Australian Journal of Basic and Applied Sciences, 8(16) October 2014, Pages: 48-55

AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com

Prediction of Roughness Coefficient For Aged Pipes Using Simulation Models

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ARTICLE INFO

Article history:
Received 8 August 2014
Received in revised form
12 September 2014
Accepted 25 September 2014
Available online 2 November 2014

Keywords:
C factor, leakage, chlorine decay, headloss gradient and aged pipes.

ABSTRACT

Many effort is exhausted lately in Egypt for adjusting data used to be introduced in a water distribution modeling software. One of these parameters that were very impressive in changing the results totally is the roughness coefficient (Hazen Williams C). The effect is seen obviously if the flows are increased so leads to higher head losses. These head losses would appear lower due to the fact that we are using uncertain value for roughness especially if we are using the standard roughness for new pipes. The outcome from precise determination of roughness coefficient is adjusting water distribution network models to cope with real field values. The aim of this research is to relate C factor to head loss gradient so engineers can find a way to estimate C factor for aged pipes based in head loss gradient whatever was the network configuration. The relationship of C factor to water quality parameters as chlorine decay is also discussed. Polynomial Equations relating chlorine concentration and Hazen Williams C factor is deduced. A validation of Watergems leakage detection module(Darwin calibrator module) makes up a part of this research. And it is concluded that leak location can be found in a range of circle with a radius of 0.25km around point detected by Darwin Calibrator. Equations of Colebrook and White are inserted in Watergems tables using user data extension tool to enter formulas to be calculated by software engine. This is a way provided to help get a fast estimate for roughness coefficient.

To Cite This Article: Rasha Yehia and Ehab Rozaik., Prediction of Roughness Coefficient For Aged Pipes Using Simulation Models. ***Aust. J. Basic & Appl. Sci.,*** *8(16): 48-55, 2014*

INTRODUCTION

Most pipes in Egypt are suffering from aging. And nearly most pipes are not renewed before it faces aging symptoms like corrosion and deposition which leads to pipe diameter reduction and roughness increase.

Roughness coefficient is playing a great role in modeling distribution networks in hydraulic modeling software. Computer programs have a well known rule which is “garbage in garbage out”. Roughness coefficient (C) is one of the confusing data that should be entered to correct to get right results. (Walski, Thomas M., et al., 1988)

In hydraulic modeling software’s as WaterGems or Epanet the value entered for Hazen William’s coefficient is very important to get correct results. Results from simulation software’s should be the same as field data collected by flow meters and pressure loggers. (Brown K. 2007)

The effect of using roughness coefficient for a new pipe for aged pipe may be very apparent in high flows with high velocities which in turn increase head loss. The calibration of distribution networks are done for two major reasons which is, the unreal roughness coefficients and the assumed demands which is inserted without any evidence that the end users really consume.

The Outcome From Precise Determination of Roughness Coefficient:

Share in adjusting the model for leakage detection analysis. (Brown K. 2007)

Putting optimal pipe renewal plan which leads to the following benefits:

1. Energy saving through decreasing pumping cost.
2. Increasing pressure.
3. Improving Reputation of the water authority.
4. Reliability and confidence in water model in comparison to real distribution network.
5. Increase the ability to add new connections

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Objective:

Currently there are two methods of determination of C factor for aged pipes, field tests and simulation software. When field tests appear to be expensive and cumbersome, computer models for calibration of distribution networks arise as a simple and more efficient method for roughness coefficient estimation. We aim through this research to help engineers find an easy and accurate way of roughness factor determination.

Relationship between C factor and head loss gradient for each pipe diameter and pipe flow is studied. Two networks are studied: Network A which is a simple main line, Network B which is a looped network with much more pipes.

The head loss gradient versus c factor graphs created for network A is checked for predicting C factor in looped network B.

The Relationship between C factor and pipe diameter reduction due to scale and aging is also introduced. The Relationship between C factor and chlorine decay and chlorine concentration is discussed.

Methodology:

A network comprised of a reservoir as a source, and five pipes, with fixed Diameters. A diameter of 4in, 6in, 8in, 10in, 12in, 16in and 24in is used in different scenarios. Network is shown in figure below. A set of different C values ranges from 150 which represent new pipes till 80 which represent old pipes is used in conjunction with diameters to form 35 scenarios.

