Water Distribution System Reliability Study

For the City of Eastpointe

November, 2009

Prepared for the City of Eastpointe
by AEW

AEW Job No. 0145-0336

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Executive Summary

This study analyzes and evaluates the existing water distribution system for the City of Eastpointe, Michigan. The analysis is performed with Pipe2008 computer modeling software using physical characteristics of the existing distribution system as input. The model outputs flow, pressure and head loss information for each pipe in the system. This output, information obtained from the City of Eastpointe, State of Michigan Safe Drinking Water Act standards, fire flow requirements and fire insurance premium guidelines are the basis for system evaluation.

Single-family residential demand was calculated based on records from the City of Eastpointe Department of Public Works. Based on their records, overall average single-family residential demand was calculated and averaged as 0.172 gpm. Average demands for most apartment complexes, condominiums, churches and schools were determined from billing records provided by the city's finance department. Average demands from businesses were either determined from city billing records or estimated based on the type and size of business.

Utilizing existing demand and peaking factors, a model of the existing water distribution system for the City of Eastpointe was developed with the use of Pipe 2008 modeling software. The model was calibrated with data obtained with the October 2008 hydrant flow tests.

Based on the model's output, the system evaluation revealed the system generally operated well under normal demand conditions. During fire demand, however, the model predicted that the system's ability to provide recommended fire flow for the surrounding zoning in several areas of the city was limited.

- During the average day, the city of Eastpointe water distribution system maintained pressures between 37 and 51 pounds per square inch (psi).
- During a day of maximum demand, such as the hottest day of the summer, the city of Eastpointe water distribution system maintained pressures between 34 psi and 50 psi.
- During peak hour, the city of Eastpointe water distribution system maintained pressures between 28 psi and 50 psi.

The following system improvements were suggested, which would improve overall system reliability and improve the fire fighting capability of the city's water distribution system:

- Replace all 6 inch diameter main with 8 inch diameter main.
- Replace the 8 inch diameter mains along Gratiot Avenue with 12 inch diameter mains.
- Loop the long dead ends on Manchester and Chesterfield Drives.
- Replace mains with a history of excessive breaks.

Scope of Work

The City of Eastpointe has never developed a complete model for its water distribution system. As part of this reliability study, the City's system was modeled and evaluated for its ability to adequately serve its customers during peak periods, as well as provide fire fighting capability while maintaining an adequate pressure in the system.

Governing Standards

Accepted design standards, in accordance with the Michigan Safe Drinking Water Act, require distribution systems to have sufficient capacity to meet instantaneous peak demands, including fire flow demands. These standards also suggest that normal working pressure not fall below 35 pounds per square inch (psi). Under peak demand, including fire flow, 20 psi must be maintained at all times throughout the system. Pressures below 20 psi may allow for groundwater infiltration into the water system, resulting in contamination of the water supply.

Beyond safe drinking water standards, fire insurance premiums also influence water system planning and design. Minimum fire insurance premiums require very large fire flows. These flows must be in quantities and pressures and for durations acceptable to the insurance companies. The National Fire Protection Association (NFPA) and the Insurance Services Office (ISO) publish data on the fire flow requirements necessary to qualify property for minimum fire insurance rates. A copy of the "Guide for Determination for Needed Fire Flow" and some information regarding Water Supply Evaluations that was downloaded from the ISO website has been included in this report. (See Appendix H).

The length of time for which the required flows must be available varies. Economic constraints may preclude construction of the storage, pumping facilities and the large diameter mains needed to deliver the amount of water in the given time period need to meet certain insurance requirements. Thus, the design of municipal water systems balances the cost of constructing the system with the benefit of reduced insurance premiums, which results in a more realistic and economical system at the cost of greater fire insurance risk.

Although many water supply systems may not minimize the fire insurance risk to business, businesses do have options available to them to further reduce their risk. If zoning requirements permit, buildings may be sited so they do not pose a risk to adjacent buildings. Businesses may also construct water storage facilities for fire fighting, or install automatic sprinkler systems. All of these measures could help keep losses in a fire and insurance premiums to a minimum.

