Water System Reliability Study

City of Muskegon Heights

WSSN #MI04580

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EXECUTIVE SUMMARY

This report represents the five year update of the City of Muskegon Heights Water System Reliability Study. Based on the three primary components of the water distribution system (the source water system and water treatment plant, the water distribution system (pipe), and the storage requirements), the following conclusions are made:

- The water supply has met the regulations for microbiological, radioactive, inorganic and volatile organic contaminants for at least the past 5 years.
- The existing supply capacity is adequate for current demands as well as water demands for Year 2034 and further into the future. The projected Year 2014 maximum daily demand of 15.6 million gallons per day (mgd) represents 62 percent of the firm supply capacity (25.2 mgd). With the West Michigan Regional Authority no longer supplied, demands projected through Year 2019 (5 year projection) represent only 13.9 percent of the current firm supply capacity. Long term demand projections through Year 2034 indicate that maximum day demands could reach only 14.2 percent of the existing firm supply capacity.
- The City provides adequate water supply for normal (non-emergency) system conditions. The distribution system meets minimum needs with respect to the hydraulic connectivity for this community; however, some improvements are recommended to improve the system transmission and distribution.
- Over the next 20 years, the City is capable of providing storage for fire protection to all residential customers equivalent to 1,000 gpm for 2 hours and to all commercial and industrial customers equivalent to 3,500 gpm for 3 hours. However, the distribution of water is limited in many areas of the City – more precisely in locations supplied by 4-inch and 6-inch mains. Specific distribution and transmission system improvements have been recommended for improved local fire protection to generally meet these goals.

- The unbilled water estimated recently is well within desired ranges. However, the City should provide more detailed accounting of known unbilled water use to determine whether “lost” water is at unacceptable levels, particularly since these could change somewhat significantly when the customer communities are no longer served.
- Field tests indicate that the distribution of water is limited in many areas. There is some question as to the source of energy loss in the system. As a result, the City should perform a more detailed field investigation on the distribution system to confirm the source of energy loss (and reduced fire flow).

I. INTRODUCTION

The City of Muskegon Heights is located in Muskegon County in the western, Lower Peninsula, approximately 30 miles northwest of Grand Rapids. The City supplies water to all City residents and businesses as well as two neighboring municipalities. The existing City water system and projected City service area is shown in Figure 1 and 2.

The City is supplied with Lake Michigan surface water from two water intakes extending into Lake Michigan. Water is purified via a conventional treatment plant. Water is then pumped to a City-wide distribution system of nearly 60 miles of water main ranging in size from 4- to 30-inches in diameter. The City operates and maintains 2.25 million gallons of storage within the City distribution system between the Sherman Boulevard Reservoirs and the Getty Street Tank.

The purpose of this report is to document the reliability of the water system for the City of Muskegon Heights. This reliability study aims to fulfill the requirements of Part 12, Rule R325.11201 through R325.11207 promulgated under Michigan's Safe Drinking Water Act, 1976, P.A. 399, as amended. A 5 and 20-year projection of water demands and an evaluation of each of the system components on five year intervals are required by the Act.

This report contains growth projections for the City water system, which at present is considered to be only within the City limits. The report identifies current and projected water demands and includes a computer assisted network analysis of the water distribution system. Recommendations for improvements to the water supply system are made with cost estimates and are presented in a capital improvements plan.

The City has completed the following work on the water distribution system over the past 5 years:

- Constructed 12-inch water main on McIlwraith Street from Sherman to Beulah Avenue.

- Added a hydrant on Hackley Avenue, west of Ray Street.
- Removed a water main on Beulah Avenue from McIlwraith Street to Jarman Street.

II. WATER DEMANDS

The City of Muskegon Heights supplies and distributes water to all of the residents and businesses within the City limits. In addition, the City currently supplies customers in neighboring City of Norton Shores and Fruitport Charter Township. The land uses within the City of Muskegon Heights are mixed with a significant amount of residential and commercial areas.

Historic water demand data was provided by the City of Muskegon Heights based on metered data and Monthly Operating Reports. The water supply data for the combined City and customer communities extends back to 2009 as summarized in Table 1. Detailed monthly water use for all customers for Years 2009 through 2013 is provided in Appendix C.

Using this data, the following parameters have been estimated: average day demand, which is the average daily water use for the year; maximum day demand, which is the highest daily use for the year; and peak hour demand, which is the estimated maximum hour of water use during the year. Figure 4 graphically illustrates the historic and projected demands based on this and additional information described further.

The 2009 City of Muskegon Heights Water System Reliability Study breaks out water demands for the three communities supplied by the City: the City of Muskegon Heights, the City of Norton Shores and Fruitport Township. Recently, however, the City of Norton Shores and Fruitport Charter Township formed the West Michigan Regional Water Authority. The new authority intends to obtain water from the City of Muskegon beginning in April 2015. Thus, the

water projections will consider only supply to the City of Muskegon Heights in the longer term for the purposes of this Water System Reliability Study.

The City of Muskegon Heights water use projections were estimated considering historic and projected water use and population. The West Michigan Shoreline Regional Development Commission (WMSRDC) provides population projections through 2024. These indicate the City of Muskegon Heights will have a growth rate of 0.12 percent from 2012 through 2024.

Table 2 and Figure 3 exhibit the historic and projected populations through 2034 for the City of Muskegon Heights as well as the City of Norton Shores and Fruitport Charter Township. The data shows that the City of Muskegon Heights population is projected to rise slightly after falling for many years. The recent number of service connections is provided in Table 3.

Population projections were prepared by using the historic data. A per capita water use of approximately 128 gallons per capita per day (gpcpd) was estimated based on data from 2010. This was applied to the population projections for the City of Muskegon Heights to project future water use. While WMSRDC population projections extend only through 2024, we have extrapolated the growth an additional 10 years to estimate water use in 2034. The resulting 2034 average day demand was projected at 1.43 mgd.

In 2013, the maximum day to average day demand ratio was approximately 2.5, which is higher than most years. This was conservatively used for maximum day projections. A peak hour to maximum day multiplier of 1.75 was used to estimate peak hour demands based on estimates for similar communities. The result is a 2034 projection of 3.58 mgd and 6.26 mgd for maximum day and peak hour demands, respectively.

Demands were projected through Year 2034 in five-year increments. These projections are provided in Table 4 for the service population.

III. WATER SUPPLY SOURCE

The City of Muskegon Heights provides water to its customers from a surface water supply. The water source is Lake Michigan, a high quality water supply. The City operates two intakes each with a steel and wood crib located offshore at a depth of approximately forty (40) feet. Raw water is pumped from a station onshore to the filtration plant, located about 930 yards east.

As mentioned in the previous section, the quantity of water available for long term supply to City of Muskegon Heights customers is adequate to meet customer demands. More information on the source water is provided in the "Water Filtration Plant Reliability Study for City of Muskegon Heights", dated June 2014.

IV. WATER SYSTEM INFRASTRUCTURE

A. Water Treatment Facilities

Water plant operators oversee the water production from the Lake Michigan source through treatment followed by pumping into the distribution system. The Water Plant is a conventional treatment facility with a capacity of 25.2 million gallons per day (MGD).

The treatment process removes suspended materials from the Lake Michigan water via coagulation, flocculation, sedimentation, and filtration. The Plant provides fluoridation in accordance with State of Michigan guidelines, and disinfection is attained through the application of chlorine in the form of sodium hypochlorite.

The City completed a separate report "Water Filtration Plant Reliability Study for City of Muskegon Heights", dated June 2014. This report evaluates the treatment plant in detail and provides recommendations.

B. Storage Facilities

There is currently one elevated storage tank in the City of Muskegon Heights distribution system, two ground storage reservoirs, and clear wells at the treatment plant. With the formation of the West Michigan Regional Water Authority, the City will no longer supply the customer communities and monitor those systems. The City will, however, continue to maintain Getty Street elevated storage tank, the Sherman ground storage tanks, and clear well storage for supply to City of Muskegon Heights residents. Data from the distribution system storage reservoirs is provided in Table 8.

C. Water Distribution Mains

A complex network of water mains provides distribution to City customers. The City limits cover an area of approximately 3.2 square miles, and water customers are supplied through a distribution network consisting of nearly 60 miles of water mains ranging from 4- to 30-inches in diameter. The original system was constructed in the early 1900's with most water mains installed in 1939, 1964 and 1974. The older water main is nearly all cast iron, while newer water main is ductile iron material. An approximate breakdown of the water mains by size, material and age is presented in Tables 9 through 11.

A grid of mains (4-inches and larger) has been constructed throughout the service area on the primary streets and alleys. This network is very well-looped. Transmission is provided to the entire system and to connections with customer communities; however, additional transmission would improve the system efficiency and overall hydraulics.

D. Standby Power

The City of Muskegon Heights owns and maintains fixed generators at the Water Treatment Plant and one of its Booster Stations. A 500 KW diesel generator is located at the Water Treatment Plant. This generator can power the treatment plant to operate at 10 MGD. The Water Treatment Plant is also supplied by dual electrical feeds.

An 80 KW natural gas generator is located at the Getty Street Booster Station. Each generator is started weekly. No auxiliary power is, however, available at the Sherman pumping station.

V. WATER SYSTEM ANALYSIS

A. Water Storage Analysis

1. Existing System

Ten State Standards states in Section 7.01: "Storage facilities should have sufficient capacity, as determined from engineering studies, to meet domestic demands and where fire protection is provided, fire flow demands".

In addition to fire demand, storage tanks must be capable of storing the maximum hour water demand in excess of the maximum day water demand for the period of time in which the maximum hour water demand occurs. This considers that the water supply system delivers the maximum day water demand.

An analysis was performed on the City of Muskegon Heights storage with consideration for the firm capacity. Storage is more than adequate during higher demand periods. Equalization storage and more than 3,500 gpm of fire flow are available for 3 hour duration from the water treatment plant and elevated storage. Table 12 provides the results of the storage analysis.

2. Future Conditions

The City storage was analyzed for future conditions to determine whether additional storage will be needed. Table 12 projects the recommended storage through Year 2034.

The analysis was completed based on demands and design firm supply capacity. Given the reduction in future demands over present figures, the pumping and storage facilities meet suggested volumes through Year 2034 and beyond. The available fire storage exceeds 3,500 gallons per minute for 3 hours.

B. Distribution System Analysis

Water distribution software, WaterCAD V8i / WaterGEMS, aided the analyzing of the City of Muskegon Heights' water supply system network. Model input data consisted of lengths, sizes, and roughness factors (Hazen-Williams coefficients) for pipes, and ground elevations and demands for nodes, storage tank elevations and volumes, and pump curves and capacities.

1. Model Development

The WaterCAD model from the 2009 Water System Reliability Study was updated for analysis of the system. Demand data was updated including existing and projected average day, maximum day and fire flow demands. Water mains 4-inch in diameter and greater are included in the model.

Hydrant testing results were used to calibrate the model. A hydrant flow test measures the distribution capabilities of a system by measuring and comparing the static pressure at a given location under typical conditions and the residual pressure at that same location for a given hydrant flow. The test data provides information for

model calibration; that is, model parameters can be adjusted so that predicted results compare favorably to measured results. In addition, the test data can provide information to determine locations at which a valve might be partially closed, or locations at which an unknown connection could exist.

Hydrant flow tests were performed by the City with assistance from Prein&Newhof personnel on May 1, 2014. The results of these tests are shown in Table 13. The tests were performed at a variety of locations dispersed throughout the system and provide data to adjust roughness coefficients and demands when necessary to simulate results.

Using the hydrant test data, the model was calibrated as follows:

- Simulate system conditions using initial parameter assumptions from the previous modeling work.
- Adjust water main roughness coefficients and system demand distribution
- Perform a sensitivity analysis on adjusted results
- Fine tune results based on previous steps

Table 14 compares the calibrated model results at the nearest model node to the 9 hydrant test sites. The initial simulations indicated that there is a lot of hydraulic loss in the smaller mains. The Hazen Williams roughness coefficient was lower than the usual ranging indicating either (1) tuberculation had reduced the diameter measurably, or (2) the low hydrant flows were the results of some other issue (e.g. a closed valve, a damaged valve, a left-handed valve, error in measurement, restriction at hydrant lead, incorrect diameters, etc.). The City did spend some time looking for closed valves once the results were obtained, but none were identified. As a result,

the system was calibrated assuming these very old mains did have significant tuberculation.

The system operation was simulated for comparison of the test results to the model results. The results for model simulations of the hydrant tests are provided in Table 14.

The hydrant test results are reasonably simulated by the model. Static pressures and residual pressures are within 2 psi and 4 psi, respectively at all test locations, and the results are within 10 percent. Given the limitations in the hydrant test data and fluctuations in system demands, the calibration results can be considered reliable.

Based on the calibration results, the Hazen-Williams coefficient ranges from 35 to 110 for distribution mains (8-inch in diameter or smaller), depending on the age and diameter of the main. This represents the effects of scaling and/or tuberculation. The Hazen-Williams coefficient generally was assumed to be higher but still ranged between 110 and 130 for the larger transmission mains. Recently constructed main throughout the system was assigned a Hazen-Williams coefficient of 130.

2. Existing System

Simulations were performed for various demand conditions using the calibrated model. Resulting pressures were examined to determine the adequacy of the system under high demand. Pressures during maximum day demands and without fires should not fall below 35 psi, nor should pressures in the system exceed approximately 90 to 100 psi.

The available fire flow is generally the standard by which a system is measured since that is typically the highest demand experienced. Typically, the available fire flow

represents the flow available at a given location without creating a low pressure problem anywhere in the system. The minimum system pressure which should be maintained at all times is 20 psi. While recommended fire flows vary based on many factors, the generally suggested fire flows are 1,000 gpm for residential customers and up to 3,500 gpm for commercial and industrial customers. Based on the available storage and system conveyance, the City does not meet recommended fire flows in many locations at present.

Results indicate that pressures within the City of Muskegon Heights are adequate throughout the system during maximum day demands. However, the model results show that the system transmission and distribution main capacity is less than desirable in some locations during maximum day demands, as older infrastructure limit the fire flow potential in some areas.

The 4-inch and 6-inch mains restrict the available fire flows to many residential locations in the system to less than 1,000 gpm. The available fire protection could be improved at the locations such as those presented in Table 15.

Appendix D includes output of the model results.

3. Future Conditions

Using the model, simulations were performed for future demand conditions to determine where improvements to the existing infrastructure may be needed. All water main Hazen Williams coefficients were reduced for 2034 demands to simulate aging. Resulting pressures were reviewed to determine the adequacy of the existing system under future demands. Available fire flows were also adequate in many locations but they are less than desirable at other locations.

Table 16 provides a summary of model results for Year 2034 demands with the existing infrastructure. The results indicate that pressures would again be mostly adequate, but the system transmission capacity would be even more limited due to further aging of water main. Available fire flows will be further reduced from existing fire flow capabilities because of the additional demands on the system from the projected growth of the City over the period. As a result, potential improvements were analyzed to improve the fire protection in the deficient locations.

Appendix D includes output of the model results for Year 2014 and 2034 simulations.

4. Distribution System Improvement Alternatives

Based on the results of the existing system analysis with future demand projections, improvement alternatives were considered. Many alternatives were considered and then selected and prioritized based on the most cost-effective alternatives to enhance the overall service to the system including fire protection.

It should be noted that due to the significant hydraulic losses witnessed during hydrant testing, a more detailed field investigation is warranted to confirm the source of the hydraulic losses. The alternatives that follow are based on the available information and the associated assertion that the small distribution mains are old and are a significant source of hydraulic losses.

Each of the following alternatives provides improved available fire flow to the system, and Figure 5 is a graphic of the potential improvements.

a. Transmission Improvements

The existing transmission system from the water treatment plant to the City is adequate; however, transmission across the system is limited in some locations.

To improve the base network, and also remove some older main, transmission projects are recommended on Sanford Street, Broadway Avenue, Sherman Boulevard, in the alley between 6th Street and 7th Street, and in the alley west of Getty Street.

b. Improved Fire Protection

The available fire flow in the system is limited at many locations. Several improvements are evaluated including:

Southwest corner of the City - In the southwest corner of the City, transmission is lacking. Two improvements options were analyzed. The first option considers constructing a transmission main loop around the City, on Norton Avenue and north to Broadway Avenue in the alley east of Seaway Drive. Alternatively, the existing transmission main on Oakwood Avenue that supplies Norton Shores can be connected to the local distribution mains at several cross-streets to increase the capacity of the distribution system. Given the condition of the 6-inch main and lack of transmission, both the transmission main and connections are recommended to increase the available fire flow to 1,000 gpm.

Southeast near Wood Street – The area of Howden Street and Wood Street and south of Summit is supplied by small diameter main, including a 2-inch dead end main. In addition the watermain to the south at the cemetary was cut and capped at the base of the hill. An 8-inch distribution main is recommended on Cleveland, from Howden Street to Wood Street to remove some dead end mains. The 4-inch main north on Wood Street is also recommended for replacement with an 8-inch main to improve the fire protection in the area.

Northeast corner of the City - In the northeast corner of the City, the transmission and available fire flow are lacking. Along with transmission improvements, the existing transmission main on Delano Avenue and Hackley Avenue should be connected to the local distribution mains at several locations to increase the capacity of the distribution system. These connections are recommended to increase the available fire flow to 1,000 gpm for residential customers.

Columbia Avenue between Sanford Street and Seventh Street – The available fire flow in this area is lacking primarily due to the existing 4-inch main. To improve the fire protection, we recommend the 4-inch mains be replaced with 8-inch main.

Baker Street area from Hovey Avenue to Hume Avenue – The available fire flow in this area is lacking primarily due to the existing 4-inch main. To improve the fire protection, we recommend the 4-inch mains be replaced with 8-inch main.

Hume Avenue from Jefferson Street to Sixth Street - The available fire flow in this area is lacking primarily due to the existing 4-inch main. To improve the fire protection, we recommend the 4-inch mains be replaced with 8-inch main.

Model simulations were performed including each of the potential improvements, as well as other alternatives. Simulation results with recommended improvements and Year 2034 demands are summarized in Table 17.

Results show that the available fire flows in the system meet the desired flows for fire protection for the City of Muskegon Heights in many cases and not in other.

VI. RELIABILITY ISSUES

A. Distribution Main Condition Assessment

The hydrant testing in the field indicated that there are significant hydraulic losses on some distribution mains. This may be isolated to a few specific distribution mains or may be widespread. In addition, the source of the hydraulic losses is not certain since there is no evidence of significant tuberculation nor has the City found closed or inoperable valves when they have searched. To better ensure the reliability of system hydraulics, a thorough evaluation of those hydraulic losses is necessary.

B. Redundancy

Redundancy is a critical issue in a complex system such as the City's. Currently, there are several areas that could be improved for better reliability:

- Connection of transmission mains that currently serve the customer communities to the distribution mains on Oakwood Avenue, Delano Avenue and Broadway Avenue to the existing distribution system.
- Construction of additional transmission main

Otherwise, the system is looped well within the City, providing adequate hydraulics during emergencies.

C. Deteriorating Mains

Most of the mains in the City of Muskegon Heights water distribution system were constructed prior to 1970. Hydrant test results indicate that many have reduced capacity due to tuberculation. These older mains and services should be systematically replaced in conjunction with other utility work and whenever possible.

D. Hydrants

With older mains and less than desirable capacity, hydrants become more critical. We recommend adding hydrants at several locations within the City to improve service during a fire. Specific location identified includes: Muskegon Heights High School (Hovey Avenue & Jefferson Street), Muskegon Heights Junior High School (Baker Street north of Manahan Avenue),Waalkes Street & Maplewood Avenue, Oakwood Avenue & Glendale Street, Lincoln Avenue west of Lemuel Street, Maffett Street north of Maplewood Avenue, Oakwood Avenue & Glade Street, Hackley Avenue west of Getty Street, Hovey Avenue west of 7th Street.