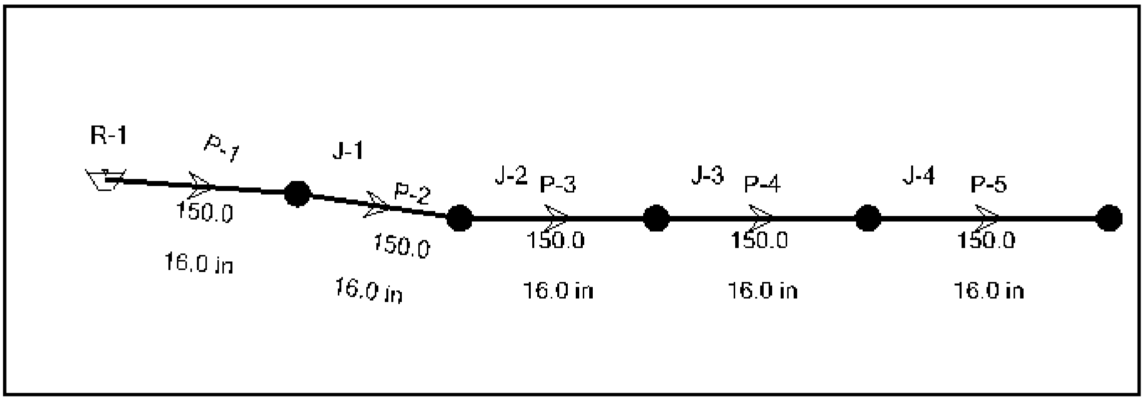

Fig.1: Network A

Another Network (B) which is a looped network is used to check for conclusions from simple network (A) to test the results between both networks

Bentley Watergems software is used in the analysis.

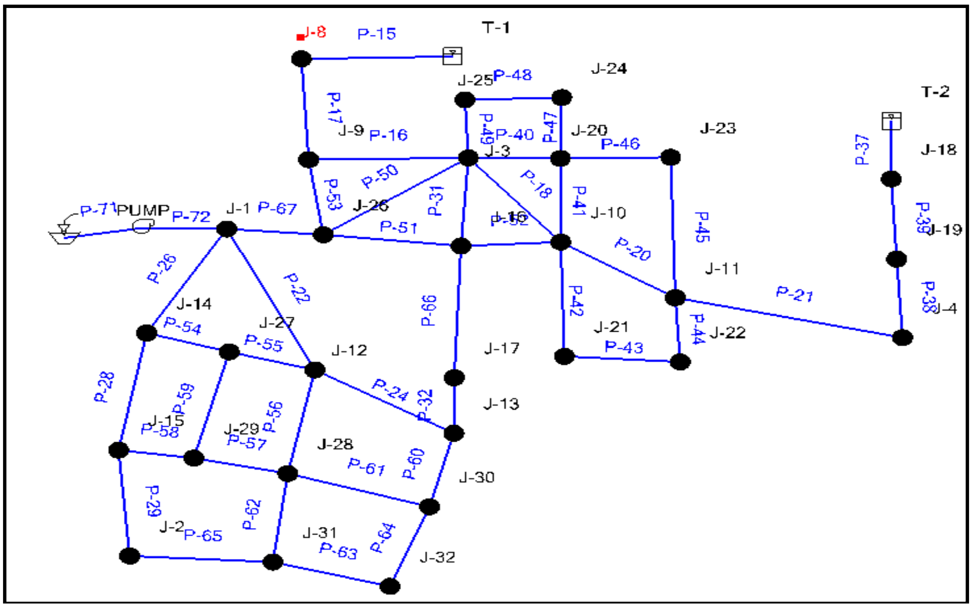

Fig. 2: Network B

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1Effect of Reduced Pipe Cross Section Due To Increased Roughness:

Using Bentley Watergems software several scenarios is done to check for the effect of diameter reduction in hydraulic grade and head loss for a series of d/D values. The diameters tested are as presented in table 2 in addition to diameters 4in, 8in, 20in, and 24in.

Table 1: d/D values checked for pipes 12in and 16in

Scenario	Attributes	D/d
Scenario 13	D=16in ,d=15.8	0.9875
Scenario 13-1	D=16in ,d=15.5	0.9675
Scenario 13-2	D=16in ,d=15.0	0.9375
Scenario 13-3	D=16in ,d=14.6	0.9125
Scenario 13-4	D=16in ,d=14.2	0.8875
Scenario 14	D=12in ,d=11.85	0.9875
Scenario 14-1	D=12in ,d=11.61	0.9675
Scenario 14-2	D=12in ,d=11.25	0.9375
Scenario 14-3	D=12in ,d=10.95	0.9125
Scenario 14-4	D=12in ,d=10.65	0.8875

4.2. C factor and Head Loss Gradient Relationship For Various Diameters:

Head loss gradient can be used as an indicator or a governing parameter to serve in determining the decrease and increase in C factor for different discharges and different diameters.