Background

The City of Eastpointe encompasses approximately 3,305 acres in southern Macomb County. As a well established community, the city is essentially built out. The city's make-up consists primarily of residential neighborhoods, with a small amount of commercial and office. Non-residential uses are generally located along the city's major roads: Gratiot Avenue, Kelly Road, Nine Mile Road and Ten Mile Road. A zoning map is located in Appendix J. The breakdown of land use as of 2003 Southeast Michigan Council of Governments (SEMCOG) data is shown in Table 1.

Breakdown of Land Use in 2003		
Land Use Type	Acres	Percent of Total (%)
Single-family	2,557	77
Multiple-family	187	6
Commercial/Office	304	9
Industrial	0	0
Transportation, Communication, Utility	31	1
Extractive	0	0
Water	0	0
Institutional	166	5
Recreational	57	2
Vacant	3	0
Woodland/Wetland	0	0
Under Development	0	0

Table 1 – Estimated Land Use SEMCOG Land Use/Land Coverage for Macomb County, 2003

Additionally, SEMCOG develops population projections as part of their regional planning for Southeastern Michigan counties. Based on the information provided, the population for the City of Eastpointe is expected to remain constant for the next twenty years. SEMCOG's population projections for the City of Eastpointe are show in Table 2.

2000	34,077	people
2010	32,852	people
2020	32,165	people
2030	31,007	people

Table 2 – Estimated Population, SEMCOG, Regional Development Forecast, 2000

Eastpointe's topography is generally level, with no pronounced hills or valleys. The city's high point is in the northwest, near the intersection of Hayes and Ten Mile Road. The city gently slopes downward toward the southeast. Grade across the city varies approximately 30 feet from the northwest corner to the southeast.

Current Flow Demands

User Demand

Single-family residential demand was calculated based on records provided by the City of Eastpointe Department of Public Works. Based on their records, overall average single-family residential demand was calculated and averaged as 0.172 gpm. Average demands for most apartment complexes, condominiums, churches and schools were determined from billing records provided by the city's finance department. Average demands from businesses were either determined from city billing records or estimated based on the type of business. The average demand correlates well with the metered flow measured by the meters at the city's two connections to the Detroit Water and Sewerage Department (DWSD) distribution system. The average flow measured by these meters over a five year period was calculated to be 2262 gallons per minute (gpm). The total demand predicted by the model was 2558 gpm.

Based on data from previous studies conducted by AEW in 2007 and 2008, the city realizes a maximum day peaking factor of 1.8 - 2.0 and a peak hour factor of 2.7 - 3.0.

Fire Demand

Fire demand is the demand placed on the system when a fire occurs in the City. This demand is imposed at a single point in the system and varies based on the nature of the fire. Typically, fire demand is less in residential areas than in commercial and industrial areas due to smaller structures in residential areas which hold fewer flammable materials. Fire demand for each of class of building can be determined by ISO guidelines. A copy of this guide was downloaded and included in Appendix H of this report. Typical values for fire flow demand based on zoning are shown in table 3.

Zoning	Demand (gpm)
Residential	1500
Commercial	3000
Industrial	4000

Table 3 – Typical Fire Flow Demand requirements based on Zoning

Existing System

System Overview

The City of Eastpointe purchases water from Detroit Water and Sewerage Department (DWSD) as the sole source of water for the City. DWSD currently services the City with two connections, at the following locations:

- Gratiot Avenue & Eight Mile Road
- Kelly Road and Eight Mile Road

The City of Roseville also has a connection to the DWSD system at Gratiot Ave and Eight Mile Road. Roseville is serviced via a 24" water main which runs through the city

of Eastpointe along Gratiot Avenue. Eastpointe has no connections to this 24" main and, as such, the main was not modeled as part of this study.

