# Modeling of Fault Detection in Water Distribution Networks for Greater Guwahati City

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**Abstract -** ***Leakage in the water distribution network at fault location incurring huge loss of scarce water resource is a serious point of concern. Assam is a flood-prone State, with heavy downpour in the catchment area of the mighty Brahmaputra. Guwahati, the capital of the State experience regular flash flood with incessant spells of heavy showers every year during rainy season. During no-flow timing, due to hydraulic gradient, pathogen and other contaminants may enter the submerged distribution network. Assam currently tops in the list of Infant Mortality Rate(IMR) in India, where water-borne disease considered to be a prime factor. Hence, under this study an effort has been made to develop models for locating the faults or leakage points in the water distribution networks for Greater Guwahati City. In this paper, Based on specific field study of 29 Piped Water Supply Schemes in and around Guwahati City, models have been developed with statistical linear regression method for location of fault, so that remedial measures could be taken up on war footing to arrest intrusion of contaminants.***

***Key Words:*** Leakage, Fault, age of pipe , material of pipe, , hydraulic gradient , Clear Water Pumping Main discharge, discharge at fault location *.*

## 1. INTODUCTION:

Unsteady flow condition develops at fault locations of Water Distribution network. The fault may correspond to age of pipe, pipe material, discharge from Clear Water Pumping Main etc. Fault in the distribution network has posed to be an added hindrance to the water quality safeguards. The Government of India and the State Governments together have emphasized over the last twenty years on water supply and sanitation services in rural India. So the corresponding wasteful transit loss is also has to be easily assessed. The reason of fault in the distribution network may be age of the pipe, pipe material, the Deep Tube Well failure, elapsing design period, depletion of ground water table etc. Here comes the importance of carriage of water, the solution is of course the pipe conduit. To address the emergence and consequences of fault in the water distribution network a study has been conducted in 29 Piped Water Supply Schemes in and around Guwahati City, which is the second largest metropolitan region in Eastern India after Kolkata. The 29 PWSS that have been extensively visited and field data collected. In this study total six linear models have been developed from the collected extensive field data for PVC and Flexible Quick Coupling GI Pipe networks. The developed models can predict the first fault location in a distribution network if either of Clear Water Pumping Main discharge, discharge at fault location or age of pipe and pipe material are known.

## 2. Literature Review:

Hassan A et al [1] elaborating water distribution system most similar to our geographic condition, states how sudden operational breakdown cause catastrophic pipe failure and also about designing of protecting equipments. Hamilton S. and Jones C [2] outlines the importance of technology and innovation, describes technologies available in assisting water utilities to save valuable quantities of water lost through leaky networks. Wu Z. et al [3] suggested relatively new approach pressure-dependant leakage detection for identifying the leakage hotspots. Giustolisi O. et al [4] presented a novel steady-state network simulation model that fully integrates into a classical hydraulic representation, pressure-driven demand and leakage at the pipe level. Laven K. et al [5] illustrated how through the Sahara Leak Location System, two leakage points were detected in the city of Houston, USA. Rogers D and Fantozzi M [6] advocated for zoning the network with installation of flow meters, which helps very accurate network analysis model and sophisticated monitoring. Stathis J and Loganathan G [7] centered on leaks or breaks in water main which contribute significant loss of potable water, thereby revenue. Covas D and Ramos H [8] focused on leak detection and location in pipe networks based on inverse transient analysis using observed pressure data with minimization of the difference between observed and calculated parameters.