So network A is used in the 35 scenarios as mentioned before and the predicted values for head loss gradient is checked through applying the head loss gradient values on network B.

Effect of Hazen Williams Roughness factor on chlorine residual:

Roughness coefficient effect on chlorine decay is studied in WaterGems software, by applying different C factors of 150,120,100, 80 on Network A.

So Different scenarios for roughness correlation factors of -300,-100, and 0 are examined with various Hazen Williams coefficients ranges from 80 for rough pipes till 150 for very smooth and new pipes.

Runs with both RCF values with different C factors and different pipe diameters are done.

Bulk reaction and wall reaction order is set to first order and for both first order reaction rates is adjusted to -0.3m/day.

RESULTS AND DISCUSSION

5.1 Effect of reduced pipe cross section due to increased roughness:

The rise of head loss due to diameter decrease ratio is constant for all flows whether the flow studied is 500l/s or 100l/s or 80l/s. And it follows the values in the table below:

Table 2: reduction in pipe diameter and corresponding increase in head loss

Percent Reduction in pipe diameter	Percent increase in headloss
88.75	78-80
91.25	57
93.75	37
96.75	17.5
98.75	6.2

5.2 C factor and Head loss gradient relationship for various diameters:

C factor reduction affects head loss more than diameter decrease. As C factor decrease from 150 to 120 a head loss increases by 51%. If C factor is decreased from 150 to 100 head loss is vigorously increased by 111%.

A reduction in roughness coefficient from 150 to 80 leads to a head loss increase by 220%.this percentages applies for all diameters and all flows.

According to the above discussion for any network with measured head loss between two points, C factor can be estimated by using graphs of C factor and head loss gradient for flow and any

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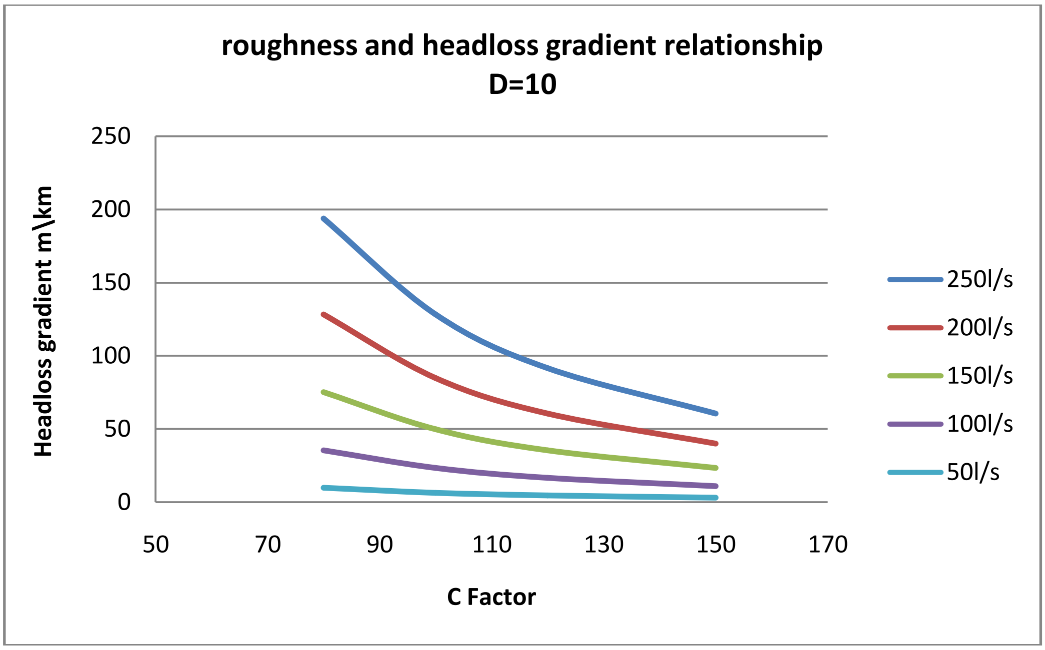