The City of Eastpointe is completely built out and, as such, the water system spans the entire area of the city. The oldest pipes in the City's system are made of cast iron, and were constructed around 1926. These pipes make up the majority of the city's water distribution system. The City is experiencing excessive breaks on the older cast iron main, which is typically located in residential areas. City staff estimates they respond to approximately 70 to 80 main breaks per year, on average. The larger transmission mains in the City, ranging from 12" to 24" in diameter, are located along the City's main transportation routes.

A map of the existing Eastpointe water distribution system is presented in Appendix I.

Pipe diameter (inches)	Total Length in System (Linear Feet)
6	173,300
8	291,500
12	60,700
20	6,900
24	15,400
	Total Length: 547,800

Table 4 – Existing Pipe Inventory for the city of Eastpointe

Fire fighting demand can severely reduce pressures in a system of small diameter pipe. Undersized pipe results in excessive head loss and a corresponding decrease in flow, even when adequate pressures are maintained in larger, nearby mains. Industry standards recommend a minimum size pipe of 6 inches. However, many progressive communities presently install nothing smaller than 8 inch diameter pipe, to ensure adequate flows and pressures. The City's water main system is extensively looped, but many mains in the system are smaller than 8 inches in diameter, which could present a problem, especially as the aging system continues to deteriorate.

Model Development

The model of the existing Eastpointe water distribution system was developed with the University of Kentucky pipe network analysis program, Pipe2008. This program performs regular simulations of steady state pressure and flow in pipe networks transporting liquids. The Pipe2008 program is extremely powerful and capable of modeling very complex pipe networks.

As powerful as Pipe2008 is, accurate data input to the program is essential to obtain meaningful results. Every effort was made in configuring the model to accurately reflect the existing system. The existing computer model system map, as presented in Appendix I, identifies each section of pipe in the model and the nodes between each section of pipe.

Fire hydrant flow tests are an essential tool used in calibrating the computer model. These tests provide actual data on the system's performance, including static pressures within the system, residual pressures while the system is under demand, flows produced, measured drops in system pressure and estimates of the condition of the interior smoothness of the pipe in the system. From the results of a hydrant flow test, the theoretical flow available from the system may be calculated at any residual pressure desired. The formula used to calculate the theoretical flow is as follows:

$$Q_R = Q_F \times \frac{H_R^{0.54}}{H_F^{0.54}}$$

where:

Q_R = theoretical flow at the desired residual pressure

Q_F = actual flow measured during the test

H_R = the drop in pressure from static to desired residual

H_F = the drop in pressure from static to actual residual during the test

In order to provide standardized results from hydrant flow tests, flows are calculated from the above formula at a desired residual pressure of 20 psi. This pressure is chosen because public health guidelines require water distribution systems to maintain a minimum of 20 psi during fire flow events. This minimum residual pressure provides protection against backflow and possible system contamination.

Hydrant flow tests were performed in October, 2008. Appendix A shows the results of these test and includes a map which identifies the locations of the hydrants tested. For the majority of the tests the pressure reading at the Gratiot Avenue connection to the DWSD system was 47 psi, and the connection at Kelly Road was offline. These boundary conditions were used during calibration so that conditions at the time of hydrant testing were accurately reflected.

To calibrate the model, eighteen hydrant flow test results were chosen from among the twenty-seven taken. The discharge measured during the hydrant flow test was input as a demand at the node nearest the location of the actual "flow" hydrant. The residual pressure measured during the hydrant flow test with input at the node nearest the location of the residual test hydrant. Hydrant flow test results are located in Appendix A.

The program was run to predict residual pressure at each node. Any discrepancy between the actual test pressure and the computer model's predicted pressure was minimized by one or more of the following measures: adjusting losses (K-factors) in the existing pipe network, adjusting pipe roughness (C-factors), adjusting demands, and closing pipes to simulate closed valves or damaged water main. The program was run again and the results were compared with the results of the test and the previous run. The process continued until the computer results matched actual flow test results as nearly as possible. The model was then checked against several of the unused flow tests to confirm the model would accurately predict flows and pressures at those locations.

