-66	150.0	AC	130.0	☐	0.000	-3.874	0.219	0.457
183: P-356	183	P-356	32	J-67	J-68	100.0	GI	130.0	☐	0.000	-0.768	0.098	0.164
189: P-168	189	P-168	33	J-71	J-72	150.0	PVC	130.0	☐	0.000	0.012	0.001	0.000

530 of 530 elements displayed

	ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
189: P-168	189	P-168	33	J-71	J-72	150.0	PVC	130.0	☐	0.000	0.012	0.001	0.000
192: P-42	192	P-42	38	J-73	J-74	300.0	AC	130.0	☐	0.000	16.290	0.230	0.223
206: P-43	206	P-43	41	J-82	J-83	300.0	AC	130.0	☐	0.000	-1.072	0.015	0.002
212: P-44	212	P-44	45	J-86	J-87	300.0	AC	130.0	☐	0.000	-4.835	0.068	0.024
215: P-45	215	P-45	47	J-88	J-89	300.0	AC	130.0	☐	0.000	-64.297	0.910	2.836
233: P-46	233	P-46	56	J-100	J-101	300.0	AC	130.0	☐	0.000	26.034	0.368	0.531
236: P-169	236	P-169	55	J-102	J-103	150.0	AC	130.0	☐	0.000	0.314	0.018	0.005
239: P-357	239	P-357	61	J-104	J-105	100.0	PVC	130.0	☐	0.000	-3.035	0.386	2.094
242: P-170	242	P-170	77	J-106	J-107	150.0	AC	130.0	☐	0.000	1.644	0.093	0.093
248: P-16	248	P-16	63	IBB TANK	J-44	450.0	D.I	130.0	☐	0.000	19.212	0.121	0.042
268: P-171	268	P-171	98	J-122	J-123	150.0	PVC	130.0	☐	0.000	-24.130	1.365	13.514
271: P-358	271	P-358	94	J-124	J-125	100.0	AC	130.0	☐	0.000	0.054	0.007	0.001
274: P-359	274	P-359	83	J-126	J-127	100.0	AC	130.0	☐	0.000	-51.687	6.581	399.201
283: P-360	283	P-360	84	J-132	J-133	100.0	PVC	130.0	☐	0.000	-0.155	0.020	0.009
286: P-361	286	P-361	87	J-134	J-135	100.0	pvc	130.0	☐	0.000	0.136	0.017	0.007
289: P-47	289	P-47	87	J-102	J-136	300.0	AC	130.0	☐	0.000	0.027	0.000	0.000
291: P-362	291	P-362	88	J-137	J-138	100.0	PVC	130.0	☐	0.000	0.180	0.023	0.011
297: P-363	297	P-363	95	J-141	J-142	100.0	AC	130.0	☐	0.000	0.093	0.012	0.004
312: P-364	312	P-364	102	J-151	J-152	100.0	AC	130.0	☐	0.000	0.047	0.006	0.001
317: P-172	317	P-172	103	J-154	J-155	150.0	AC	130.0	☐	0.000	-4.805	0.272	0.681
332: P-365	332	P-365	109	J-164	J-165	100.0	AC	130.0	☐	0.000	0.016	0.002	0.000
338: P-366	338	P-366	111	J-168	J-169	100.0	PVC	130.0	☐	0.000	0.055	0.007	0.001
341: P-367	341	P-367	126	J-170	J-171	100.0	PVC	130.0	☐	0.000	0.062	0.008	0.001
351: P-368	351	P-368	123	J-176	J-177	100.0	PVC	130.0	☐	0.000	4.333	0.552	4.049
354: P-369	354	P-369	162	J-178	J-179	100.0	AC	130.0	☐	0.000	0.027	0.003	0.000
363: P-173	363	P-173	126	J-184	J-154	150.0	AC	130.0	☐	0.000	7.093	0.401	1.400
365: P-370	365	P-370	127	J-185	J-186	100.0	PVC	130.0	☐	0.000	0.194	0.025	0.013
373: P-371	373	P-371	130	J-190	J-191	100.0	PVC	130.0	☐	0.000	1.546	0.197	0.600
381: P-372	381	P-372	135	J-195	J-196	100.0	PVC	130.0	☐	0.000	0.325	0.041	0.033
390: P-373	390	P-373	141	J-201	J-202	100.0	PVC	130.0	☐	0.000	0.503	0.064	0.075
395: P-174	395	P-174	148	J-123	J-204	150.0	AC	130.0	☐	0.000	-25.524	1.444	14.995
402: P-374	402	P-374	150	J-185	J-208	100.0	PVC	130.0	☐	0.000	-0.226	0.029	0.017
404: P-375	404	P-375	152	J-209	J-210	100.0	AC	130.0	☐	0.000	0.029	0.004	0.000

	ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
10: P-48	410	P-48	165	J-59	J-213	300.0	AC	130.0	☐	0.000	-2.887	0.041	0.009
15: P-376	415	P-376	160	J-216	J-217	100.0	PVC	130.0	☐	0.000	0.436	0.056	0.058
37: P-175	437	P-175	173	J-230	J-231	150.0	AC	130.0	☐	0.000	0.015	0.001	0.000
40: P-377	440	P-377	177	J-186	J-232	100.0	PVC	130.0	☐	0.000	0.117	0.015	0.005
45: P-378	445	P-378	178	J-235	J-236	100.0	PVC	130.0	☐	0.000	-0.265	0.034	0.023
51: P-176	451	P-176	257	J-239	J-240	150.0	GI	130.0	☐	0.000	0.277	0.016	0.003
56: P-379	456	P-379	223	J-242	J-243	100.0	PVC	130.0	☐	0.000	0.106	0.013	0.004
59: P-380	459	P-380	203	J-244	J-191	100.0	PVC	130.0	☐	0.000	2.125	0.271	1.082
61: P-381	461	P-381	201	J-245	J-246	100.0	PVC	130.0	☐	0.000	1.078	0.137	0.308
64: P-382	464	P-382	186	J-247	J-248	100.0	PVC	130.0	☐	0.000	0.025	0.003	0.000
70: P-177	470	P-177	192	J-251	J-224	150.0	AC	130.0	☐	0.000	0.123	0.007	0.001
76: P-383	476	P-383	190	J-254	J-255	100.0	PVC	130.0	☐	0.000	-0.251	0.032	0.021
82: P-178	482	P-178	194	J-258	J-259	150.0	PVC	130.0	☐	0.000	0.799	0.045	0.025
85: P-384	485	P-384	1,137	J-28	J-84	100.0	AC	130.0	☐	0.000	14.636	1.863	38.580
86: P-179	486	P-179	194	J-260	J-261	150.0	AC	130.0	☐	0.000	0.017	0.001	0.000
89: P-385	489	P-385	219	J-262	J-263	100.0	PVC	130.0	☐	0.000	0.502	0.064	0.075
92: P-180	492	P-180	194	J-155	J-264	150.0	AC	130.0	☐	0.000	-4.845	0.274	0.691
99: P-181	499	P-181	275	J-268	J-269	150.0	AC	130.0	☐	0.000	0.656	0.037	0.017
17: P-386	517	P-386	214	J-280	J-281	100.0	PVC	130.0	☐	0.000	0.206	0.026	0.014
23: P-387	523	P-387	263	J-284	J-285	100.0	AC	130.0	☐	0.000	-0.305	0.039	0.030
26: P-388	526	P-388	221	J-286	J-287	100.0	PVC	130.0	☐	0.000	0.332	0.042	0.035
34: P-389	534	P-389	236	J-291	J-292	100.0	GI	130.0	☐	0.000	3.497	0.445	2.722
40: P-182	540	P-182	224	J-295	J-296	150.0	AC	130.0	☐	0.000	-0.043	0.002	0.000
43: P-390	543	P-390	228	J-297	J-298	100.0	AC	130.0	☐	0.000	-3.848	0.490	3.249
48: P-391	548	P-391	231	J-138	J-301	100.0	PVC	130.0	☐	0.000	0.087	0.011	0.003
50: P-183	550	P-183	232	J-264	J-302	150.0	AC	130.0	☐	0.000	-4.932	0.279	0.714
54: P-392	554	P-392	234	J-304	J-305	100.0	PVC	130.0	☐	0.000	0.720	0.092	0.146
64: P-393	564	P-393	238	J-310	J-311	100.0	PVC	130.0	☐	0.000	-0.109	0.014	0.004
67: P-394	567	P-394	238	J-312	J-313	100.0	PVC	130.0	☐	0.000	-0.253	0.032	0.021
78: P-395	578	P-395	240	J-320	J-321	100.0	PVC	130.0	☐	0.000	-0.230	0.029	0.018
83: P-49	583	P-49	245	J-324	J-325	300.0	D. I	130.0	☐	0.000	12.712	0.180	0.141
92: P-396	592	P-396	243	J-330	J-331	100.0	PVC	130.0	☐	0.000	-0.250	0.032	0.021
95: P-184	595	P-184	242	J-332	J-333	150.0	PVC	130.0	☐	0.000	0.412	0.023	0.007

	ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
595: P-184	595	P-184	242	J-332	J-333	150.0	PVC	130.0	☐	0.000	0.412	0.023	0.007
598: P-397	598	P-397	243	J-334	J-335	100.0	PVC	130.0	☐	0.000	-1.506	0.192	0.572
604: P-398	604	P-398	245	J-338	J-339	100.0	PVC	130.0	☐	0.000	-0.049	0.006	0.001
610: P-50	610	P-50	247	J-45	J-342	300.0	D. I	130.0	☐	0.000	13.019	0.184	0.147
612: P-141	612	P-141	248	J-343	J-67	200.0	AC	130.0	☐	0.000	-0.713	0.023	0.005
617: P-399	617	P-399	288	J-346	J-347	100.0	PVC	130.0	☐	0.000	-0.412	0.052	0.052
632: P-400	632	P-400	261	J-356	J-357	100.0	AC	130.0	☐	0.000	0.030	0.004	0.000
638: P-121	638	P-121	269	IBB TANK	J-360	250.0	AC	130.0	☐	0.000	2.036	0.041	0.011
640: P-401	640	P-401	271	J-177	J-361	100.0	PVC	130.0	☐	0.000	4.107	0.523	3.667
642: P-17	642	P-17	301	J-362	J-324	450.0	G. I	130.0	☐	0.000	12.726	0.080	0.020
649: P-185	649	P-185	286	J-367	J-368	150.0	AC	130.0	☐	0.000	0.970	0.055	0.035
652: P-186	652	P-186	279	J-204	J-154	150.0	AC	130.0	☐	0.000	-11.868	0.672	3.631
672: P-187	672	P-187	290	J-382	J-31	150.0	AC	130.0	☐	0.000	4.851	0.275	0.693
686: P-402	686	P-402	292	J-191	J-291	100.0	PVC	130.0	☐	0.000	3.620	0.461	2.902
687: P-188	687	P-188	362	J-391	J-392	150.0	AC	130.0	☐	0.000	0.200	0.011	0.002
690: P-189	690	P-189	294	J-393	J-351	150.0	AC	130.0	☐	0.000	3.345	0.189	0.348
692: P-403	692	P-403	466	J-394	J-395	100.0	PVC	130.0	☐	0.000	0.196	0.025	0.013
706: P-404	706	P-404	323	J-403	J-404	100.0	PVC	130.0	☐	0.000	0.530	0.067	0.083
709: P-405	709	P-405	343	J-405	J-406	100.0	PVC	130.0	☐	0.000	1.221	0.156	0.388
724: P-406	724	P-406	320	J-413	J-414	100.0	PVC	130.0	☐	0.000	-8.121	1.034	12.960
735: P-190	735	P-190	338	J-419	J-420	150.0	AC	130.0	☐	0.000	-2.717	0.154	0.237
740: P-407	740	P-407	329	J-422	J-423	100.0	AC	130.0	☐	0.000	0.094	0.012	0.003
755: P-408	755	P-408	484	J-432	J-433	100.0	AC	130.0	☐	0.000	0.593	0.075	0.102
770: P-409	770	P-409	416	J-441	J-442	100.0	PVC	130.0	☐	0.000	0.989	0.126	0.263
773: P-191	773	P-191	351	J-443	J-444	150.0	AC	130.0	☐	0.000	0.084	0.005	0.000
782: P-6	782	P-6	374	J-449	J-450	500.0	GI	130.0	☐	0.000	0.135	0.001	0.000
797: P-192	797	P-192	366	J-459	J-460	150.0	PVC	130.0	☐	0.000	1.030	0.058	0.039
800: P-410	800	P-410	376	J-461	J-352	100.0	PVC	130.0	☐	0.000	-14.649	1.865	38.643
804: P-193	804	P-193	364	J-463	J-464	150.0	AC	130.0	☐	0.000	-0.425	0.024	0.008
810: P-411	810	P-411	457	J-467	J-468	100.0	PVC	130.0	☐	0.000	0.194	0.025	0.013
827: P-194	827	P-194	389	J-479	J-480	150.0	AC	130.0	☐	0.000	0.225	0.013	0.002
843: P-412	843	P-412	399	J-490	J-491	100.0	PVC	130.0	☐	0.000	0.867	0.110	0.206
849: P-413	849	P-413	429	J-494	J-495	100.0	PVC	130.0	☐	0.000	0.649	0.083	0.120

	ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
52: P-414	852	P-414	491	J-496	J-497	100.0	PVC	130.0	☐	0.000	0.107	0.014	0.004
55: P-195	855	P-195	443	J-498	J-499	150.0	AC	130.0	☐	0.000	0.587	0.033	0.014
64: P-415	864	P-415	549	J-504	J-505	100.0	PVC	130.0	☐	0.000	-0.906	0.115	0.223
70: P-196	870	P-196	465	J-508	J-509	150.0	AC	130.0	☐	0.000	0.649	0.037	0.017
76: P-197	876	P-197	430	J-512	J-513	150.0	AC	130.0	☐	0.000	2.129	0.120	0.151
79: P-416	879	P-416	444	J-514	J-515	100.0	GI	130.0	☐	0.000	0.105	0.013	0.004
00: P-417	900	P-417	502	J-527	J-528	100.0	GI	130.0	☐	0.000	0.237	0.030	0.019
03: P-142	903	P-142	508	J-61	J-529	200.0	DI	130.0	☐	0.000	9.306	0.296	0.570
20: P-418	920	P-418	656	J-539	J-540	100.0	PVC	130.0	☐	0.000	2.238	0.285	1.191
26: P-419	926	P-419	688	J-543	J-544	100.0	PVC	130.0	☐	0.000	0.489	0.062	0.071
38: P-420	938	P-420	1,774	J-551	J-552	100.0	PVC	130.0	☐	0.000	0.154	0.020	0.008
49: P-122	949	P-122	544	J-558	J-559	250.0	AC	130.0	☐	0.000	13.771	0.281	0.397
61: P-421	961	P-421	558	J-566	J-567	100.0	PVC	130.0	☐	0.000	-0.223	0.028	0.017
66: P-198	966	P-198	575	J-569	J-268	150.0	AC	130.0	☐	0.000	0.761	0.043	0.022
69: P-199	969	P-199	589	J-570	J-571	150.0	AC	130.0	☐	0.000	2.166	0.123	0.156
75: P-423	975	P-423	589	J-574	J-494	100.0	PVC	130.0	☐	0.000	0.882	0.112	0.212
77: P-424	977	P-424	591	J-575	J-576	100.0	AC	130.0	☐	0.000	0.881	0.112	0.212
80: P-425	980	P-425	591	J-577	J-578	100.0	PVC	130.0	☐	0.000	0.253	0.032	0.021
89: P-426	989	P-426	683	J-583	J-484	100.0	PVC	130.0	☐	0.000	1.058	0.135	0.297
94: P-427	994	P-427	616	J-263	J-586	100.0	PVC	130.0	☐	0.000	0.416	0.053	0.053
96: P-200	996	P-200	631	J-587	J-588	150.0	AC	130.0	☐	0.000	-0.743	0.042	0.021
002: P-428	1002	P-428	630	J-591	J-564	100.0	PVC	130.0	☐	0.000	-0.490	0.062	0.071
004: P-201	1004	P-201	636	J-592	J-393	150.0	AC	130.0	☐	0.000	9.567	0.541	2.436
016: P-429	1016	P-429	733	J-599	J-600	100.0	PVC	130.0	☐	0.000	-0.884	0.113	0.213
021: P-430	1021	P-430	660	J-602	J-176	100.0	PVC	130.0	☐	0.000	7.357	0.937	10.794
023: P-431	1023	P-431	674	J-603	J-50	100.0	PVC	130.0	☐	0.000	-0.098	0.013	0.004
030: P-51	1030	P-51	683	J-325	J-607	300.0	A.C	130.0	☐	0.000	12.565	0.178	0.138
032: P-52	1032	P-52	690	J-342	J-608	300.0	A.C	130.0	☐	0.000	12.845	0.182	0.144
048: P-432	1048	P-432	841	J-618	J-619	100.0	PVC	130.0	☐	0.000	-2.556	0.325	1.523
053: P-433	1053	P-433	745	J-621	J-51	100.0	PVC	130.0	☐	0.000	0.583	0.074	0.099
055: P-53	1055	P-53	754	J-622	J-623	300.0	AC	130.0	☐	0.000	0.150	0.002	0.000
064: P-434	1064	P-434	759	J-628	J-629	100.0	AC	130.0	☐	0.000	0.325	0.041	0.034
079: P-54	1079	P-54	819	J-66	J-637	300.0	AC	130.0	☐	0.000	-4.730	0.067	0.023

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	ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
1081: P-55	1081	P-55	804	J-459	J-638	300.0	AC	130.0	☐	0.000	-6.867	0.097	0.045
1093: P-56	1093	P-56	829	J-525	J-607	300.0	AC	130.0	☐	0.000	-17.527	0.248	0.255
1094: P-435	1094	P-435	825	J-581	J-645	100.0	PVC	130.0	☐	0.000	0.205	0.026	0.014
1096: P-202	1096	P-202	1,123	J-103	J-646	150.0	AC/PVC	130.0	☐	0.000	0.220	0.012	0.002
1098: P-129	1098	P-129	872	J-647	J-638	225.0	AC	130.0	☐	0.000	9.246	0.233	0.317
1101: P-436	1101	P-436	902	J-648	J-649	100.0	PVC	130.0	☐	0.000	-3.657	0.466	2.957
1109: P-437	1109	P-437	948	J-654	J-655	100.0	PVC	130.0	☐	0.000	0.325	0.041	0.033
1115: P-438	1115	P-438	1,051	J-279	J-137	100.0	PVC	130.0	☐	0.000	1.015	0.129	0.276
1124: P-203	1124	P-203	1,019	J-661	J-662	150.0	PVC	130.0	☐	0.000	0.954	0.054	0.034
1133: P-204	1133	P-204	1,055	J-666	BI WATER T...	150.0	AC	130.0	☐	0.000	-1.026	0.058	0.039
1136: P-205	1136	P-205	1,052	J-668	J-122	150.0	PVC	130.0	☐	0.000	-23.906	1.353	13.282
1138: P-439	1138	P-439	1,090	J-669	J-670	100.0	PVC	130.0	☐	0.000	-0.260	0.033	0.022
1141: P-206	1141	P-206	1,065	J-591	J-671	150.0	AC/PVC	130.0	☐	0.000	0.185	0.010	0.002
1149: P-143	1149	P-143	1,139	J-449	J-675	200.0	AC	130.0	☐	0.000	-0.613	0.020	0.004
1156: P-32	1156	P-32	1,219	J-679	J-680	400.0	D I	130.0	☐	0.000	-1.284	0.010	0.001
1159: P-440	1159	P-440	1,232	J-681	J-424	100.0	PVC	130.0	☐	0.000	-2.278	0.290	1.231
1161: P-441	1161	P-441	1,221	J-682	J-683	100.0	PVC/AC	130.0	☐	0.000	-3.136	0.399	2.224
1180: P-442	1180	P-442	1,625	J-693	J-694	100.0	PVC	130.0	☐	0.000	1.765	0.225	0.767
1187: P-144	1187	P-144	1,943	J-697	J-698	200.0	AC	130.0	☐	0.000	3.166	0.101	0.077
1236: P-157	1236	P-157	458	BI WATER T...	J-1	152.4	Ductile Iron	130.0	☐	0.000	-40.549	2.223	32.710
1240: P-18	1240	P-18	310	J-1	J-724	450.0	Ductile Iron	130.0	☐	0.000	-40.814	0.257	0.170
1241: P-19	1241	P-19	190	J-724	J-2	450.0	Ductile Iron	130.0	☐	0.000	13.442	0.085	0.022
1243: P-20	1243	P-20	357	J-2	J-725	450.0	Ductile Iron	130.0	☐	0.000	13.228	0.083	0.021
1244: P-21	1244	P-21	137	J-725	J-4	450.0	Ductile Iron	130.0	☐	0.000	12.756	0.080	0.020
1245: P-22	1245	P-22	266	J-4	J-697	450.0	Ductile Iron	130.0	☐	0.000	12.458	0.078	0.019
1246: P-23	1246	P-23	62	J-697	J-693	450.0	Ductile Iron	130.0	☐	0.000	9.116	0.057	0.011
1247: P-24	1247	P-24	468	J-693	J-286	450.0	Ductile Iron	130.0	☐	0.000	7.201	0.045	0.007
1248: P-25	1248	P-25	131	J-286	J-347	450.0	Ductile Iron	130.0	☐	0.000	6.844	0.043	0.006
1249: P-26	1249	P-26	156	J-347	SHIRORO TANK	450.0	Ductile Iron	130.0	☐	0.000	6.233	0.039	0.005
1252: P-443	1252	P-443	126	J-562	J-407	100.0	PVC	130.0	☐	0.000	0.082	0.010	0.003
1253: P-444	1253	P-444	167	J-217	J-386	100.0	PVC	130.0	☐	0.000	-0.238	0.030	0.019
1254: P-445	1254	P-445	13	J-386	J-562	100.0	PVC	130.0	☐	0.000	0.068	0.009	0.001
1258: P-207	1258	P-207	112	J-127	J-29	150.0	AC	130.0	☐	0.000	-71.439	4.043	100.869

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	ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
1259: P-446	1259	P-446	7	J-84	J-126	100.0	G. I	130.0	☐	0.000	14.110	1.797	36.056
1260: P-447	1260	P-447	37	J-126	J-85	100.0	G. I	130.0	☐	0.000	65.782	8.376	623.938
1261: P-57	1261	P-57	1,505	J-637	J-85	300.0	AC	130.0	☐	0.000	-11.150	0.158	0.111
1277: P-130	1277	P-130	42	J-285	J-464	225.0	AC	130.0	☐	0.000	-3.580	0.090	0.055
1279: P-131	1279	P-131	35	J-464	J-651	225.0	AC	130.0	☐	0.000	-4.009	0.101	0.068
1280: P-132	1280	P-132	15	J-651	J-76	225.0	AC	130.0	☐	0.000	-4.324	0.109	0.078
1282: P-208	1282	P-208	38	J-76	J-77	150.0	AC	130.0	☐	0.000	0.035	0.002	0.000
1284: P-209	1284	P-209	54	J-322	J-651	150.0	AC	130.0	☐	0.000	-0.314	0.018	0.005
1285: P-210	1285	P-210	702	J-29	J-367	150.0	AC	130.0	☐	0.000	-86.496	4.895	143.745
1287: P-133	1287	P-133	273	J-76	J-486	225.0	AC	130.0	☐	0.000	-4.368	0.110	0.079
1288: P-134	1288	P-134	679	J-486	J-637	225.0	AC	130.0	☐	0.000	-5.659	0.142	0.128
1290: P-211	1290	P-211	94	J-314	J-322	150.0	AC	130.0	☐	0.000	-0.281	0.016	0.004
1292: P-212	1292	P-212	63	J-299	J-314	150.0	AC	130.0	☐	0.000	-0.224	0.013	0.002
1294: P-213	1294	P-213	71	J-487	J-299	150.0	AC	130.0	☐	0.000	0.015	0.001	0.000
1296: P-214	1296	P-214	114	J-463	J-487	150.0	AC	130.0	☐	0.000	-1.026	0.058	0.039
1298: P-215	1298	P-215	168	J-456	J-463	150.0	AC	130.0	☐	0.000	-1.068	0.060	0.042
1299: P-216	1299	P-216	406	J-650	J-366	150.0	AC	130.0	☐	0.000	-0.867	0.049	0.029
1300: P-217	1300	P-217	196	J-366	J-456	150.0	AC	130.0	☐	0.000	-0.851	0.048	0.028
1301: P-218	1301	P-218	355	J-643	J-650	150.0	AC	130.0	☐	0.000	0.218	0.012	0.002
1302: P-219	1302	P-219	457	J-650	J-644	150.0	AC	130.0	☐	0.000	0.935	0.053	0.033
1303: P-220	1303	P-220	251	J-477	J-365	150.0	AC	130.0	☐	0.000	-0.561	0.032	0.013
1304: P-221	1304	P-221	199	J-365	J-478	150.0	AC	130.0	☐	0.000	-0.801	0.045	0.025
1305: P-222	1305	P-222	92	J-455	J-478	150.0	AC	130.0	☐	0.000	0.757	0.043	0.022
1306: P-223	1306	P-223	267	J-478	J-456	150.0	AC	130.0	☐	0.000	-0.080	0.005	0.000
1307: P-135	1307	P-135	195	J-579	J-569	225.0	AC	130.0	☐	0.000	-1.281	0.032	0.008
1310: P-448	1310	P-448	154	J-216	J-386	100.0	PVC	130.0	☐	0.000	0.356	0.045	0.040
1311: P-449	1311	P-449	159	BI WATER T...	J-180	100.0	PVC	130.0	☐	0.000	1.325	0.169	0.451
1312: P-450	1312	P-450	6	J-180	J-216	100.0	PVC	130.0	☐	0.000	0.802	0.102	0.181
1313: P-451	1313	P-451	35	J-180	J-195	100.0	PVC	130.0	☐	0.000	0.487	0.062	0.071
1314: P-452	1314	P-452 P-26	87	J-195	J-181	100.0	PVC	130.0	☐	0.000	0.115	0.015	0.005
1316: P-453	1316	P-453	446	J-196	J-563	100.0	PVC	130.0	☐	0.000	0.189	0.024	0.012
1317: P-454	1317	P-454	95	J-562	J-168	100.0	PVC	130.0	☐	0.000	-0.055	0.007	0.001
1318: P-455	1318	P-455	20	J-168	J-196	100.0	PVC	130.0	☐	0.000	-0.117	0.015	0.005

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	ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
1319: P-58	1319	P-58	628	J-21	J-245	300.0	Ductile Iron	130.0	☐	0.000	211.000	2.985	25.617
1321: P-59	1321	P-59	1,487	J-245	J-539	300.0	Ductile Iron	130.0	☐	0.000	209.860	2.969	25.361
1322: P-60	1322	P-60	33	J-539	TOP MEDICA...	300.0	Ductile Iron	130.0	☐	0.000	206.300	2.919	24.570
1343: P-61	1343	P-61	373	J-525	J-543	300.0	AC	130.0	☐	0.000	0.736	0.010	0.001
1344: P-62	1344	P-62	173	J-543	J-526	300.0	AC	130.0	☐	0.000	0.140	0.002	0.000
1346: P-145	1346	P-145	211	J-74	J-696	200.0	AC	130.0	☐	0.000	15.813	0.503	1.521
1348: P-224	1348	P-224	337	J-588	J-696	150.0	AC	130.0	☐	0.000	-15.751	0.891	6.133
1350: P-225	1350	P-225	71	J-658	J-588	150.0	AC	130.0	☐	0.000	-14.916	0.844	5.545
1351: P-226	1351	P-226	244	J-658	J-614	150.0	AC	130.0	☐	0.000	7.861	0.445	1.693
1353: P-456	1353	P-456	104	J-614	J-208	100.0	AC	130.0	☐	0.000	1.977	0.252	0.946
1355: P-457	1355	P-457	427	J-208	J-178	100.0	AC	130.0	☐	0.000	1.715	0.218	0.727
1356: P-458	1356	P-458	180	J-178	J-615	100.0	AC	130.0	☐	0.000	1.638	0.209	0.668
1358: P-227	1358	P-227	231	J-615	J-685	150.0	AC	130.0	☐	0.000	1.710	0.097	0.100
1360: P-228	1360	P-228	716	J-685	J-658	150.0	AC	130.0	☐	0.000	-6.956	0.394	1.350
1362: P-229	1362	P-229	144	J-577	J-615	150.0	AC	130.0	☐	0.000	0.142	0.008	0.001
1364: P-230	1364	P-230	331	J-610	J-577	150.0	AC	130.0	☐	0.000	0.498	0.028	0.010
1366: P-231	1366	P-231	79	J-612	J-610	150.0	AC	130.0	☐	0.000	-1.050	0.059	0.041
1370: P-232	1370	P-232	191	J-611	J-612	150.0	AC	130.0	☐	0.000	-1.297	0.073	0.060
1372: P-459	1372	P-459	96	J-236	J-611	100.0	AC	130.0	☐	0.000	-0.038	0.005	0.001
1374: P-460	1374	P-460	263	J-290	J-236	100.0	AC	130.0	☐	0.000	0.267	0.034	0.023
1375: P-461	1375	P-461	178	J-290	J-457	100.0	PVC	130.0	☐	0.000	0.361	0.046	0.041
1376: P-462	1376	P-462	128	J-457	J-170	100.0	PVC	130.0	☐	0.000	0.111	0.014	0.005
1377: P-233	1377	P-233	111	J-684	J-458	150.0	AC	130.0	☐	0.000	-0.099	0.006	0.001
1379: P-234	1379	P-234	23	J-458	J-335	150.0	AC	130.0	☐	0.000	0.292	0.017	0.003
1380: P-235	1380	P-235	157	J-335	J-611	150.0	AC	130.0	☐	0.000	-1.231	0.070	0.055
1381: P-463	1381	P-463	272	J-457	J-235	100.0	PVC	130.0	☐	0.000	0.178	0.023	0.011
1382: P-464	1382	P-464	87	J-235	J-458	100.0	PVC	130.0	☐	0.000	0.403	0.051	0.050
1383: P-465	1383	P-465	255	J-391	J-254	100.0	AC	130.0	☐	0.000	0.446	0.057	0.060
1384: P-466	1384	P-466	91	J-254	J-290	100.0	AC	130.0	☐	0.000	0.667	0.085	0.127
1385: P-236	1385	P-236	266	J-676	J-514	150.0	G I	130.0	☐	0.000	2.714	0.154	0.236
1386: P-237	1386	P-237	455	J-514	J-432	150.0	G I	130.0	☐	0.000	2.581	0.146	0.215
1389: P-238	1389	P-238	25	J-613	J-676	150.0	AC	130.0	☐	0.000	3.427	0.194	0.363
1390: P-239	1356	P-239	166	J-676	J-391	150.0	AC	130.0	☐	0.000	0.698	0.040	0.019

	ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
1390: P-239	1390	P-239	166	J-676	J-391	150.0	AC	130.0	☐	0.000	0.698	0.040	0.019
1391: P-240	1391	P-240	475	J-614	J-609	150.0	AC	130.0	☐	0.000	5.801	0.328	0.964
1392: P-241	1392	P-241	79	J-609	J-613	150.0	AC	130.0	☐	0.000	4.002	0.226	0.485
1393: P-467	1393	P-467	455	J-612	J-255	100.0	PVC	130.0	☐	0.000	-0.259	0.033	0.022
1394: P-468	1394	P-468	251	J-255	J-613	100.0	PVC	130.0	☐	0.000	-0.566	0.072	0.093
1397: P-469	1397	P-469	57	J-433	J-334	100.0	AC	130.0	☐	0.000	-1.357	0.173	0.472
1398: P-470	1398	P-470	226	J-334	J-550	100.0	AC	130.0	☐	0.000	0.117	0.015	0.005
1400: P-471	1400	P-471	37	J-244	J-433	100.0	AC	130.0	☐	0.000	-1.939	0.247	0.913
1401: P-472	1401	P-472	25	J-340	J-190	100.0	PVC	130.0	☐	0.000	-0.055	0.007	0.000
1402: P-473	1402	P-473	221	J-190	J-341	100.0	PVC	130.0	☐	0.000	-1.611	0.205	0.648
1403: P-474	1403	P-474	62	J-549	J-341	100.0	AC	130.0	☐	0.000	1.842	0.235	0.831
1404: P-475	1404	P-475	144	J-341	J-244	100.0	AC	130.0	☐	0.000	0.207	0.026	0.014
1405: P-242	1405	P-242	229	J-432	J-549	150.0	G I	130.0	☐	0.000	1.966	0.111	0.130
1406: P-243	1406	P-243	211	J-549	J-677	150.0	G I	130.0	☐	0.000	0.059	0.003	0.000
1407: P-27	1407	P-27	135	J-398	J-362	450.0	G. I	130.0	☐	0.000	6.761	0.043	0.006
1408: P-28	1408	P-28	279	J-362	J-44	450.0	G. I	130.0	☐	0.000	-6.068	0.038	0.005
1409: P-3	1409	P-3	75	J-398	J-360	600.0	D I	130.0	☐	0.000	-6.880	0.024	0.001
1411: P-4	1411	P-4	57	J-360	J-558	600.0	D I	130.0	☐	0.000	-4.900	0.017	0.001
1412: P-5	1412	P-5	305	J-558	IBB TANK	600.0	D I	130.0	☐	0.000	-18.861	0.067	0.010
1413: P-123	1413	P-123	445	J-559	J-106	250.0	AC	130.0	☐	0.000	12.941	0.264	0.354
1415: P-124	1415	P-124	33	J-106	J-508	250.0	AC	130.0	☐	0.000	11.196	0.228	0.271
1417: P-125	1417	P-125	779	J-508	J-394	250.0	AC	130.0	☐	0.000	10.347	0.211	0.234
1421: P-127	1421	P-127	166	J-512	J-688	250.0	AC	130.0	☐	0.000	7.666	0.156	0.134
1422: P-128	1422	P-128	568	J-688	J-675	250.0	AC	130.0	☐	0.000	1.910	0.039	0.010
1423: P-146	1423	P-146	471	J-688	J-507	200.0	AC	130.0	☐	0.000	5.087	0.162	0.186
1424: P-147	1424	P-147	841	J-507	J-689	200.0	AC	130.0	☐	0.000	4.117	0.131	0.126
1425: P-476	1425	P-476	92	J-506	J-513	100.0	AC	130.0	☐	0.000	-1.263	0.161	0.413
1426: P-477	1426	P-477	349	J-513	J-507	100.0	AC	130.0	☐	0.000	0.676	0.086	0.130
1428: P-63	1428	P-63	38	J-527	J-449	300.0	AC	130.0	☐	0.000	-0.254	0.004	0.000
1429: P-244	1429	P-244	236	J-626	J-598	150.0	AC	130.0	☐	0.000	-0.098	0.006	0.000
1431: P-245	1431	P-245	496	J-597	J-496	150.0	PVC	130.0	☐	0.000	-17.107	0.968	7.147
1432: P-246	1432	P-246	167	J-496	J-598	150.0	PVC	130.0	☐	0.000	-17.338	0.981	7.327
1433: P-247	1433	P-247	166	J-288	J-298	150.0	AC	130.0	☐	0.000	3.916	0.222	0.466

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	ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
1433: P-247	1433	P-247	166	J-288	J-298	150.0	AC	130.0	☐	0.000	3.916	0.222	0.466
1434: P-248	1434	P-248	55	J-298	J-289	150.0	AC	130.0	☐	0.000	0.050	0.003	0.000
1435: P-64	1435	P-64	274	J-621	J-627	300.0	AC	130.0	☐	0.000	7.626	0.108	0.055
1437: P-65	1437	P-65	258	J-627	J-288	300.0	AC	130.0	☐	0.000	-6.218	0.088	0.037
1439: P-66	1439	P-66	727	J-288	J-83	300.0	AC	130.0	☐	0.000	-10.250	0.145	0.095
1443: P-67	1443	P-67	71	J-82	J-592	300.0	AC	130.0	☐	0.000	-9.540	0.135	0.083
1447: P-68	1447	P-68	65	J-592	J-87	300.0	AC	130.0	☐	0.000	-19.129	0.271	0.301
1449: P-69	1449	P-69	7	J-35	J-86	300.0	AC	130.0	☐	0.000	-19.040	0.269	0.295
1451: P-70	1451	P-70	124	J-87	J-653	300.0	AC	130.0	☐	0.000	-23.999	0.340	0.457
1453: P-478	1453	P-478	378	J-533	J-495	100.0	PVC	130.0	☐	0.000	-8.230	1.048	13.284
1454: P-479	1454	P-479	123	J-495	J-534	100.0	PVC	130.0	☐	0.000	-7.681	0.978	11.690
1457: P-148	1457	P-148	1,334	J-695	J-573	200.0	AC	130.0	☐	0.000	-0.238	0.008	0.001
1458: P-149	1458	P-149	193	J-573	J-74	200.0	AC	130.0	☐	0.000	-0.435	0.014	0.002
1459: P-71	1459	P-71	344	J-525	J-73	300.0	AC	130.0	☐	0.000	16.604	0.235	0.231
1460: P-72	1460	P-72	766	J-73	J-674	300.0	AC	130.0	☐	0.000	0.248	0.004	0.000
1461: P-480	1461	P-480	702	J-656	J-467	100.0	PVC	130.0	☐	0.000	-0.278	0.035	0.025
1462: P-481	1462	P-481	241	J-467	J-343	100.0	PVC	130.0	☐	0.000	-0.659	0.084	0.124
1463: P-249	1463	P-249	2,794	J-20	J-68	150.0	AC	130.0	☐	0.000	-18.834	1.066	8.540
1464: P-250	1464	P-250	1,194	J-68	J-127	150.0	AC	130.0	☐	0.000	-19.718	1.116	9.298
1465: P-73	1465	P-73	1,374	J-85	J-488	300.0	AC	130.0	☐	0.000	54.559	0.772	2.092
1466: P-74	1466	P-74	80	J-488	J-724	300.0	AC	130.0	☐	0.000	54.284	0.768	2.073
1467: P-251	1467	P-251	142	J-488	J-36	150.0	DI	130.0	☐	0.000	0.246	0.014	0.003
1468: P-252	1468	P-252	325	J-36	J-489	150.0	DI	130.0	☐	0.000	0.122	0.007	0.001
1469: P-482	1469	P-482	69	J-437	J-262	100.0	PVC	130.0	☐	0.000	-0.099	0.013	0.004
1470: P-483	1470	P-483	280	J-262	BAHAGO UN...	100.0	PVC	130.0	☐	0.000	-0.653	0.083	0.122
1473: P-75	1473	P-75	3	J-630	J-414	300.0	AC	130.0	☐	0.000	135.932	1.923	11.355
1475: P-484	1475	P-484	84	J-630	J-670	100.0	GI	130.0	☐	0.000	6.940	0.884	9.688
1476: P-485	1476	P-485	735	J-670	J-631	100.0	GI	130.0	☐	0.000	6.532	0.832	8.658
1477: P-76	1477	P-76	280	J-414	J-353	300.0	AC	130.0	☐	0.000	127.796	1.808	10.121
1479: P-486	1479	P-486	199	J-642	J-413	100.0	PVC	130.0	☐	0.000	-6.861	0.874	9.485
1480: P-487	1480	P-487	793	J-413	J-311	100.0	PVC	130.0	☐	0.000	0.917	0.117	0.228
1481: P-488	1481	P-488	35	J-352	J-642	100.0	PVC	130.0	☐	0.000	-14.723	1.875	39.008
1482: P-489	1482	P-489	261	J-642	J-353	100.0	PVC	130.0	☐	0.000	-7.891	1.005	12.290

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1482: P-489	1482	P-489	261	J-642	J-353	100.0	PVC	130.0	☐	0.000	-7.891	1.005	12.290
1484: P-490	1484	P-490	94	J-461	J-134	100.0	PVC	130.0	☐	0.000	0.170	0.022	0.010
1485: P-77	1485	P-77	480	J-353	J-631	300.0	AC	130.0	☐	0.000	119.781	1.695	8.977
1487: P-78	1487	P-78	67	J-631	J-207	300.0	AC	130.0	☐	0.000	126.259	1.786	9.897
1490: P-253	1490	P-253	146	J-276	J-207	150.0	PVC	130.0	☐	0.000	-98.959	5.600	184.442
1491: P-491	1491	P-491	9	J-462	J-441	100.0	PVC	130.0	☐	0.000	-13.420	1.709	32.858
1492: P-492	1492	P-492	264	J-441	J-461	100.0	PVC	130.0	☐	0.000	-14.435	1.838	37.606
1493: P-493	1493	P-493	92	J-276	J-462	100.0	PVC	130.0	☐	0.000	-12.326	1.569	28.067
1494: P-494	1494	P-494	142	J-462	J-277	100.0	PVC	130.0	☐	0.000	1.073	0.137	0.305
1495: P-79	1495	P-79	230	J-207	J-239	300.0	AC	130.0	☐	0.000	27.276	0.386	0.579
1497: P-80	1497	P-80	293	J-239	J-690	300.0	AC	130.0	☐	0.000	26.918	0.381	0.565
1498: P-81	1498	P-81	29	J-690	J-647	300.0	AC	130.0	☐	0.000	9.827	0.139	0.088
1499: P-254	1499	P-254	1,072	J-692	J-193	150.0	PVC	130.0	☐	0.000	-3.494	0.198	0.377
1500: P-255	1500	P-255	352	J-193	J-459	150.0	PVC	130.0	☐	0.000	-4.501	0.255	0.603
1501: P-256	1501	P-256	26	J-193	J-258	150.0	PVC	130.0	☐	0.000	1.002	0.057	0.037
1502: P-257	1502	P-257	132	J-258	J-194	150.0	PVC	130.0	☐	0.000	0.124	0.007	0.001
1503: P-258	1503	P-258	133	J-97	J-480	150.0	AC	130.0	☐	0.000	0.118	0.007	0.001
1504: P-259	1504	P-259	254	J-480	J-434	150.0	AC	130.0	☐	0.000	0.283	0.016	0.004
1505: P-260	1505	P-260	22	J-96	J-251	150.0	AC	130.0	☐	0.000	0.263	0.015	0.003
1506: P-261	1506	P-261	41	J-251	J-97	150.0	AC	130.0	☐	0.000	0.130	0.007	0.001
1507: P-262	1507	P-262	232	J-387	J-96	150.0	AC	130.0	☐	0.000	0.281	0.016	0.004
1508: P-263	1508	P-263	55	J-96	J-388	150.0	AC	130.0	☐	0.000	0.009	0.001	0.000
1511: P-264	1511	P-264	61	J-516	J-296	150.0	AC	130.0	☐	0.000	0.491	0.028	0.010
1512: P-265	1512	P-265	103	J-296	J-387	150.0	AC	130.0	☐	0.000	0.426	0.024	0.008
1513: P-266	1513	P-266	404	J-593	J-516	150.0	AC	130.0	☐	0.000	1.001	0.057	0.037
1514: P-267	1514	P-267	240	J-516	J-479	150.0	AC	130.0	☐	0.000	0.382	0.022	0.006
1515: P-268	1515	P-268	148	J-387	J-260	150.0	AC	130.0	☐	0.000	0.108	0.006	0.001
1517: P-269	1517	P-269	75	J-260	J-230	150.0	AC	130.0	☐	0.000	0.059	0.003	0.000
1518: P-270	1518	P-270	65	J-230	J-517	150.0	AC	130.0	☐	0.000	0.028	0.002	0.000
1519: P-271	1519	P-271	75	J-223	J-273	150.0	AC	130.0	☐	0.000	-0.024	0.001	0.000
1520: P-272	1520	P-272	97	J-273	J-224	150.0	AC	130.0	☐	0.000	-0.109	0.006	0.001
1521: P-273	1521	P-273	163	J-272	J-71	150.0	AC	130.0	☐	0.000	-0.051	0.003	0.000
1522: P-274	1522	P-274	36	J-71	J-273	150.0	AC	130.0	☐	0.000	-0.071	0.004	0.000

