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Estimated Storage Tank Size and Selection Of Suitable Pump Capacity For Public Micro Water Scheme Distribution

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***Abstract**: Accurate determination of required pump capacity and storage tank size are one of the important parameters that cannot be over emphasized in water supply project design. In this paper, a computer software is developed for determining pump capacity and storage tank size that can make water readily available to the users as at when due taking into account effective water distribution scheme. The software was developed using C# dot NET (C Sharp dot NET) programming language. Application of the developed software to a community set of people as case study showed that the capacity of the storage tank is obtained as 123,194litres. The pump capacity estimated based on the pump flow rate (Q) and the total head in a pump (H) are obtained as 2.852litres/secs and 41m respectively for the total population of the people it contained. Once the details information of a site or a particular location is known in terms of topographical and total population of the people in a community, the software can help plumbing designer practitioner in forecasting accurately the expected water storage capacity needed by the users.*

***Keywords:** C# dot NET, Pump capacity, Storage tank size, Total population.*

I. Introduction

The importance of water supply sustainability either for domestic and non-domestic purposes cannot be over emphasized in water supply system implementation. This is due to the fact that, many water projects which appeared successful at the beginning fell short of sustainability after few years of use or less. Water supply is the provision of water for public utilities, commercial organizations, community endeavors by individuals, usually via a system of pumps, storage tank, and pipes. It is difficult to establish the exact degree of the importance of water to man in his arduous climb up the ladder of civilization. It is certain, however, that without water there would be no life of any kind on the earth and that, without water readily available in adequate quantity and free pathogenic organisms, man's progress is tremendously hindered. It was also emphasized in the studies of (Graf et al. [1]; Enger et al.[2]) that, unless the target population widely and consistently practised household water treatment and safe storage systems (HWTS) over the long term, health and economic benefits may not be realised. According to Browns et al. [3], water supply projects for communities are more motivated when a safe water supply is a real community problem and when it has priority. The design of any water supply begins with a check of the water system from which the water will be obtained. Basically, water is available through government owned system which serves the community or through private system. The results from the study of Ngai and Fenner [4] which involved designing programme implementation strategies to increase the adoption and use of biosand water filters in rural India showed that the optimal choice of strategy is influenced by the macroeconomic situation, donor funding, presence of alternative options, and the evaluation time frame. Guerquin et al. [5] point out some redundant causes for water project problems such as operation and maintenance problem, cost recovery, gender issue, hygiene education and financial support. The authors concluded that these problems need to be addressed. Similarly, Stephen [6] reported that a water supply pipe network is a complex hydraulic system, and requires specialized knowledge in order to create a functioning product. Schouten et al. [7] give a wide definition of a sustainable water supply by considering also equity and water resources sustainability in addition to community management, technical, institutional and indefinite sustainability. Moreso, the report from the study of Ray [8] which is on integrated network management approach for cost effective control of water reticulation systems stressed that proper use of simulation tools helps the engineer to foresee possible breakdown, to plan rehabilitation program and to gain benefit from it. Simulation enables computation of a much broader class of reliability measures than do analytical methods, but it requires considerably more computer time and its results are less easy to generalize.

Wagner et al. [9] propose a simulation model of system reliability in water supply networks which focuses on pipe and pump failures. Marks et al. [10] present a hazard failure model giving the probability, at any small interval that a pipe will break based on several factors including the age of the pipe, the number of previous breaks, and the time since the last break. Jon [11] worked on statistical modelling of pipe failures in water networks. The output from the statistical models can be used for a variety of purposes in water network management. Quimpo and Shamsi [12] used the exponential distribution when describing the break rate for each pipe, in order to estimate the reliability of the water supply network. This reliability model uses the minimal cut set or the minimal path set approach to calculate the reliability of the system. Wu et al. [13] address the problem of quantifying the reliability of water distribution networks on the basis of the connectivity of the demand point to the water source alone. The authors introduce a capacity weighted index that takes into account partial satisfaction of demand in addition to a minimal path set method to calculate the connectivity from source to a point in the network. Walski [14] pointed out the importance of valve location when assessing the reliability of water distribution networks. The author argued that a description of the valve system provides a better representation of reliability than the link-node approach normally used. However, accurate determination of required pump capacity and storage tank size are one of the important parameters that cannot be over emphasized in water supply project design. Manual calculation or judgmental estimation of these parameters based on experience of plumbing engineer practitioner is liable to error due to unforeseen human error which could leads to ineffective safe water supply to the expected users at a particular point in time. Determination of these parameters through computer automation is likely to make a positive impact in alleviating these problems.