In order for the model to calibrate, large losses (K-factors) and low roughness (C-factors) was required through mains constructed prior to 1950. However, this corroborates information from the city's Department of Public Works. City staff has reported that some of their oldest mains have significantly corroded to the point that many 6 inch mains have only 4 to 5 inches of effective area remaining. Losses may also be due to partially closed or broken valves.

Additionally, several pipes had to be closed outright during calibration, simulating a closed valve or obstruction in the line. Closures at the following locations were required for the model to calibrate:

- Camden Street, between Henrietta and Gratiot
- Beechwood Avenue, south of Nine Mile
- Eight Mile Road, east of Gratiot
- Ten Mile Road, west of Schroeder

Overall, the calibration tests show the model can reasonably predict the system's response to varying demands. Further refinement to the model is recommended and will require field investigation and additional hydrant flow testing. Calibration results are located in Appendix C.

Results

Using the calibrated model, the water distribution system was studied for average day, maximum day and peak hour demands. Based on data from previous studies conducted by AEW in 2007 and 2008, the city realizes a maximum day peaking factor of 1.8 - 2.0 and a peak hour factor of 2.7 - 3.0. To be conservative, a peaking factor of 2.0 was used for maximum day and 3.0 for the peak hour. For the average day condition, it was assumed only the Gratiot Avenue connection to the DWSD system was open, operating at 47 psi. For maximum day and peak hour conditions, the assumed settings at the Gratiot Avenue and Kelly Road connections were 45 psi and 50 psi, respectively.

Additionally, a fire flow analysis was performed to determine the capacity of each pipe in the system while maintaining a system pressure of at least 20 psi. This analysis was performed under average day and maximum day conditions. The results of the fire flow analysis are presented in Appendix D.

Average Day

The system model was run for the average day scenario to determine, in general, how well the distribution system is currently working. Based on the model's output (Appendix E) the Eastpointe's water system generally provides adequate pressure during the average day demand scenario. Pressures throughout the system ran between 37 and 51 psi.

Maximum Day

The existing model was run for the maximum day demand scenario (2 times average day demand) to determine, in general, how well the distribution system is currently working during the summer months, when water demand is typically the greatest.

During maximum day demands, the model predicts the water system for the City of Eastpointe operates at pressures between 34 and 50 psi.

Peak Hour

The existing model was run for the peak hour demand scenario (3 times average day demand) to determine, in general, how well the distribution system is currently working during peak hour conditions. During peak hour demands, the model predicts the water system for the City of Eastpointe operates at pressures between 28 and 50 psi.

Fire Flow

A fire flow analysis was performed for the average and maximum day using the Pipe2008 software. Although the DWSD connection at Kelly Road is not used during the average day, it is available to be opened during periods of higher demand, such as those encountered for fire fighting. As such, it was assumes the Kelly Road connection is in operation for purposes of the fire flow analysis on the average day.

The analysis predicts the city's existing system will have difficulty providing adequate fire flow in all areas of the city on both the average and maximum days. These areas are concentrated in the residential areas which are served by the oldest 6 inch diameter mains. Maps highlighting the results of these analyses are located in Appendix D.

Discussion and Recommendations

Overall, the city's system is very well looped, which greatly enhances system reliability. Looped mains lessen the likelihood of prolonged water service interruption in the event of a water main break. To increase reliability, the city of Eastpointe should consider looping any dead end mains. Mains that are impractical or impossible to loop should be a minimum of 8" in diameter or larger, depending on the length of the dead end.

Eastpointe's water system appears to work well during average day, maximum day and peak hour scenarios during periods of regular user demand. However, during fire demand, the model predicts that the aging small diameter main prevalent in some areas of the city may be unable to accommodate fire demands on both the average and maximum day. As Eastpointe continues to maintain and improve its system, it is recommended the city undertake a program of systematically replacing any 6 inch diameter water main throughout the city with main at least 8 inches in diameter.