E. Emergency Interconnects

The City of Muskegon Heights has always provided substantial reliability of water supply to customers via interconnects. At present, there are 14 interconnects. Six of those interconnects are connected directly to the City of Norton Shores or Fruitport Charter Township. These are listed in Table 19.

Once the City of Norton Shores and Fruitport Charter Township are no longer customers, we would recommend that the City maintain the existing connections to the City of Norton Shores for emergency purposes.

F. Maintaining Multiple Facilities

The City has more than enough storage volume and high service pumping capacity to supply future 2034 demands. Since the City has storage and high service pumping at the Water Filtration Plant and Sherman Boulevard Storage Tank and Booster Station, consideration should be given as to whether to continue to maintain all the current infrastructure once the customer communities are not served. This is also discussed in the 2014 Report “Water Filtration Plant Reliability Study for City of Muskegon Heights”.

The current infrastructure provides excellent reliability and redundancy; yet maintaining facilities is costly and there are also interconnects that are available in an emergency. Modeling results indicate that some additional transmission and connections would be needed if the Sherman storage tank and booster station were abandoned. Thus, it is recommended that these long term improvements be considered based on maintenance needs.

G. Backup Power

The City of Muskegon Heights owns and operates two generators to provide emergency back-up power. The generators are located at the Water Treatment Plant and at the Getty Street Booster Station. These sites are maintained by City staff and the generators are started weekly to assure that the unit is in "ready" condition. In addition, both generators are load tested monthly. Both the Water Treatment Plant and the Getty Street Booster Station can be operated in an emergency using the generators however the Water Treatment Plant capacity is reduced to 10 MGD. To provide additional back-up power both the Water Treatment Plant and the Sherman Street Pump Station are provided with dual electrical feeds.

H. Maintenance Programs

The City of Muskegon Heights provides operation and maintenance services on the distribution system. Specific maintenance programs for reliability include:

1. Water Accountability Plan

The City tracks monthly water meter readings in detail, comparing pumping volumes with billing data. This includes detailed accounting of all meters to each of the customer communities. The unbilled volume of water has ranged from 30 percent to

39 percent in recent years, as shown in Table 18 and represented graphically in Figure 6. The unbilled water had been relatively steady.

This is a high volume of water and is significantly higher than typical acceptable standards.. However, this could change once the customer communities are no longer supplied and a detailed accountability program is in place. Other known unbilled water use such as hydrant flushing, street sweeping, firefighting, and main breaks are not estimated at present. These can represent a substantial volume and should be tracked to better gauge how much water is "lost" since this can have a significant financial impact. The City should move forward with this accountability program to ensure the financial viability of the system.

2. Meter Testing/Replacement Program

The City currently has an effective meter change out program. Approximately 300 meters are replaced each year. In addition, meters are tested at the request of customers or as circumstances arise. In 2013, thirty residential (5/8") meters were tested for accuracy and all but three were found to be within the established guidelines. These three meters were removed from service and tested to adjust the water use for the accountability program. Large meters have not been tested in the past, but the City plans to begin such testing in 2014.

3. Valve Exercising and Hydrant Flushing Program

Valve exercising enhances the reliability of the system and improves public protection. Hydrant flushing improves water quality while also improving system reliability.

The City currently has a valve exercising and hydrant flushing program in place. The City is divided into five (5) sections, one of which is addressed in full each year over a 5-year cycle. Valves are operated and hydrants are flushed in one of the five sections each year. In addition, dead end hydrants are flushed both in the spring and fall each year.

4. Cross Connection Control Program

The City maintains a Cross-Connection Control Program in accordance with the MDEQ rules and regulations. A Cross-Connection Control Ordinance was adopted in 1965 (Chapter 82, Division 3, Sections 82.76 – 82.81).

I. Main Depth

The winter of 2014 brought some of the most consistent cold weather the area has seen. Temperatures were below freezing most of the winter, resulting in additional maintenance work on water systems throughout the northern United States–especially where the water services are shallow and systems with large elevated tanks. Colder weather creates a deeper frost line and shallow service mains freeze more frequently.

Muskegon Heights had many frozen services over the winter of 2013 due to the shallow depths. More specifically, many services were 3 or 4 feet deep in the southwestern portions of the system.

We recommend replacing any City mains that are shallow when feasible, and providing public educational materials regarding how to reduce the likelihood of a water service freezing.

J. Emergency Response (Water Shortage Response) Plan

The City of Muskegon Heights currently does not have a specific water shortage response plan. The City's existing contingency plan does not address necessary actions if there is no water available. If there is an emergency that does not impact the City of Muskegon, the interconnect between the City's would be opened.

We recommend the City prepare a Water Shortage Response Plan for MDEQ approval.

VII. RECOMMENDATIONS FOR IMPROVEMENTS

The following categories of improvements to the City's water system were used to prioritize the recommended system improvements.

A. Recommended Projects

These projects will improve the level of service to City customers by improving system transmission and increasing fire protection in areas that have less than suggested available fire flow.

Short-Term (0-5 Years)

Project 1: Replace 2200 feet of 4-inch and 6" main with 12-inch main on Keating Avenue between Park Street & 5th Street

Project 2: Replace 1900 feet of 4-inch main with 8-inch main in the alley between 6th Street & 7th Street from Barney Avenue to Keating Avenue

Project 3: Replace 2700' of 6" main with 12" main in alley between Ray Street & Getty Street from Hume Avenue to Delano Avenue

Project 4: Construct 3,200' of 8" main on Cleveland Avenue, Howden Street to Wood Street, north to Summit Avenue and northwest and west on Collins Avenue

Project 5: Add Hydrants: Muskegon Heights High School (Hovey Avenue & Jefferson Street), Muskegon Heights Junior High School (Baker Street north of Manahan Avenue),Waalkes Street & Maplewood Avenue, Oakwood Avenue & Glendale

Avenue, Lincoln Avenue west of Lemuel Street, Maffett Street north of Maplewood Avenue, Oakwood Avenue & Seaway Drive, Hackley Avenue west of Getty Street, Hovey Avenue west of 7th Street.

Project 6: Connect Oakwood Avenue, Delano Avenue and Hackley Avenue transmission mains to distribution mains that cross at intersections.

Project 7: Replace 800 feet of 6-inch main with 12-inch main on Barney Avenue from Dyson Street to Getty Street

Project 8: Replace 350 feet of 6-inch main with 12-inch main on Hume Avenue between Ray Street and Getty Street

Long-Term (5-20 years)

Project 9: Replace 700 feet of 2-inch main with 8-inch main on Ray Street between Hume Avenue and Sherman Boulevard

Project 10: Replace 1100 feet of 8-inch main with 12-inch main on Getty Street between Broadway Avenue and Sherman Boulevard

Project 11: Replace 3800 feet of 4-inch and 6-inch main with 12-inch in Sanford Street from Norton to Broadway Avenue

Project 12: Replace 1100 feet of 4-inch main with 8-inch main in 7th Street and 5th Street from Summit Avenue to Broadway Avenue

Project 13: Replace 1100 feet of 6-inch main with 12-inch transmission main on Norton Avenue between alley east of Glade Street and Park Street

Project 14: Replace 7100 feet of 6-inch main with 12-inch transmission main on alley east of Glade Street from Norton Avenue to Barney Avenue

Project 15: Replace 2000 feet of 4-inch main with 8-inch main in Leahy Street from Sherman Boulevard to Barney Avenue

Project 16: Replace 4500 feet of 6-inch main with 12-inch main on Sherman Boulevard between Glade Street & 5th Street and Jarman Street & Getty Street

Project 17: Replace 2300 feet of 4-inch main with 8-inch main from Norton Avenue & Hoyt Street to Mona Lake Park

Project 18: Replace 2300 feet of 8-inch main on Broadway Avenue from Seaway Drive to 8th Street and Hoyt Street to Reynolds Street

B. General Recommendations

1. Perform Detailed Investigate of System Losses

A high priority recommendation is to thoroughly investigate the system to determine the source of the significant hydraulic losses. This would include measuring pressures and flows at adjacent locations to quantify losses. This process will identify whether the hydrant flow limitations are as extensive as determine by the calibration in this study. Record plans may also be reviewed as part of this process. A detailed plan of approach should be prepared.

2. Water Accountability Plan (Year 2014-15)

The City should expand the water accountability program, reviewing all potential sources of unbilled (and billed) water use. Tracking the unbilled water will enable the City to confirm whether a significant source of lost revenue exists and must ultimately be identified.

3. Replace Older, Deteriorating Mains (Year 2014-2034)

Some older, deteriorating mains were addressed with specific recommended projects (Projects #2, #9, #12, #13 and #15). At present, the remaining older 4- and 6-inch mains are either still able to pass the minimum desired flow for fire protection or can be sufficiently served by nearby hydrants (the fire department has 3 trucks, each with a 1,000 foot long 4” or 5” diameter hose. These small diameter mains are therefore not all considered deficient under current conditions. However, the City should

continue its effort to replace all old distribution mains, as well as any other deteriorating mains, with 8-inch mains.

Replacement of other old, small-diameter main should be done in conjunction with other street and utility projects. Significant tuberculation may have occurred on some of these distribution mains; therefore, these should be replaced when other construction is completed in these areas.

4. Reliability Study (2019)

This report represents the 5 year update of the Water System Reliability Study. Given the uncertainty of growth, demand projections should be reviewed periodically. In addition, infrastructure and system operation should be evaluated as needed to ensure efficient and cost effective operation.

5. Other Maintenance Programs (2014-2034)

The City should continue current maintenance programs including hydrant flushing, valve exercising, meter changeout, cross-connection control and tank maintenance.

5. Water Shortage Response Plan (2014-2034)

The City should develop a Water Shortage Response Plan, which would be included or used in conjunction with the Emergency Response Plan.

6. Dead End Mains (2014-2034)

Dead end mains should be looped whenever possible. Water tends to become stagnant in dead end mains; this affects the quality of water provided to customers served by the main. Therefore, whenever feasible, dead end mains should be removed

by closing loops to improve the circulation of water and increase fire protection capability.

VIII. COST ESTIMATES

An Opinion of Project Costs has been prepared for each recommended project. Costs for projects of similar size and scope that have been constructed in western Michigan were reviewed for relevant information.

The water main cost estimates have been prepared including an allowance of approximately 25% above the estimated construction cost. This allowance is intended to include the cost of construction contingencies (issues which are presently unknown), legal fees, engineering design and construction services (including preliminary and final design, soil borings, topographic survey, bidding assistance, construction staking, compaction testing, construction observation and project administration during the entire project) and administrative expenses related to the project.

It has been assumed that land is available for construction of the described improvements. No provision has been made in the cost estimate for extraordinary cost of land or right-of-way purchase or easements.

Cost estimates are included in Table 20.

Appendix A

Tables

City of Muskegon Heights
Water System Reliability Study

Table 1
Historic Water Supply Data

Fiscal Year	Systemwide Average Day Pumpage (mgd)	Systemwide Maximum Day Pumpage (mgd)	Muskegon Heights Average Day Pumpage (mgd)	Muskegon Heights Maximum Day Pumpage (mgd)	Muskegon Heights Max/Avg Ratio
2009	5.9	10.9	1.6	3.0	1.9
2010	5.6	11.2	1.4	2.8	2.0
2011	5.2	11.6	1.4	3.1	2.2
2012	5.6	17.3	1.3	4.0	3.1
2013	5.2	12.2	1.3	3.0	2.3
5-year Avg	5.5	12.6	1.4	3.1	2.2

1. Data based on Monthly Operating Reports
2. Water Supply includes water to customer communities as well as the City.

City of Muskegon Heights
Water System Reliability Study

Table 2
Historic and Projected Populations

Year	Muskegon County [4]	City of Muskegon Heights	City of Norton Shores	Fruitport Township	Population of Supplied Communities
1970 [1]	157,426	17,304	22,271	10,214	49,789
1980 [1]	157,589	14,611	22,025	10,646	47,282
1990 [1]	158,983	13,176	21,755	11,485	46,416
2000 [1]	170,200	12,049	22,527	12,533	47,109
2010 [1]	172,188	10,856	23,994	13,598	48,448
2014 [2]	173,016	10,908	24,109	13,663	10,908
2015 [2]	173,223	10,921	24,138	13,680	10,921
2024 [2]	175,103	11,040	24,400	13,828	11,040
2034 [3]		11,173			11,173

Notes:
1. Population through 2010 based on United States Census data.
2. Population projections from West Michigan Shoreline Regional Development Commission (increase of 0.12% per year from 2012 through 2024).
3. Projected for Muskegon Heights based on the same 0.12% population increase through 2034
4. Muskegon County population data provided for informational purposes.
5. Shaded is not part of the service population
6. See Figure 2 for the location the future service area.

City of Muskegon Heights
Water System Reliability Study

Table 3
Existing Service Connections

Fiscal Year	Service Connections
Residential	3,918
Commercial/Industrial	730
Total	4,648

Note: Service Connection data provided by the City for 2013.

Table 4
Water Use Projections

Year	Demand Projections, mgd		
	Average Day	Maximum Day	Peak Hour
2014	1.40	3.49	6.11
2019	1.40	3.51	6.15
2024	1.41	3.50	6.18
2029	1.42	3.55	6.22
2034	1.43	3.58	6.26

Note: Projections based on population growth projection and historic per capita water use.

City of Muskegon Heights
Water System Reliability Study

Table 5
High Service Pump Data

Pump No.	Location	Capacity (MGD)	Design Total Dynamic Head (ft)	Motor (hp)	Year Installed
1	Water Filtration High Service Pumps to MH	4.5	162	75	1965
2		6.0	185	75	1965
3		2.0	142	125	1973
Firm Capacity		6.5			
5	Water Filtration High Service Pumps to NS & FCT	5.0	210	250	2002
6		5.0	210	250	2002
7		5.0	210	250	2002
8		5.0	210	250	2002
Firm Capacity		15.0			
Pump 1	Sherman Boulevard Pumps to MH	2.00	155	100	1965
Pump 2		6.00 *	155	200	1941
Pump 3		2.20	152	75	1965
Pump 4		4.00 *	180	150	1941
Firm Capacity		8.2			
Pump 1	Getty Street Booster Station to NS/FCT	2.59	48	30	2002
Pump 2		2.59	48	30	2002
Pump 3		2.59	48	30	2002
Firm Capacity		5.18			

Notes: 1. Sherman Boulevard Pump 2 and 4 are currently not in operation due to a valve issue.

2. Data obtained from the June 2014 Water Filtration Plant Reliability Study.

City of Muskegon Heights
Water System Reliability Study

Table 6
Treatment Plant Element Capacities

Element	Number of Units	Rated Capacity (MGD)
Intake	2	50.8
Low Service Pumps	6	25.3
Rapid Mix	2	NA
Flocculation Basins	6	38.02
Filters	12	25.20
High Service Pumps	7	35.48

City of Muskegon Heights
Water System Reliability Study

Table 7
Existing Pump Stations

Site / Location	Old High Service Station at WTP	New High Service Station at WTP	Sherman Booster	Getty Street Booster
Pumps	3	4	4	3
Year Installed	1965	2000	1941	2002
Type	Vertical Turbine	Vertical Turbine	Centrifugal	Centrifugal
Permit Capacity	4,500 gpm	10,420 gpm	6,390 gpm	2 @ 1800 gpm
Horsepower	1 @ 250 hp 1 @ 150 hp 1 @ 100 hp	250 hp each	1 @ 200 hp 1 @ 150 hp 1 @ 100 hp 1 @ 75 hp	30 hp each
Last Inspection				
Last Efficiency Test				
Auxiliary Power Type	WTP Generator / Dual Feed	WTP Generator / Dual Feed	Dual Feed	Generator
Auxiliary Power Rating	500 KW	500 KW	275 KW	80 KW
Auxiliary Power Fuel Type	Diesel	Diesel	NA	Natural Gas
Auxiliary Power Capacity			1500 gpm	5400 gpm
Auxiliary Power Starting Freq.	Weekly	Weekly		Weekly
Auxiliary Power Load Testing	Monthly	Monthly		Monthly

City of Muskegon Heights
Water System Reliability Study

Table 8
Existing Storage Facility Data

Tank Site / Location	Sherman Boulevard (East)	Sherman Boulevard (West)	Getty Street
Volume, Gallons	1,000,000	500,000	750,000
Usable Storage, Gallons	1,000,000	500,000	750,000
Type	Ground	Ground	Multi-leg Elevated
Date Constructed	1941	1941	1964
Last Inspection	11/2005	11/2005	05/2007
Last Painted Interior	NA	NA	2000
Last Painted Exterior	NA	NA	2000
Tank Drain	Portable Pump	Portable Pump	Hydrant
Cathodic Protection	N/A	N/A	Yes
Altitude Valve	No	No	Yes, Not Used
Overflow Elev, ft			767
Total Head Range, ft	10	10	35
Normal HW Level, ft	35	35	23
Normal LW Level, ft	30	30	35
Normal Operating Range, ft	5	5	12

City of Muskegon Heights
Water System Reliability Study

Table 9
Water Main Sizes and Lengths

Water Main Diameter (inches)	Approximate Length of Water Main (feet)	Approximate Length of Water Main (miles)	Percentage of Total (%)
4	30,224	5.7	9.6
6	191,556	36.3	60.6
8	9,400	1.8	3.1
10	30,300	5.7	9.6
12	13,380	2.5	4.1
14	13,500	2.6	4.3
16	4,145	0.8	1.3
18	8,139	1.5	2.6
20	5,800	1.1	1.8
24	6,520	1.2	2.1
30	2,920	0.6	0.9
Total	315,884	59.8	100

Source: City of Muskegon Heights MDEQ Sanitary Survey and 2014 WaterCAD V8i Model.