## 3. COLLECTION OF FIELD DATA :

Public Health Engineering Department (PHED), Assam is engaged in providing drinking water to the rural masses of the State since 1956 (but it became a major Department later). The public water supply got boosted from 1972 onwards, as Government of India adopted the Accelerated Rural Water Supply Programme (ARWSP). Several programmes, such as Tribal Sub-Plan, Minimum Needs Programme, Submission- to address Quality-Affected areas etc are adopted from time to time to boost public water supply system. Initially, in the State of Assam, in the Brahmaputra valley, ground water sources were preferred, while surface sources were adopted in the Barak valley. Within the ambit of National Rural Drinking Water Programme (NRDWP), Ministry of Drinking Water and Sanitation, Government of India adopted a long term Strategic Plan (2011-22) for ensuring drinking water security to all rural household. The Strategic Plan aims to cover 90% of households with Piped Water and at least 80% of households with tap connections during this period. The conventional spot water sources such as Hand pump No.6, India Mark-II Hand Pump, India Mark-III Hand Pump, Singur Hand Pump, Tara Hand Pumps and ring wells, used from the beginning in transition, till date are no longer encouraged, if otherwise warranted. As such, Piped Water Supply has become inevitable in public water supply system. . Here under this work 29 Piped Water Supply Schemes in and around Guwahati City have been studied on for modeling location of fault. The data collected are the amount of discharge released from the Clear water pumping main, discharge at successive fault locations, distance of fault location with respect to the Clear Water Pumping, size of pipe and material of pipe . Fig -1 and Fig -2 shows the photographs taken at two fault locations at greater Guwahati area.

**Fig -1:** Water getting wasted at a fault location in pipe network of Guwahati City

**Fig -2:** Water splashed through conduit fault

## 4. Modeling of location of fault :

Analysis of the extensive data collected from 29 Piped Water Supply Schemes in and around Guwahati City i.e., the amount of discharge released from the Clear water pumping main, discharge at successive fault locations, distance of fault location with respect to the Clear Water Pumping main (CWPM), size of pipe, age of pipe and material of pipe have been made. It has was quite interesting to observe form the field data that all faults were found for second step of the distribution networks i.e., with 90 mm diameter pipe size ,where in the first step network stars with 100 mm diameter pipe. Therefore in modeling pipe size is not taken as a variable and all the models are developed for 90 mm diameter size pipe. Ages of pipe networks have been calculated with respect to year 2015. Total three models have presented here, one for PVC Pipe networks and two for Flexible Quick Coupling GI Pipe networks.

### 4.1 Fault Location modeling for Flexible Quick Coupling GI Pipe networks:

Three models have been developed to locate the first fault in the Flexible Quick Coupling GI Pipe networks based on discharge Flexible Quick Coupling GI Pipe released from the Clear water pumping main, discharge at first fault location and pipe age.

**4.1.1 Location (distance) of first fault from the CWPM (KM) with respect to Discharge at first fault location (LPM) :**

The date collected for Flexible Quick Coupling GI Pipe networks based on Discharge at first fault location (LPM) has been presented in Fig –3.

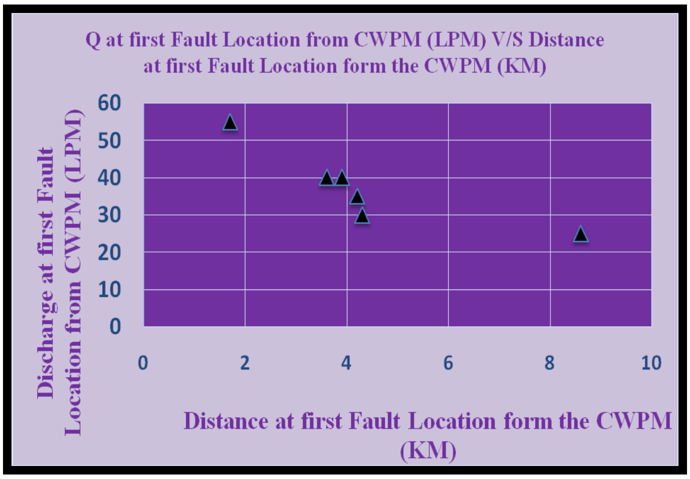


**Fig -3: Representation of Distance at first fault location with respect to discharge at first fault location**

Considering Distance of Fault Location form the CWPM as independent variable and therefore it is denoted by "X" and from Discharged at Fault Location from CWPM as dependent variable and therefore it is denoted by "Y".

X = Distance at first Fault Location form the CWPM (KM)
Y =Discharge at first Fault Location from CWPM (LPM)
Now by calculation from the above set of data for 90% confidence level by linear regression method we get the following observations.