In the present study, in order to alleviate problem face by the expected water users either in rural/urban communities due to ineffective safe water supply, a computer software is developed for water distribution scheme using C# dot NET (C Sharp dot NET) programming language. The software is developed taking into account design calculations and necessary requirements that will provides suggestions of actions to be taken which can improve the sustainability of the water system in terms of designing effective and safe water supply for the expected users.

II. Model Development

The whole software was developed in the Microsoft Visual Studio, a popular C# dot net IDE. The software is developed for determining pump capacity and storage tank size that can make water readily available to the users as at when due taking into account effective water distribution scheme. The software input data are number of total number of people and houses in a catchment area, tower height, reservoir fill time, longest pipe run and head loss in ball valve associated with estimation of pump capacity and storage tank size. Figure 1 shows the GUI (Graphical User Interface) of the developed software.

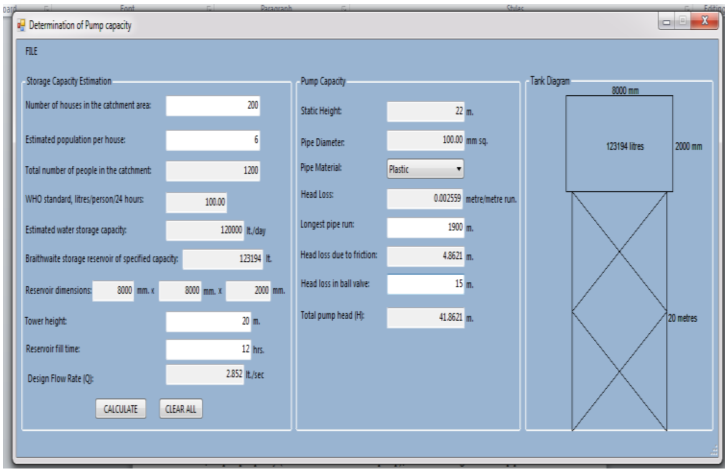


Fig. 1 GUI (Graphical User Interface) of the developed software.

Water supply design requires the calculation of water tank stand for the size of water storage tank, the pump capacity (flow rate and head of the pump), and the loading unit of the pipes to be used. In this section, design calculations and necessary requirements that will aid effective water supply for expected users are given in the following subsections:

2.1 Determination of Water Storage Capacity

Size of water storage tank is determined taking into account the total population of the people in a catchment area that is a community and the type of buildings with their respective liters/head for 24hrs according to WHO (World Health Organization) standards as presented in table 1

Table 1 Various Buildings With Their Respective Litres/Head For 24hrs

Types of building	**Per head**	**Litres**
Dwelling house and flats	Per head	90
Hostel	Per head	90
Community	Per head	100

Boarding schools	Per head	90
Nurses home	Per head	110
Hotels	Per head	135

2.2 Determination of Water Storage Tank Size

The storage tank size is calculated taking into consideration the needed litres / quantity of water to satisfy the expected number people in a location at a particular point in time is given as follows:

The size of Braithwaite pressed steel tank that can hold the litres / quantity of water needed to serve the expected number people were obtained from the Braithwaite pressed steel tank brochure in terms of capacity, length, breadth, and height of the tank respectively as presented in table 2. It is interesting to highlight that, Braithwaite is synonymous with water storage worldwide; it has gained reputation for quality and reliability of his product.

Table 2 The Typical Tank Capacity Chart For Braithwaite Pressed Steel Tank.