Table 10
Water Main Materials

Type Distribution	Approximate Length of Water Main (feet)	Approximate Length of Water Main (miles)	Percentage of Total (%)
Cast Iron	154,768	29.3	49
Ductile Iron	157,957	29.9	50
Concrete	3,159	0.6	1
Total	315,884	59.8	100

Source: City of Muskegon Heights MDEQ Sanitary Survey

City of Muskegon Heights
Water System Reliability Study

Table 11
Approximate Water Main Age

Year Installed	Approximate Length of Water Main (feet)	Approximate Length of Water Main (miles)	Percentage of Total (%)
1900-1930	140,618	26.6	44.5%
1931-1959	6,300	1.2	2.0%
1960-1979	152,732	28.9	48.3%
1980-1999	11,853	2.3	3.8%
2000-2014	4,381	0.8	1.4%
Total	315,884	59.8	100.0%

Source: Estimates based on information provided by City personnel

City of Muskegon Heights
Water System Reliability Study
Table 12
Storage Analysis Summary

Year	Firm Pump Capacity (gpm)	Maximum Day Demand (gpm)	Peak Hour Demand (gpm)	Suggested Fire-Flow[1] (gpm)	Duration[1] (hours)	Water Supplied[2] (gallons)	Typical Customer Demand[3] (gallons)	Fire Demand[4] (gallons)	Recommended Storage Vol. (gallons)	Storage Volume Provided (gallons)	Recommended Additional Storage Vol. (gallons)
2014	15050	2424	4242	1000	2	1806000	400000	120000	0	2250000	0
2014	15050	2424	4242	2500	2	1806000	400000	300000	0	2250000	0
2014	15050	2424	4242	3500	3	2709000	545000	630000	0	2250000	0
2024	15050	2458	4293	1000	2	1806000	405000	120000	0	2250000	0
2024	15050	2458	4293	2500	2	1806000	405000	300000	0	2250000	0
2024	15050	2458	4293	3500	3	2709000	553000	630000	0	2250000	0
2034	15050	2487	4345	1000	2	1806000	410000	120000	0	2250000	0
2034	15050	2487	4345	2500	2	1806000	410000	300000	0	2250000	0
2034	15050	2487	4345	3500	3	2709000	559000	630000	0	2250000	0

Notes:
1. Fire demand and duration based on Table 1-1 of AWWA M-31 Manual
2. Water Supply Volume based on firm capacity for the given duration
3. Customer Demand Volume based on one hour of peak demand and maximum day demands for the remaining duration.
4. Emergency Storage based on Fire Flow Demand over the duration.
5. Example Calculation: Year 2034

   Firm Pump Capacity = 15050gpm (High Service Pump Firm Capacity)
   Maximum Day Demand = 2034 projected max day demand (3.58 mgd) ÷ 24hrs/day ÷ 60min/hr = 2,487 gpm
   Peak Hour Demand = 2034 projected peak hour demand (6.26 mgd) ÷ 24 ÷ 60 = 4,345 gpm
   Water Supplied = firm pump capacity x duration = 15050gpm x 2hrs x 60min/hr = 1,806,000 gal
   Typ Customer Demand=1hr of peak hour demand+1hr of max day demand=1hr x 4242 gpm + 1hr x 2424gpm = 410,000 gal
   Fire Demand = standard fire flow x duration = 1000gpm x 2hr x 60min/hr = 120,000gal
   Recommended Stor Vol = Typ. Customer Demand + Fire Demand - Water Supplied = 410,000 + 120,000 – 1,806,000 < 0 gal (firm cap > demands)
   Storage Volume Provided = total of two storage tanks = 2,250,000 gallons
   Recommended Additional Storage Volume = Recommended Storage Volume - Storage Volume Provided = 0

City of Muskegon Heights
Water System Reliability Study

Table 13

Hydrant Test Results

Hydrant Test No.	Time	Static Hydrant Location(s)	Hydrant Flow (gpm)	Static Pressure (psi)	Residual Pressure (psi)	Pumps Operating		Tank Level (ft)	
						Filtration Plant	Sherman PS	Getty	Sherman
1	8:40 AM	Maplewood Ave. between Seaway Dr. & Lemuel St.	790	54	31	#3	#3	37.7	14.8
2	9:01 AM	Summit Ave. & Ninth St.	740	55	48	#3	#3	37.7	14.8
3	10:20 AM	Amsterdam Ave. & Sanford St.	120	54	26	#3	#3	35.5	14.8
4	10:54 AM	Overbook St., Third West Hydrant from Woodcliff Dr.	640	54	34	#3	#3	34.5	14.8
5	11:13 AM	Sherman Ave. & Ray St.	875	60	40	#3	#3	34.0	14.8
6	1:25 PM	Hackley Ave. & Park St.	760	55	26	#3	#3	30.0	14.7
7	2:05 PM	Hoyt St. & Keating Ave.	490	53	45	#3	#3	27.4	14.4
8	2:20 PM	Keating Ave., east of Mcilwraith St.	780	52	38	#3	#3	26.5	14.3
9	2:45 PM	Hoyt St. & Maplewood	1250	64	58	#3	#3	24.9	14.1

Notes: Hydrant tests were performed on May 1, 2014

City of Muskegon Heights
Water System Reliability Study

Table 14
Comparison of Calibrated Model to Field Test Pressures

Test No.	Model Node No.	Static Hydrant Location(s)	Hydrant Test Flow (gpm)	Field Tests			Model Results			Percent Difference
				Static Pressure, psi	Residual Pressure, psi	Available Fire Flow at 20 psi (gpm)	Static Pressure, psi	Residual Pressure, psi	Available Fire Flow at 20 psi (gpm)	
1	J706	Maplewood Avenue between Seaway Drive & Lemuel Street	790	54	31	976	54	27	895	-8%
2	J273	Summit Avenue & Ninth Street	740	55	48	1765	57	48	1588	-10%
3	J718	Amsterdam Avenue & Sanford Street	120	54	26	133	54	27	136	2%
4	J608	Overbook Street, third West Hydrant from Woodcliff Drive	640	54	34	852	52	36	931	9%
5	J585	Sherman Avenue & Ray Street	875	60	40	1272	61	36	1143	-10%
6	J430	Hackley Avenue & Park Street	760	55	26	841	55	25	826	-2%
7	J228	Hoyt Street & Keating Avenue	490	53	45	1053	52	45	1113	6%
8	J238	Keating Avenue, east of Mcilwraith Street	780	52	38	1219	52	41	1388	14%
9	J179	Hoyt Street, north of Seaway Drive	1250	64	58	3666	64	59	4045	10%

Notes: 1. Hydrant tests were performed on May 1, 2014.

2.Simulations assume Pump #3 operating at WTP and Pump #3 at the Sherman Pump Station

City of Muskegon Heights
Water System Reliability Study

Table 15
Model Results for Existing Conditions

Jct Number	Location	Description	Pressure (psi)		Available Fire Flow (gpm)
			Average Day Demands	Maximum Day Demands	
J-523	Muskegon Heights High School	School	62	54	180
J-486	Muskegon Heights Middle School	School	65	58	1,360
J-93	Martin Luther King Elementary School	School	60	52	2,680
J-229	Charles A. Lindbergh Elementary School	School	60	52	3,230
J-418	Ellen Grace Loftis Elementary School	School	64	55	280
J-518	Glendale Elementary School	School	60	52	2,640
J-460	Edgewood Elementary School	School	64	57	1,720
J-2	Dana Corporation	Industrial	62	54	2,420
J-46	Lift-Tech International	Industrial	63	51	1,260
J-117	Webb Chemical Services Corporation	Industrial	64	57	3,200
J-384	Columbia Court Apartments	Residential	64	57	1,450
J-704	Amsterdam & Ninth	Residential	57	46	540
J-398	Oakwood & Mona	Residential	57	45	520
J-701	Lincoln & Waalkes	Residential	56	45	530
J-5	Leahy just south of Hovey	Residential	62	54	180

Notes:
1. Average Day and Max Day Demand Pressures are based on tanks 5' below the top.
2. Available Fire Flows are based on maximum day demands and with one pump operating at WTP
3. ISO typically suggests an available fire flow 1,000-1,500 gpm for Residential Areas. The recommended available fire flows represents that necessary for full credit toward insurance rating, but is not required.
4. Locations represent the extremities of the system plus other important locations within the City.

City of Muskegon Heights
Water System Reliability Study

Table 16
Model Results for Year 2034 Demands with Existing Infrastructure

Jct Number	Location	Description	Pressure (psi)		Available Fire Flow (gpm)
			Average Day Demands	Maximum Day Demands	
J-523	Muskegon Heights High School	School	62	54	240
J-486	Muskegon Heights Middle School	School	65	57	1,320
J-93	Martin Luther King Elementary School	School	60	52	2,610
J-229	Charles A. Lindbergh Elementary School	School	60	52	3,160
J-418	Ellen Grace Loftis Elementary School	School	64	54	370
J-518	Glendale Elementary School	School	60	52	2,580
J-460	Edgewood Elementary School	School	64	56	1,730
J-2	Dana Corporation	Industrial	62	54	2,380
J-46	Lift-Tech International	Industrial	63	50	1,230
J-117	Webb Chemical Services Corporation	Industrial	64	56	3,960
J-384	Columbia Court Apartments	Residential	64	56	1,420
J-704	Amsterdam & Ninth	Residential	57	45	510
J-398	Oakwood & Mona	Residential	56	45	460
J-701	Lincoln & Waalkes	Residential	56	44	500
J-5	Leahy just south of Hovey	Residential	62	54	250

Notes:
1. Average Day and Max Day Demand Pressures are based on tanks 5' below the top.
2. Available Fire Flows are based on maximum day demands and with one pump operating at WTP
3. ISO typically suggests an available fire flow 1,000-1,500 gpm for Residential Areas. The recommended available fire flows represents that necessary for full credit toward insurance rating, but is not required.
4. Locations represent the extremities of the system plus other important locations within the City.

City of Muskegon Heights
Water System Reliability Study

Table 17
Model Results for Year 2034 Demands with Recommended Projects

Jct Number	Location	Description	Pressure (psi)		Available Fire Flow (gpm)
			Average Day Demands	Maximum Day Demands	
J-524	Muskegon Heights High School	School	65	59	6,000
J-486	Muskegon Heights Middle School	School	65	59	1,790
J-93	Martin Luther King Elementary School	School	60	54	5,410
J-229	Charles A. Lindbergh Elementary School	School	61	54	5,730
J-418	Ellen Grace Loftis Elementary School	School	65	59	1,050
J-518	Glendale Elementary School	School	61	54	5,090
J-460	Edgewood Elementary School	School	69	63	2,500
J-2	Dana Corporation	Industrial	63	56	4,090
J-46	Lift-Tech International	Industrial	65	59	4,140
J-117	Webb Chemical Services Corporation	Industrial	64	59	5,770
J-384	Columbia Court Apartments	Residential	65	59	1,950
J-704	Amsterdam & Ninth	Residential	59	53	1,010
J-398	Oakwood & Mona	Residential	59	54	5,510
J-701	Lincoln & Waalkes	Residential	59	53	950
J-5	Leahy just south of Hovey	Residential	63	57	3,810

Notes:
1. Average Day and Max Day Demand Pressures are based on tanks 5' below the top.
2. Available Fire Flows are based on maximum day demands and with one pump operating at WTP
3. ISO typically suggests an available fire flow 1,000-1,500 gpm for Residential Areas. The recommended available fire flows represents that necessary for full credit toward insurance rating, but is not required.
4. Locations represent the extremities of the system plus other important locations within the City.

City of Muskegon Heights
Water System Reliability Study
Table 18
History of Total Unbilled Water

Year	Total Metered, million gallons	Billed Volume, million gallons	Percent Unbilled Water
2004	499.000	318.875	36.1%
2005	700.673	536.997	23.4%
2006	674.748	501.578	25.7%
2007	655.880	469.1596	28.5%
2008	643.695	446.5529	30.6%
2009	562.107	369.119	30.3%
2010	484.263	347.728	30.5%
2011	492.161	297.721	39.1%
2012	437.916	-	-
2013	432.504	-	-

Note: Billing Data not available for 2012-13.

City of Muskegon Heights
Water System Reliability Study

Table 19
Interconnects

Location	Main Size	Metered	Status	Community
Water Treatment Plant	20”	2002 Mag	Regular	Norton Shores
Seminole & McCracken	30”x12”		Emergency [1]	Norton Shores
Seminole & Henry	24”x12”	8-inch	Emergency	Roosevelt Park
Getty & Norton	18”x16”	8-inch	Emergency [1]	Fruitport Twp
Broadway & Getty	14”x12”	8-inch	Emergency [1]	Norton Shores
Broadway & Glade (Seaway)	8”x8”	6-inch	Emergency [1]	Norton Shores
Seminole & Lake Harbor	30”x12”	none	Emergency [1]	Norton Shores
Glade (Seaway) & Oakwood	10”x10”	none	Emergency [1]	Norton Shores
Hackley & Glade	10”x6”	none	Emergency	City of Muskegon
Park & Keating	6”x6”	none	Emergency	City of Muskegon
Keating & 5th Street Alley	36”x12”	none	Emergency	City of Muskegon
Keating McIlwraith	36”x6”	none	Emergency	City of Muskegon
Delano & Getty	14”x14”	none	Emergency	City of Muskegon
Barney & Getty	6”x6”	none	Emergency	City of Muskegon

Note: 1. In 2015, indirect regular connections to Fruitport Township and Norton Shores will become emergency connections
2. Valves for emergency connections are exercised annually.

City of Muskegon Heights
Water System Reliability Study

Table 20

Cost Opinions for Recommended Improvements

Improvement Project	Opinion of Probable Project Cost	Time Frame (Years)
P-1 Replace 2200' of 4" and 6" main with 12" main on Keating Avenue between Park Street & 5th Street	$ 250,000	2014-15
P-2 Replace 1900' of 4" main with 8" main in alley between 6th Street & 7th Street from Barney Avenue to Keating Avenue	$ 190,000	2014-15
P-3 Replace 2700' of 6" main with 12" main in alley between Ray Street & Getty Street from Hume Avenue to Delano Avenue	$ 310,000	2014-16
P-4 Construct 3,200' of 8" main on Cleveland Ave., Howden St. to Wood St., north to Summit Ave., and northwest and west on Collins Ave.	$ 300,000	2014-24
P-5 Add Hydrants at 9 locations	$ 60,000	2014-24
P-6 Connect Oakwood Avenue, Delano Avenue and Hackley Avenue transmission mains to crossing distribution mains	$ 320,000	2015-24
P-7 Replace 800' of 6" main with 12" main on Barney Avenue from Dyson Street to Getty Street	$ 60,000	2016
P-8 Replace 350' of 6" main with 12" main on Hume Avenue between Ray Street and Getty Street	$ 40,000	2017
P-9 Replace 700' of 2" main with 8" main on Ray Street between Hume Avenue and Sherman Boulevard	$ 70,000	2019-24
P-10 Replace 1100' of 8" main with 12" main on Getty Street between Broadway Avenue and Sherman Boulevard	$ 130,000	2019-24
P-11 Replace 3800' of 4" and 6" main with 12" in Sanford Street from Norton Avenue to Broadway Avenue	$ 430,000	2019-24
P-12 Replace 1100' of 4" main with 8" main in 7th Street and 5th Street from Summit Avenue to Broadway Avenue	$ 220,000	2019-24
P-13 Replace 1100' of 6" main with 12" main on Norton Avenue between all e. of Glade Street and Park Street	$ 130,000	2019-24
P-14 Replace 7100' of 6" main with 12" main on Glade Street and alley from Norton Avenue to Barney Avenue	$ 800,000	2019-24
P-15 Replace 2000' of 4" main with 8" main in Leahy Street from Sherman Boulevard to Barney Avenue	$ 200,000	2024-29
P-16 Replace 4500 LF of 6" main with 12" main on Sherman Boulevard between Glade Street & 5th Street and Jarman Street & Getty Street	$ 500,000	2024-29
P-17 Replace 2300' of 4" main with 8" main from Norton Avenue & Hoyt Street to Mona Lake Park	$ 230,000	2029-34
P-18 Replace 2300' of 8" main on Broadway from Seaway Drive to 8th Street and Hoyt Street to Reynolds Street	$ 260,000	2029-34
Grand Total	$ 4,500,000	

Notes: 1. Opinion of Cost includes 25 percent allowance for legal and administrative costs, engineering and contingencies.