**Table -1:** Regression Statistics-Model-I

| Regression Statistics-I | |
|---|---|
| R | 0.8629 |
| R Square | 0.7446 |
| Adjusted R Square | 0.6807 |
| Standard Error | 5.8583 |
| Observations | 6 |

Since we assumed 90% confidence level that means our significance level is 10%
Critical value for this analysis is, α = 0.1 F-Test
Calculated F-critical value for this calculation is = 4.5447
Calculated F value for this calculation is = 11.6616
Since F-value is greater than that of F-critical value so we can say that there is some degree of correlation between variable X and Y.
Correlation between X and Y is

$$R = \sqrt{R^2} = \sqrt{0.7446} = 0.8629$$

There is a strong correlation between X and Y
R square value is $0.7446$hat means we are able to explain 74.46 % variability of Y with respect to X.
Now let us use t-test and p-value test for evaluation of Y-intercept and X variable coefficient.

Y-intercept:
Calculated Y-intercept = 54.7413
Let's assume null hypothesis, H0: Y-intercept = 0
And alternate hypothesis, H1: Y-intercept ≠ 0
The T statistic value for Y-intercept is t = 9.7986and p-value is = 0.0006
Since we have assumed that the critical value to be α = 0.1 and therefore we observe that p-value is less than α. This means that there is enough that null hypothesis H0 must be rejected and we must adopt alternate hypothesis H1.
Hence Y-intercept = 54.7413is accepted.
X-variable coefficient:
Calculated X-variable coefficient = -3.9334
Let's assume that the null hypothesis, H0: X-variable coefficient = 0
And the alternate hypothesis, H1: X-variable coefficient ≠ 0
The T statistic value for X-variable coefficient is t = -3.4149
And p-value is = 0.02690
Since we have assumed that the critical value to be α = 0.1 and therefore we observe that p-value is less than α. This means that there is enough evidence that null hypothesis H0 must be rejected and we must adopt alternate hypothesis H1.
Hence X-variable coefficient = -3.9334is accepted.
Based on the above analysis we can form the straight line equation for the liner regression between X and Y
X = Distance at first Fault Location form the CWPM (KM)
Y =Discharge at first Fault Location from CWPM (LPM)

$$Y = -3.9334X + 54.7413 \quad \text{-----------[1]}$$

**4.1.2 Location (distance) of first fault from the CWPM (KM) with respect to Age of pipes as on 2015 (years):**

The data collected for Flexible Quick Coupling GI Pipe networks based on Age of pipes as on 2015 (years): has been presented in Fig –4.
Let us consider Age of pipe with reference from 2015 as independent variable and therefore it is denoted by "X" and from Distance of Fault Location form the CWPM as dependent variable and therefore it is denoted by "Y".
X = Age of pipe (Years)
Y = Distance at first Fault Location form the CWPM (KM)
Now by calculation from the above set of data for 90% confidence level by linear regression method we get the following observations.

**Table -2:** Regression Statistics-Model-II

| Regression Statistics | |
|---|---|
| R | 0.7812 |
| R Square | 0.6103 |
| Adjusted R Square | 0.5128 |
| Standard Error | 1.5876 |
| Observations | 6 |

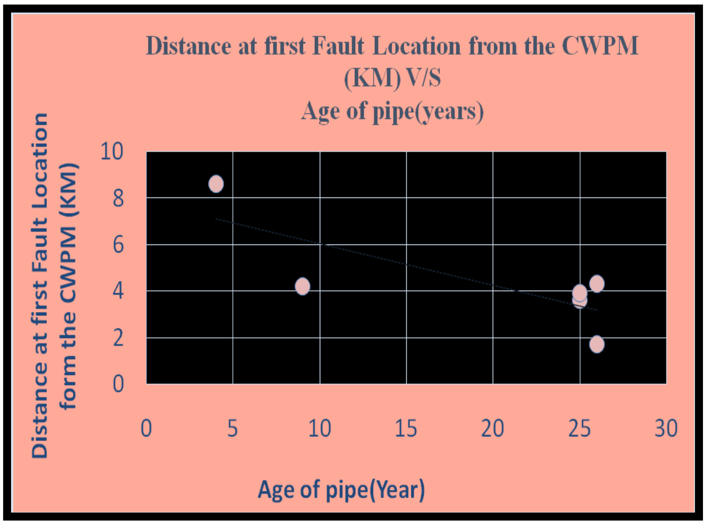


**Fig -4: Representation of Distance at first fault location with respect to Age of pipe**

Since we have assumed 90% confidence level that means our significance level is 10%
Critical value for this analysis is,α = 0.1
F-Test
Calculated F-critical value for this calculation is = 4.5448
Calculated F value for this calculation is = 6.2632
Since F-value is greater than that of F-critical value so we can say that there is some degree of correlation between variable X and Y.
Correlation between X and Y is