LENGTH (mm)	BREADTH (mm)	1000	2000	3000	4000
1000	1000	821	1,675	2,529	3,383
2000	1000	1,710	3,488	5,266	7,044
3000	1000	2,599	5,301	8,003	10,704
2000	2000	3,561	7,263	10,965	14,666
3000	2000	5,412	11,038	16,664	22,289
4000	2000	7,263	14,813	22,362	29,912
3000	3000	8,225	16,775	25,324	33,874
4000	3000	11,038	22,512	33,985	45,459
4000	4000	14,813	30,210	45,608	61,006
5000	4000	18,588	37,909	57,231	76,553
5000	5000	23,324	47,570	71,816	96,062
6000	5000	28,061	57,231	84,401	115,571
6000	6000	33,760	68,854	103,948	139,042
7000	6000	39,459	80,477	121,495	162,512
8000	6000	45,158	92,100	139,042	185,983
7000	7000	46,120	94,062	142,004	189,945
8000	7000	52,781	107,647	162,512	217,378
9000	7000	59,442	121,232	183,021	244,811
8000	8000	60,404	123,194	185,983	248,773
9000	8000	68,027	138,740	209,454	280,168
10000	8000	75,650	154,287	232,925	311,563
9000	9000	76,612	156,249	235,887	315,525
10000	9000	85,196	173,758	262,320	350,882

LENGTH (mm)	BREADTH (mm)	1220	2440	3660	4880
1220	1220	1,547	3,144	4,740	6,337
2440	1220	3,197	6,496	9,795	13,095
3660	1220	4,846	9,848	14,851	19,853
2440	2440	6,606	13,424	20,242	27,059
3660	2440	10,015	20,351	30,668	41,024
4880	2440	13,424	27,279	41,134	54,989
3660	3660	15,183	30,854	46,525	62,196
4880	3660	20,351	41,357	62,362	83,367
4880	4880	27,279	55,434	83,590	111,746
6100	4880	34,206	69,512	104,818	140,124
6100	6100	42,893	87,165	131,437	175,709
7320	6100	51,580	104,818	158,056	211,294
7320	7320	62,026	126,046	190,066	254,087
8540	7320	72,472	147,274	222,076	296,879
9760	7320	82,918	168,502	254,087	339,671
8540	8540	84,678	172,078	259,478	346,877
9760	8540	96,883	196,881	296,879	396,876
10980	8540	109,089	221,684	334,280	446,875
9760	9760	110,848	225,259	339,671	454,082
10980	9760	124,813	253,638	382,463	511,288
12220	9760	138,777	282,016	425,255	568,493
10980	10980	140,537	285,591	430,646	575,700
12220	10980	156,261	317,545	478,829	640,113

2.3 Determination of the pump capacity

The capacity of the pump required for the water supply to a place at a particular point in time is obtained taking taking into consideration the following parameters:

(i) The Pump flow rate (Q) and
(ii) Total head in a pump (H)
(iii)

2.3.1 Calculation of the Pump Flow Rate (Q)

The required flow rate for the pump is obtained as follows:

$$\text{Pump flow rate } (Q) = \frac{V(liters)}{T(sec\,s)} \tag{1}$$

where,
V is the Volume of the tank (liters)
T is the time assumed time to fill the tank (secs.)

2.3.2 Calculation of Total Head in Pump (H)

The total head in pump is determined as using Eq. (2)

$$\text{Total head in pump } (H) = H_S + H_D \tag{2}$$

where,
H_S is static head/height
H_D is dynamic head

The Static head/height is obtained taken into account the summation of height of the tower on which the tank will be placed and height of the tank. It is interesting to point out that the height of the tower which the tank is placed on depends on the topography of the location.
The dynamic head is generated as a result of friction within the system. In this study, the dynamic head is modelled from the basic Darcy Weisbach equation given by:

$$H_D = \frac{KU^2}{2g} \tag{3}$$

where

K is the loss coefficient and is considered as the function of head loss due to friction in the pipe
U is the velocity in the pipe (m/sec)
g is the acceleration due to gravity (m/sec^2)
The velocity (U) in the pipe is calculated as follows:

$$U = \frac{Q}{A} \tag{4}$$

where
Q is the pump flow rate through the pipe
A is the pipe cross sectional area (m^2)
The term K in eq. (3) in the present study is given as function of longest run of pipe, L multiply by the head loss in the pipe, f in metres/metre run.
The longest run of the pipe, L is calculated as follows:

$$L = \frac{DK_{pipe}}{f} \tag{5}$$

where

D is the pipe diameter
K_{pipe} is a dimensionless term associated with the straight lengths of pipe used within the system and is considered as the loss coefficient K given in Eq. (3).
f is the friction coefficient / head loss in the pipe and is calculated as follows:

$$f = \frac{0.25}{\left[log\left\{ \frac{k}{3.7xD} + \frac{5.74}{Re^{0.9}} \right\} \right]^2} \tag{6}$$

where

k is the pipe roughness factor (m)
Re is the Reynolds number

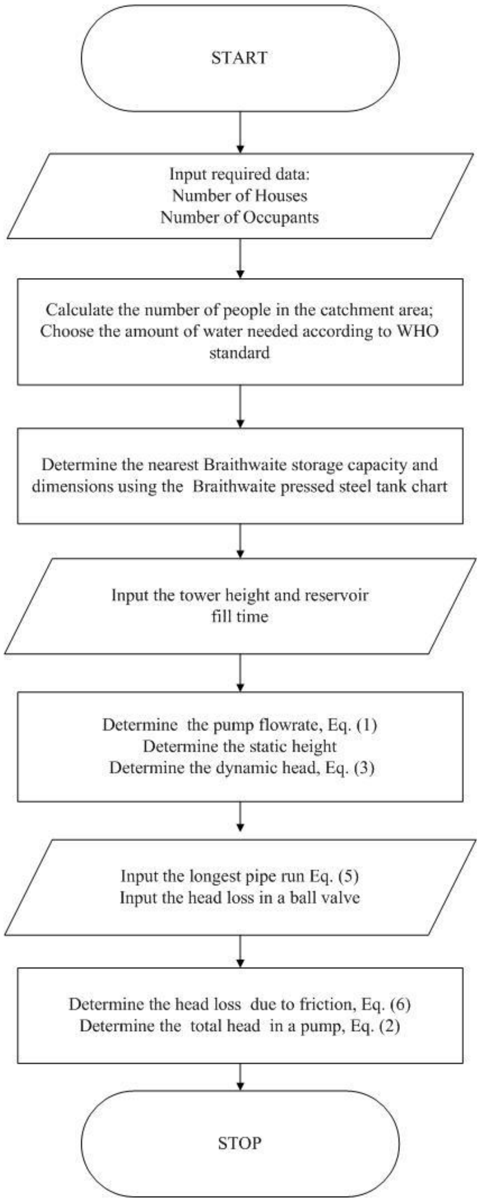
The term Reynolds number, Re, is a dimensionless quantity associated with the smoothness of flow of a fluid in the pipe and is relating to the energy absorbed within the fluid as it moves through the pipe and is calculated as follows:

$$Re = \frac{UD}{\nu} \tag{7}$$

where

ν is the Kinematic viscosity (m^2/s)

After all the parameters are given, the software computes according to the following flowchart:



III. Case Study And Results

To test the software developed for determining pump capacity and storage tank size that can make water readily available to the users as at when due, a community set of people leaving in a place at a particular point in time with following characteristics was assumed:

- The total number of houses in the community :200
- The total number of occupants per house in the community :6
- The provision of water for a particular person in a community is obtained as 100 liters/ head for 24 hours as given in (Table 1)

Considering the above stated assumed characteristics, the estimated capacity of the storage tank of the software developed is 120,000. Thus the water storage tank size, that is the reservoir dimensions estimated in terms of product between Length (L), Breadth (B), and height (H) of the tank is obtained as 8000mm, 8000mm and 2000mm respectively. The result is very close to that of typical tank capacity chart for Braithwaite pressed steel tank (Table 2) obtained as 123,194 liters/day.