2. The Opinion of Cost is based on current dollars.

Appendix B

Figures

CITY OF MUSKEGON HEIGHTS
WATER DISTRIBUTION SYSTEM RELIABILITY STUDY

WATER DISTRIBUTION MAP

FIGURE 1

Prein&Newhof

2130684

CITY OF MUSKEGON HEIGHTS
WATER DISTRIBUTION SYSTEM RELIABILITY STUDY

SERVICE AREA BOUNDARY

FIGURE 2

Prein&Newhof

2130684

FIGURE 3

City of Muskegon Heights Water System
Population Data and Projection

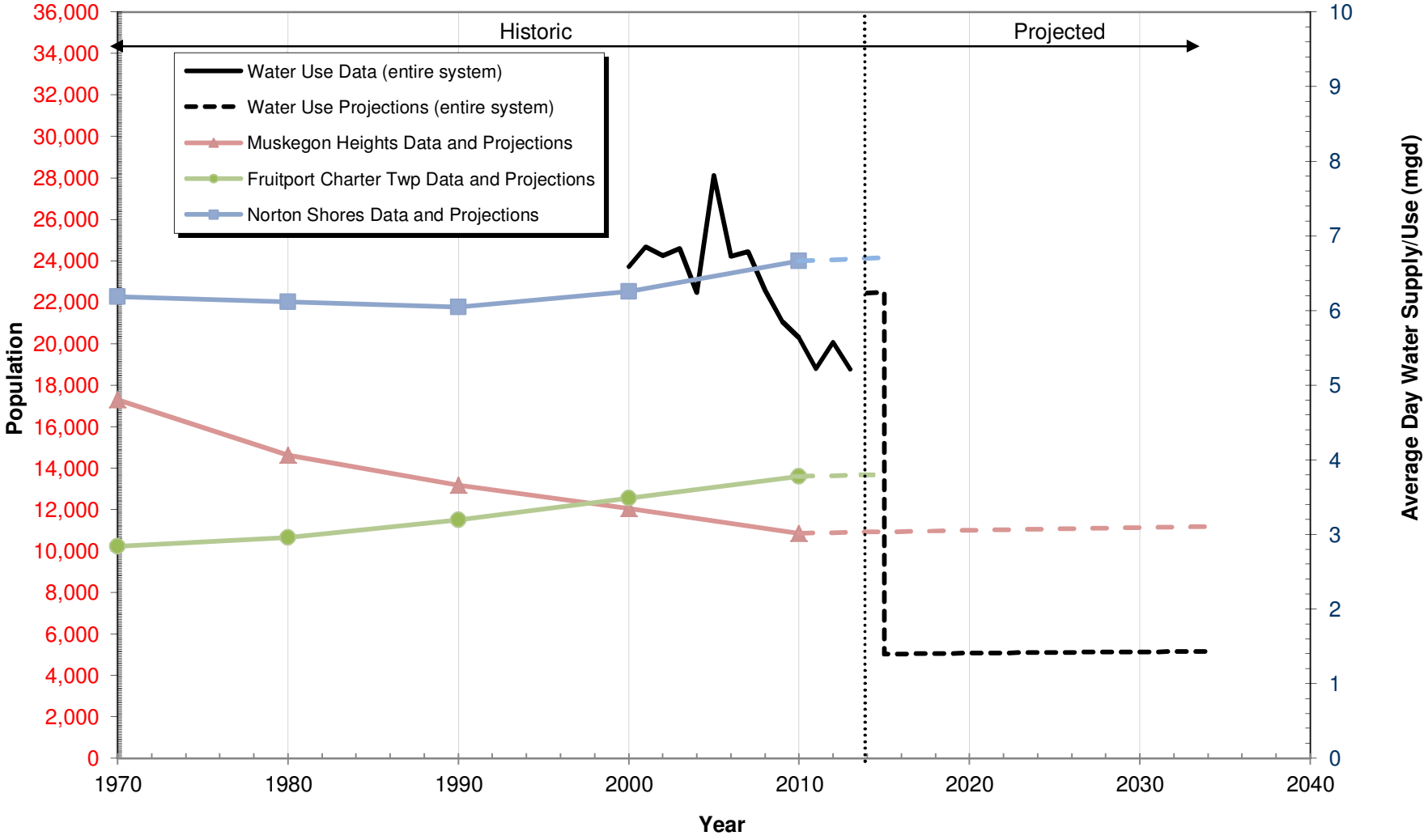
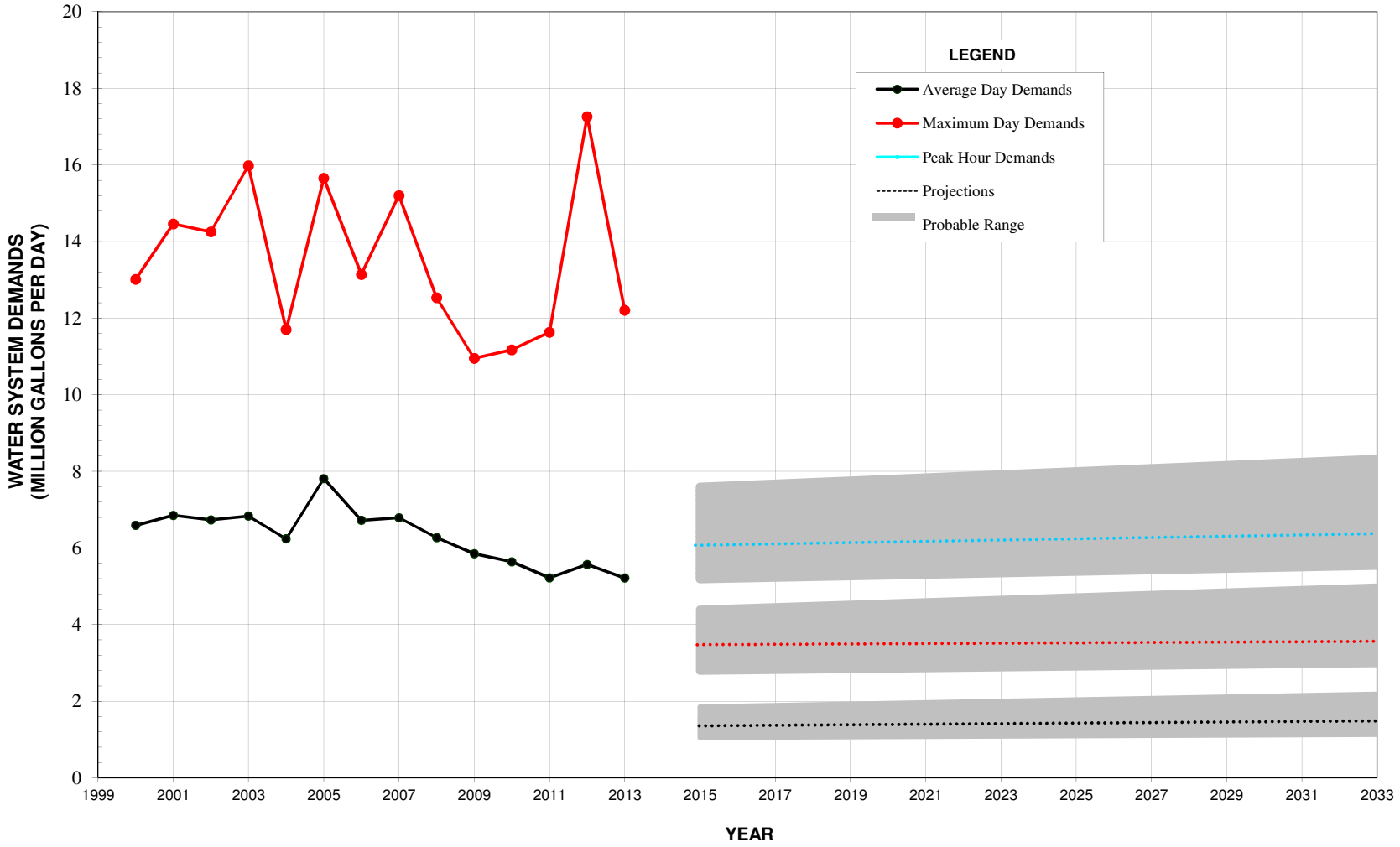
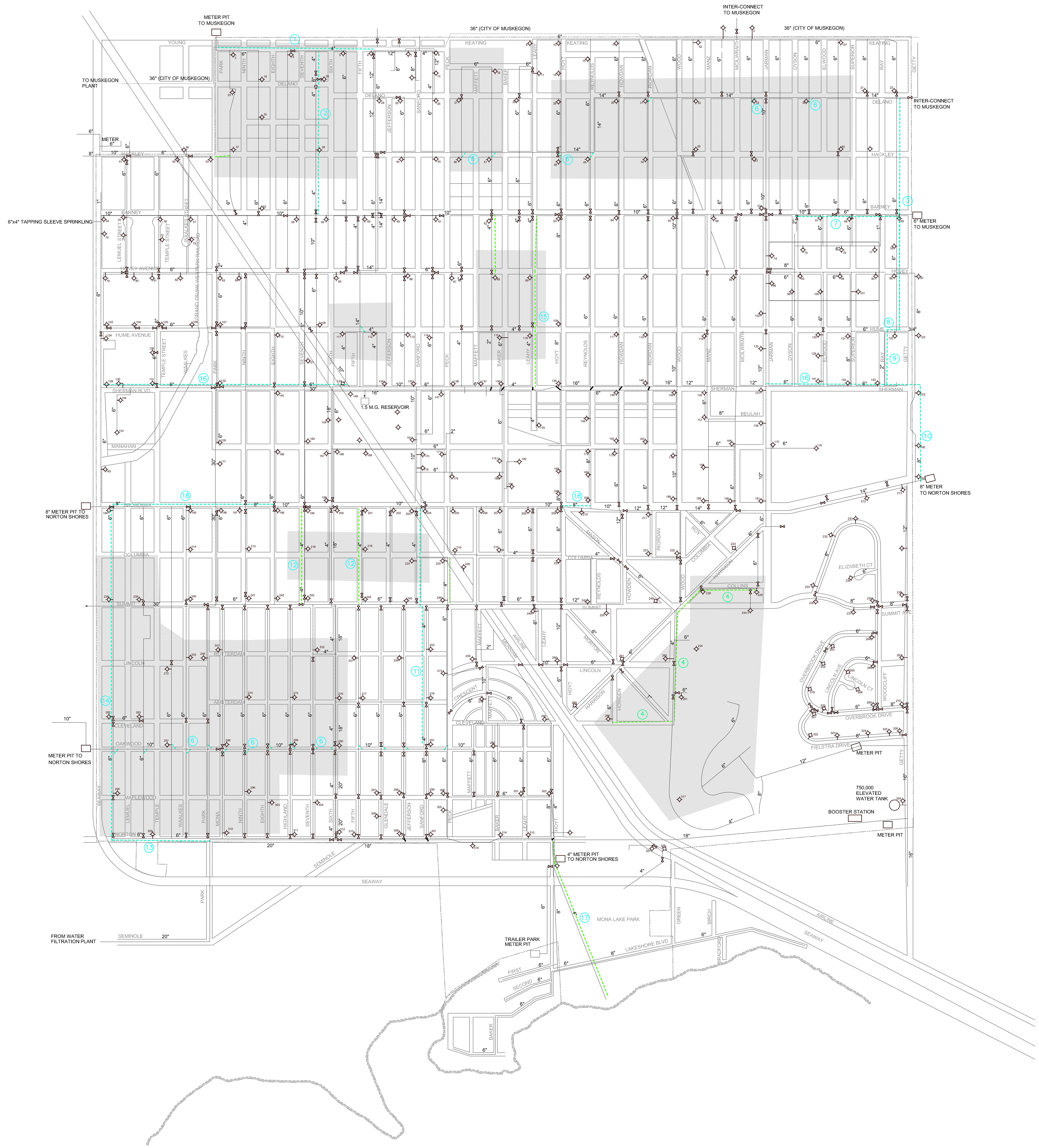
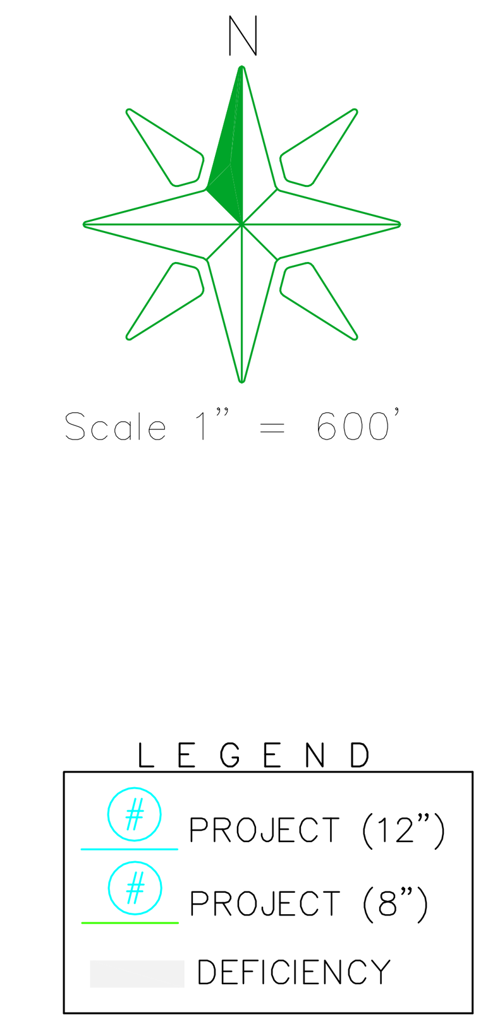


FIGURE 4

City of Muskegon Heights
Historic And Projected Water System Demands







CITY OF MUSKEGON HEIGHTS
WATER DISTRIBUTION SYSTEM RELIABILITY STUDY

GENERAL PLAN MAP

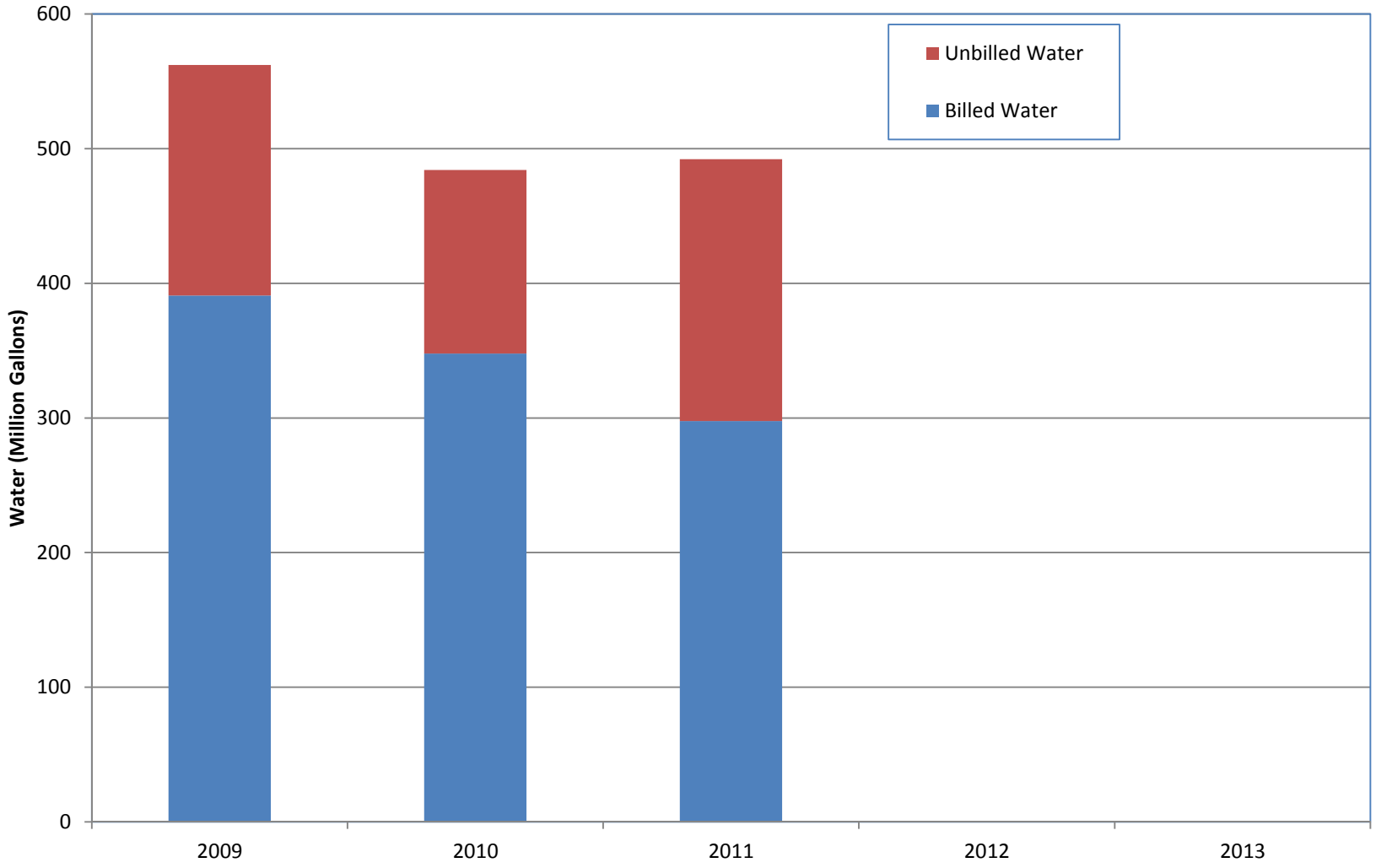
FIGURE 5

Prein&Newhof

2130684

FIGURE 6

City of Muskegon Heights
Historic Unbilled Water Data

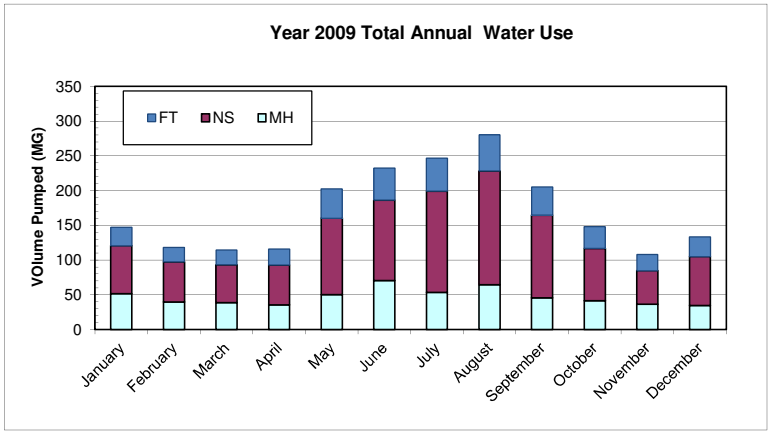


Appendix C

Monthly Water Supply Data

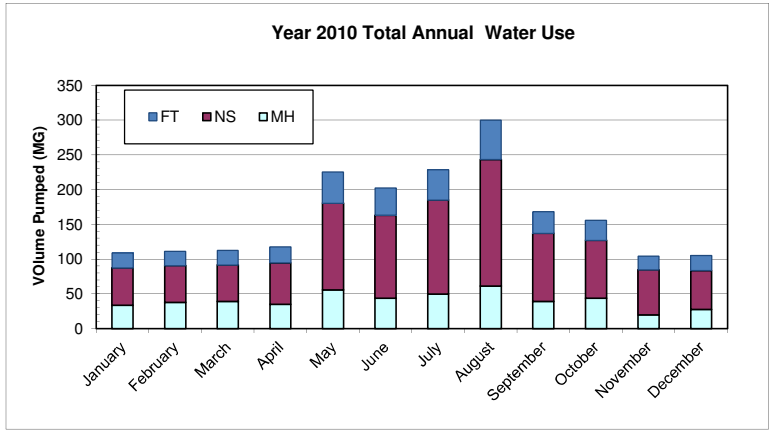
Annual Billing 2009

Month	MH	NS	FT	Total Output (mg)
January	51.652	69.025	26.459	147.136
February	39.707	57.512	20.992	118.211
March	38.800	54.369	21.083	114.252
April	35.362	57.346	22.981	115.689
May	50.296	109.903	42.132	202.331
June	70.567	115.646	45.957	232.170
July	53.546	145.477	47.747	246.770
August	64.369	163.854	51.943	280.166
September	45.646	118.823	40.750	205.219
October	41.246	75.315	31.329	147.890
November	36.334	48.267	23.326	107.927
December	34.582	70.334	28.543	133.459
Total Yearly Volume Billed (mg)				2051.22
Average Daily Billed (mgd)				5.620
Total Yearly Volume Billed for MH (mg)				562.107
Average Day Billed for MH (mgd)				1.54



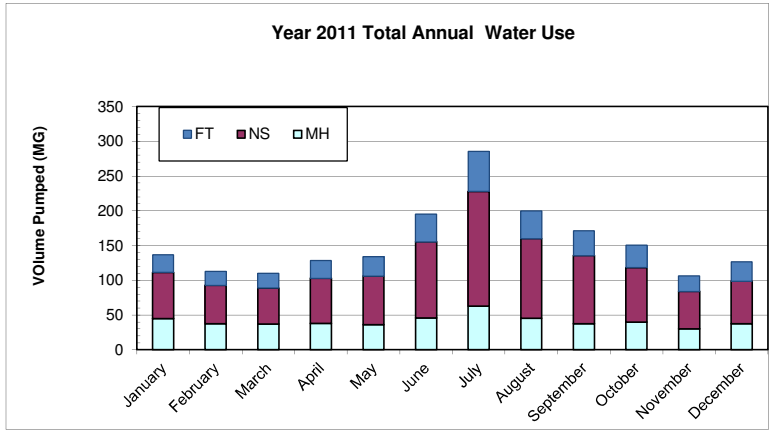
Annual Billing 2010

Month	MH	NS	FT	Total Output (mg)
January	33.603	53.577	21.804	108.984
February	37.737	52.795	20.428	110.960
March	38.951	52.486	20.931	112.368
April	35.028	59.278	23.380	117.686
May	55.377	124.831	45.188	225.396
June	43.505	119.598	38.977	202.080
July	49.741	135.252	43.713	228.706
August	61.014	182.199	56.826	300.039
September	38.842	98.187	31.177	168.206
October	43.419	83.496	28.914	155.829
November	19.743	64.691	19.877	104.311
December	27.303	56.014	21.639	104.956
Total Yearly Volume Billed (mg)				1939.52
Average Daily Billed (mgd)				5.314
Total Yearly Volume Billed for MH (mg)				484.263
Average Day Billed for MH (mgd)				1.33



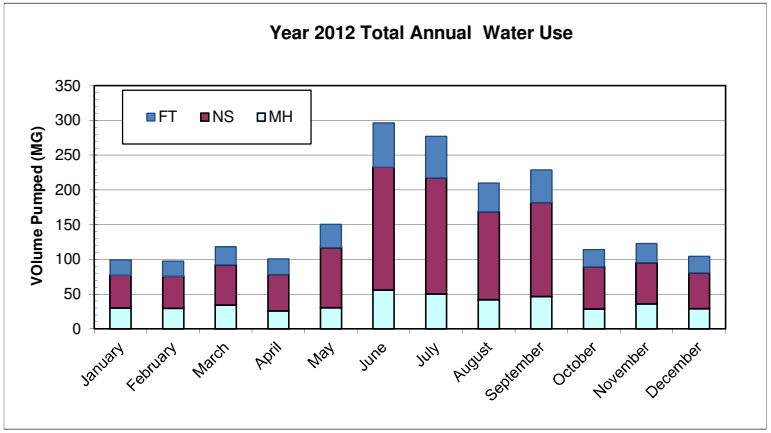
Annual Billing 2011

Month	MH	NS	FT	Total Output (mg)
January	44.746	66.556	25.254	136.556
February	37.581	54.948	20.316	112.845
March	37.175	51.615	21.048	109.838
April	38.08	64.746	25.422	128.248
May	36.175	69.904	27.982	134.061
June	45.823	109.435	39.832	195.090
July	62.942	164.786	57.89	285.618
August	45.23	114.597	39.963	199.790
September	37.479	97.952	35.703	171.134
October	39.608	78.568	32.323	150.499
November	29.91	54.024	22.411	106.345
December	37.412	61.151	28.254	126.817
Total Yearly Volume Billed (mg)				1856.84
Average Daily Billed (mgd)				5.087
Total Yearly Volume Billed for MH (mg)				492.161
Average Day Billed for MH (mgd)				1.35