$R = \sqrt{R^2} = \sqrt{0.6103} = 0.7812$ i.e. there is a strong correlation between X and Y

R square value is $0.6103$ that mean we are able to explain 61.03 % variability of Y with respect to X.
Now let us use t-test and p-value test for evaluation of Y-intercept and X variable coefficient.
Y-intercept:
Calculated Y-intercept = 7.8067
Let's assume null hypothesis, H0: Y-intercept = 0
And alternate hypothesis, H1: Y-intercept ≠ 0
The T statistic value for Y-intercept is t = 5.1574 and p-value is = 0.0067

Since we have assumed that the critical value to be α = 0.1 and therefore we observe that p-value is less than α. This means that there is enough that null hypothesis H0 must be rejected and we must adopt alternate hypothesis H1.
Hence Y-intercept = 7.8067 is accepted.
X-variable coefficient:
Calculated X-variable coefficient = -0.1786

Let's assume that the null hypothesis, H0: X-variable coefficient = 0
And the alternate hypothesis, H1: X-variable coefficient ≠ 0
The T statistic value for X-variable coefficient is t = -2.5026
And p-value is = 0.0666

Since we have assumed that the critical value to be α = 0.1 and therefore we observe that p-value is less than α. This means that there is enough that null hypothesis H0 must be rejected and we must adopt alternate hypothesis H1.
Hence X-variable coefficient = -0.1786is accepted.

Based on the above analysis we can form the straight line equation for the liner regression between X and Y
X = Age of pipe (Years)
Y = Distance at first Fault Location form the CWPM (KM)

$$\mathbf{Y = -0.1786X + 7.8067} \quad \text{--------------[2]}$$

**4.1.3 Location (distance) of first fault from the CWPM (KM) with respect to Discharge from CWPM (LPM):**

Modeling of Location (distance) of first fault from the CWPM (KM) with respect to Discharge from CWPM (LPM) could not taken under consideration for this study as the date collected for all the Flexible Quick Coupling GI Pipe networks, discharge released from the Clear water pumping main has same 220 LPM (as in Fig –5). Hence it is not possible to develop the model considering CWPM Discharge (LPM) as a variable. Considering the collected available data of fault distance from the CWPM at an average value of 4.38 km from CWPM first fault can be expected

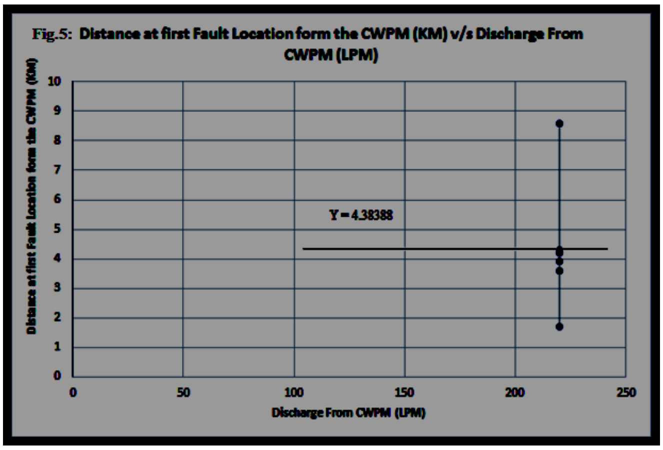


**Fig -5: Representation of Distance at first fault location with respect to Discharge from CWPM (LPM)**

### 4.2 Fault Location modeling for PVC Pipe networks:

**Location (distance) of first fault from the CWPM (KM) with respect to Discharge from CWPM (LPM):**

The date collected for PVC pipe networks based on discharge released from the Clear water pumping main has been presented in Fig –6.