Fig. 3: head loss gradient and C factor D=10

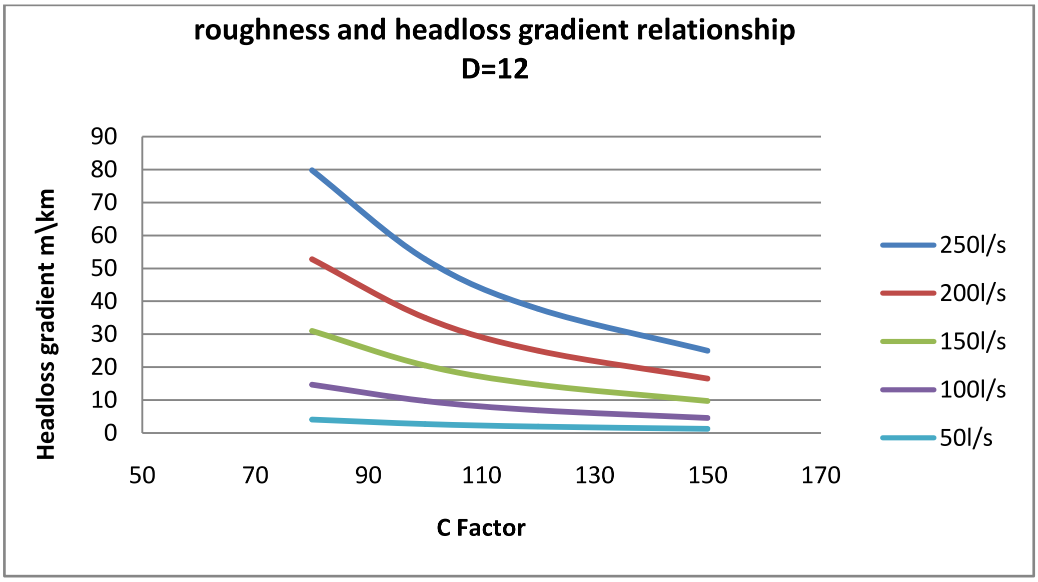

Fig. 4: head loss gradient and C factor D=12

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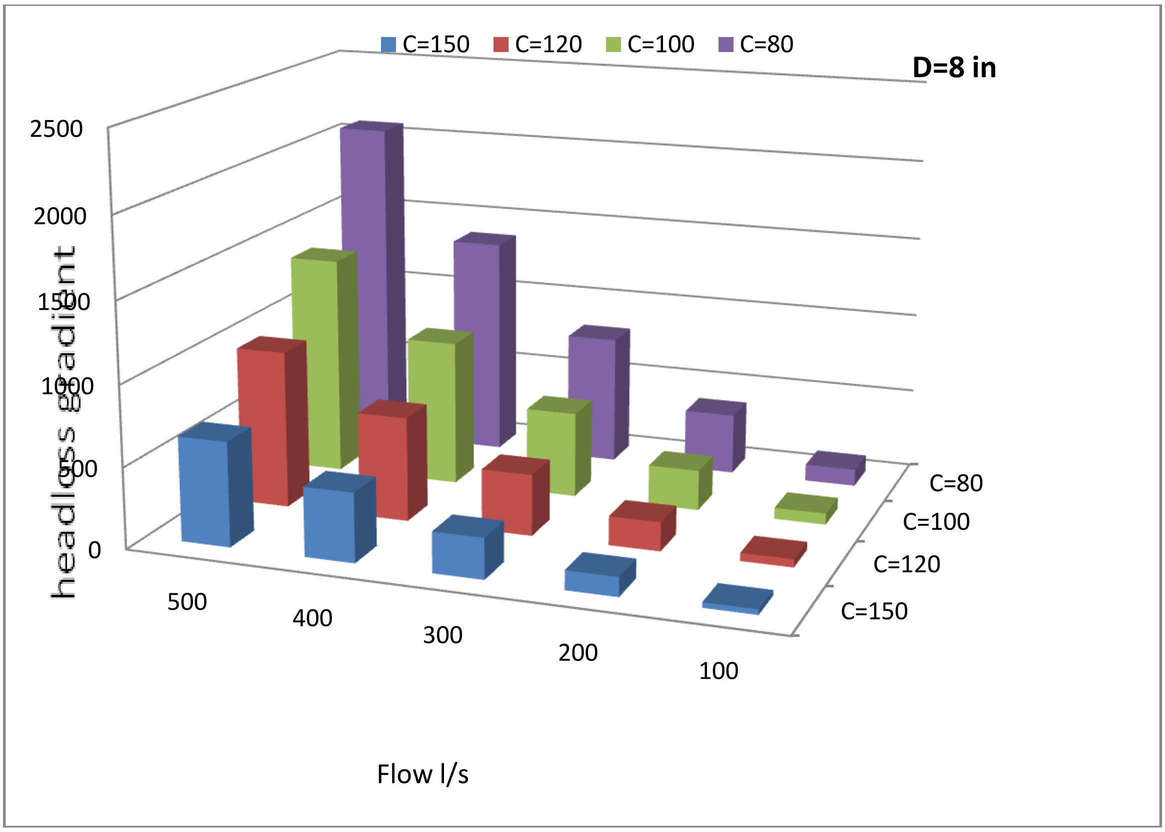