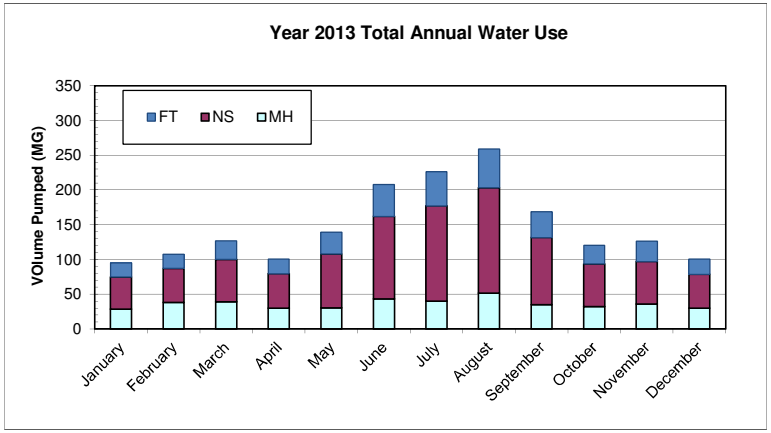
Annual Billing 2012

Month	MH	NS	FT	Total Output (mg)
January	29.934	47.272	21.944	99.150
February	29.292	46.389	21.867	97.548
March	34.150	57.558	26.235	117.943
April	25.995	52.125	22.359	100.479
May	30.592	85.983	33.839	150.414
June	55.576	177.024	63.711	296.311
July	50.444	166.822	59.615	276.881
August	41.929	126.549	41.562	210.040
September	46.584	135.273	46.710	228.567
October	28.361	60.966	24.567	113.894
November	36.018	58.922	28.010	122.950
December	29.041	51.255	24.014	104.310
			Total Yearly Volume Billed (mg)	1918.49
			Average Daily Billed (mgd)	5.256
			Total Yearly Volume Billed for MH (mg)	437.916
			Average Day Billed for MH (mgd)	1.20



Annual Billing 2013

Month	MH	NS	FT	Total Output (mg)
January	28.403	46.206	20.266	94.875
February	38.013	49.061	20.527	107.601
March	39.125	60.756	26.968	126.849
April	29.879	49.455	21.008	100.342
May	30.243	77.586	31.265	139.094
June	43.345	118.586	45.834	207.765
July	39.833	137.273	48.928	226.034
August	51.258	151.802	55.887	258.947
September	34.926	96.523	37.189	168.638
October	31.991	61.466	26.660	120.117
November	35.695	61.304	29.206	126.205
December	29.793	48.711	22.044	100.548
			Total Yearly Volume Billed (mg)	1777.02
			Average Daily Billed (mgd)	4.869
			Total Yearly Volume Billed for MH (mg)	432.504
			Average Day Billed for MH (mgd)	1.18



Appendix D

Model Input / Output

CITY OF MUSKEGON HEIGHTS
WATER DISTRIBUTION SYSTEM RELIABILITY STUDY

NODE NUMBERING

FIGURE A

Prein&Newhof

2130684

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL INPUT - EXISTING INFRASTRUCTURE

Label	Start Node	Stop Node	Diameter (in)	Approx Length (ft)	Hazen-Williams C
P-1	J-46	J-1	6	483	60
P-2	J-1	J-551	6	626	60
P-7	J-269	J-4	6	583	50
P-8	J-4	J-539	6	710	50
P-9	J-82	J-402	6	320	60
P-11	J-403	J-402	6	340	60
P-12	J-407	J-409	6	53	60
P-13	J-469	J-664	6	777	50
P-18	J-588	J-198	6	327	50
P-19	J-588	J-595	6	49	50
P-20	J-15	J-603	6	286	50
P-21	J-141	J-140	6	790	50
P-23	J-16	J-17	6	323	50
P-26	J-19	J-18	6	1,555	50
P-27	J-16	J-20	6	700	50
P-28	J-16	J-21	6	152	50
P-29	J-21	J-22	6	573	50
P-30	J-21	J-23	6	1,785	50
P-39	J-402	J-28	6	983	60
P-40	J-159	J-194	6	327	50
P-40	J-28	J-552	6	358	60
P-43	J-194	J-413	6	660	50
P-44	J-701	J-30	6	1,071	60
P-45	J-30	J-251	6	980	60
P-49	J-247	J-32	6	1,059	60
P-50	J-32	J-702	6	993	60
P-65	J-262	J-424	6	1,110	60
P-69	J-425	J-253	6	1,111	60
P-70	J-424	J-425	6	255	60
P-71	J-256	J-426	6	1,109	60
P-73	J-425	J-426	6	257	60
P-77	J-426	J-427	6	257	60
P-83	J-419	J-429	6	73	60
P-86	J-428	J-195	6	656	50
P-88	J-430	J-431	6	306	60
P-89	J-431	J-196	6	130	60
P-90	J-196	J-432	6	187	60
P-91	J-432	J-433	6	325	60
P-92	J-433	J-434	6	44	60
P-94	J-435	J-436	6	121	60
P-94	J-466	J-47	6	758	50
P-95	J-436	J-437	6	231	60
P-95	J-47	J-64	6	1,116	50
P-96	J-438	J-436	6	133	60
P-96	J-411	J-48	6	472	60
P-97	J-96	J-438	6	271	60

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL INPUT - EXISTING INFRASTRUCTURE

Label	Start Node	Stop Node	Diameter (in)	Approx Length (ft)	Hazen-Williams C
P-97	J-48	J-273	6	626	60
P-100	J-434	J-439	6	676	60
P-100	J-706	J-53	6	497	60
P-101	J-53	J-89	6	339	60
P-103	J-439	J-440	6	645	60
P-104	J-440	J-202	6	75	60
P-104	J-53	J-54	6	72	60
P-107	J-432	J-441	6	671	60
P-109	J-442	J-440	6	355	60
P-110	J-441	J-442	6	649	60
P-111	J-442	J-222	6	631	60
P-121	J-135	J-384	6	567	50
P-122	J-384	J-30	6	283	50
P-125	J-384	J-444	6	548	50
P-126	J-135	J-445	6	319	50
P-127	J-213	J-446	6	717	50
P-128	J-687	J-67	6	116	130
P-129	J-445	J-446	6	328	50
P-133	J-445	J-447	6	557	50
P-133	J-694	J-69	6	670	50
P-134	J-69	J-281	6	728	50
P-136	J-446	J-448	6	565	50
P-137	J-448	J-214	6	548	50
P-138	J-447	J-443	6	556	50
P-139	J-210	J-449	6	798	50
P-140	J-449	J-377	6	102	50
P-141	J-377	J-287	6	840	50
P-143	J-76	J-61	6	47	60
P-144	J-72	J-60	6	42	60
P-148	J-451	J-452	6	169	50
P-151	J-42	J-453	6	153	50
P-161	J-81	J-488	6	53	130
P-164	J-82	J-487	6	45	130
P-165	J-454	J-166	6	398	50
P-168	J-454	J-455	6	395	50
P-169	J-454	J-123	6	376	50
P-174	J-456	J-459	6	103	50
P-175	J-459	J-457	6	572	50
P-176	J-458	J-459	6	247	50
P-177	J-123	J-460	6	79	50
P-179	J-173	J-460	6	543	50
P-180	J-460	J-172	6	528	50
P-189	J-293	J-461	6	57	50
P-190	J-79	J-461	6	317	50
P-202	J-47	J-464	6	235	50
P-203	J-464	J-465	6	153	50

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL INPUT - EXISTING INFRASTRUCTURE

Label	Start Node	Stop Node	Diameter (in)	Approx Length (ft)	Hazen-Williams C
P-204	J-465	J-466	6	321	50
P-206	J-65	J-468	6	323	50
P-207	J-468	J-469	6	405	50
P-212	J-244	J-471	6	649	50
P-213	J-471	J-472	6	1,871	50
P-218	J-474	J-475	6	1,869	50
P-219	J-475	J-245	6	649	50
P-220	J-196	J-476	6	709	60
P-221	J-476	J-197	6	654	60
P-240	J-274	J-485	6	709	50
P-242	J-7	J-485	6	173	50
P-243	J-485	J-486	6	333	50
P-244	J-486	J-487	6	340	50
P-245	J-413	J-488	6	969	50
P-246	J-488	J-267	6	631	50
P-247	J-487	J-488	6	143	50
P-291	J-148	J-91	6	159	50
P-292	J-91	J-233	6	168	50
P-293	J-233	J-325	6	147	50
P-296	J-325	J-499	6	191	50
P-297	J-499	J-147	6	179	50
P-298	J-337	J-500	6	136	50
P-345	J-520	J-354	6	46	50
P-365	J-496	J-279	6	1,999	50
P-368	J-193	J-530	6	1,311	50
P-369	J-234	J-531	6	1,330	50
P-370	J-531	J-235	6	661	50
P-372	J-74	J-532	6	293	50
P-373	J-530	J-533	6	144	50
P-374	J-533	J-531	6	51	50
P-375	J-532	J-533	6	399	50
P-376	J-216	J-534	6	1,991	50
P-378	J-236	J-237	6	1,986	50
P-384	J-225	J-206	6	312	50
P-385	J-206	J-226	6	1,683	50
P-386	J-206	J-535	6	155	50
P-389	J-535	J-536	6	1,681	50
P-392	J-537	J-538	6	346	50
P-394	J-494	J-138	6	661	50
P-398	J-378	J-539	6	328	50
P-399	J-485	J-540	6	1,301	50
P-400	J-540	J-492	6	652	50
P-401	J-539	J-540	6	315	50
P-402	J-540	J-138	6	332	50
P-408	J-541	J-543	6	750	50
P-409	J-543	J-544	6	628	50

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL INPUT - EXISTING INFRASTRUCTURE

Label	Start Node	Stop Node	Diameter (in)	Approx Length (ft)	Hazen-Williams C
P-412	J-544	J-545	6	527	50
P-413	J-544	J-85	6	325	50
P-415	J-378	J-379	6	211	50
P-416	J-379	J-245	6	126	50
P-417	J-245	J-189	6	341	50
P-418	J-189	J-477	6	128	50
P-419	J-477	J-244	6	200	50
P-420	J-244	J-272	6	480	50
P-421	J-272	J-219	6	329	50
P-422	J-219	J-197	6	323	60
P-423	J-197	J-442	6	337	60
P-424	J-219	J-314	6	96	60
P-425	J-219	J-547	6	634	60
P-428	J-547	J-548	6	676	60
P-429	J-548	J-220	6	646	50
P-432	J-272	J-549	6	634	50
P-434	J-550	J-548	6	335	50
P-435	J-549	J-550	6	669	50
P-436	J-550	J-411	6	1,372	50
P-437	J-551	J-250	6	251	60
P-438	J-250	J-175	6	110	60
P-439	J-175	J-248	6	59	60
P-440	J-248	J-273	6	261	60
P-441	J-273	J-260	6	252	60
P-442	J-260	J-268	6	76	60
P-443	J-268	J-255	6	181	60
P-444	J-255	J-391	6	163	60
P-445	J-391	J-258	6	96	60
P-447	J-258	J-429	6	180	60
P-448	J-429	J-419	6	73	60
P-449	J-419	J-262	6	266	60
P-450	J-262	J-388	6	37	60
P-451	J-388	J-253	6	220	60
P-452	J-253	J-390	6	103	60
P-453	J-390	J-256	6	155	60
P-454	J-256	J-367	6	149	60
P-455	J-367	J-395	6	109	60
P-456	J-395	J-261	6	239	50
P-457	J-261	J-135	6	329	50
P-463	J-89	J-552	6	339	60
P-464	J-82	J-251	6	169	60
P-465	J-251	J-247	6	248	60
P-466	J-247	J-71	6	172	60
P-467	J-71	J-70	6	249	60
P-468	J-70	J-254	6	266	60
P-469	J-254	J-259	6	252	60

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL INPUT - EXISTING INFRASTRUCTURE

Label	Start Node	Stop Node	Diameter (in)	Approx Length (ft)	Hazen-Williams C
P-470	J-259	J-68	6	259	60
P-471	J-68	J-69	6	249	60
P-473	J-69	J-252	6	259	60
P-474	J-252	J-257	6	267	60
P-475	J-257	J-60	6	258	60
P-476	J-60	J-61	6	257	60
P-477	J-61	J-185	6	245	50
P-478	J-185	J-554	6	603	50
P-479	J-554	J-555	6	622	50
P-488	J-556	J-260	6	1,594	60
P-496	J-559	J-363	6	1,039	60
P-497	J-363	J-258	6	565	60
P-499	J-259	J-558	6	1,073	60
P-502	J-252	J-560	6	1,040	60
P-503	J-560	J-424	6	508	60
P-506	J-257	J-561	6	1,044	60
P-507	J-561	J-425	6	509	60
P-510	J-426	J-562	6	514	60
P-512	J-165	J-61	6	1,063	60
P-513	J-185	J-184	6	461	50
P-516	J-184	J-563	6	574	50
P-517	J-563	J-109	6	357	50
P-518	J-184	J-116	6	299	50
P-519	J-116	J-145	6	270	50
P-520	J-145	J-143	6	297	50
P-521	J-143	J-179	6	316	50
P-528	J-145	J-146	6	839	50
P-529	J-143	J-144	6	838	50
P-530	J-179	J-140	6	838	50
P-531	J-140	J-144	6	316	50
P-532	J-144	J-146	6	297	50
P-533	J-146	J-180	6	134	50
P-534	J-108	J-144	6	585	50
P-535	J-109	J-108	6	521	50
P-536	J-109	J-100	6	459	50
P-537	J-100	J-261	6	805	50
P-543	J-100	J-566	6	335	50
P-544	J-566	J-565	6	118	50
P-545	J-323	J-566	6	217	50
P-546	J-323	J-135	6	512	50
P-549	J-150	J-149	6	911	50
P-550	J-130	J-149	6	590	50
P-551	J-130	J-567	6	1,266	50
P-553	J-120	J-567	6	568	50
P-554	J-567	J-568	6	93	50
P-557	J-210	J-569	6	862	50

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL INPUT - EXISTING INFRASTRUCTURE

Label	Start Node	Stop Node	Diameter (in)	Approx Length (ft)	Hazen-Williams C
P-558	J-569	J-149	6	102	50
P-559	J-569	J-568	6	56	50
P-560	J-50	J-51	6	182	50
P-568	J-495	J-573	6	2,001	50
P-569	J-573	J-105	6	624	50
P-570	J-572	J-573	6	333	50
P-573	J-573	J-574	6	330	50
P-576	J-574	J-575	6	329	50
P-577	J-575	J-576	6	326	50
P-578	J-105	J-577	6	331	50
P-579	J-577	J-571	6	149	50
P-586	J-443	J-578	6	209	50
P-587	J-578	J-413	6	180	50
P-588	J-83	J-578	6	47	50
P-589	J-83	J-579	6	295	50
P-592	J-76	J-168	6	315	50
P-595	J-168	J-580	6	368	50
P-596	J-117	J-118	6	549	50
P-599	J-75	J-167	6	311	50
P-600	J-166	J-75	6	727	50
P-601	J-75	J-76	6	298	50
P-606	J-11	J-582	6	326	50
P-607	J-582	J-583	6	320	50
P-608	J-583	J-584	6	331	50
P-609	J-584	J-585	6	376	50
P-610	J-585	J-586	6	136	50
P-614	J-582	J-588	6	1,292	50
P-617	J-590	J-589	6	126	50
P-618	J-590	J-591	6	323	50
P-619	J-591	J-592	6	339	50
P-620	J-592	J-593	6	300	50
P-622	J-592	J-91	6	353	50
P-623	J-591	J-93	6	357	50
P-626	J-595	J-590	6	249	50
P-628	J-499	J-304	6	654	50
P-629	J-304	J-596	6	668	50
P-632	J-127	J-113	6	672	50
P-635	J-596	J-597	6	130	50
P-636	J-597	J-113	6	388	50
P-642	J-203	J-600	6	783	50
P-643	J-600	J-601	6	258	50
P-644	J-601	J-602	6	306	50
P-645	J-602	J-603	6	321	50
P-646	J-603	J-599	6	410	50
P-647	J-599	J-181	6	299	50
P-648	J-181	J-139	6	336	50

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL INPUT - EXISTING INFRASTRUCTURE

Label	Start Node	Stop Node	Diameter (in)	Approx Length (ft)	Hazen-Williams C
P-649	J-139	J-604	6	543	50
P-650	J-604	J-605	6	520	50
P-651	J-605	J-606	6	234	50
P-652	J-606	J-607	6	584	50
P-653	J-607	J-608	6	224	50
P-654	J-608	J-181	6	601	50
P-655	J-139	J-609	6	270	50
P-656	J-609	J-610	6	293	50
P-657	J-610	J-605	6	373	50
P-661	J-604	J-290	6	338	50
P-675	J-622	J-623	6	50	50
P-676	J-623	J-624	6	839	50
P-680	J-163	J-626	6	151	50
P-681	J-626	J-132	6	1,018	50
P-682	J-132	J-79	6	545	50
P-683	J-79	J-133	6	164	50
P-701	J-630	J-631	6	202	50
P-704	J-280	J-297	6	707	50
P-705	J-297	J-574	6	663	50
P-707	J-263	J-632	6	184	50
P-709	J-195	J-632	6	710	50
P-713	J-633	J-240	6	750	50
P-714	J-632	J-634	6	195	50
P-715	J-634	J-633	6	128	50
P-716	J-634	J-189	6	1,301	50
P-717	J-633	J-635	6	354	50
P-718	J-635	J-550	6	322	50
P-720	J-635	J-218	6	672	50
P-721	J-218	J-549	6	329	50
P-722	J-549	J-547	6	327	50
P-723	J-547	J-222	6	659	60
P-724	J-222	J-128	6	27	60
P-728	J-128	J-636	6	632	60
P-729	J-636	J-264	6	675	60
P-730	J-271	J-264	6	1,354	50
P-731	J-264	J-110	6	327	60
P-732	J-110	J-129	6	312	60
P-734	J-129	J-548	6	672	60
P-735	J-111	J-637	6	337	60
P-736	J-637	J-110	6	193	60
P-737	J-116	J-115	6	542	50
P-738	J-178	J-383	6	563	50
P-739	J-383	J-177	6	551	50
P-740	J-30	J-29	6	78	50
P-741	J-29	J-104	6	480	50
P-742	J-194	J-639	6	264	50

CITY OF MUSKEGON HEIGHTS
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MODEL INPUT - EXISTING INFRASTRUCTURE

Label	Start Node	Stop Node	Diameter (in)	Approx Length (ft)	Hazen-Williams C
P-743	J-639	J-414	6	336	50
P-745	J-610	J-640	6	248	50
P-746	J-225	J-228	6	326	50
P-747	J-228	J-278	6	335	50
P-748	J-278	J-279	6	327	50
P-749	J-279	J-281	6	220	50
P-750	J-281	J-234	6	435	50
P-751	J-234	J-193	6	184	50
P-752	J-193	J-534	6	325	50
P-754	J-641	J-238	6	165	50
P-755	J-238	J-236	6	326	50
P-756	J-236	J-230	6	330	50
P-757	J-230	J-227	6	334	50
P-758	J-227	J-232	6	329	50
P-759	J-232	J-32	6	244	50
P-760	J-32	J-31	6	98	50
P-761	J-210	J-173	6	84	50
P-762	J-173	J-457	6	297	50
P-763	J-457	J-642	6	929	50
P-764	J-642	J-265	6	277	50
P-765	J-456	J-642	6	649	50
P-766	J-128	F-2	6	284	60
P-767	F-2	J-129	6	386	60
P-771	J-534	J-646	6	30	50
P-772	J-646	J-641	6	141	50
P-773	J-646	F-4	6	132	50
P-774	J-187	J-649	6	717	50
P-775	J-649	J-583	6	577	50
P-776	F-5	J-649	6	82	50
P-779	J-127	J-199	6	357	50
P-786	J-82	J-655	6	1,068	60
P-789	J-398	J-71	6	1,000	60
P-790	J-174	J-175	6	1,112	60
P-791	J-562	J-657	6	529	60
P-792	J-657	J-60	6	511	60
P-796	F-10	J-659	6	39	50
P-799	J-424	J-660	6	272	60
P-800	J-303	J-268	6	1,113	60
P-805	J-539	J-662	6	577	50
P-806	J-662	J-491	6	79	50
P-808	J-588	J-187	6	330	50
P-809	J-187	J-127	6	316	50
P-814	J-664	J-465	6	468	50
P-815	J-270	J-665	6	648	60
P-816	J-665	J-636	6	640	60
P-817	J-440	J-665	6	296	60