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	ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
1522: P-274	1522	P-274	36	J-71	J-273	150.0	AC	130.0	☐	0.000	-0.071	0.004	0.000
1523: P-495	1523	P-495	143	J-278	J-405	100.0	PVC	130.0	☐	0.000	2.316	0.295	1.269
1524: P-496	1524	P-496	70	J-405	J-279	100.0	PVC	130.0	☐	0.000	1.050	0.134	0.293
1525: P-497	1525	P-497	394	J-699	J-278	100.0	PVC	130.0	☐	0.000	4.240	0.540	3.890
1526: P-498	1526	P-498	1,801	J-278	J-700	100.0	PVC	130.0	☐	0.000	1.137	0.145	0.340
1527: P-275	1527	P-275	761	J-565	J-699	150.0	PVC	130.0	☐	0.000	4.666	0.264	0.644
1528: P-276	1528	P-276	43	J-699	J-632	150.0	PVC	130.0	☐	0.000	0.339	0.019	0.005
1530: P-7	1530	P-7	5	J-529	J-672	500.0	DI	130.0	☐	0.000	0.273	0.001	0.000
1532: P-8	1532	P-8	14	J-632	J-529	500.0	DI	130.0	☐	0.000	-9.022	0.046	0.005
1533: P-277	1533	P-277	310	J-564	J-466	150.0	AC	130.0	☐	0.000	-0.604	0.034	0.015
1534: P-278	1534	P-278	242	J-466	J-565	150.0	AC	130.0	☐	0.000	1.628	0.092	0.092
1535: P-279	1535	P-279	140	J-465	J-333	150.0	PVC	130.0	☐	0.000	1.983	0.112	0.132
1536: P-280	1536	P-280	224	J-333	J-466	150.0	PVC	130.0	☐	0.000	2.337	0.132	0.179
1537: P-281	1537	P-281	303	J-560	J-465	150.0	PVC	130.0	☐	0.000	-0.125	0.007	0.001
1538: P-282	1538	P-282	242	J-465	J-561	150.0	PVC	130.0	☐	0.000	-2.190	0.124	0.159
1540: P-283	1540	P-283	272	J-561	J-582	150.0	AC	130.0	☐	0.000	-5.779	0.327	0.958
1541: P-284	1541	P-284	213	J-565	J-332	150.0	AC	130.0	☐	0.000	-3.096	0.175	0.301
1542: P-285	1542	P-285	142	J-332	J-561	150.0	AC	130.0	☐	0.000	-3.549	0.201	0.388
1543: P-150	1543	P-150	571	J-60	J-593	200.0	DI	130.0	☐	0.000	-9.488	0.302	0.591
1544: P-151	1544	P-151	22	J-593	J-581	200.0	DI	130.0	☐	0.000	-10.506	0.334	0.713
1545: P-152	1545	P-152	284	J-581	J-582	200.0	AC	130.0	☐	0.000	-10.740	0.342	0.743
1546: P-153	1546	P-153	1,034	J-582	J-690	200.0	AC	130.0	☐	0.000	-16.967	0.540	1.733
1549: P-82	1549	P-82	6	J-39	J-57	300.0	AC	130.0	☐	0.000	63.173	0.894	2.744
1550: P-83	1550	P-83	729	J-57	J-630	300.0	AC	130.0	☐	0.000	142.962	2.022	12.457
1551: P-499	1551	P-499	1,051	J-691	J-567	100.0	PVC	130.0	☐	0.000	-0.422	0.054	0.054
1553: P-500	1553	P-500	144	J-567	J-662	100.0	PVC	130.0	☐	0.000	-1.051	0.134	0.294
1554: P-501	1554	P-501	228	J-662	J-655	100.0	PVC	130.0	☐	0.000	-0.240	0.031	0.019
1555: P-9	1555	P-9	358	DUTSEN KUR...	J-661	500.0	DI	130.0	☐	0.000	-5.950	0.030	0.003
1557: P-10	1557	P-10	266	J-661	J-654	500.0	DI	130.0	☐	0.000	-7.785	0.040	0.005
1558: P-11	1558	P-11	479	J-654	J-632	500.0	DI	130.0	☐	0.000	-8.893	0.045	0.006
1560: P-84	1560	P-84	21	J-88	J-705	300.0	AC	130.0	☐	0.000	0.059	0.001	0.000
1562: P-85	1562	P-85	267	J-683	J-88	300.0	AC	130.0	☐	0.000	-64.169	0.908	2.826
1564: P-86	1564	P-86	176	J-100	J-683	300.0	AC	130.0	☐	0.000	-60.900	0.862	2.565

530 of 530 elements displayed

	ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
1564: P-86	1564	P-86	176	J-100	J-683	300.0	AC	130.0		0.000	-60.900	0.862	2.565
1565: P-87	1565	P-87	904	J-86	J-55	300.0	AC	130.0		0.000	-14.211	0.201	0.173
1566: P-88	1566	P-88	20	J-55	J-701	300.0	AC	130.0		0.000	-17.602	0.249	0.257
1567: P-154	1567	P-154	2,834	J-213	J-56	200.0	AC	130.0		0.000	-3.007	0.096	0.070
1568: P-155	1568	P-155	104	J-56	J-102	200.0	AC	130.0		0.000	0.345	0.011	0.001
1570: P-89	1570	P-89	274	J-583	J-100	300.0	AC	130.0		0.000	-34.860	0.493	0.913
1572: P-90	1572	P-90	162	J-570	J-583	300.0	AC	130.0		0.000	-33.722	0.477	0.858
1573: P-91	1573	P-91	456	J-653	J-575	300.0	AC	130.0		0.000	-30.516	0.432	0.713
1574: P-92	1574	P-92	25	J-575	J-570	300.0	AC	130.0		0.000	-31.500	0.446	0.756
1576: P-502	1576	P-502	269	J-576	J-485	100.0	AC	130.0		0.000	3.941	0.502	3.397
1577: P-503	1577	P-503	103	J-484	J-571	100.0	AC	130.0		0.000	1.004	0.128	0.270
1578: P-504	1578	P-504	24	J-571	J-576	100.0	AC	130.0		0.000	3.135	0.399	2.225
1581: P-505	1581	P-505	297	J-633	J-201	100.0	PVC	130.0		0.000	1.895	0.241	0.875
1582: P-506	1582	P-506	22	J-201	J-242	100.0	PVC	130.0		0.000	1.345	0.171	0.463
1583: P-507	1583	P-507	89	J-242	J-600	100.0	PVC	130.0		0.000	1.227	0.156	0.391
1584: P-508	1584	P-508	410	J-600	J-634	100.0	PVC	130.0		0.000	0.272	0.035	0.024
1586: P-286	1586	P-286	216	J-652	J-351	150.0	AC	130.0		0.000	5.722	0.324	0.940
1587: P-287	1587	P-287	27	J-350	J-551	150.0	AC	130.0		0.000	-4.292	0.243	0.552
1588: P-288	1588	P-288	38	J-551	J-652	150.0	AC	130.0		0.000	-4.465	0.253	0.594
1592: P-289	1592	P-289	234	J-417	J-350	150.0	AC	130.0		0.000	-2.578	0.146	0.215
1594: P-290	1594	P-290	86	J-687	J-417	150.0	AC	130.0		0.000	-2.699	0.153	0.234
1596: P-291	1596	P-291	386	J-532	J-687	150.0	AC	130.0		0.000	-2.829	0.160	0.255
1597: P-292	1597	P-292	482	J-680	J-628	150.0	AC	130.0		0.000	-2.998	0.170	0.284
1598: P-293	1598	P-293	288	J-628	J-532	150.0	AC	130.0		0.000	-3.577	0.202	0.394
1600: P-294	1600	P-294	319	J-328	J-687	150.0	AC/PVC	130.0		0.000	0.264	0.015	0.003
1601: P-509	1601	P-509	173	J-416	J-305	100.0	AC	130.0		0.000	-0.511	0.065	0.077
1602: P-510	1602	P-510	150	J-305	J-417	100.0	AC	130.0		0.000	0.170	0.022	0.010
1603: P-511	1603	P-511	89	J-328	J-416	100.0	AC	130.0		0.000	-0.523	0.067	0.080
1604: P-512	1604	P-512	153	J-416	J-329	100.0	AC	130.0		0.000	-0.033	0.004	0.000
1606: P-295	1606	P-295	61	J-330	J-328	150.0	AC/PVC	130.0		0.000	-0.210	0.012	0.002
1608: P-296	1608	P-296	84	J-312	J-330	150.0	AC/PVC	130.0		0.000	-0.439	0.025	0.008
1610: P-297	1610	P-297	57	J-420	J-312	150.0	AC/PVC	130.0		0.000	-0.671	0.038	0.018
1612: P-298	1612	P-298	23	J-320	J-420	150.0	AC/PVC	130.0		0.000	2.058	0.116	0.141

	ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
1612: P-298	1612	P-298	23	J-320	J-420	150.0	AC/PVC	130.0		0.000	2.058	0.116	0.141
1614: P-299	1614	P-299	102	J-338	J-320	150.0	AC/PVC	130.0		0.000	1.846	0.104	0.116
1616: P-300	1616	P-300	62	J-428	J-338	150.0	AC/PVC	130.0		0.000	1.822	0.103	0.113
1618: P-301	1618	P-301	191	J-505	J-428	150.0	AC/PVC	130.0		0.000	2.011	0.114	0.135
1619: P-302	1619	P-302	201	J-686	J-682	150.0	AC/PVC	130.0		0.000	-0.066	0.004	0.000
1620: P-303	1620	P-303	199	J-682	J-505	150.0	AC/PVC	130.0		0.000	2.976	0.168	0.280
1621: P-513	1621	P-513	52	J-424	J-504	100.0	PVC	130.0		0.000	-0.653	0.083	0.121
1622: P-514	1622	P-514	306	J-504	J-425	100.0	PVC	130.0		0.000	0.195	0.025	0.013
1623: P-304	1623	P-304	487	J-532	J-419	150.0	AC	130.0		0.000	-0.987	0.056	0.036
1624: P-305	1624	P-305	9	J-419	J-424	150.0	AC	130.0		0.000	1.680	0.095	0.096
1625: P-306	1625	P-306	246	J-428	J-415	150.0	PVC	130.0		0.000	0.152	0.009	0.001
1626: P-307	1626	P-307	91	J-415	J-429	150.0	PVC	130.0		0.000	-0.453	0.026	0.009
1627: P-515	1627	P-515	68	J-415	J-339	100.0	PVC	130.0		0.000	0.574	0.073	0.096
1629: P-516	1629	P-516	102	J-339	J-321	100.0	PVC	130.0		0.000	0.508	0.065	0.076
1631: P-517	1631	P-517	73	J-321	J-313	100.0	PVC	130.0		0.000	0.251	0.032	0.021
1632: P-518	1632	P-518	715	J-313	J-188	100.0	PVC	130.0		0.000	-0.028	0.004	0.000
1633: P-519	1633	P-519	628	J-188	J-331	100.0	AC	130.0		0.000	-0.039	0.005	0.001
1635: P-520	1635	P-520	86	J-331	J-329	100.0	AC	130.0		0.000	-0.296	0.038	0.028
1636: P-521	1636	P-521	643	J-329	J-189	100.0	AC	130.0		0.000	-0.348	0.044	0.038
1638: P-308	1638	P-308	914	J-189	J-429	150.0	AC	130.0		0.000	0.540	0.031	0.012
1639: P-309	1639	P-309	147	J-350	J-304	150.0	AC	130.0		0.000	1.694	0.096	0.099
1640: P-310	1640	P-310	711	J-304	J-189	150.0	AC	130.0		0.000	0.929	0.053	0.032
1641: P-311	1641	P-311	294	J-652	J-485	150.0	PVC	130.0		0.000	-10.219	0.578	2.752
1642: P-312	1642	P-312	618	J-485	J-653	150.0	PVC	130.0		0.000	-6.399	0.362	1.157
1643: P-313	1643	P-313	111	J-393	J-382	150.0	AC	130.0		0.000	6.153	0.348	1.075
1644: P-314	1644	P-314	85	J-382	J-184	150.0	AC	130.0		0.000	1.274	0.072	0.058
1645: P-315	1645	P-315	198	J-184	J-302	150.0	AC	130.0		0.000	-5.848	0.331	0.979
1646: P-316	1646	P-316	469	J-302	J-604	150.0	AC	130.0		0.000	-10.889	0.616	3.096
1648: P-93	1648	P-93	236	J-604	J-82	300.0	AC	130.0		0.000	-10.568	0.150	0.100
1649: P-317	1649	P-317	100	J-351	J-31	150.0	AC	130.0		0.000	9.007	0.510	2.179
1650: P-318	1650	P-318	208	J-31	J-204	150.0	AC	130.0		0.000	13.776	0.780	4.785
1651: P-94	1651	P-94	83	J-83	J-534	300.0	AC	130.0		0.000	-11.345	0.161	0.114
1652: P-95	1652	P-95	42	J-534	J-35	300.0	AC	130.0		0.000	-19.032	0.269	0.298

	ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
53: P-96	1653	P-96	246	J-18	J-89	300.0	Ductile Iron	130.0		0.000	130.231	1.842	10.481
55: P-97	1655	P-97	388	J-701	J-574	300.0	Ductile Iron	130.0		0.000	74.236	1.050	3.701
56: P-98	1656	P-98	8	J-574	J-633	300.0	Ductile Iron	130.0		0.000	73.266	1.037	3.611
58: P-99	1658	P-99	775	J-597	J-9	300.0	Ductile Iron	130.0		0.000	95.391	1.350	5.888
59: P-158	1659	P-158	1,408	J-10	J-11	152.4	Ductile Iron	130.0		0.000	-22.692	1.244	11.162
50: P-100	1660	P-100	1,509	J-633	J-533	300.0	Ductile Iron	130.0		0.000	71.182	1.007	3.424
51: P-101	1661	P-101	482	J-533	J-597	300.0	Ductile Iron	130.0		0.000	78.736	1.114	4.127
52: P-102	1662	P-102	462	J-89	J-101	300.0	Ductile Iron	130.0		0.000	65.857	0.932	2.965
53: P-103	1663	P-103	109	J-101	J-701	300.0	Ductile Iron	130.0		0.000	91.856	1.299	5.491
55: P-104	1665	P-104	682	J-58	J-621	300.0	AC	130.0		0.000	8.214	0.116	0.063
57: P-105	1667	P-105	6	J-63	J-58	300.0	AC	130.0		0.000	5.349	0.076	0.026
58: P-106	1668	P-106	503	J-64	J-452	300.0	AC	130.0		0.000	1.894	0.027	0.004
71: P-319	1671	P-319	190	J-247	J-452	150.0	PVC	130.0		0.000	-0.266	0.015	0.003
73: P-320	1673	P-320	9	J-151	J-247	150.0	PVC	130.0		0.000	-0.225	0.013	0.000
74: P-321	1674	P-321	81	J-451	J-141	150.0	PVC	130.0		0.000	-0.065	0.004	0.000
75: P-322	1675	P-322	74	J-141	J-151	150.0	PVC	130.0		0.000	-0.172	0.010	0.002
76: P-323	1676	P-323	188	J-635	J-132	150.0	PVC	130.0		0.000	0.779	0.044	0.024
78: P-522	1678	P-522	261	J-510	J-133	100.0	PVC	130.0		0.000	-0.032	0.004	0.001
79: P-523	1679	P-523	187	J-133	J-511	100.0	PVC	130.0		0.000	-0.242	0.031	0.019
31: P-107	1681	P-107	953	J-511	J-604	300.0	AC	130.0		0.000	0.498	0.007	0.000
32: P-108	1682	P-108	198	J-452	J-635	300.0	AC	130.0		0.000	1.566	0.022	0.003
33: P-109	1683	P-109	77	J-635	J-511	300.0	AC	130.0		0.000	0.770	0.011	0.001
34: P-324	1684	P-324	371	J-598	J-297	150.0	AC	130.0		0.000	-17.536	0.992	7.482
35: P-325	1685	P-325	169	J-297	J-627	150.0	AC	130.0		0.000	-13.772	0.779	4.783
02: P-110	1702	P-110	4,867	J-22	J-716	300.0	Ductile Iron	130.0		0.000	-71.097	1.006	3.417
04: P-111	1704	P-111	1,624	J-716	J-105	300.0	Ductile Iron	130.0		0.000	-81.463	1.152	4.396
06: P-112	1706	P-112	364	J-105	J-668	300.0	Ductile Iron	130.0		0.000	-84.786	1.199	4.734
07: P-113	1707	P-113	2,058	J-668	DUTSEN KUR…	300.0	Ductile Iron	130.0		0.000	-61.326	0.868	2.598
08: P-326	1708	P-326	120	J-123	J-443	150.0	AC	130.0		0.000	1.368	0.077	0.066
10: P-327	1710	P-327	275	J-443	J-422	150.0	AC	130.0		0.000	1.231	0.070	0.055
12: P-328	1712	P-328	63	J-422	J-356	150.0	AC	130.0		0.000	1.068	0.060	0.042
14: P-329	1714	P-329	218	J-356	J-482	150.0	AC	130.0		0.000	0.954	0.054	0.034
16: P-330	1716	P-330	181	J-482	J-403	150.0	AC	130.0		0.000	0.573	0.032	0.013