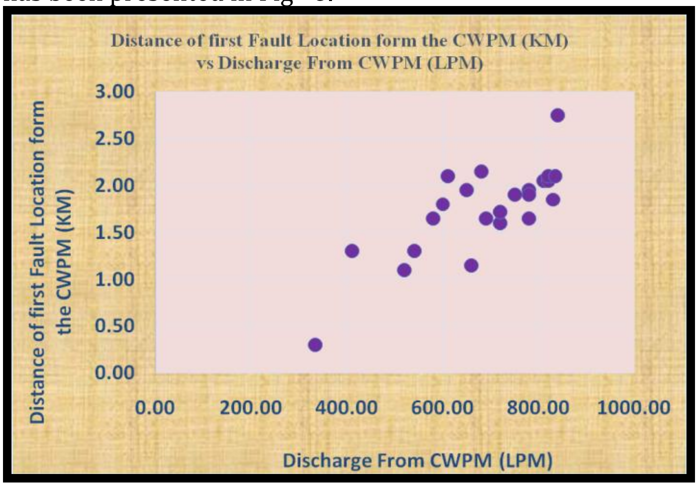


**Fig -6: Representation of Distance at first fault location with respect to Discharge from CWPM (LPM) for PVC Networks**

Considering Discharge from CWPM as independent variable and therefore it is denoted by "X" and Distance of first Fault Location form the CWPM as dependent variable and therefore it is denoted by "Y".

X = Discharge from CWPM (LPM)

Y =Distance of first Fault Location form the CWPM (KM)

Now by calculation from the above set of data for 90% confidence level by linear regression analysis, we get the following observations.

**Table -3:** Regression Statistics-Model-III

| Regression Statistics | |
|---|---|
| R | 0.783854958 |
| R Square | 0.614428595 |
| Adjusted R Square | 0.596068052 |
| Standard Error | 0.308603269 |
| Observations | 23 |

Correlation between X and Y is

$$R = \sqrt{R^2} = \sqrt{0.614428} = 0.7838549$$

There exist a strong positive correlation between X and Y. R Square value is 0.614428that means we are able to explain 61.44% variability of Y with respect to X.

F-Test:

Calculated F-critical value for this calculation is = 2.9609

Calculated F value for this calculation is = 33.4646

Since F-value is greater than that of F-critical value so we can say that there is some degree of correlation between variable X and Y. Now let us use t-test and p-value test for evaluation of Y-intercept and X coefficients.

Y-intercept:

Calculated Y-intercept = -0.13030815

Let's assume null hypothesis, H0: Y-intercept = 0

And alternate hypothesis, H1: Y-intercept ≠ 0

The t-statistic value for Y-intercept is t = -0.394848

And p-value is = 0.696936

Since we have assumed that the critical value to be α = 0.10 and therefore we observe that p-value is greater than α. This means that there is enough evidence that null hypothesis H0 must be accepted and we must reject alternate hypothesis H1.

Hence Y-intercept = -0.13030815 is rejected.

X-coefficient:

Calculated X-variable coefficient = 0.0027329

Let's assume that the null hypothesis, $H_0$: X-variable coefficient = 0 and the alternate hypothesis, $H_1$: X-variable coefficient ≠ 0

The t-statistic value for X-variable coefficient is t = 5.7848

And p-value is = $9.64576 \times 10^{-6}$

Since we have assumed that the critical value to be α = 0.10 and therefore we observe that p-value is less than α. This means that there is enough evidence that null hypothesis H0 must be rejected and we must accept alternate hypothesis H1.

Hence $X_1$-variable coefficient = 0.0027329is accepted.

Based on the above analysis we can form the straight line equation for the linear regression between "X = Discharge from CWPM (LPM)", "Distance of first Fault Location form the CWPM (KM)", which is given as,

$$Y = 0.0027329X \text{ -------------------[3]}$$

## 3. CONCLUSIONS

Model developed for PVC pipe networks indicates that as discharge from CWPM increases, there will be a linear increase in the distance of first fault location from the CWPM. The first model developed for Flexible Quick Coupling GI Pipe networks shows that as distance of first fault location increases from the CWPM, discharge at that first fault location decreases and vice-versa. Second model developed for Flexible Quick Coupling GI Pipe networks indicates that with increase in age i. e. life of the pipe, the distance of first fault location approaches nearer to the CWPM and vice-versa.

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