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL INPUT - EXISTING INFRASTRUCTURE

Label	Start Node	Stop Node	Diameter (in)	Approx Length (ft)	Hazen-Williams C
P-818	J-466	J-472	6	332	50
P-819	J-474	J-518	6	310	50
P-830	J-446	J-178	6	327	50
P-838	J-233	J-232	6	1,996	50
P-839	J-31	J-499	6	1,960	50
P-841	J-672	J-499	6	1,322	50
P-847	J-497	J-675	6	710	50
P-849	J-278	J-676	6	1,384	50
P-850	J-676	J-495	6	617	50
P-851	J-581	J-677	6	1,237	50
P-852	J-677	J-223	6	723	50
P-853	J-580	J-678	6	566	50
P-854	J-678	J-242	6	1,395	50
P-855	J-675	J-679	6	678	50
P-856	J-679	J-575	6	618	50
P-857	J-496	J-680	6	1,368	50
P-858	J-680	J-574	6	635	50
P-859	J-491	J-681	6	631	50
P-860	J-681	J-85	6	710	50
P-861	J-492	J-684	6	652	50
P-862	J-684	J-354	6	712	50
P-863	J-538	J-63	6	1,044	50
P-864	J-63	J-494	6	629	50
P-865	J-137	J-686	6	616	50
P-866	J-686	J-537	6	1,063	50
P-868	J-687	J-229	6	593	50
P-871	J-230	J-689	6	701	50
P-872	J-689	J-231	6	1,290	50
P-873	J-227	J-690	6	1,257	50
P-874	J-690	J-148	6	739	50
P-876	J-691	J-239	6	628	50
P-877	J-238	J-692	6	711	50
P-878	J-692	J-691	6	656	50
P-879	J-228	J-693	6	720	50
P-880	J-693	J-687	6	682	50
P-881	J-497	J-694	6	615	50
P-883	J-303	J-695	6	623	50
P-884	J-695	J-635	6	738	50
P-885	J-241	J-696	6	747	50
P-886	J-696	J-633	6	626	50
P-887	J-414	J-697	6	590	50
P-888	J-697	J-195	6	362	50
P-889	J-89	J-698	6	1,387	60
P-890	J-698	J-87	6	1,064	60
P-891	J-552	J-699	6	1,530	60
P-892	J-699	J-88	6	1,063	60

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL INPUT - EXISTING INFRASTRUCTURE

Label	Start Node	Stop Node	Diameter (in)	Approx Length (ft)	Hazen-Williams C
P-893	J-655	J-700	6	863	60
P-894	J-700	J-45	6	1,841	60
P-895	J-551	J-701	6	615	60
P-898	J-702	J-250	6	610	60
P-899	J-398	J-703	6	1,128	60
P-900	J-703	J-248	6	530	60
P-901	J-399	J-704	6	599	60
P-902	J-704	J-273	6	1,073	60
P-903	J-558	J-705	6	519	60
P-904	J-705	J-255	6	1,072	60
P-905	J-403	J-706	6	483	60
P-907	J-70	J-707	6	504	60
P-908	J-707	J-399	6	492	60
P-909	J-254	J-708	6	409	60
P-910	J-708	J-556	6	658	60
P-911	J-68	J-709	6	397	60
P-912	J-709	J-559	6	663	60
P-913	J-460	J-710	6	371	50
P-914	J-710	J-124	6	479	50
P-915	J-169	J-711	6	485	50
P-916	J-711	J-76	6	244	50
P-919	J-575	J-713	6	585	50
P-920	J-713	J-282	6	781	50
P-923	J-586	J-674	6	206	50
P-924	J-31	J-715	6	541	50
P-925	J-715	J-672	6	98	50
P-939	J-247	J-720	6	41	60

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2014 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
F-2	625	64.0	54.0	990
F-4	635	60.0	52.0	740
F-5	625	64.0	56.0	670
F-10	625	62.0	57.0	2,090
J-1	625	63.0	51.0	800
J-2	630	62.0	54.0	2,420
J-3	625	65.0	58.0	3,310
J-4	630	63.0	55.0	910
J-5	630	62.0	54.0	180
J-7	625	65.0	58.0	3,330
J-10	625	64.0	57.0	3,210
J-11	625	64.0	57.0	3,210
J-13	635	60.0	51.0	2,690
J-14	625	66.0	59.0	3,510
J-15	625	60.0	59.0	6,000
J-15	625	61.0	58.0	580
J-16	584	83.0	80.0	1,800
J-17	584	83.0	80.0	840
J-18	586	82.0	79.0	360
J-19	584	83.0	80.0	770
J-20	583	83.0	80.0	600
J-21	584	83.0	80.0	1,100
J-22	583	83.0	80.0	590
J-23	580	84.0	81.0	370
J-24	586	80.0	78.0	240
J-25	637	58.0	51.0	1,040
J-27	638	58.0	50.0	990
J-28	640	56.0	43.0	480
J-29	625	64.0	57.0	1,080
J-29	636	59.0	51.0	1,070
J-30	625	64.0	57.0	1,090
J-30	640	56.0	45.0	500
J-31	635	59.0	52.0	660
J-31	635	59.0	51.0	1,110
J-32	635	59.0	52.0	690
J-32	640	56.0	45.0	510
J-33	634	60.0	52.0	1,200
J-34	628	62.0	55.0	1,670
J-35	633	60.0	53.0	1,260
J-37	632	61.0	53.0	1,330
J-38	631	61.0	54.0	1,400
J-39	630	61.0	54.0	1,450
J-40	627	63.0	56.0	1,880
J-41	629	62.0	54.0	1,560
J-42	595	76.0	67.0	80
J-43	628	63.0	55.0	1,790

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2014 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-44	626	63.0	56.0	2,040
J-45	625	63.0	50.0	1,160
J-45	590	78.0	69.0	70
J-46	625	63.0	51.0	1,260
J-46	635	59.0	52.0	1,150
J-47	635	59.0	50.0	330
J-47	635	59.0	51.0	480
J-48	625	63.0	53.0	950
J-49	625	64.0	56.0	200
J-50	625	63.0	57.0	3,190
J-51	625	63.0	57.0	960
J-53	640	56.0	43.0	470
J-54	639	58.0	50.0	940
J-58	600	74.0	65.0	50
J-60	620	69.0	65.0	4,360
J-60	630	62.0	54.0	180
J-61	615	71.0	67.0	4,300
J-61	630	62.0	54.0	3,620
J-62	635	60.0	52.0	3,070
J-63	630	62.0	54.0	650
J-64	635	60.0	51.0	2,170
J-65	635	59.0	51.0	2,060
J-65	635	60.0	52.0	3,100
J-67	635	60.0	52.0	3,020
J-68	625	64.0	55.0	1,160
J-68	635	60.0	52.0	2,750
J-69	625	64.0	56.0	1,160
J-69	635	60.0	52.0	680
J-70	640	57.0	46.0	890
J-70	635	60.0	52.0	2,940
J-71	640	57.0	45.0	860
J-72	613	72.0	69.0	6,000
J-74	635	60.0	52.0	3,260
J-75	625	64.0	57.0	1,660
J-76	625	64.0	57.0	1,640
J-76	610	73.0	70.0	6,000
J-77	625	64.0	57.0	3,210
J-78	625	64.0	57.0	3,210
J-79	625	60.0	58.0	660
J-79	625	64.0	57.0	3,220
J-80	625	64.0	57.0	3,240
J-81	625	65.0	58.0	3,260
J-82	640	56.0	44.0	690
J-82	625	65.0	58.0	3,270
J-83	625	64.0	57.0	1,120
J-85	635	60.0	52.0	800

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2014 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-87	625	62.0	48.0	860
J-88	625	62.0	49.0	1,000
J-89	640	56.0	43.0	520
J-91	635	59.0	52.0	1,510
J-93	635	60.0	52.0	2,680
J-96	635	59.0	50.0	450
J-100	625	64.0	57.0	1,390
J-102	640	57.0	49.0	890
J-103	625	63.0	55.0	940
J-104	625	64.0	57.0	3,190
J-105	625	64.0	57.0	1,160
J-108	625	64.0	57.0	2,490
J-109	625	64.0	57.0	1,320
J-110	625	63.0	53.0	910
J-111	625	63.0	53.0	480
J-113	625	64.0	56.0	1,020
J-115	625	64.0	57.0	2,290
J-116	622	65.0	59.0	1,590
J-117	625	64.0	57.0	3,200
J-118	625	64.0	57.0	540
J-120	600	75.0	67.0	540
J-123	625	64.0	57.0	1,460
J-124	625	64.0	57.0	2,950
J-127	625	64.0	56.0	860
J-128	630	61.0	52.0	1,210
J-129	625	63.0	54.0	1,060
J-130	625	64.0	57.0	2,200
J-132	625	60.0	58.0	410
J-133	625	60.0	58.0	550
J-135	625	64.0	57.0	1,770
J-137	625	64.0	56.0	3,200
J-138	630	62.0	54.0	1,060
J-139	625	60.0	58.0	1,340
J-140	618	67.0	61.0	1,510
J-141	625	64.0	57.0	2,360
J-143	605	73.0	67.0	1,840
J-144	625	64.0	57.0	1,810
J-145	620	66.0	60.0	1,570
J-146	625	64.0	57.0	1,760
J-147	635	59.0	52.0	670
J-148	635	60.0	52.0	2,520
J-149	618	67.0	60.0	960
J-150	625	64.0	57.0	2,380
J-159	625	64.0	57.0	3,250
J-163	625	60.0	58.0	260
J-165	625	67.0	63.0	500

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2014 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-166	625	64.0	57.0	3,130
J-167	625	64.0	57.0	3,210
J-168	625	64.0	57.0	2,990
J-169	625	64.0	57.0	3,080
J-172	625	64.0	57.0	3,040
J-173	618	67.0	60.0	1,140
J-174	625	63.0	52.0	1,490
J-175	625	63.0	52.0	1,150
J-177	625	64.0	57.0	3,020
J-178	625	64.0	57.0	2,410
J-179	605	73.0	70.0	3,840
J-180	625	64.0	57.0	2,540
J-181	625	60.0	58.0	1,530
J-184	625	64.0	58.0	1,470
J-185	600	76.0	72.0	1,990
J-187	625	64.0	56.0	1,110
J-189	635	60.0	51.0	1,530
J-193	635	60.0	52.0	1,130
J-194	625	64.0	57.0	1,500
J-195	625	64.0	56.0	1,220
J-196	635	59.0	50.0	910
J-197	635	59.0	50.0	1,250
J-198	625	64.0	57.0	3,260
J-199	625	64.0	56.0	520
J-202	630	62.0	52.0	980
J-203	625	61.0	58.0	1,810
J-206	635	60.0	52.0	850
J-210	618	67.0	60.0	1,220
J-213	625	64.0	57.0	2,280
J-214	625	64.0	57.0	3,060
J-216	635	60.0	52.0	3,260
J-218	630	61.0	52.0	860
J-219	635	59.0	50.0	1,180
J-220	625	64.0	54.0	420
J-222	630	61.0	52.0	1,230
J-223	635	60.0	52.0	3,270
J-225	635	60.0	52.0	820
J-226	635	60.0	52.0	3,070
J-227	635	59.0	52.0	980
J-228	635	60.0	52.0	970
J-229	635	60.0	52.0	3,230
J-230	635	60.0	52.0	1,040
J-231	635	60.0	52.0	2,820
J-232	635	59.0	52.0	840
J-233	635	59.0	52.0	1,200
J-234	635	60.0	52.0	1,120

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2014 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-235	635	60.0	52.0	3,260
J-236	635	60.0	52.0	1,070
J-237	635	60.0	52.0	3,240
J-238	635	60.0	52.0	1,080
J-239	635	60.0	52.0	3,270
J-240	630	62.0	54.0	2,980
J-241	625	64.0	55.0	2,550
J-242	635	60.0	52.0	3,260
J-244	635	60.0	51.0	1,390
J-245	635	60.0	51.0	1,310
J-247	640	56.0	45.0	830
J-248	625	63.0	52.0	1,150
J-251	640	56.0	44.0	760
J-252	625	65.0	57.0	1,360
J-253	625	64.0	56.0	1,390
J-254	640	57.0	47.0	930
J-255	625	64.0	54.0	1,270
J-256	625	64.0	56.0	1,390
J-257	625	65.0	59.0	1,690
J-258	625	64.0	54.0	1,260
J-259	640	57.0	47.0	970
J-260	625	63.0	53.0	1,290
J-261	625	64.0	57.0	1,440
J-262	625	64.0	56.0	1,350
J-263	625	64.0	56.0	3,310
J-264	625	63.0	53.0	950
J-265	625	64.0	56.0	370
J-267	625	64.0	57.0	770
J-268	625	63.0	54.0	1,340
J-269	625	65.0	58.0	3,330
J-270	635	59.0	50.0	1,630
J-271	625	62.0	47.0	810
J-272	635	59.0	50.0	1,130
J-273	625	63.0	53.0	1,280
J-274	625	65.0	57.0	3,280
J-278	635	60.0	52.0	1,050
J-279	635	60.0	52.0	1,110
J-280	625	64.0	57.0	2,840
J-281	635	60.0	52.0	1,110
J-282	625	64.0	57.0	2,930
J-283	635	59.0	50.0	790
J-286	625	64.0	57.0	2,870
J-287	625	64.0	57.0	2,980
J-288	625	64.0	57.0	3,260
J-290	625	60.0	58.0	6,000
J-293	625	60.0	58.0	3,950

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2014 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-294	625	60.0	58.0	2,240
J-296	625	64.0	57.0	3,210
J-297	625	64.0	57.0	2,300
J-298	625	61.0	58.0	4,820
J-299	625	60.0	58.0	6,000
J-302	625	61.0	47.0	740
J-303	625	64.0	54.0	2,330
J-304	625	63.0	57.0	1,600
J-305	625	63.0	57.0	3,510
J-311	625	60.0	59.0	6,000
J-314	635	59.0	50.0	890
J-316	635	60.0	52.0	2,960
J-319	625	64.0	55.0	30
J-323	625	64.0	57.0	1,200
J-325	635	59.0	52.0	1,040
J-329	625	64.0	57.0	420
J-331	590	72.0	19.0	0
J-332	625	72.0	69.0	6,000
J-333	625	73.0	71.0	6,000
J-334	625	60.0	59.0	6,000
J-335	625	68.0	65.0	6,000
J-337	635	60.0	52.0	940
J-338	625	(N/A)	(N/A)	#VALUE!
J-339	625	64.0	57.0	3,040
J-345	625	63.0	57.0	3,320
J-347	625	63.0	57.0	3,460
J-349	625	63.0	57.0	3,510
J-351	625	60.0	58.0	6,000
J-352	625	60.0	58.0	6,000
J-354	630	62.0	54.0	1,640
J-356	625	63.0	57.0	3,520
J-359	635	60.0	51.0	2,110
J-363	640	57.0	48.0	720
J-367	625	64.0	56.0	1,280
J-368	625	64.0	57.0	3,320
J-374	625	64.0	56.0	300
J-375	625	64.0	56.0	3,250
J-376	625	64.0	57.0	2,480
J-377	625	64.0	57.0	1,660
J-378	635	60.0	52.0	1,120
J-379	635	60.0	51.0	1,170
J-380	635	60.0	51.0	2,720
J-382	630	62.0	55.0	320
J-383	625	64.0	57.0	1,160
J-384	625	64.0	57.0	1,450
J-385	625	64.0	55.0	2,730

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2014 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-387	625	64.0	56.0	2,950
J-388	625	64.0	56.0	1,340
J-389	625	64.0	56.0	3,220
J-390	625	64.0	56.0	1,350
J-391	625	64.0	54.0	1,240
J-393	625	64.0	57.0	390
J-395	625	64.0	56.0	1,230
J-396	625	64.0	57.0	120
J-398	640	57.0	45.0	520
J-399	640	57.0	46.0	540
J-402	640	56.0	43.0	580
J-403	640	56.0	43.0	480
J-407	625	68.0	65.0	6,000
J-409	625	66.0	60.0	3,620
J-410	625	66.0	60.0	3,560
J-411	625	63.0	53.0	1,840
J-412	625	64.0	56.0	220
J-413	625	64.0	57.0	1,380
J-414	625	65.0	57.0	3,270
J-415	625	64.0	57.0	3,230
J-416	625	64.0	56.0	190
J-417	625	64.0	55.0	360
J-418	625	64.0	55.0	280
J-419	625	64.0	55.0	1,230
J-421	625	64.0	61.0	6,000
J-423	625	68.0	65.0	6,000
J-424	625	64.0	57.0	1,290
J-425	625	64.0	57.0	1,480
J-426	625	64.0	57.0	1,300
J-427	625	64.0	56.0	80
J-428	625	64.0	55.0	2,760
J-429	625	64.0	55.0	1,230
J-430	635	59.0	50.0	510
J-431	635	59.0	50.0	700
J-432	635	59.0	50.0	1,000
J-433	635	59.0	50.0	840
J-434	635	59.0	50.0	830
J-435	635	59.0	50.0	810
J-436	635	59.0	50.0	660
J-437	635	59.0	50.0	520
J-438	635	59.0	50.0	560
J-439	635	59.0	50.0	1,710
J-440	635	59.0	50.0	1,200
J-441	635	59.0	50.0	1,790
J-442	635	59.0	50.0	1,370
J-443	625	64.0	57.0	3,110

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2014 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-444	625	64.0	57.0	3,150
J-445	625	64.0	57.0	1,540
J-446	625	64.0	57.0	1,890
J-447	625	64.0	57.0	1,230
J-448	625	64.0	57.0	1,250
J-449	625	64.0	57.0	2,630
J-450	625	64.0	57.0	2,540
J-451	610	70.0	61.0	130
J-452	610	70.0	61.0	130
J-453	595	76.0	67.0	80
J-454	625	64.0	57.0	1,670
J-455	625	64.0	57.0	3,050
J-456	625	64.0	56.0	440
J-457	625	64.0	56.0	580
J-458	625	64.0	56.0	380
J-459	625	64.0	56.0	450
J-460	625	64.0	57.0	1,720
J-461	625	60.0	58.0	1,690
J-462	635	60.0	52.0	3,270
J-463	635	60.0	52.0	2,920
J-464	635	59.0	50.0	380
J-465	635	59.0	50.0	420
J-466	635	59.0	50.0	430
J-468	635	59.0	50.0	710
J-469	635	59.0	50.0	530
J-471	635	60.0	51.0	2,410
J-472	635	60.0	51.0	340
J-473	635	60.0	51.0	270
J-474	635	60.0	51.0	340
J-475	635	60.0	51.0	2,710
J-476	635	59.0	50.0	1,870
J-477	635	60.0	51.0	2,750
J-478	635	60.0	51.0	2,740
J-479	635	60.0	51.0	2,690
J-480	635	60.0	51.0	150
J-481	625	66.0	59.0	3,490
J-482	625	65.0	58.0	3,340
J-483	625	64.0	57.0	3,240
J-484	625	64.0	57.0	3,230
J-485	625	65.0	58.0	2,040
J-486	625	65.0	58.0	1,360
J-487	625	65.0	58.0	3,270
J-488	625	65.0	58.0	3,260
J-489	625	64.0	57.0	3,240
J-490	625	64.0	57.0	330
J-491	635	60.0	52.0	2,830