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1716: P-330	1716	P-330	181	J-482	J-403	150.0	AC	130.0	☐	0.000	0.573	0.032	0.013
1717: P-331	1717	P-331	39	J-403	J-348	150.0	AC	130.0	☐	0.000	-0.023	0.001	0.000
1718: P-332	1718	P-332	47	J-348	J-274	150.0	AC	130.0	☐	0.000	-0.050	0.003	0.000
1719: P-333	1719	P-333	205	J-274	J-349	150.0	AC	130.0	☐	0.000	0.050	0.003	0.000
1720: P-524	1720	P-524	54	J-274	J-164	100.0	AC	130.0	☐	0.000	-0.105	0.013	0.005
1721: P-525	1721	P-525	150	J-164	J-275	100.0	AC	130.0	☐	0.000	-0.132	0.017	0.006
1722: P-526	1722	P-526	63	J-482	J-275	100.0	AC	130.0	☐	0.000	0.243	0.031	0.020
1724: P-527	1724	P-527	142	J-275	J-209	100.0	AC	130.0	☐	0.000	0.092	0.012	0.003
1725: P-528	1725	P-528	189	J-209	J-483	100.0	AC	130.0	☐	0.000	0.036	0.005	0.001
1726: P-334	1726	P-334	554	J-132	J-490	150.0	PVC	130.0	☐	0.000	0.922	0.052	0.032
1727: P-335	1727	P-335	43	J-490	J-636	150.0	PVC	130.0	☐	0.000	0.026	0.001	0.000
1734: P-336	1734	P-336	974	J-292	J-584	150.0	AC	130.0	☐	0.000	3.437	0.195	0.366
1735: P-337	1735	P-337	69	J-584	J-663	150.0	AC	130.0	☐	0.000	-7.063	0.400	1.389
1736: P-529	1736	P-529	109	J-584	J-602	100.0	PVC	130.0	☐	0.000	10.308	1.312	20.156
1737: P-530	1737	P-530	547	J-602	J-585	100.0	PVC	130.0	☐	0.000	2.807	0.357	1.811
1739: P-338	1739	P-338	986	J-498	J-685	150.0	AC	130.0	☐	0.000	-8.050	0.456	1.769
1740: P-339	1740	P-339	122	J-663	J-280	150.0	AC	130.0	☐	0.000	-7.076	0.400	1.394
1741: P-340	1741	P-340	169	J-280	J-498	150.0	AC	130.0	☐	0.000	-7.321	0.414	1.484
1742: P-341	1742	P-341	567	J-609	J-124	150.0	GI	130.0	☐	0.000	1.696	0.096	0.099
1743: P-342	1743	P-342	140	J-124	J-610	150.0	GI	130.0	☐	0.000	1.594	0.090	0.088
1750: P-343	1750	P-343	3,428	J-367	J-649	150.0	AC	130.0	☐	0.000	-87.867	4.972	147.992
1753: P-114	1753	P-114	5,463	J-46	J-21	300.0	Ductile Iron	130.0	☐	0.000	291.335	4.122	46.560
1754: P-344	1754	P-344	24	J-47	J-606	150.0	DI	130.0	☐	0.000	4.265	0.241	0.547
1755: P-345	1755	P-345	4	J-606	J-62	150.0	DI	130.0	☐	0.000	0.563	0.032	0.009
1756: P-346	1756	P-346	28	J-605	J-619	150.0	AC	130.0	☐	0.000	-0.797	0.045	0.024
1757: P-347	1757	P-347	644	J-619	J-606	150.0	AC	130.0	☐	0.000	-3.697	0.209	0.419
1762: P-136	1762	P-136	185	J-569	J-643	225.0	AC	130.0	☐	0.000	-2.311	0.058	0.024
1763: P-137	1763	P-137	231	J-643	J-477	225.0	AC	130.0	☐	0.000	-2.794	0.070	0.035
1764: P-138	1764	P-138	376	J-477	J-455	225.0	AC	130.0	☐	0.000	-2.446	0.062	0.027
1765: P-139	1765	P-139	122	J-455	J-285	225.0	AC	130.0	☐	0.000	-3.257	0.082	0.046
1766: P-115	1766	P-115	6	J-51	J-622	300.0	AC	130.0	☐	0.000	0.434	0.006	0.000
1767: P-116	1767	P-116	453	J-622	J-527	300.0	AC	130.0	☐	0.000	0.212	0.003	0.000
1773: P-350	1773	P-350	431	J-649	PMP-2	150.0	AC	130.0	☐	0.000	-92.706	5.246	163.440

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1734: P-336	1734	P-336	974	J-292	J-584	150.0	AC	130.0	☐	0.000	3.437	0.195	0.366
1735: P-337	1735	P-337	69	J-584	J-663	150.0	AC	130.0	☐	0.000	-7.063	0.400	1.389
1736: P-529	1736	P-529	109	J-584	J-602	100.0	PVC	130.0	☐	0.000	10.308	1.312	20.156
1737: P-530	1737	P-530	547	J-602	J-585	100.0	PVC	130.0	☐	0.000	2.807	0.357	1.811
1739: P-338	1739	P-338	986	J-498	J-685	150.0	AC	130.0	☐	0.000	-8.050	0.456	1.769
1740: P-339	1740	P-339	122	J-663	J-280	150.0	AC	130.0	☐	0.000	-7.076	0.400	1.394
1741: P-340	1741	P-340	169	J-280	J-498	150.0	AC	130.0	☐	0.000	-7.321	0.414	1.484
1742: P-341	1742	P-341	567	J-609	J-124	150.0	GI	130.0	☐	0.000	1.696	0.096	0.099
1743: P-342	1743	P-342	140	J-124	J-610	150.0	GI	130.0	☐	0.000	1.594	0.090	0.088
1750: P-343	1750	P-343	3,428	J-367	J-649	150.0	AC	130.0	☐	0.000	-87.867	4.972	147.992
1753: P-114	1753	P-114	5,463	J-46	J-21	300.0	Ductile Iron	130.0	☐	0.000	291.335	4.122	46.560
1754: P-344	1754	P-344	24	J-47	J-606	150.0	DI	130.0	☐	0.000	4.265	0.241	0.547
1755: P-345	1755	P-345	4	J-606	J-62	150.0	DI	130.0	☐	0.000	0.563	0.032	0.009
1756: P-346	1756	P-346	28	J-605	J-619	150.0	AC	130.0	☐	0.000	-0.797	0.045	0.024
1757: P-347	1757	P-347	644	J-619	J-606	150.0	AC	130.0	☐	0.000	-3.697	0.209	0.419
1762: P-136	1762	P-136	185	J-569	J-643	225.0	AC	130.0	☐	0.000	-2.311	0.058	0.024
1763: P-137	1763	P-137	231	J-643	J-477	225.0	AC	130.0	☐	0.000	-2.794	0.070	0.035
1764: P-138	1764	P-138	376	J-477	J-455	225.0	AC	130.0	☐	0.000	-2.446	0.062	0.027
1765: P-139	1765	P-139	122	J-455	J-285	225.0	AC	130.0	☐	0.000	-3.257	0.082	0.046
1766: P-115	1766	P-115	6	J-51	J-622	300.0	AC	130.0	☐	0.000	0.434	0.006	0.000
1767: P-116	1767	P-116	453	J-622	J-527	300.0	AC	130.0	☐	0.000	0.212	0.003	0.000
1773: P-350	1773	P-350	431	J-649	PMP-2	150.0	AC	130.0	☐	0.000	-92.706	5.246	163.440
1774: P-351	1774	P-351	3	PMP-2	BI WATER R...	150.0	AC	130.0	☐	0.000	-92.706	5.246	163.439
1776: P-29	1776	P-29	4	BI WATER R...	PMP-3	450.0	Ductile Iron	130.0	☐	0.000	420.566	2.644	12.752
1777: P-30	1777	P-30	5,711	PMP-3	BI WATER T...	450.0	Ductile Iron	130.0	☐	0.000	420.566	2.644	12.751
1779: P-117	1779	P-117	4	IMPRESIT CL...	IMPRESSIT 1...	300.0	Ductile Iron	130.0	☐	0.000	295.857	4.186	47.909
1780: P-118	1780	P-118	381	IMPRESSIT 1...	J-46	300.0	Ductile Iron	130.0	☐	0.000	295.857	4.186	47.907
1782: P-119	1782	P-119	4	J-607	J-608	300.0	AC	130.0	☐	0.000	-5.171	0.073	0.029
1785: P-31	1785	P-31	5	R-6	J-276	150.0	PVC	130.0	☐	0.000	-111.255	6.296	229.116
1791: P-126(1)	1791	P-126(1)	3	J-394	PRV-1	250.0	AC	130.0	☐	0.000	9.913	0.202	0.207
1792: P-126(2)	1792	P-126(2)	424	PRV-1	J-512	250.0	AC	130.0	☐	0.000	9.913	0.202	0.216
1794: P-120(1)	1794	P-120(1)	2	J-608	PRV-2	300.0	AC	130.0	☐	0.000	7.525	0.106	0.063
1795: P-120(2)	1795	P-120(2)	404	PRV-2	J-63	300.0	AC	130.0	☐	0.000	7.525	0.106	0.053

APPENDIX D: JUNCTIONS/NODES

	ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Pressure Head (m)	Hydraulic Grade (m)	Pressure (kPa)
31: J-1	31	J-1	256.32	<None>	<Collection:	0.264	31.65	287.97	310
32: J-2	32	J-2	245.04	<None>	<Collection:	0.215	42.99	288.02	421
36: J-4	36	J-4	236.07	<None>	<Collection:	0.299	51.94	288.01	508
45: J-9	45	J-9	276.88	<None>	<Collection:	0.165	40.15	317.03	393
47: J-10	47	J-10	275.43	<None>	<Collection:	0.264	41.57	317.00	407
48: J-11	48	J-11	289.04	<None>	<Collection:	0.215	43.68	332.72	428
85: J-16	85	J-16	293.37	<None>	<Collection:	0.015	40.62	334.00	398
88: J-17	88	J-17	293.29	<None>	<Collection:	0.008	40.71	334.00	398
93: J-18	93	J-18	294.60	<None>	<Collection:	0.051	40.16	334.76	393
96: J-20	96	J-20	270.86	<None>	<Collection:	0.152	41.16	312.01	403
105: J-21	105	J-21	260.99	<None>	<Collection:	0.709	105.64	366.63	1,034
108: J-22	108	J-22	248.53	<None>	<Collection:	0.067	35.63	284.16	349
121: J-28	121	J-28	245.20	<None>	<Collection:	0.215	112.78	357.98	1,104
122: J-29	122	J-29	245.35	<None>	<Collection:	0.106	112.95	358.31	1,105
125: J-31	125	J-31	263.83	<None>	<Collection:	0.083	64.33	328.16	630
130: J-34	130	J-34	258.32	<None>	<Collection:	0.008	71.73	330.05	702
131: J-35	131	J-35	258.36	<None>	<Collection:	0.001	71.69	330.05	702
133: J-36	133	J-36	252.47	<None>	<Collection:	0.038	35.71	288.19	350
134: J-37	134	J-37	252.37	<None>	<Collection:	0.087	35.82	288.19	351
136: J-38	136	J-38	294.63	<None>	<Collection:	0.002	40.31	334.93	395
137: J-39	137	J-39	294.83	<None>	<Collection:	0.001	40.08	334.91	392
145: J-44	145	J-44	295.00	<None>	<Collection:	0.013	39.00	334.00	382
146: J-45	146	J-45	295.00	<None>	<Collection:	0.112	39.00	334.00	382
149: J-46	149	J-46	77.37	<None>	<Collection:	0.181	543.64	621.01	5,321
150: J-47	150	J-47	62.84	<None>	<Collection:	0.075	558.16	621.01	5,463
156: J-50	156	J-50	250.61	<None>	<Collection:	0.043	79.28	329.89	776
157: J-51	157	J-51	250.82	<None>	<Collection:	0.008	79.07	329.89	774
160: J-52	160	J-52	245.42	<None>	<Collection:	0.100	112.56	357.98	1,102
165: J-55	165	J-55	273.00	<None>	<Collection:	0.021	57.21	330.21	560
166: J-56	166	J-56	273.41	<None>	<Collection:	0.017	56.79	330.21	556
168: J-57	168	J-57	294.93	<None>	<Collection:	0.045	39.95	334.89	391
170: J-58	170	J-58	245.43	<None>	<Collection:	0.010	84.58	330.01	828
171: J-59	171	J-59	245.18	<None>	<Collection:	0.011	84.82	330.01	830

	ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Pressure Head (m)	Hydraulic Grade (m)	Pressure (kPa)
171: J-59	171	J-59	245.18	<None>	<Collection:	0.011	84.82	330.01	830
173: J-60	173	J-60	269.73	<None>	<Collection:	0.047	45.58	315.31	446
174: J-61	174	J-61	269.50	<None>	<Collection:	0.135	45.79	315.29	448
176: J-62	176	J-62	62.78	<None>	<Collection:	0.563	558.22	620.99	5,463
178: J-63	178	J-63	245.57	<None>	<Collection:	0.069	84.44	330.01	826
179: J-64	179	J-64	245.31	<None>	<Collection:	0.214	84.70	330.01	829
181: J-65	181	J-65	221.93	<None>	<Collection:	3.874	68.94	290.87	675
182: J-66	182	J-66	221.75	<None>	<Collection:	0.856	69.13	290.88	677
184: J-67	184	J-67	263.91	<None>	<Collection:	0.055	71.97	335.87	704
185: J-68	185	J-68	264.65	<None>	<Collection:	0.116	71.23	335.88	697
190: J-71	190	J-71	269.68	<None>	<Collection:	0.008	45.95	315.63	450
191: J-72	191	J-72	269.10	<None>	<Collection:	0.012	46.53	315.63	455
193: J-73	193	J-73	260.51	<None>	<Collection:	0.065	73.06	333.57	715
194: J-74	194	J-74	260.29	<None>	<Collection:	0.043	73.27	333.56	717
198: J-76	198	J-76	238.03	<None>	<Collection:	0.009	52.76	290.79	516
199: J-77	199	J-77	238.83	<None>	<Collection:	0.035	51.96	290.79	509
207: J-82	207	J-82	256.81	<None>	<Collection:	0.044	73.21	330.03	717
208: J-83	208	J-83	256.85	<None>	<Collection:	0.024	73.18	330.03	716
210: J-84	210	J-84	246.89	<None>	<Collection:	0.525	67.22	314.11	658
211: J-85	211	J-85	247.63	<None>	<Collection:	0.073	43.44	291.06	425
213: J-86	213	J-86	258.44	<None>	<Collection:	0.006	71.61	330.05	701
214: J-87	214	J-87	258.60	<None>	<Collection:	0.034	71.45	330.05	699
216: J-88	216	J-88	286.32	<None>	<Collection:	0.070	45.73	332.05	448
217: J-89	217	J-89	287.39	<None>	<Collection:	0.077	44.79	332.18	438
228: J-96	228	J-96	272.01	<None>	<Collection:	0.009	43.62	315.63	427
229: J-97	229	J-97	270.78	<None>	<Collection:	0.012	44.86	315.63	439
234: J-100	234	J-100	275.92	<None>	<Collection:	0.005	54.92	330.84	538
235: J-101	235	J-101	275.28	<None>	<Collection:	0.035	55.53	330.81	543
237: J-102	237	J-102	275.18	<None>	<Collection:	0.004	55.03	330.21	539
238: J-103	238	J-103	275.89	<None>	<Collection:	0.094	54.31	330.21	532
240: J-104	240	J-104	241.09	<None>	<Collection:	3.035	66.71	307.80	653
241: J-105	241	J-105	241.86	<None>	<Collection:	0.288	66.07	307.93	647
243: J-106	243	J-106	287.51	<None>	<Collection:	0.102	46.12	333.62	451

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	ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Pressure Head (m)	Hydraulic Grade (m)	Pressure (kPa)
243: J-106	243	J-106	287.51	<None>	<Collection:	0.102	46.12	333.62	451
244: J-107	244	J-107	287.47	<None>	<Collection:	1.644	46.14	333.62	452
269: J-122	269	J-122	256.94	<None>	<Collection:	0.224	66.69	323.62	653
270: J-123	270	J-123	257.45	<None>	<Collection:	0.026	67.50	324.95	661
272: J-124	272	J-124	250.24	<None>	<Collection:	0.048	79.62	329.85	779
273: J-125	273	J-125	250.04	<None>	<Collection:	0.054	79.81	329.85	781
275: J-126	275	J-126	247.00	<None>	<Collection:	0.016	66.87	313.88	654
276: J-127	276	J-127	246.31	<None>	<Collection:	0.034	100.67	346.98	985
284: J-132	284	J-132	245.40	<None>	<Collection:	0.012	84.60	330.00	828
285: J-133	285	J-133	246.52	<None>	<Collection:	0.055	83.48	330.00	817
287: J-134	287	J-134	284.96	<None>	<Collection:	0.034	18.91	303.87	185
288: J-135	288	J-135	282.49	<None>	<Collection:	0.136	21.38	303.87	209
290: J-136	290	J-136	276.68	<None>	<Collection:	0.027	53.52	330.21	524
292: J-137	292	J-137	278.18	<None>	<Collection:	0.836	34.80	312.98	341
293: J-138	293	J-138	277.44	<None>	<Collection:	0.093	35.54	312.98	348
298: J-141	298	J-141	242.46	<None>	<Collection:	0.013	87.55	330.00	857
299: J-142	299	J-142	241.28	<None>	<Collection:	0.093	88.73	330.00	868
313: J-151	313	J-151	242.80	<None>	<Collection:	0.006	87.20	330.00	853
314: J-152	314	J-152	241.59	<None>	<Collection:	0.047	88.41	330.00	865
318: J-154	318	J-154	255.72	<None>	<Collection:	0.031	72.46	328.18	709
319: J-155	319	J-155	253.91	<None>	<Collection:	0.040	74.34	328.25	728
333: J-164	333	J-164	241.79	<None>	<Collection:	0.011	83.12	324.91	814
334: J-165	334	J-165	241.19	<None>	<Collection:	0.016	83.72	324.91	819
339: J-168	339	J-168	257.65	<None>	<Collection:	0.007	15.27	272.92	149
340: J-169	340	J-169	254.38	<None>	<Collection:	0.055	18.54	272.92	181
342: J-170	342	J-170	248.29	<None>	<Collection:	0.049	81.53	329.82	798
343: J-171	343	J-171	249.61	<None>	<Collection:	0.062	80.21	329.82	785
352: J-176	352	J-176	233.22	<None>	<Collection:	3.024	85.01	318.22	832
353: J-177	353	J-177	234.20	<None>	<Collection:	0.226	83.52	317.73	817
355: J-178	355	J-178	244.25	<None>	<Collection:	0.050	85.70	329.96	839
356: J-179	356	J-179	241.98	<None>	<Collection:	0.027	87.97	329.96	861
358: J-180	358	J-180	260.00	<None>	<Collection:	0.037	12.93	272.93	127
359: J-181	359	J-181	260.00	<None>	<Collection:	0.115	12.93	272.93	126

	ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Pressure Head (m)	Hydraulic Grade (m)	Pressure (kPa)
359: J-181	359	J-181	260.00	<None>	<Collection:	0.115	12.93	272.93	126
364: J-184	364	J-184	258.08	<None>	<Collection:	0.028	70.28	328.36	688
366: J-185	366	J-185	251.07	<None>	<Collection:	0.032	79.20	330.27	775
367: J-186	367	J-186	248.16	<None>	<Collection:	0.078	82.10	330.26	803
371: J-188	371	J-188	270.63	<None>	<Collection:	0.011	57.85	328.48	566
372: J-189	372	J-189	273.00	<None>	<Collection:	0.041	55.51	328.51	543
374: J-190	374	J-190	247.41	<None>	<Collection:	0.010	82.07	329.48	803
375: J-191	375	J-191	244.65	<None>	<Collection:	0.051	84.75	329.40	829
379: J-193	379	J-193	288.79	<None>	<Collection:	0.005	28.35	317.14	277
380: J-194	380	J-194	291.79	<None>	<Collection:	0.124	25.35	317.14	248
382: J-195	382	J-195	260.00	<None>	<Collection:	0.047	12.93	272.93	127
383: J-196	383	J-196	257.70	<None>	<Collection:	0.018	15.22	272.92	149
391: J-201	391	J-201	276.01	<None>	<Collection:	0.047	52.48	328.49	514
392: J-202	392	J-202	277.39	<None>	<Collection:	0.503	51.09	328.48	500
396: J-204	396	J-204	260.44	<None>	<Collection:	0.119	66.73	327.17	653
401: J-207	401	J-207	284.18	<None>	<Collection:	0.023	33.79	317.97	331
403: J-208	403	J-208	252.03	<None>	<Collection:	0.035	78.23	330.27	766
405: J-209	405	J-209	242.80	<None>	<Collection:	0.027	82.11	324.91	804
406: J-210	406	J-210	244.55	<None>	<Collection:	0.029	80.36	324.91	786
411: J-213	411	J-213	242.95	<None>	<Collection:	0.120	87.06	330.01	852
416: J-216	416	J-216	260.00	<None>	<Collection:	0.010	12.93	272.93	127
417: J-217	417	J-217	260.00	<None>	<Collection:	0.674	12.92	272.92	126
427: J-223	427	J-223	267.98	<None>	<Collection:	0.024	47.65	315.63	466
428: J-224	428	J-224	270.72	<None>	<Collection:	0.015	44.91	315.63	440
438: J-230	438	J-230	275.65	<None>	<Collection:	0.016	39.98	315.63	391
439: J-231	439	J-231	271.85	<None>	<Collection:	0.015	43.78	315.63	428
441: J-232	441	J-232	244.41	<None>	<Collection:	0.117	85.85	330.26	840
446: J-235	446	J-235	243.65	<None>	<Collection:	0.041	86.17	329.82	843
447: J-236	447	J-236	246.27	<None>	<Collection:	0.040	83.56	329.83	818
452: J-239	452	J-239	281.36	<None>	<Collection:	0.082	36.48	317.83	357
453: J-240	453	J-240	278.18	<None>	<Collection:	0.277	39.65	317.83	388
457: J-242	457	J-242	276.50	<None>	<Collection:	0.012	51.97	328.48	509
458: J-243	458	J-243	280.84	<None>	<Collection:	0.106	47.64	328.48	466

	ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Pressure Head (m)	Hydraulic Grade (m)	Pressure (kPa)
458: J-243	458	J-243	280.84	<None>	<Collection:	0.106	47.64	328.48	466
460: J-244	460	J-244	245.64	<None>	<Collection:	0.021	83.98	329.62	822
462: J-245	462	J-245	267.86	<None>	<Collection:	0.061	82.67	350.53	809
463: J-246	463	J-246	270.00	<None>	<Collection:	1.078	80.47	350.47	788
465: J-247	465	J-247	242.85	<None>	<Collection:	0.016	87.16	330.00	853
466: J-248	466	J-248	245.16	<None>	<Collection:	0.025	84.84	330.00	830
471: J-251	471	J-251	271.84	<None>	<Collection:	0.009	43.79	315.63	429
477: J-254	477	J-254	247.17	<None>	<Collection:	0.030	82.67	329.84	809
478: J-255	478	J-255	249.49	<None>	<Collection:	0.056	80.36	329.85	786
483: J-258	483	J-258	288.75	<None>	<Collection:	0.078	28.39	317.14	278
484: J-259	484	J-259	284.96	<None>	<Collection:	0.799	32.18	317.14	315
487: J-260	487	J-260	276.45	<None>	<Collection:	0.031	39.18	315.63	383
488: J-261	488	J-261	271.90	<None>	<Collection:	0.017	43.73	315.63	428
490: J-262	490	J-262	291.89	<None>	<Collection:	0.052	43.07	334.97	422
491: J-263	491	J-263	293.96	<None>	<Collection:	0.086	40.98	334.95	401
493: J-264	493	J-264	251.65	<None>	<Collection:	0.087	76.74	328.39	751
500: J-268	500	J-268	220.54	<None>	<Collection:	0.105	70.20	290.74	687
501: J-269	501	J-269	219.75	<None>	<Collection:	0.656	70.98	290.74	695
506: J-272	506	J-272	271.14	<None>	<Collection:	0.051	44.49	315.63	435
507: J-273	507	J-273	269.31	<None>	<Collection:	0.013	46.32	315.63	453
509: J-274	509	J-274	240.72	<None>	<Collection:	0.005	84.19	324.91	824
510: J-275	510	J-275	244.05	<None>	<Collection:	0.019	80.87	324.91	791
512: J-276	512	J-276	289.98	<None>	<Collection:	0.030	1.08	291.06	11
513: J-277	513	J-277	291.21	<None>	<Collection:	1.073	2.38	293.59	23
515: J-278	515	J-278	262.94	<None>	<Collection:	0.787	50.54	313.47	495
516: J-279	516	J-279	265.77	<None>	<Collection:	0.035	47.50	313.27	465
518: J-280	518	J-280	246.49	<None>	<Collection:	0.038	81.33	327.82	796
519: J-281	519	J-281	244.02	<None>	<Collection:	0.206	83.80	327.82	820
524: J-284	524	J-284	242.46	<None>	<Collection:	0.305	48.31	290.78	473
525: J-285	525	J-285	239.17	<None>	<Collection:	0.018	51.61	290.78	505
527: J-286	527	J-286	245.11	<None>	<Collection:	0.025	42.90	288.00	420
528: J-287	528	J-287	245.28	<None>	<Collection:	0.332	42.71	287.99	418
530: J-288	530	J-288	252.38	<None>	<Collection:	0.116	77.58	329.96	759

	ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Pressure Head (m)	Hydraulic Grade (m)	Pressure (kPa)
530: J-288	530	J-288	252.38	<None>	<Collection:	0.116	77.58	329.96	759
531: J-289	531	J-289	256.61	<None>	<Collection:	0.050	73.27	329.88	717
533: J-290	533	J-290	246.69	<None>	<Collection:	0.039	83.14	329.83	814
535: J-291	535	J-291	242.64	<None>	<Collection:	0.123	85.91	328.55	841
536: J-292	536	J-292	243.45	<None>	<Collection:	0.059	84.46	327.91	827
541: J-295	541	J-295	273.29	<None>	<Collection:	0.043	42.34	315.63	414
542: J-296	542	J-296	278.97	<None>	<Collection:	0.022	36.66	315.63	359
544: J-297	544	J-297	252.94	<None>	<Collection:	0.084	76.20	329.14	746
545: J-298	545	J-298	255.45	<None>	<Collection:	0.019	74.43	329.88	728
546: J-299	546	J-299	233.46	<None>	<Collection:	0.018	57.33	290.79	561
547: J-300	547	J-300	231.64	<None>	<Collection:	0.221	59.14	290.79	579
549: J-301	549	J-301	274.35	<None>	<Collection:	0.087	38.63	312.98	378
551: J-302	551	J-302	255.03	<None>	<Collection:	0.110	73.52	328.55	720
555: J-304	555	J-304	272.23	<None>	<Collection:	0.045	56.30	328.53	551
556: J-305	556	J-305	267.56	<None>	<Collection:	0.038	60.93	328.50	596
565: J-310	565	J-310	297.20	<None>	<Collection:	0.109	24.24	321.44	237
566: J-311	566	J-311	313.74	<None>	<Collection:	0.808	7.71	321.44	75
568: J-312	568	J-312	263.66	<None>	<Collection:	0.021	64.81	328.47	634
569: J-313	569	J-313	269.91	<None>	<Collection:	0.025	58.57	328.48	573
570: J-314	570	J-314	234.78	<None>	<Collection:	0.019	56.01	290.79	548
571: J-315	571	J-315	232.64	<None>	<Collection:	0.038	58.15	290.79	569
579: J-320	579	J-320	263.08	<None>	<Collection:	0.019	65.39	328.48	640
580: J-321	580	J-321	269.02	<None>	<Collection:	0.027	59.46	328.48	582
581: J-322	581	J-322	237.09	<None>	<Collection:	0.012	53.69	290.79	525
582: J-323	582	J-323	233.97	<None>	<Collection:	0.021	56.82	290.79	556
584: J-324	584	J-324	295.00	<None>	<Collection:	0.014	38.99	333.99	382
585: J-325	585	J-325	292.72	<None>	<Collection:	0.148	41.23	333.96	404
590: J-328	590	J-328	264.44	<None>	<Collection:	0.049	64.04	328.48	627
591: J-329	591	J-329	271.13	<None>	<Collection:	0.019	57.35	328.48	561
593: J-330	593	J-330	264.13	<None>	<Collection:	0.021	64.35	328.48	630
594: J-331	594	J-331	270.68	<None>	<Collection:	0.008	57.80	328.48	566
596: J-332	596	J-332	279.81	<None>	<Collection:	0.042	35.75	315.56	350
597: J-333	597	J-333	278.07	<None>	<Collection:	0.058	37.49	315.56	367

	ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Pressure Head (m)	Hydraulic Grade (m)	Pressure (kPa)
597: J-333	597	J-333	278.07	<None>	<Collection:	0.058	37.49	315.56	367
599: J-334	599	J-334	243.47	<None>	<Collection:	0.032	86.21	329.68	844
600: J-335	600	J-335	243.72	<None>	<Collection:	0.017	86.10	329.82	843
605: J-338	605	J-338	262.66	<None>	<Collection:	0.024	65.83	328.49	644
606: J-339	606	J-339	267.91	<None>	<Collection:	0.018	60.58	328.49	593
608: J-340	608	J-340	247.19	<None>	<Collection:	0.055	82.28	329.48	805
609: J-341	609	J-341	248.70	<None>	<Collection:	0.024	80.92	329.62	792
611: J-342	611	J-342	292.53	<None>	<Collection:	0.175	41.43	333.96	405
613: J-343	613	J-343	265.81	<None>	<Collection:	0.053	70.06	335.87	686
618: J-346	618	J-346	247.82	<None>	<Collection:	0.412	40.17	287.99	393
619: J-347	619	J-347	248.09	<None>	<Collection:	0.200	39.91	288.00	391
621: J-348	621	J-348	240.66	<None>	<Collection:	0.027	84.26	324.91	825
622: J-349	622	J-349	241.07	<None>	<Collection:	0.050	83.84	324.91	821
624: J-350	624	J-350	270.01	<None>	<Collection:	0.019	58.54	328.54	573
625: J-351	625	J-351	265.67	<None>	<Collection:	0.060	62.70	328.38	614
627: J-352	627	J-352	291.72	<None>	<Collection:	0.075	26.66	318.38	261
628: J-353	628	J-353	281.11	<None>	<Collection:	0.124	41.83	322.94	409
633: J-356	633	J-356	248.52	<None>	<Collection:	0.084	76.40	324.92	748
634: J-357	634	J-357	245.23	<None>	<Collection:	0.030	79.69	324.92	780
639: J-360	639	J-360	284.67	<None>	<Collection:	0.056	49.32	334.00	483
641: J-361	641	J-361	235.07	<None>	<Collection:	4.107	81.67	316.73	799
643: J-362	643	J-362	293.42	<None>	<Collection:	0.102	40.58	334.00	397
647: J-365	647	J-365	238.17	<None>	<Collection:	0.064	52.60	290.77	515
648: J-366	648	J-366	229.28	<None>	<Collection:	0.160	61.49	290.77	602
650: J-367	650	J-367	240.52	<None>	<Collection:	0.401	218.68	459.20	2,140
651: J-368	651	J-368	236.20	<None>	<Collection:	0.970	222.99	459.19	2,182
673: J-382	673	J-382	259.53	<None>	<Collection:	0.028	68.84	328.36	674
679: J-386	679	J-386	257.83	<None>	<Collection:	0.050	15.09	272.92	148
681: J-387	681	J-387	277.89	<None>	<Collection:	0.038	37.75	315.63	369
682: J-388	682	J-388	270.64	<None>	<Collection:	0.009	44.99	315.63	440
688: J-391	688	J-391	249.94	<None>	<Collection:	0.052	79.92	329.86	782
689: J-392	689	J-392	257.91	<None>	<Collection:	0.200	71.94	329.86	704
691: J-393	691	J-393	262.04	<None>	<Collection:	0.069	66.44	328.48	650

	ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Pressure Head (m)	Hydraulic Grade (m)	Pressure (kPa)
691: J-393	691	J-393	262.04	<None>	<Collection:	0.069	66.44	328.48	650
693: J-394	693	J-394	295.00	<None>	<Collection:	0.238	38.43	333.43	376
694: J-395	694	J-395	295.00	<None>	<Collection:	0.196	38.43	333.43	376
699: J-398	699	J-398	286.31	<None>	<Collection:	0.119	47.69	334.00	467
707: J-403	707	J-403	241.52	<None>	<Collection:	0.066	83.40	324.91	816
708: J-404	708	J-404	238.72	<None>	<Collection:	0.530	86.16	324.89	843
710: J-405	710	J-405	264.45	<None>	<Collection:	0.044	48.84	313.29	478
711: J-406	711	J-406	268.32	<None>	<Collection:	1.221	44.84	313.16	439
713: J-407	713	J-407	254.13	<None>	<Collection:	0.082	18.79	272.92	184
725: J-413	725	J-413	291.70	<None>	<Collection:	0.343	29.92	321.63	293
726: J-414	726	J-414	282.41	<None>	<Collection:	0.014	43.36	325.77	424
728: J-415	728	J-415	267.21	<None>	<Collection:	0.031	61.29	328.50	600
731: J-416	731	J-416	267.09	<None>	<Collection:	0.022	61.39	328.48	601
732: J-417	732	J-417	266.36	<None>	<Collection:	0.049	62.13	328.49	608
736: J-419	736	J-419	254.70	<None>	<Collection:	0.050	73.69	328.39	721
737: J-420	737	J-420	263.34	<None>	<Collection:	0.012	65.14	328.47	637
741: J-422	741	J-422	249.34	<None>	<Collection:	0.069	75.59	324.92	740
742: J-423	742	J-423	245.91	<None>	<Collection:	0.094	79.01	324.92	773
744: J-424	744	J-424	254.62	<None>	<Collection:	0.054	73.77	328.39	722
745: J-425	745	J-425	257.72	<None>	<Collection:	0.195	70.67	328.40	692
750: J-428	750	J-428	262.42	<None>	<Collection:	0.037	66.08	328.50	647
751: J-429	751	J-429	268.64	<None>	<Collection:	0.087	59.85	328.50	586
756: J-432	756	J-432	249.81	<None>	<Collection:	0.022	79.89	329.70	782
757: J-433	757	J-433	244.82	<None>	<Collection:	0.011	84.83	329.65	830
759: J-434	759	J-434	272.04	<None>	<Collection:	0.283	43.59	315.63	427
764: J-437	764	J-437	290.13	<None>	<Collection:	0.099	44.84	334.97	439
771: J-441	771	J-441	292.99	<None>	<Collection:	0.025	0.96	293.94	9
772: J-442	772	J-442	307.51	<None>	<Collection:	0.989	-13.68	293.83	-134
774: J-443	774	J-443	254.87	<None>	<Collection:	0.053	70.07	324.94	686
775: J-444	775	J-444	249.52	<None>	<Collection:	0.084	75.42	324.94	738
783: J-449	783	J-449	257.15	<None>	<Collection:	0.224	72.74	329.89	712
784: J-450	784	J-450	272.48	<None>	<Collection:	0.135	57.41	329.89	562
786: J-451	786	J-451	242.05	<None>	<Collection:	0.065	87.95	330.00	861

	ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Pressure Head (m)	Hydraulic Grade (m)	Pressure (kPa)
786: J-451	786	J-451	242.05	<None>	<Collection:	0.065	87.95	330.00	861
787: J-452	787	J-452	243.90	<None>	<Collection:	0.062	86.11	330.00	843
792: J-455	792	J-455	240.41	<None>	<Collection:	0.055	50.37	290.78	493
793: J-456	793	J-456	229.73	<None>	<Collection:	0.137	61.05	290.78	597
795: J-457	795	J-457	246.36	<None>	<Collection:	0.072	83.46	329.82	817
796: J-458	796	J-458	243.39	<None>	<Collection:	0.012	86.42	329.82	846
798: J-459	798	J-459	297.22	<None>	<Collection:	1.335	20.13	317.35	197
799: J-460	799	J-460	288.68	<None>	<Collection:	1.030	28.66	317.34	280
801: J-461	801	J-461	288.03	<None>	<Collection:	0.044	15.84	303.87	155
803: J-462	803	J-462	292.94	<None>	<Collection:	0.021	0.69	293.63	7
805: J-463	805	J-463	230.29	<None>	<Collection:	0.384	60.49	290.78	592
806: J-464	806	J-464	238.74	<None>	<Collection:	0.004	52.04	290.79	509
808: J-465	808	J-465	278.22	<None>	<Collection:	0.082	37.36	315.58	366
809: J-466	809	J-466	273.78	<None>	<Collection:	0.106	41.74	315.52	408
811: J-467	811	J-467	257.18	<None>	<Collection:	0.188	78.67	335.84	770
812: J-468	812	J-468	256.35	<None>	<Collection:	0.194	79.49	335.84	778
825: J-477	825	J-477	238.41	<None>	<Collection:	0.213	52.36	290.77	512
826: J-478	826	J-478	237.89	<None>	<Collection:	0.036	52.89	290.78	518
828: J-479	828	J-479	276.54	<None>	<Collection:	0.157	39.10	315.63	383
829: J-480	829	J-480	269.45	<None>	<Collection:	0.060	46.18	315.63	452
833: J-482	833	J-482	244.89	<None>	<Collection:	0.139	80.02	324.91	783
834: J-483	834	J-483	243.81	<None>	<Collection:	0.036	81.11	324.91	794
836: J-484	836	J-484	275.00	<None>	<Collection:	0.054	55.39	330.39	542
837: J-485	837	J-485	267.87	<None>	<Collection:	0.121	61.52	329.39	602
838: J-486	838	J-486	233.70	<None>	<Collection:	0.224	57.11	290.81	559
839: J-487	839	J-487	232.05	<None>	<Collection:	0.026	58.74	290.79	575
841: J-488	841	J-488	250.58	<None>	<Collection:	0.028	37.61	288.19	368
842: J-489	842	J-489	259.56	<None>	<Collection:	0.122	28.63	288.19	280
844: J-490	844	J-490	239.67	<None>	<Collection:	0.030	90.31	329.98	884
845: J-491	845	J-491	235.46	<None>	<Collection:	0.867	94.44	329.90	924
850: J-494	850	J-494	262.78	<None>	<Collection:	0.233	65.88	328.65	645
851: J-495	851	J-495	258.07	<None>	<Collection:	0.100	70.53	328.60	690
853: J-496	853	J-496	259.30	<None>	<Collection:	0.125	65.84	325.14	644

	ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Pressure Head (m)	Hydraulic Grade (m)	Pressure (kPa)
853: J-496	853	J-496	259.30	<None>	<Collection:	0.125	65.84	325.14	644
854: J-497	854	J-497	255.62	<None>	<Collection:	0.107	69.51	325.13	680
856: J-498	856	J-498	244.23	<None>	<Collection:	0.142	83.84	328.07	821
857: J-499	857	J-499	237.09	<None>	<Collection:	0.587	90.97	328.06	890
865: J-504	865	J-504	254.99	<None>	<Collection:	0.058	73.41	328.40	718
866: J-505	866	J-505	261.78	<None>	<Collection:	0.060	66.74	328.52	653
868: J-506	868	J-506	293.94	<None>	<Collection:	1.263	35.88	329.82	351
869: J-507	869	J-507	294.64	<None>	<Collection:	1.645	35.17	329.81	344
871: J-508	871	J-508	287.85	<None>	<Collection:	0.200	45.77	333.61	448
872: J-509	872	J-509	294.79	<None>	<Collection:	0.649	38.82	333.61	380
874: J-510	874	J-510	243.80	<None>	<Collection:	0.032	86.20	330.00	844
875: J-511	875	J-511	247.73	<None>	<Collection:	0.030	82.28	330.00	805
877: J-512	877	J-512	293.92	<None>	<Collection:	0.118	36.00	329.92	352
878: J-513	878	J-513	294.16	<None>	<Collection:	0.190	35.70	329.86	349
880: J-514	880	J-514	249.18	<None>	<Collection:	0.029	80.62	329.80	789
881: J-515	881	J-515	250.53	<None>	<Collection:	0.105	79.26	329.80	776
883: J-516	883	J-516	280.14	<None>	<Collection:	0.128	35.49	315.63	347
884: J-517	884	J-517	274.98	<None>	<Collection:	0.028	40.65	315.63	398
897: J-525	897	J-525	264.84	<None>	<Collection:	0.187	68.81	333.65	673
898: J-526	898	J-526	273.73	<None>	<Collection:	0.140	59.92	333.65	586
901: J-527	901	J-527	256.87	<None>	<Collection:	0.229	73.02	329.89	715
902: J-528	902	J-528	250.70	<None>	<Collection:	0.237	79.18	329.88	775
904: J-529	904	J-529	259.64	<None>	<Collection:	0.011	55.37	315.01	542
909: J-532	909	J-532	251.70	<None>	<Collection:	0.239	76.68	328.38	750
911: J-533	911	J-533	270.80	<None>	<Collection:	0.676	52.78	323.58	517
912: J-534	912	J-534	257.84	<None>	<Collection:	0.005	72.19	330.04	707
921: J-539	921	J-539	272.24	<None>	<Collection:	1.322	40.57	312.81	397
922: J-540	922	J-540	274.76	<None>	<Collection:	2.238	37.27	312.03	365
927: J-543	927	J-543	268.68	<None>	<Collection:	0.107	64.96	333.65	636
928: J-544	928	J-544	263.65	<None>	<Collection:	0.489	69.95	333.60	685
936: J-549	936	J-549	250.00	<None>	<Collection:	0.065	79.67	329.67	780
937: J-550	937	J-550	239.70	<None>	<Collection:	0.117	89.98	329.68	881
939: J-551	939	J-551	270.16	<None>	<Collection:	0.019	58.40	328.56	572

	ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Pressure Head (m)	Hydraulic Grade (m)	Pressure (kPa)
939: J-551	939	J-551	270.16	<None>	<Collection:	0.019	58.40	328.56	572
940: J-552	940	J-552	275.00	<None>	<Collection:	0.154	53.55	328.55	524
950: J-558	950	J-558	283.55	<None>	<Collection:	0.190	50.45	334.00	494
951: J-559	951	J-559	280.27	<None>	<Collection:	0.830	53.51	333.78	524
953: J-560	953	J-560	273.11	<None>	<Collection:	0.125	42.47	315.58	416
954: J-561	954	J-561	281.87	<None>	<Collection:	0.040	33.75	315.62	330
956: J-562	956	J-562	257.49	<None>	<Collection:	0.041	15.43	272.92	151
957: J-563	957	J-563	256.96	<None>	<Collection:	0.189	15.95	272.92	156
959: J-564	959	J-564	275.39	<None>	<Collection:	0.114	40.12	315.51	393
960: J-565	960	J-565	275.60	<None>	<Collection:	0.058	39.90	315.50	390
962: J-566	962	J-566	263.34	<None>	<Collection:	0.223	51.57	314.91	505
963: J-567	963	J-567	270.76	<None>	<Collection:	0.406	44.17	314.92	432
967: J-569	967	J-569	230.36	<None>	<Collection:	0.268	60.39	290.76	591
970: J-570	970	J-570	268.19	<None>	<Collection:	0.056	62.26	330.45	609
971: J-571	971	J-571	274.24	<None>	<Collection:	0.034	56.12	330.36	549
974: J-573	974	J-573	257.45	<None>	<Collection:	0.166	76.11	333.56	745
976: J-574	976	J-574	271.01	<None>	<Collection:	0.088	57.76	328.78	565
978: J-575	978	J-575	267.74	<None>	<Collection:	0.103	62.69	330.43	614
979: J-576	979	J-576	273.82	<None>	<Collection:	0.075	56.49	330.31	553
981: J-577	981	J-577	245.56	<None>	<Collection:	0.103	84.27	329.84	825
982: J-578	982	J-578	246.85	<None>	<Collection:	0.253	82.98	329.82	812
983: J-579	983	J-579	227.27	<None>	<Collection:	0.988	63.49	290.75	621
984: J-580	984	J-580	138.63	<None>	<Collection:	0.293	152.13	290.75	1,489
986: J-581	986	J-581	281.59	<None>	<Collection:	0.028	34.08	315.66	333
988: J-582	988	J-582	283.93	<None>	<Collection:	0.448	31.95	315.88	313
990: J-583	990	J-583	271.10	<None>	<Collection:	0.080	59.49	330.59	582
992: J-584	992	J-584	246.79	<None>	<Collection:	0.193	80.76	327.55	790
993: J-585	993	J-585	238.30	<None>	<Collection:	2.807	86.06	324.36	842
995: J-586	995	J-586	282.26	<None>	<Collection:	0.416	52.66	334.92	515
997: J-587	997	J-587	253.80	<None>	<Collection:	0.743	77.37	331.16	757
998: J-588	998	J-588	255.83	<None>	<Collection:	0.091	75.35	331.18	737
1003: J-591	1003	J-591	271.57	<None>	<Collection:	0.305	43.89	315.47	430
1005: J-592	1005	J-592	257.75	<None>	<Collection:	0.022	72.28	330.03	707

	ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Pressure Head (m)	Hydraulic Grade (m)	Pressure (kPa)
1005: J-592	1005	J-592	257.75	<None>	<Collection:	0.022	72.28	330.03	707
1007: J-593	1007	J-593	281.24	<None>	<Collection:	0.017	34.41	315.65	337
1014: J-597	1014	J-597	273.10	<None>	<Collection:	0.452	48.50	321.59	475
1015: J-598	1015	J-598	255.06	<None>	<Collection:	0.100	71.30	326.36	698
1017: J-599	1017	J-599	295.86	<None>	<Collection:	0.884	32.43	328.29	317
1018: J-600	1018	J-600	278.43	<None>	<Collection:	0.070	50.01	328.44	489
1022: J-602	1022	J-602	245.71	<None>	<Collection:	0.144	79.64	325.35	779
1024: J-603	1024	J-603	246.90	<None>	<Collection:	0.098	82.98	329.89	812
1026: J-604	1026	J-604	253.95	<None>	<Collection:	0.177	76.05	330.00	744
1028: J-605	1028	J-605	88.91	<None>	<Collection:	0.797	531.81	620.72	5,205
1029: J-606	1029	J-606	62.90	<None>	<Collection:	0.005	558.10	620.99	5,462
1031: J-607	1031	J-607	255.32	<None>	<Collection:	0.209	78.55	333.86	769
1033: J-608	1033	J-608	255.17	<None>	<Collection:	0.149	78.69	333.86	770
1035: J-609	1035	J-609	250.84	<None>	<Collection:	0.103	79.07	329.91	774
1036: J-610	1036	J-610	250.00	<None>	<Collection:	0.045	79.84	329.84	781
1038: J-611	1038	J-611	246.39	<None>	<Collection:	0.028	83.43	329.83	817
1040: J-612	1040	J-612	250.00	<None>	<Collection:	0.012	79.84	329.84	781
1041: J-613	1041	J-613	249.96	<None>	<Collection:	0.009	79.91	329.87	782
1043: J-614	1043	J-614	254.23	<None>	<Collection:	0.083	76.14	330.37	745
1044: J-615	1044	J-615	242.41	<None>	<Collection:	0.070	87.43	329.84	856
1049: J-618	1049	J-618	170.90	<None>	<Collection:	2.556	448.54	619.44	4,390
1050: J-619	1050	J-619	76.24	<None>	<Collection:	0.345	544.49	620.72	5,329
1054: J-621	1054	J-621	247.01	<None>	<Collection:	0.005	82.96	329.96	812
1056: J-622	1056	J-622	250.90	<None>	<Collection:	0.073	78.99	329.89	773
1057: J-623	1057	J-623	244.13	<None>	<Collection:	0.150	85.76	329.89	839
1062: J-626	1062	J-626	255.78	<None>	<Collection:	0.098	70.57	326.36	691
1063: J-627	1063	J-627	250.96	<None>	<Collection:	0.071	78.99	329.95	773
1065: J-628	1065	J-628	249.13	<None>	<Collection:	0.254	79.13	328.26	774
1066: J-629	1066	J-629	243.47	<None>	<Collection:	0.325	84.76	328.24	830
1068: J-630	1068	J-630	282.45	<None>	<Collection:	0.090	43.36	325.81	424
1069: J-631	1069	J-631	284.50	<None>	<Collection:	0.053	34.13	318.63	334
1071: J-632	1071	J-632	259.57	<None>	<Collection:	0.468	55.44	315.01	543
1073: J-633	1073	J-633	271.06	<None>	<Collection:	0.189	57.69	328.75	565

	ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Pressure Head (m)	Hydraulic Grade (m)	Pressure (kPa)
1073: J-633	1073	J-633	271.06	<None>	<Collection:	0.189	57.69	328.75	565
1074: J-634	1074	J-634	292.02	<None>	<Collection:	0.272	36.41	328.43	356
1076: J-635	1076	J-635	246.61	<None>	<Collection:	0.017	83.39	330.00	816
1077: J-636	1077	J-636	239.47	<None>	<Collection:	0.026	90.51	329.98	886
1080: J-637	1080	J-637	232.49	<None>	<Collection:	0.761	58.41	290.90	572
1082: J-638	1082	J-638	303.52	<None>	<Collection:	2.379	13.87	317.39	136
1089: J-642	1089	J-642	290.26	<None>	<Collection:	0.029	29.48	319.74	288
1091: J-643	1091	J-643	233.88	<None>	<Collection:	0.266	56.88	290.76	557
1092: J-644	1092	J-644	214.30	<None>	<Collection:	0.935	76.45	290.74	748
1095: J-645	1095	J-645	275.82	<None>	<Collection:	0.205	39.84	315.65	390
1097: J-646	1097	J-646	267.83	<None>	<Collection:	0.220	62.37	330.20	610
1099: J-647	1099	J-647	279.67	<None>	<Collection:	0.581	38.00	317.67	372
1102: J-648	1102	J-648	141.81	<None>	<Collection:	3.657	822.04	963.85	8,045
1103: J-649	1103	J-649	80.18	<None>	<Collection:	1.182	886.33	966.51	8,674
1104: J-650	1104	J-650	219.85	<None>	<Collection:	0.149	70.90	290.76	694
1105: J-651	1105	J-651	238.26	<None>	<Collection:	0.001	52.53	290.79	514
1107: J-652	1107	J-652	269.36	<None>	<Collection:	0.032	59.22	328.58	580
1108: J-653	1108	J-653	260.24	<None>	<Collection:	0.119	69.86	330.11	684
1110: J-654	1110	J-654	268.32	<None>	<Collection:	0.783	46.68	315.00	457
1111: J-655	1111	J-655	275.31	<None>	<Collection:	0.084	39.66	314.97	388
1113: J-656	1113	J-656	241.56	<None>	<Collection:	0.278	94.27	335.83	923
1119: J-658	1119	J-658	253.97	<None>	<Collection:	0.099	76.81	330.78	752
1125: J-661	1125	J-661	275.40	<None>	<Collection:	0.881	39.60	315.00	388
1126: J-662	1126	J-662	272.93	<None>	<Collection:	0.143	42.03	314.97	411
1129: J-663	1129	J-663	246.04	<None>	<Collection:	0.013	81.61	327.65	799
1134: J-666	1134	J-666	245.05	<None>	<Collection:	1.026	27.91	272.96	273
1137: J-668	1137	J-668	242.52	<None>	<Collection:	0.446	67.13	309.65	657
1139: J-669	1139	J-669	264.82	<None>	<Collection:	0.260	60.15	324.98	589
1140: J-670	1140	J-670	281.04	<None>	<Collection:	0.148	43.96	325.00	430
1142: J-671	1142	J-671	263.63	<None>	<Collection:	0.185	51.84	315.47	507
1144: J-672	1144	J-672	259.66	<None>	<Collection:	0.273	55.34	315.01	542
1148: J-674	1148	J-674	256.85	<None>	<Collection:	0.248	76.72	333.57	751
1150: J-675	1150	J-675	270.69	<None>	<Collection:	1.297	59.20	329.89	579

	ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Pressure Head (m)	Hydraulic Grade (m)	Pressure (kPa)
1142: J-671	1142	J-671	263.63	<None>	<Collection:	0.185	51.84	315.47	507
1144: J-672	1144	J-672	259.66	<None>	<Collection:	0.273	55.34	315.01	542
1148: J-674	1148	J-674	256.85	<None>	<Collection:	0.248	76.72	333.57	751
1150: J-675	1150	J-675	270.69	<None>	<Collection:	1.297	59.20	329.89	579
1152: J-676	1152	J-676	249.90	<None>	<Collection:	0.014	79.97	329.86	783
1153: J-677	1153	J-677	248.83	<None>	<Collection:	0.059	80.84	329.67	791
1157: J-679	1157	J-679	273.91	<None>	<Collection:	1.284	54.21	328.13	531
1158: J-680	1158	J-680	254.10	<None>	<Collection:	1.713	74.03	328.13	725
1160: J-681	1160	J-681	265.42	<None>	<Collection:	2.278	61.46	326.88	601
1162: J-682	1162	J-682	262.31	<None>	<Collection:	0.094	66.27	328.58	649
1163: J-683	1163	J-683	279.08	<None>	<Collection:	0.134	52.21	331.29	511
1165: J-684	1165	J-684	241.98	<None>	<Collection:	0.099	87.84	329.82	860
1166: J-685	1166	J-685	239.26	<None>	<Collection:	0.617	90.56	329.81	886
1168: J-686	1168	J-686	263.64	<None>	<Collection:	0.066	64.94	328.58	636
1169: J-687	1169	J-687	264.10	<None>	<Collection:	0.134	64.38	328.47	630
1171: J-688	1171	J-688	289.63	<None>	<Collection:	0.669	40.27	329.90	394
1172: J-689	1172	J-689	286.92	<None>	<Collection:	4.117	42.78	329.71	419
1174: J-690	1174	J-690	279.54	<None>	<Collection:	0.125	38.13	317.67	373
1176: J-691	1176	J-691	254.04	<None>	<Collection:	0.422	60.83	314.87	595
1178: J-692	1178	J-692	287.07	<None>	<Collection:	3.494	29.67	316.74	290
1181: J-693	1181	J-693	235.73	<None>	<Collection:	0.150	52.27	288.00	512
1182: J-694	1182	J-694	232.04	<None>	<Collection:	1.765	54.72	286.76	536
1185: J-695	1185	J-695	264.94	<None>	<Collection:	0.238	68.62	333.56	672
1186: J-696	1186	J-696	263.62	<None>	<Collection:	0.061	69.62	333.24	681
1188: J-697	1188	J-697	234.93	<None>	<Collection:	0.176	53.08	288.01	519
1189: J-698	1189	J-698	234.11	<None>	<Collection:	3.166	53.75	287.86	526
1191: J-699	1191	J-699	259.87	<None>	<Collection:	0.087	55.14	315.01	540
1192: J-700	1192	J-700	285.62	<None>	<Collection:	1.137	27.24	312.86	267
1195: J-701	1195	J-701	273.29	<None>	<Collection:	0.018	56.92	330.21	557
1205: J-705	1205	J-705	287.03	<None>	<Collection:	0.059	45.02	332.05	441
1221: J-716	1221	J-716	236.29	<None>	<Collection:	10.365	64.50	300.79	631
1237: J-724	1237	J-724	248.96	<None>	<Collection:	0.028	39.06	288.02	382
1242: J-725	1242	J-725	238.03	<None>	<Collection:	0.472	49.98	288.01	489

APPENDIX E: ATTRIBUTES OF TANKS

FlexTable: Tank Table (Current Time: 0.000 hours) (MINNA PROJECT_210,000m3_day.wtg)

	ID	Label	Zone	Elevation (Base) (m)	Elevation (Minimum) (m)	Elevation (Initial) (m)	Elevation (Maximum) (m)	Volume (Inactive) (ML)	Diameter (m)	Flow (Out net) (L/s)	Hydraulic Grade (m)
55: BI WATER	55	BI WATER T...	SHANGO,GIDAN	260.00	270.00	273.00	274.00	0.00	3.05	-609.421	273.00
58: SHIRORO	58	SHIRORO TANK	TUNGA LOW CO	248.24	258.24	288.00	289.00	0.00	3.05	-6.233	288.00
59: DUTSEN K	59	DUTSEN KUR...	DUTSEN KURA H	275.60	285.60	315.00	316.00	0.00	3.05	55.376	315.00
61: PAIDA	61	PAIDA	F.LAYOUT ,WOR	277.04	287.04	317.00	318.00	0.00	3.05	-117.654	317.00
63: IBB TANK	63	IBB TANK	LMAWA,KWANG	294.46	304.46	334.00	335.00	0.00	3.05	97.413	334.00
65: INEC TANK	65	INEC TANK	SABON GARI,TU	272.98	282.98	312.00	313.00	0.00	3.05	-53.056	312.00
69: TOP MEDI	69	TOP MEDICA...	TUNGA TOP MED	272.81	282.81	312.00	313.00	0.00	3.05	-206.300	312.00
73: BAHAGO U	73	BAHAGO UN...	BOSSO A	295.30	305.30	335.00	336.00	0.00	3.05	273.945	335.00
77: paiko	77	paiko	<None>	351.59	361.59	391.00	392.00	0.00	3.05	0.000	391.00

APPENDIX F: ATTRIBUTES OF RESERVOUIRS.

	ID	Label	Elevation (m)	Zone	Flow (Out net) (L/s)	Hydraulic Grade (m)
56: BI WATER RESERVOIR	56	BI WATER RESERVOIR	150.33	<None>	513.272	150.33
101: IMPRESIT CLEAR WATER TAN	101	IMPRESIT CLEAR WATER TANK	209.58	<None>	295.857	209.58
1768: R-6	1768	R-6	289.91	<None>	-111.255	289.91

APPENDIX G: ATTRIBUTES OF PUMPS.

	ID	Label	Elevation (m)	Pump Definition	Status (Initial)	Hydraulic Grade (Suction) (m)	Hydraulic Grade (Discharge) (m)	Flow (Total) (L/s)	Pump Head (m)
1772: PMP-2	1772	PMP-2	148.78	BIWATER 805KW	On	149.85	1,036.92	92.706	887.07
1775: PMP-3	1775	PMP-3	148.43	BIWATER 805KW	On	150.28	345.82	420.566	195.54
1778: IMPRESS	1778	IMPRESSIT 1...	210.59	IMPRESIT 1245KW	On	209.39	639.28	295.857	429.89