Since Eastpointe's water system is looped, large pressure drops witnessed during some of the hydrant flow tests would indicate further research is necessary to determine the cause. A significant drop may indicate a closed or broken valve, a broken water main, or a blockage in the main. Table 5 lists locations which indicate an area that the city DPW should investigate. Additionally, the DPW should also follow up on the areas identified in the calibration discussion where mains had to be closed in order for the model to calibrate.

Flow Test No.	Location	Static Pressure (psi)	Residual Pressure (psi)	Possible Explanation
2	Camden and Grove	43	14	Closed valve or obstruction between Gratiot and Grove
11	22071 Beechwood	42	19	Closed valve or obstruction at Nine Mile and Beechwood
15	17003 Forest	45	16	Closed valve(s) or obstructed pipe in the vicinity

Table 5 – Areas for further investigation, based on hydrant flow test and model results

The model was altered to open all closed lines and replace all 6 inch diameter main with 8 inch mains. The two long dead end mains along Manchester and Chesterfield Drives were looped, as well. Since the mains along Gratiot Avenue are vital to the entire water distribution network for the city, the two old 8 inch mains running along Gratiot Avenue were replaced with new twelve inch mains. A fire fighting analysis was again performed during the average and maximum day scenarios to determine how these alterations improved the system. The results of this analysis are included in Appendix D.

The results of the analysis shows that the improvements discussed in the previous paragraph result in a marked improvement of system response to fire demand during both the average day and maximum day scenarios.

Master Planning

Since the City of Eastpointe is built-out, the water system is built out as well. There are no plans for expansion of the water system, and the population of the City is not expected to grow over the next 20 years. Since there will be no expansion of the existing system, the model of existing conditions will match the model of the future system, with minor modifications as discussed in the previous section of this report:

- Replace all 6 inch diameter main with 8 inch diameter main.
- Replace the 8 inch diameter mains along Gratiot Avenue with 12 inch diameter mains.
- Loop the long dead ends on Manchester and Chesterfield Drives.

Analysis shows the above improvements would greatly improve overall system reliability, especially during fire demand. It is also recommended the city schedule the replacement of mains with an excessive break history.

The City has an underground water reservoir tank but currently does not use it. The City is currently studying the feasibility of renovating and upgrading their system 4,000,000 gallon water reservoir tank located on Ten Mile Road just east of Brittany Avenue in an effort to attenuate its demand for water during DWSD's peak periods. Since DWSD charges higher rates for communities whose peaks coincide with their peak, the use of this water reservoir tank should prove to be an economic benefit to the City.

In addition to the projected financial benefit, the water reservoir tank has the potential to enhance system reliability. In the event the water supply from DWSD is temporarily interrupted or degraded, the water reservoir tank may be able to supply water to the City for brief periods.

Conclusion

Overall, the model shows that the City of Eastpointe's water distribution system currently operates within an acceptable pressure range during average day, maximum day and peak hour demand scenarios throughout the city. However, the fire flow analysis and the hydrant flow testing in the field showed significant pressure drops when a greater fire fighting demand is needed in certain areas of the city. Considering how well the system is "looped" in some of these areas, other factors should be considered such as blocked or partially blocked pipes or closed or partially closed gate valves.

The City should consider other upgrades to its system. These upgrades include replacing all 6 inch diameter mains with 8 inch diameter water main and looping dead end mains. Upgrading the mains along Gratiot Avenue is recommended, given their importance to the entire system. The city should also continue to replace older water main with emphasis on repairing those experiencing frequent water main breaks.

Additionally, the City should continue its study on the feasibility of upgrading and using the existing 4,000,000 gallon water reservoir. The storage reservoir has the potential to significantly increase reliability during periods of high demand or if the DWSD becomes temporarily unable to service the city.

Please note:

A copy of Appendix A through Appendix J noted on the Table of Contents can be obtained from the City Manager's Office.