Fig. 5: flow and head loss gradient relationship for various C factors and D=12

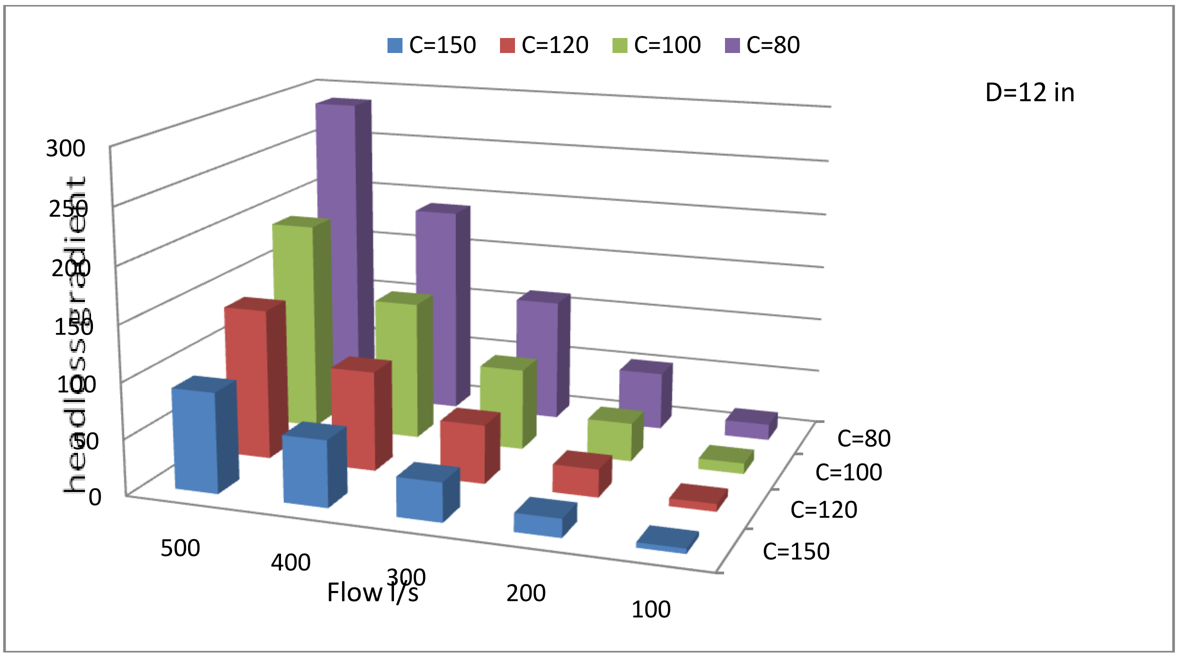

Fig. 6: flow and head loss gradient relationship for various C factors and D=12in

Relating head loss gradient to C factor, discharge and d/D ratio:

The following graph show this superimposing C factor and d/D for discharge of 200 l/s for pipe diameters 8in and 6in.

The point of intersection between the C factor and d/D is also shown and it is deduced that the point of intersection always intersects at C factor 100 or 108.