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2014 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-492	630	62.0	54.0	3,030
J-494	630	62.0	54.0	3,040
J-495	635	60.0	52.0	3,230
J-496	635	60.0	52.0	3,260
J-497	635	60.0	52.0	3,260
J-499	635	59.0	52.0	1,030
J-500	635	60.0	52.0	2,350
J-501	635	60.0	52.0	2,480
J-515	635	60.0	52.0	2,970
J-516	635	60.0	52.0	3,000
J-517	635	60.0	52.0	3,190
J-518	635	60.0	52.0	2,640
J-519	630	62.0	54.0	2,500
J-520	630	62.0	54.0	2,360
J-521	625	64.0	56.0	3,310
J-522	630	62.0	54.0	180
J-523	630	62.0	54.0	180
J-524	625	64.0	56.0	3,310
J-525	635	60.0	52.0	3,310
J-526	635	60.0	52.0	3,310
J-528	635	60.0	52.0	3,210
J-529	635	60.0	52.0	2,500
J-530	635	60.0	52.0	920
J-531	635	60.0	52.0	1,190
J-532	635	60.0	52.0	1,090
J-533	635	60.0	52.0	1,190
J-534	635	60.0	52.0	1,090
J-535	625	64.0	56.0	820
J-536	625	64.0	56.0	3,280
J-537	625	64.0	56.0	530
J-538	630	62.0	54.0	520
J-539	635	60.0	52.0	1,520
J-540	630	62.0	54.0	1,560
J-541	635	60.0	52.0	510
J-543	635	60.0	52.0	3,200
J-544	635	60.0	52.0	1,120
J-545	635	60.0	52.0	2,630
J-547	630	61.0	52.0	1,320
J-548	625	64.0	54.0	1,160
J-549	630	61.0	52.0	1,250
J-550	625	64.0	54.0	1,350
J-551	625	63.0	51.0	920
J-552	640	56.0	43.0	520
J-554	595	78.0	75.0	1,230
J-555	590	80.0	77.0	6,000
J-556	640	57.0	47.0	550

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2014 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-558	640	57.0	47.0	560
J-559	640	57.0	48.0	590
J-560	625	64.0	57.0	890
J-561	625	65.0	57.0	940
J-562	625	65.0	59.0	1,000
J-563	625	64.0	57.0	1,010
J-564	625	64.0	57.0	2,520
J-565	625	64.0	57.0	2,430
J-566	625	64.0	57.0	1,820
J-567	618	67.0	60.0	770
J-568	618	67.0	60.0	730
J-569	618	67.0	60.0	820
J-571	625	64.0	57.0	1,020
J-572	625	64.0	57.0	3,220
J-573	625	64.0	57.0	3,220
J-574	625	64.0	57.0	3,210
J-575	625	64.0	57.0	3,200
J-576	625	64.0	57.0	3,190
J-577	625	64.0	57.0	3,130
J-578	625	64.0	57.0	1,400
J-579	625	64.0	57.0	620
J-580	625	64.0	57.0	3,210
J-581	625	64.0	57.0	3,210
J-582	625	64.0	57.0	1,380
J-583	625	64.0	56.0	1,130
J-584	625	64.0	56.0	1,010
J-585	625	64.0	56.0	540
J-586	625	64.0	56.0	480
J-588	625	64.0	56.0	2,300
J-589	625	64.0	56.0	840
J-590	625	64.0	56.0	1,260
J-591	625	64.0	56.0	1,430
J-592	625	64.0	56.0	1,100
J-593	625	64.0	56.0	600
J-595	625	64.0	56.0	2,830
J-596	625	63.0	57.0	860
J-597	625	63.0	56.0	860
J-598	625	63.0	57.0	1,630
J-599	625	61.0	58.0	3,170
J-600	625	61.0	58.0	760
J-601	625	61.0	58.0	740
J-602	625	61.0	58.0	770
J-603	625	61.0	58.0	900
J-604	625	60.0	58.0	1,540
J-605	625	60.0	58.0	1,480
J-606	625	60.0	58.0	2,240

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2014 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-607	625	60.0	58.0	920
J-608	625	60.0	58.0	910
J-609	625	60.0	58.0	1,020
J-610	625	60.0	58.0	1,000
J-611	625	60.0	58.0	2,360
J-612	625	60.0	58.0	2,510
J-622	625	65.0	62.0	3,430
J-623	625	65.0	62.0	1,780
J-624	625	65.0	62.0	450
J-626	625	60.0	58.0	270
J-627	625	74.0	72.0	6,000
J-628	590	80.0	77.0	6,000
J-629	590	80.0	77.0	6,000
J-630	590	80.0	77.0	6,000
J-631	590	80.0	77.0	1,180
J-632	625	64.0	56.0	1,760
J-633	625	64.0	55.0	1,730
J-634	625	64.0	56.0	1,640
J-635	625	64.0	54.0	1,440
J-636	630	61.0	52.0	1,040
J-637	625	63.0	53.0	660
J-639	625	64.0	57.0	1,240
J-640	625	60.0	58.0	640
J-641	635	60.0	52.0	1,020
J-642	625	64.0	56.0	430
J-644	635	60.0	52.0	2,790
J-646	635	60.0	52.0	1,060
J-649	625	64.0	56.0	770
J-651	625	64.0	57.0	2,490
J-652	625	64.0	56.0	430
J-655	640	56.0	44.0	430
J-657	625	66.0	61.0	1,090
J-659	625	62.0	57.0	4,050
J-660	625	64.0	56.0	820
J-662	640	58.0	49.0	1,430
J-664	640	57.0	48.0	420
J-665	635	59.0	50.0	1,140
J-671	635	60.0	52.0	2,600
J-672	635	60.0	52.0	2,530
J-673	625	64.0	56.0	220
J-674	625	63.0	57.0	1,950
J-675	635	60.0	52.0	430
J-676	635	60.0	52.0	720
J-677	625	64.0	57.0	800
J-678	625	64.0	57.0	840
J-679	625	64.0	56.0	320

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2014 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-680	625	64.0	57.0	820
J-681	630	62.0	54.0	780
J-684	630	62.0	54.0	860
J-686	630	62.0	54.0	650
J-687	630	62.0	54.0	750
J-688	635	60.0	51.0	150
J-689	635	60.0	52.0	680
J-690	635	60.0	52.0	690
J-691	635	60.0	52.0	720
J-692	635	60.0	52.0	680
J-693	635	60.0	52.0	660
J-694	635	60.0	52.0	730
J-695	625	64.0	54.0	830
J-696	625	64.0	55.0	850
J-697	625	64.0	56.0	990
J-698	625	62.0	48.0	520
J-699	625	62.0	49.0	530
J-700	640	56.0	44.0	410
J-701	640	56.0	45.0	530
J-702	640	56.0	45.0	550
J-703	640	57.0	45.0	580
J-704	640	57.0	46.0	540
J-705	640	57.0	47.0	570
J-706	640	56.0	43.0	450
J-707	640	57.0	46.0	590
J-708	640	57.0	47.0	640
J-709	640	57.0	48.0	690
J-710	626	63.0	56.0	1,120
J-711	625	64.0	57.0	1,220
J-712	625	64.0	57.0	3,120
J-713	625	64.0	57.0	950
J-714	625	64.0	57.0	270
J-715	635	(N/A)	(N/A)	#VALUE!
J-716	625	64.0	54.0	210
J-717	625	64.0	56.0	450
J-718	625	64.0	56.0	120
J-720	640	64.0	61.0	6,000
J-721	584	82.0	79.0	70

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
F-2	625	63.0	53.0	840
F-4	635	60.0	51.0	700
F-5	625	64.0	56.0	640
F-10	625	62.0	57.0	2,290
J-1	625	63.0	50.0	760
J-2	630	62.0	54.0	2,380
J-3	625	65.0	57.0	5,250
J-4	629.51	62.0	54.0	860
J-5	629.59	62.0	54.0	250
J-7	625	65.0	57.0	5,030
J-10	625	64.0	56.0	4,960
J-11	625	64.0	56.0	4,480
J-13	635	60.0	51.0	2,630
J-14	625	66.0	59.0	5,450
J-15	625	60.0	59.0	6,000
J-15	625	61.0	57.0	550
J-16	584	83.0	80.0	1,790
J-17	584	83.0	80.0	810
J-18	586	82.0	79.0	340
J-19	584	83.0	80.0	750
J-20	583	83.0	80.0	570
J-21	584	83.0	80.0	1,070
J-22	583	83.0	80.0	560
J-23	580	84.0	81.0	350
J-24	586	80.0	78.0	240
J-25	636.62	58.0	50.0	1,040
J-27	637.69	58.0	50.0	980
J-28	640	56.0	42.0	450
J-29	625	64.0	56.0	1,030
J-29	636.01	59.0	50.0	1,070
J-30	625	64.0	56.0	1,040
J-30	640	56.0	44.0	470
J-31	635	59.0	51.0	620
J-31	635.22	59.0	51.0	1,110
J-32	635	59.0	51.0	650
J-32	640	56.0	44.0	480
J-33	633.76	60.0	52.0	1,200
J-34	628.48	62.0	54.0	1,660
J-35	632.87	60.0	52.0	1,260
J-37	631.95	61.0	53.0	1,320
J-38	631.09	61.0	53.0	1,390
J-39	630.47	61.0	53.0	1,450
J-40	626.98	63.0	55.0	1,880
J-41	629.37	62.0	54.0	1,560
J-42	595	76.0	67.0	110
J-43	627.6	63.0	55.0	1,780

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-44	626.1	63.0	56.0	2,040
J-45	625	62.0	49.0	1,130
J-45	590	78.0	70.0	100
J-46	625	63.0	50.0	1,230
J-46	634.61	59.0	51.0	1,140
J-47	635	59.0	50.0	310
J-47	635	59.0	50.0	450
J-48	625	63.0	52.0	900
J-49	625	64.0	56.0	270
J-50	625	63.0	56.0	5,100
J-51	625	63.0	56.0	910
J-53	640	56.0	42.0	430
J-54	638.57	58.0	49.0	940
J-58	600	74.0	65.0	70
J-60	620	69.0	66.0	6,000
J-60	630	62.0	54.0	230
J-61	615	71.0	68.0	6,000
J-61	630.14	62.0	54.0	3,540
J-62	635	60.0	52.0	3,010
J-63	630	62.0	53.0	610
J-64	635	59.0	50.0	2,120
J-65	635	59.0	50.0	2,000
J-65	635	60.0	52.0	3,040
J-67	635	60.0	52.0	2,960
J-68	625	64.0	54.0	1,110
J-68	635	60.0	52.0	2,700
J-69	625	64.0	55.0	1,130
J-69	635	60.0	51.0	650
J-70	640	57.0	45.0	850
J-70	635	60.0	52.0	2,890
J-71	640	56.0	45.0	810
J-72	620	69.0	66.0	6,000
J-74	635	60.0	52.0	3,410
J-75	625	64.0	56.0	1,570
J-76	625	64.0	56.0	1,560
J-76	615	71.0	68.0	6,000
J-77	625	64.0	57.0	4,970
J-78	625	64.0	57.0	5,000
J-79	625	60.0	58.0	630
J-79	625	64.0	57.0	5,020
J-80	625	64.0	57.0	5,090
J-81	625	65.0	57.0	5,130
J-82	640	56.0	43.0	640
J-82	625	65.0	57.0	5,140
J-83	625	64.0	56.0	1,060
J-85	635	60.0	51.0	760

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-87	625	62.0	47.0	850
J-88	625	62.0	48.0	980
J-89	640	56.0	42.0	470
J-91	635	59.0	52.0	1,440
J-93	635	60.0	52.0	2,610
J-96	635	59.0	49.0	430
J-100	625	64.0	56.0	1,330
J-102	640	57.0	48.0	890
J-103	625	63.0	55.0	940
J-104	625	64.0	56.0	3,710
J-105	625	64.0	57.0	1,100
J-108	625	64.0	56.0	2,890
J-109	625	64.0	57.0	1,300
J-110	625	63.0	52.0	810
J-111	625	63.0	52.0	440
J-113	625	64.0	56.0	970
J-115	625	64.0	56.0	2,290
J-116	622	65.0	59.0	1,610
J-117	625	64.0	56.0	3,960
J-118	625	64.0	56.0	510
J-120	600	75.0	67.0	510
J-123	625	64.0	56.0	1,460
J-124	625	64.0	56.0	4,780
J-127	625	64.0	56.0	810
J-128	630	61.0	51.0	1,090
J-129	625	63.0	53.0	950
J-130	625	64.0	56.0	3,430
J-132	625	60.0	58.0	390
J-133	625	60.0	58.0	520
J-135	625	64.0	56.0	1,740
J-137	625	64.0	56.0	3,150
J-138	630	62.0	53.0	1,040
J-139	625	60.0	58.0	1,270
J-140	618	67.0	60.0	1,450
J-141	625	64.0	56.0	3,220
J-143	605	73.0	67.0	1,760
J-144	625	64.0	57.0	1,740
J-145	620	66.0	60.0	1,510
J-146	625	64.0	57.0	1,700
J-147	635	59.0	52.0	630
J-148	635	60.0	52.0	2,460
J-149	618	67.0	59.0	1,370
J-150	625	64.0	56.0	3,790
J-159	625	64.0	56.0	3,820
J-163	625	60.0	58.0	250
J-165	625	67.0	63.0	480

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-166	625	64.0	56.0	5,030
J-167	625	64.0	56.0	4,110
J-168	625	64.0	56.0	2,920
J-169	625	64.0	56.0	4,970
J-172	625	64.0	56.0	4,960
J-173	618	67.0	59.0	1,090
J-174	625	63.0	51.0	1,460
J-175	625	63.0	51.0	1,090
J-177	625	64.0	56.0	4,050
J-178	625	64.0	56.0	3,850
J-179	605	73.0	70.0	3,840
J-180	625	64.0	56.0	2,630
J-181	625	60.0	58.0	1,450
J-184	625	64.0	58.0	1,540
J-185	600	76.0	72.0	2,230
J-187	625	64.0	56.0	1,060
J-189	635	60.0	51.0	1,460
J-193	635	60.0	51.0	1,070
J-194	625	64.0	56.0	1,420
J-195	625	64.0	55.0	1,150
J-196	635	59.0	49.0	810
J-197	635	59.0	49.0	1,090
J-198	625	64.0	56.0	3,580
J-199	625	64.0	56.0	490
J-202	630	61.0	51.0	920
J-203	625	61.0	57.0	1,770
J-206	635	60.0	51.0	800
J-210	618	67.0	59.0	1,160
J-213	625	64.0	56.0	3,330
J-214	625	64.0	56.0	3,870
J-216	635	60.0	52.0	3,350
J-218	630	61.0	51.0	810
J-219	635	59.0	49.0	1,070
J-220	625	63.0	53.0	460
J-222	630	61.0	51.0	1,110
J-223	635	60.0	52.0	3,370
J-225	635	60.0	51.0	780
J-226	635	60.0	51.0	3,010
J-227	635	59.0	51.0	930
J-228	635	60.0	51.0	920
J-229	635	60.0	52.0	3,160
J-230	635	59.0	51.0	990
J-231	635	60.0	52.0	2,750
J-232	635	59.0	51.0	800
J-233	635	59.0	52.0	1,140
J-234	635	60.0	51.0	1,070

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-235	635	60.0	52.0	3,480
J-236	635	60.0	51.0	1,020
J-237	635	60.0	52.0	3,160
J-238	635	60.0	51.0	1,040
J-239	635	60.0	52.0	3,400
J-240	630	62.0	53.0	2,910
J-241	625	64.0	54.0	2,490
J-242	635	60.0	52.0	3,370
J-244	635	60.0	50.0	1,330
J-245	635	60.0	51.0	1,270
J-247	640	56.0	44.0	780
J-248	625	63.0	51.0	1,090
J-251	640	56.0	44.0	720
J-252	625	65.0	57.0	1,340
J-253	625	64.0	56.0	1,390
J-254	640	57.0	46.0	880
J-255	625	64.0	53.0	1,220
J-256	625	64.0	56.0	1,410
J-257	625	65.0	59.0	1,700
J-258	625	64.0	54.0	1,240
J-259	640	57.0	47.0	930
J-260	625	63.0	53.0	1,220
J-261	625	64.0	56.0	1,490
J-262	625	64.0	55.0	1,350
J-263	625	64.0	56.0	3,670
J-264	625	63.0	52.0	890
J-265	625	64.0	56.0	350
J-267	625	64.0	56.0	830
J-268	625	63.0	53.0	1,260
J-269	625	65.0	57.0	4,450
J-270	635	59.0	50.0	1,540
J-271	625	62.0	46.0	800
J-272	635	59.0	49.0	1,090
J-273	625	63.0	52.0	1,220
J-274	625	65.0	57.0	4,110
J-278	635	60.0	51.0	1,000
J-279	635	60.0	51.0	1,050
J-280	625	64.0	56.0	4,650
J-281	635	60.0	51.0	1,050
J-282	625	64.0	56.0	4,750
J-283	635	59.0	49.0	740
J-286	625	64.0	56.0	4,110
J-287	625	64.0	56.0	3,960
J-288	625	64.0	56.0	3,600
J-290	625	60.0	58.0	6,000
J-293	625	60.0	58.0	3,950

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-294	625	60.0	58.0	2,240
J-296	625	64.0	56.0	4,030
J-297	625	64.0	56.0	2,250
J-298	625	61.0	57.0	6,000
J-299	625	60.0	58.0	6,000
J-302	625	61.0	46.0	730
J-303	625	64.0	54.0	2,270
J-304	625	63.0	56.0	1,560
J-305	625	63.0	57.0	5,100
J-311	625	60.0	59.0	6,000
J-314	635	59.0	49.0	820
J-316	635	60.0	52.0	2,890
J-319	625	64.0	55.0	40
J-323	625	64.0	56.0	1,150
J-325	635	59.0	52.0	990
J-329	625	64.0	56.0	540
J-331	590	75.0	39.0	0
J-332	625	72.0	69.0	6,000
J-333	625	73.0	71.0	6,000
J-334	625	60.0	59.0	6,000
J-335	625	68.0	65.0	6,000
J-337	635	60.0	52.0	900
J-338	625	(N/A)	(N/A)	#VALUE!
J-339	625	64.0	56.0	4,950
J-345	625	63.0	57.0	5,090
J-347	625	63.0	57.0	5,180
J-349	625	63.0	57.0	3,470
J-351	625	60.0	58.0	6,000
J-352	625	60.0	58.0	6,000
J-354	630	62.0	54.0	1,580
J-356	625	63.0	57.0	5,220
J-359	635	59.0	50.0	2,050
J-363	640	57.0	48.0	700
J-367	625	64.0	56.0	1,320
J-368	625	64.0	56.0	3,960
J-374	625	64.0	56.0	400
J-375	625	64.0	56.0	3,570
J-376	625	64.0	56.0	3,920
J-377	625	64.0	56.0	1,610
J-378	635	60.0	51.0	1,100
J-379	635	60.0	51.0	1,150
J-380	635	60.0	51.0	2,660
J-382	630	62.0	54.0	420
J-383	625	64.0	56.0	1,230
J-384	625	64.0	56.0	1,420
J-385	625	64.0	55.0	2,670

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-387	625	64.0	55.0	2,900
J-388	625	64.0	55.0	1,340
J-389	625	64.0	56.0	3,170
J-390	625	64.0	56.0	1,370
J-391	625	64.0	54.0	1,210
J-393	625	64.0	56.0	510
J-395	625	64.0	56.0	1,280
J-396	625	64.0	57.0	160
J-398	640	56.0	45.0	460
J-399	640	57.0	45.0	510
J-402	640	56.0	42.0	540
J-403	640	56.0	42.0	450
J-407	625	68.0	65.0	6,000
J-409	625	66.0	59.0	5,220
J-410	625	66.0	59.0	5,340
J-411	625	63.0	52.0	1,800
J-412	625	64.0	56.0	300
J-413	625	64.0	56.0	1,310
J-414	625	64.0	57.0	3,970
J-415	625	64.0	56.0	3,790
J-416	625	64.0	56.0	250
J-417	625	64.0	54.0	460
J-418	625	64.0	54.0	370
J-419	625	64.0	54.0	1,220
J-421	625	64.0	61.0	6,000
J-423	625	68.0	65.0	6,000
J-424	625	64.0	56.0	1,290
J-425	625	64.0	57.0	1,480
J-426	625	65.0	57.0	1,290
J-427	625	64.0	55.0	90
J-428	625	64.0	55.0	2,710
J-429	625	64.0	54.0	1,220
J-430	635	59.0	49.0	470
J-431	635	59.0	49.0	640
J-432	635	59.0	49.0	910
J-433	635	59.0	49.0	780
J-434	635	59.0	49.0	780
J-435	635	59.0	49.0	760
J-436	635	59.0	49.0	620
J-437	635	59.0	49.0	480
J-438	635	59.0	49.0	530
J-439	635	59.0	50.0	1,630
J-440	635	59.0	49.0	1,130
J-441	635	59.0	50.0	1,720
J-442	635	59.0	49.0	1,270
J-443	625	64.0	56.0	3,790