The pump capacity manually estimated based on the pump flow rate (Q), Eq. (1) and Total head in pump (H), Eq. (2) are obtained as 2.852litres/secs and 41m respectively. The estimated results values obtained manually is the same with those values estimated using the developed software with (Graphical User Interface) presented in Fig. 1. It is interesting to point out that in this study, the height of the tower on which the tank is placed is assumed to be 20 m which can be altered depends on any design consideration in terms of the topography of any chosen location and the loss of head in ball valve is taking as 15m which is a constant value. Figures 2 shows graphical representation of the value generated using the software developed in terms of plotting number of people in the catchment/ area / population against the tank storage capacity and the total pump head respectively. According to Figures 2a and 2b, the result revealed that the higher the population of a particular location, the higher the tank storage capacity and the total pump head respectively required to sustain water supply sufficiently at a particular in time in that location. Similar behavior is observed with the pump flow rate (Q) and Head loss due to friction as presented in table (3). Table 3 is also prepared using the software developed taking into consideration the number of houses as 300 in the catchment area considered and varying number of occupants from 1-10 persons. Thus, the developed software can be useful in plumbing engineering services such in forecasting the expected size of storage tank and accurate pump selection that can hold sufficient quantity of water needed in a community and water supply sustainability either for domestic and non-domestic purposes provided the number of people in the location are known.

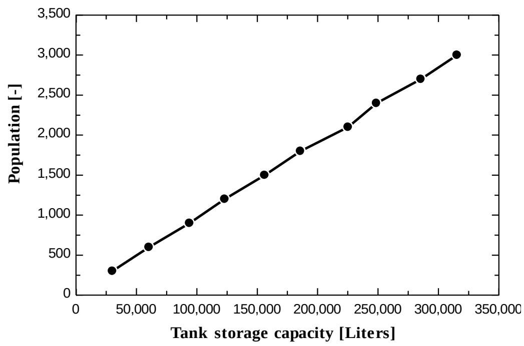


Fig. (2a) Variation of population against tank storage capacity

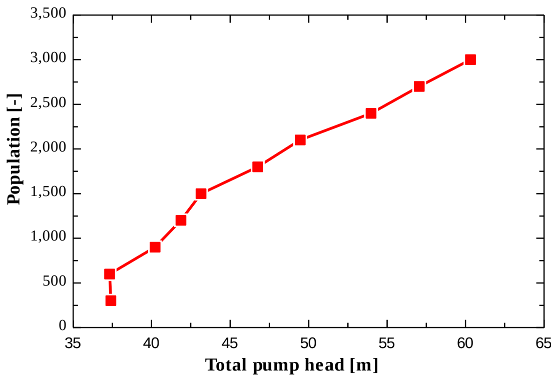


Fig. (2b) Variation of population against total pump head

Table 3.The Values Obtained From The Software Developed

No of persons/house	Total population	Pump Flow rate (Q) (m/s^3)	Head loss due to friction (f)
1	300	0.669	0.3952
2	600	1.398	1.3129
3	900	2.177	3.2148
4	1200	2.852	4.8621
5	1500	3.617	6.1446
6	1800	4.305	8.759
7	2100	5.214	12.0213
8	2400	5.759	14.9758
9	2700	6.611	19.6023
10	3000	7.304	21.3085

IV. Conclusions

The study has developed a system framework for estimating the size of a water tank stand and the pump capacity in volume/hr using a c-sharp programming language. The developed software was validated with manually calculated parameters. Although the features of this software may be limited when compared with those commercial packages in the market, it does provide an effective and user-friendly way of determining pump capacity and storage tank size that can make water readily available to the users as at when due taking into account effective water distribution scheme. In addition, tank storage capacity dimensions and total pump head can be made variable depending on the number of people in the catchments area. Thus, the software can help plumbing designer in forecasting expected water storage capacity by the users provided the total population of the people in a community is known. Moreover, this software can be used as a reference for educational purposes.

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