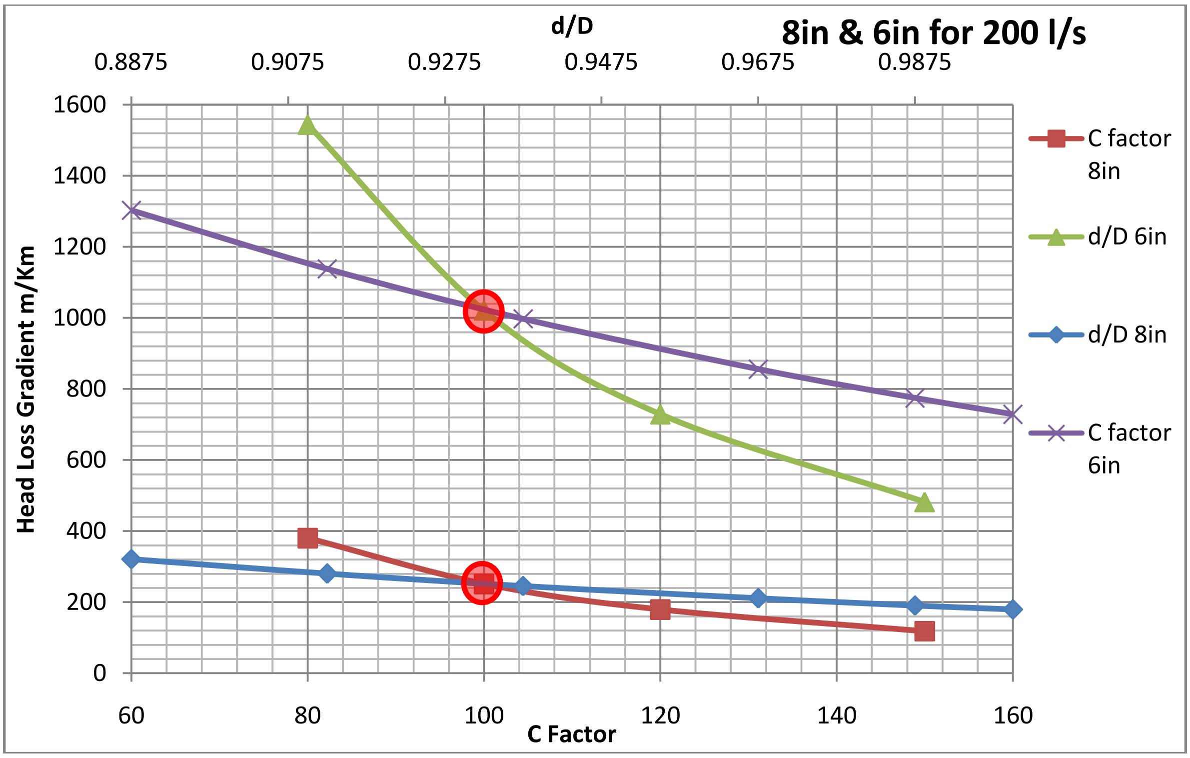

Fig. 7: Superimposing of C factor VS head loss curve with d/D VS head loss gradient curve

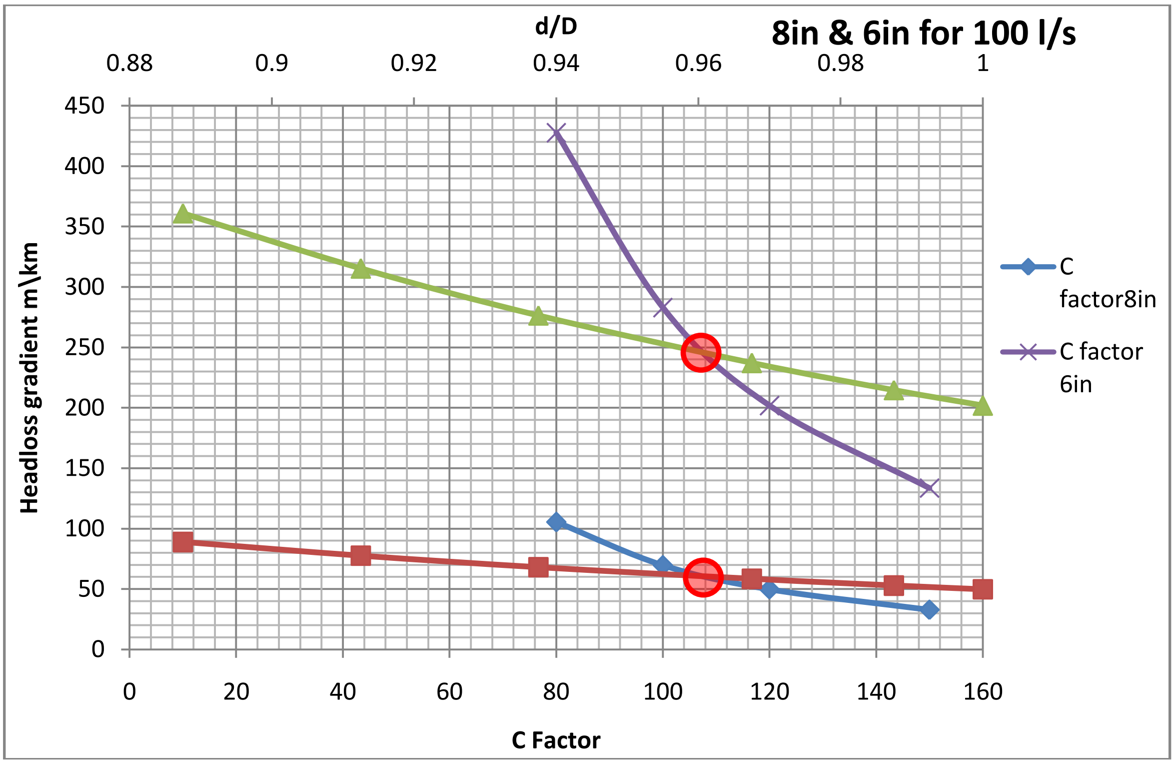

Fig. 8: Superimposing of C factor VS head loss curve with d/D VS head loss gradient curve

In the graph above, at the point of intersection of C factor curve and d/D curve, roughness coefficient equals 108 is equivalent to d/D equals 96%.

If using model network A the head loss gradient for using either d/D equals 96% or C factor equals 108.each case will yield head loss gradient 60m/km and 240m/km for 8in and 6in pipe respectively.

If we use both C factor 108 and d/D equals 96% in the same run this yields an increase in head loss gradient to 299 m/km and 73.7m/km for 6in and 8in pipe respectively.

The point of intersection of Hazen Williams C factor curve and d/D curve is always laying at C equals 108 and d/D percentage of 96%.

In combination of C factor of 108 and d/D percentage 96% the head loss observed for different diameters is about 25% in excess of using c factor reduction with reduced diameter.

For 4in pipe diameter with flow 100l/s an increase 25% in head loss. For 6in and 8in pipes with the same flow the increase in head loss is 24.5% and 22.8% respectively.

For 16in and 20in pipes with flow 200l/s, the increase in head loss is 21.2% and 27.7% respectively.

Effect of Hazen Williams Roughness factor on chlorine residual:

It can be implied from results that as RCF absolute value increase, the chlorine decay rate increase. From figures 6.5.7, 6.5.8, and 6.5.9 that each RCF value gives a certain trend for chlorine decay. For small diameter 4in pipes the equation relating C factor and chorine diminishing is exponential equation. For other larger diameter pipes the equation representing the relation is polynomial equation.

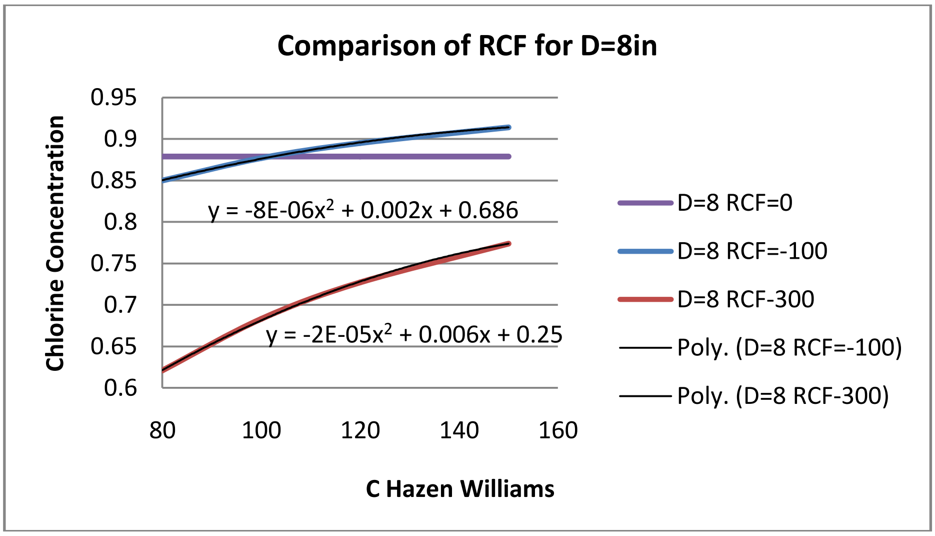

Fig. 9: chlorine concentration decrease with reduced C factor (different RCF)

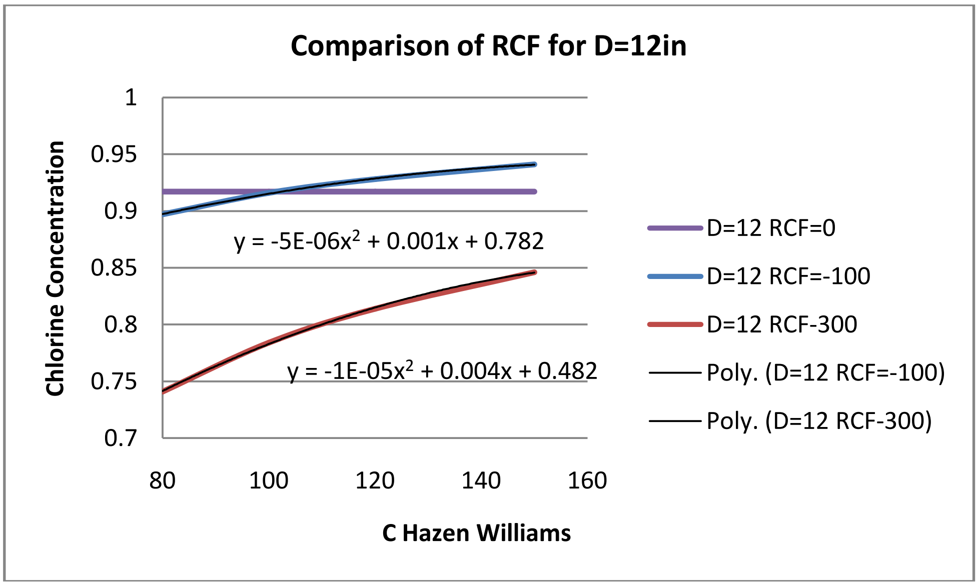

Fig. 10: Chlorine concentration decrease with reduced C factor (different RCF)

The following equations are for RCF equals -100 for 8in and 12in pipes

y = -8E-06x2 + 0.0027x + 0.6863 -------- 8in

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y = -5E-06x2 + 0.0019x + 0.7824 ------- 12in

And the equations below is for RCF equals -300 for 8in and 12in pipes

$y = -2E\text{-}05x^2 + 0.006x + 0.25$---------- 8in

$y = -1E\text{-}05x^2 + 0.0042x + 0.4829$ ----12in

Where y is chorine concentration and x is the C factor .The exponential equations representing pipes smaller than 4in are as follows

$y = 0.2493x^{0.2434}$

$y = 0.0112x^{0.7953}$

Conclusion:

Hazen Williams' roughness coefficient is a very impressive parameter in distribution systems modeling. C factor affects and is affected by nearly most important variables that is included in network modeling as chlorine decay, internal pipe diameter, roughness height, age of pipe, head loss gradient and leakage.

The importance of precise determination of roughness coefficient arise due to the fact that a network simulated with unreal value of roughness coefficient leads to incorrect results. This makes the model not valuable and limits the huge benefits of simulation modeling.

Simulation modeling software as WaterGems can be used in prediction of C factor. But in case we provide the software with good field data for flow and pressure. Another approach introduced within this research that you can predict a very near value to the correct C factor by knowing the head loss gradient of a pipe in network through graphs deduced for this purpose. The problem associated with this approach that aged pipes not only have reduced roughness coefficient but also reduced internal diameter.

This issue is solved by the increase of the head loss gradient by 25% to compensate for pipe diameter decrease. This percent is validated within this research and is coping with literature.

The accuracy of Darwin Calibrator in leakage location detection and leakage quantities determination is judged to conclude that leak location can be found in a range of circle with a radius of 0.25km if field data is selected with nimbleness.

It is deduced that as C factor decrease, the quantity of leakage decrease, and water lost to soil is lowered. And this is compatible with other researches that stated that leakage can be controlled by decreasing pressure. that as roughness factor decrease pressure is decreased.

It is also implied that as roughness coefficient decrease this is accompanied by increase in chorine decay. And the equation relating C factor to chorine concentration is polynomial equation. And this agrees with literature.

REFERENCES

AWWA, 2005. edited by William C. Lauer ,Water Quality In The Distribution System,chapter, 9: 197-199.

Bentley Watergems users Manual, 2010.

Brown, K., 2007. MODELING LEAKAGE IN WATER DISTRIBUTION SYSTEMS, (master thesis), Florida State university.

Colebrook, C.F. and C.M. White, 1937. "The Reduction of Carrying Capacity of Pipes with Age," J. Inst. Civil Eng. London, 10: 99.

Ormsbee, L.E., S. Lingireddy, 1996. Calibration of hydraulic network models, p: 14.3 to 14.15.

Walski, Thomas M., W. Sharp, Wayne and F. Shields, Jr. Douglas, 1988. "Predicting Internal Roughness in Water Mains," Miscellaneous Paper EL-88-2, US Army Engineer Waterways Experiment Station,Vicksburg, Miss.