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-444	625	64.0	56.0	3,700
J-445	625	64.0	56.0	1,480
J-446	625	64.0	56.0	1,810
J-447	625	64.0	56.0	1,250
J-448	625	64.0	56.0	1,280
J-449	625	64.0	56.0	4,240
J-450	625	64.0	56.0	4,020
J-451	610	70.0	61.0	180
J-452	610	70.0	61.0	190
J-453	595	76.0	67.0	120
J-454	625	64.0	56.0	2,810
J-455	625	64.0	56.0	4,960
J-456	625	64.0	56.0	420
J-457	625	64.0	56.0	540
J-458	625	64.0	56.0	360
J-459	625	64.0	56.0	420
J-460	625	64.0	56.0	1,730
J-461	625	60.0	58.0	1,620
J-462	635	60.0	52.0	3,490
J-463	635	60.0	52.0	2,870
J-464	635	59.0	50.0	360
J-465	635	59.0	50.0	400
J-466	635	59.0	50.0	400
J-468	635	59.0	50.0	670
J-469	635	59.0	50.0	500
J-471	635	60.0	50.0	2,350
J-472	635	60.0	50.0	360
J-473	635	60.0	50.0	330
J-474	635	60.0	50.0	360
J-475	635	60.0	51.0	2,650
J-476	635	59.0	50.0	1,810
J-477	635	60.0	51.0	2,690
J-478	635	60.0	51.0	2,680
J-479	635	60.0	51.0	2,630
J-480	635	60.0	50.0	200
J-481	625	66.0	59.0	5,530
J-482	625	65.0	58.0	5,350
J-483	625	64.0	57.0	5,080
J-484	625	64.0	57.0	5,070
J-485	625	65.0	57.0	2,130
J-486	625	65.0	57.0	1,320
J-487	625	65.0	57.0	2,710
J-488	625	65.0	57.0	2,780
J-489	625	64.0	57.0	4,590
J-490	625	64.0	56.0	440
J-491	635	60.0	51.0	2,780

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-492	630	62.0	53.0	2,970
J-494	630	62.0	53.0	2,980
J-495	635	60.0	52.0	3,160
J-496	635	60.0	52.0	3,190
J-497	635	60.0	52.0	3,260
J-499	635	59.0	52.0	980
J-500	635	60.0	52.0	2,320
J-501	635	60.0	52.0	2,440
J-515	635	60.0	52.0	2,910
J-516	635	60.0	52.0	2,940
J-517	635	60.0	52.0	3,120
J-518	635	60.0	52.0	2,580
J-519	630	62.0	54.0	2,460
J-520	630	62.0	54.0	2,320
J-521	625	64.0	56.0	3,540
J-522	630	62.0	54.0	240
J-523	630	62.0	54.0	240
J-524	625	64.0	56.0	3,860
J-525	635	60.0	52.0	3,280
J-526	635	60.0	52.0	3,260
J-528	635	60.0	52.0	3,140
J-529	635	60.0	52.0	2,450
J-530	635	60.0	51.0	880
J-531	635	60.0	51.0	1,130
J-532	635	60.0	52.0	1,030
J-533	635	60.0	51.0	1,130
J-534	635	60.0	51.0	1,050
J-535	625	64.0	56.0	770
J-536	625	64.0	56.0	3,240
J-537	625	64.0	55.0	510
J-538	630	62.0	53.0	490
J-539	635	60.0	51.0	1,510
J-540	630	62.0	53.0	1,500
J-541	635	60.0	51.0	520
J-543	635	60.0	52.0	3,130
J-544	635	60.0	51.0	1,070
J-545	635	60.0	52.0	2,580
J-547	630	61.0	51.0	1,220
J-548	625	63.0	53.0	1,090
J-549	630	61.0	51.0	1,200
J-550	625	63.0	53.0	1,280
J-551	625	63.0	50.0	840
J-552	640	56.0	42.0	480
J-554	595	78.0	75.0	1,280
J-555	590	80.0	77.0	6,000
J-556	640	57.0	46.0	490

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-558	640	57.0	47.0	540
J-559	640	57.0	48.0	540
J-560	625	64.0	56.0	860
J-561	625	65.0	57.0	910
J-562	625	65.0	59.0	980
J-563	625	64.0	57.0	1,040
J-564	625	64.0	56.0	2,500
J-565	625	64.0	56.0	3,080
J-566	625	64.0	56.0	1,750
J-567	618	67.0	59.0	1,020
J-568	618	67.0	59.0	1,150
J-569	618	67.0	59.0	1,290
J-571	625	64.0	57.0	970
J-572	625	64.0	57.0	4,590
J-573	625	64.0	57.0	4,510
J-574	625	64.0	57.0	4,510
J-575	625	64.0	57.0	4,520
J-576	625	64.0	56.0	4,770
J-577	625	64.0	57.0	3,140
J-578	625	64.0	56.0	1,330
J-579	625	64.0	56.0	580
J-580	625	64.0	56.0	4,680
J-581	625	64.0	56.0	4,580
J-582	625	64.0	56.0	1,310
J-583	625	64.0	56.0	1,070
J-584	625	64.0	56.0	960
J-585	625	64.0	56.0	520
J-586	625	64.0	56.0	460
J-588	625	64.0	56.0	2,200
J-589	625	64.0	56.0	800
J-590	625	64.0	56.0	1,200
J-591	625	64.0	56.0	1,360
J-592	625	64.0	56.0	1,040
J-593	625	64.0	56.0	570
J-595	625	64.0	56.0	2,760
J-596	625	63.0	56.0	820
J-597	625	63.0	56.0	820
J-598	625	63.0	56.0	1,590
J-599	625	61.0	57.0	3,070
J-600	625	61.0	57.0	720
J-601	625	61.0	57.0	700
J-602	625	61.0	57.0	730
J-603	625	61.0	57.0	850
J-604	625	60.0	58.0	1,450
J-605	625	60.0	58.0	1,400
J-606	625	60.0	58.0	2,070

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-607	625	60.0	58.0	870
J-608	625	60.0	58.0	860
J-609	625	60.0	58.0	970
J-610	625	60.0	58.0	950
J-611	625	60.0	58.0	2,180
J-612	625	60.0	58.0	2,320
J-622	625	65.0	62.0	3,430
J-623	625	65.0	62.0	1,710
J-624	625	65.0	62.0	430
J-626	625	60.0	58.0	260
J-627	625	74.0	72.0	6,000
J-628	590	80.0	77.0	6,000
J-629	590	80.0	77.0	6,000
J-630	590	80.0	77.0	6,000
J-631	590	80.0	77.0	1,120
J-632	625	64.0	55.0	1,680
J-633	625	64.0	55.0	1,640
J-634	625	64.0	55.0	1,560
J-635	625	64.0	54.0	1,370
J-636	630	61.0	51.0	940
J-637	625	63.0	52.0	600
J-639	625	64.0	57.0	1,180
J-640	625	60.0	58.0	600
J-641	635	60.0	51.0	1,000
J-642	625	64.0	56.0	410
J-644	635	60.0	51.0	2,730
J-646	635	60.0	51.0	1,030
J-649	625	64.0	56.0	730
J-651	625	64.0	56.0	2,440
J-652	625	64.0	55.0	560
J-655	640	56.0	43.0	380
J-657	625	66.0	61.0	1,080
J-659	625	62.0	57.0	5,540
J-660	625	64.0	56.0	840
J-662	640	57.0	49.0	1,540
J-664	640	57.0	48.0	400
J-665	635	59.0	49.0	1,020
J-671	635	60.0	52.0	2,560
J-672	635	60.0	52.0	2,490
J-673	625	64.0	55.0	290
J-674	625	63.0	57.0	1,910
J-675	635	60.0	52.0	400
J-676	635	60.0	51.0	690
J-677	625	64.0	56.0	760
J-678	625	64.0	56.0	800
J-679	625	64.0	56.0	310

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH EXISTING INFRASTRUCTURE

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-680	625	64.0	56.0	770
J-681	630	62.0	53.0	740
J-684	630	62.0	53.0	810
J-686	630	62.0	53.0	620
J-687	630	62.0	54.0	710
J-688	635	60.0	50.0	190
J-689	635	60.0	51.0	640
J-690	635	60.0	51.0	650
J-691	635	60.0	51.0	690
J-692	635	60.0	51.0	640
J-693	635	60.0	51.0	630
J-694	635	60.0	51.0	690
J-695	625	64.0	54.0	790
J-696	625	64.0	54.0	810
J-697	625	64.0	56.0	940
J-698	625	62.0	47.0	440
J-699	625	62.0	48.0	500
J-700	640	56.0	43.0	380
J-701	640	56.0	44.0	500
J-702	640	56.0	44.0	520
J-703	640	56.0	45.0	540
J-704	640	57.0	45.0	510
J-705	640	57.0	47.0	540
J-706	640	56.0	42.0	420
J-707	640	57.0	45.0	560
J-708	640	57.0	46.0	590
J-709	640	57.0	48.0	650
J-710	626	63.0	56.0	1,240
J-711	625	64.0	56.0	1,150
J-712	625	64.0	56.0	4,020
J-713	625	64.0	56.0	900
J-714	625	64.0	56.0	360
J-715	635	(N/A)	(N/A)	#VALUE!
J-716	625	64.0	54.0	280
J-717	625	64.0	56.0	560
J-718	625	64.0	55.0	140
J-720	640	64.0	61.0	6,000
J-721	584	82.0	79.0	100

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH RECOMMENDED IMPROVEMENTS

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
F-2	625	65.0	59.0	1,570
F-4	635	60.0	54.0	990
F-5	625	65.0	59.0	980
F-10	635	58.0	54.0	2,500
J-1	625	65.0	59.0	1,260
J-2	630	63.0	56.0	4,090
J-3	625	65.0	60.0	6,000
J-4	629.51	63.0	57.0	1,180
J-5	629.59	63.0	57.0	3,810
J-7	625	65.0	60.0	6,000
J-10	625	65.0	59.0	6,000
J-11	625	65.0	59.0	6,000
J-13	635	61.0	54.0	5,400
J-14	625	66.0	60.0	6,000
J-15	635	55.0	54.0	6,000
J-15	625	61.0	59.0	720
J-16	584	82.0	78.0	1,010
J-17	584	82.0	78.0	740
J-18	586	81.0	77.0	390
J-19	584	82.0	78.0	690
J-20	583	82.0	79.0	600
J-21	584	82.0	78.0	850
J-22	583	82.0	79.0	590
J-23	580	83.0	80.0	400
J-24	586	80.0	77.0	160
J-25	636.62	61.0	55.0	5,520
J-27	637.69	60.0	55.0	5,060
J-28	640	59.0	54.0	4,900
J-29	625	65.0	59.0	1,430
J-29	636.01	61.0	55.0	5,730
J-30	625	65.0	59.0	1,440
J-30	640	59.0	54.0	5,430
J-31	635	60.0	54.0	1,160
J-31	635.22	61.0	56.0	5,850
J-32	635	60.0	54.0	1,170
J-32	640	59.0	54.0	5,530
J-33	633.76	62.0	56.0	5,770
J-34	628.48	64.0	58.0	5,760
J-35	632.87	62.0	56.0	5,690
J-37	631.95	62.0	57.0	5,660
J-38	631.09	63.0	57.0	5,650
J-39	630.47	63.0	57.0	5,630
J-40	626.98	64.0	59.0	5,630
J-41	629.37	63.0	58.0	5,700
J-42	615	69.0	63.0	1,120
J-43	627.6	64.0	59.0	5,770

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH RECOMMENDED IMPROVEMENTS

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-44	626.1	65.0	59.0	5,400
J-45	625	65.0	59.0	4,170
J-45	617.13	68.0	62.0	1,850
J-46	625	65.0	59.0	4,140
J-46	634.61	62.0	56.0	5,850
J-47	635	61.0	54.0	970
J-47	635	61.0	54.0	960
J-48	625	65.0	59.0	1,320
J-49	625	65.0	59.0	2,500
J-50	615	69.0	63.0	6,000
J-51	625	64.0	59.0	1,230
J-53	640	60.0	54.0	6,000
J-54	638.57	60.0	54.0	4,430
J-58	623.04	65.0	60.0	120
J-60	620	67.0	63.0	4,960
J-60	630	63.0	57.0	6,000
J-61	615	69.0	65.0	4,940
J-61	630.14	63.0	57.0	6,000
J-62	635	61.0	54.0	6,000
J-63	630	63.0	56.0	6,000
J-64	635	61.0	54.0	4,590
J-65	635	61.0	54.0	4,440
J-65	635	61.0	54.0	6,000
J-67	635	60.0	54.0	6,000
J-68	625	65.0	60.0	1,970
J-68	635	60.0	54.0	5,890
J-69	625	65.0	60.0	1,980
J-69	635	60.0	54.0	5,780
J-70	640	59.0	54.0	1,910
J-70	635	60.0	54.0	5,990
J-71	640	60.0	55.0	2,320
J-72	621.71	67.0	63.0	6,000
J-74	635	60.0	54.0	5,530
J-75	625	65.0	59.0	2,110
J-76	625	65.0	59.0	2,100
J-76	620.59	67.0	63.0	6,000
J-77	625	65.0	59.0	6,000
J-78	625	65.0	59.0	6,000
J-79	635	55.0	54.0	750
J-79	625	65.0	59.0	6,000
J-80	625	65.0	59.0	6,000
J-81	625	65.0	59.0	6,000
J-82	640	60.0	56.0	6,000
J-82	625	65.0	59.0	6,000
J-83	625	65.0	59.0	1,470
J-85	635	61.0	54.0	1,060

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH RECOMMENDED IMPROVEMENTS

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-87	625	65.0	59.0	6,000
J-88	625	65.0	59.0	4,450
J-89	640	59.0	54.0	6,000
J-91	635	60.0	54.0	5,640
J-93	635	60.0	54.0	5,410
J-96	635	61.0	54.0	530
J-100	625	65.0	59.0	1,850
J-102	640	59.0	54.0	3,170
J-103	625	66.0	60.0	2,530
J-104	625	65.0	59.0	5,970
J-105	625	65.0	59.0	1,490
J-108	625	65.0	59.0	5,370
J-109	625	65.0	59.0	1,760
J-110	625	65.0	59.0	5,890
J-111	625	65.0	59.0	690
J-113	625	65.0	59.0	5,510
J-115	625	65.0	59.0	5,350
J-116	622	66.0	61.0	2,120
J-117	625	64.0	59.0	5,770
J-118	625	64.0	59.0	690
J-120	615	69.0	63.0	1,670
J-123	615	69.0	63.0	2,070
J-124	625	65.0	59.0	6,000
J-127	625	65.0	59.0	1,310
J-128	630	63.0	56.0	2,050
J-129	625	65.0	59.0	5,900
J-130	625	65.0	59.0	5,440
J-132	635	55.0	54.0	470
J-133	635	55.0	54.0	630
J-135	625	65.0	59.0	2,380
J-137	625	65.0	59.0	5,650
J-138	630	63.0	57.0	1,440
J-139	635	56.0	54.0	1,520
J-140	615	69.0	64.0	1,900
J-141	625	65.0	59.0	5,370
J-143	615	69.0	64.0	2,030
J-144	615	69.0	64.0	2,530
J-145	620	67.0	62.0	2,010
J-146	625	65.0	59.0	2,480
J-147	635	60.0	54.0	5,500
J-148	635	60.0	54.0	5,560
J-149	615	69.0	63.0	2,100
J-150	625	65.0	59.0	5,920
J-159	625	65.0	59.0	6,000
J-163	615	64.0	63.0	340
J-165	625	65.0	60.0	5,540

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH RECOMMENDED IMPROVEMENTS

Label	Elevation	Pressure (psi)		Available Fire Flow
	(ft)	Avg Day	Max Day	(gpm)
J-166	615	69.0	63.0	6,000
J-167	625	65.0	59.0	4,100
J-168	625	65.0	59.0	3,430
J-169	625	64.0	59.0	6,000
J-172	625	64.0	59.0	6,000
J-173	615	69.0	63.0	2,090
J-174	625	65.0	59.0	4,180
J-175	625	65.0	59.0	2,230
J-177	625	65.0	59.0	6,000
J-178	625	65.0	59.0	6,000
J-179	615	69.0	64.0	2,180
J-180	625	65.0	59.0	5,330
J-181	635	56.0	54.0	1,750
J-184	625	65.0	60.0	1,880
J-185	600	76.0	71.0	2,410
J-187	625	65.0	59.0	1,700
J-189	635	61.0	54.0	2,230
J-193	635	60.0	54.0	1,560
J-194	625	65.0	59.0	2,000
J-195	625	65.0	59.0	1,680
J-196	635	61.0	54.0	1,200
J-197	635	61.0	54.0	1,820
J-198	625	65.0	59.0	5,520
J-199	625	65.0	59.0	710
J-202	630	63.0	56.0	1,360
J-203	635	57.0	54.0	1,970
J-206	635	61.0	54.0	1,150
J-210	615	69.0	63.0	2,110
J-213	625	65.0	59.0	5,410
J-214	625	65.0	59.0	5,890
J-216	635	60.0	54.0	5,450
J-218	630	63.0	56.0	1,320
J-219	635	61.0	54.0	1,740
J-220	625	65.0	59.0	630
J-222	630	63.0	56.0	2,040
J-223	635	60.0	54.0	5,540
J-225	635	60.0	54.0	1,130
J-226	635	61.0	54.0	5,670
J-227	635	60.0	54.0	1,470
J-228	635	60.0	54.0	1,390
J-229	635	61.0	54.0	5,730
J-230	635	60.0	54.0	1,680
J-231	635	60.0	54.0	5,370
J-232	635	60.0	54.0	1,350
J-233	635	60.0	54.0	5,740
J-234	635	60.0	54.0	1,560

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH RECOMMENDED IMPROVEMENTS

Label	Elevation	Pressure (psi)		Available Fire Flow
	(ft)	Avg Day	Max Day	(gpm)
J-235	635	60.0	54.0	5,740
J-236	635	60.0	54.0	1,570
J-237	635	60.0	54.0	5,650
J-238	635	60.0	54.0	1,690
J-239	635	60.0	54.0	5,740
J-240	630	63.0	57.0	4,940
J-241	625	65.0	59.0	5,610
J-242	635	60.0	54.0	5,460
J-244	635	61.0	54.0	2,060
J-245	635	61.0	54.0	1,860
J-247	640	61.0	56.0	6,000
J-248	625	65.0	59.0	2,210
J-251	640	61.0	56.0	6,000
J-252	625	65.0	60.0	2,030
J-253	625	65.0	59.0	2,000
J-254	640	59.0	54.0	1,810
J-255	625	65.0	59.0	2,360
J-256	625	65.0	59.0	1,850
J-257	625	65.0	60.0	2,210
J-258	625	65.0	59.0	2,460
J-259	640	59.0	53.0	1,780
J-260	625	65.0	59.0	2,250
J-261	625	65.0	59.0	1,900
J-262	625	65.0	59.0	2,240
J-263	625	65.0	59.0	6,000
J-264	625	65.0	59.0	5,980
J-265	625	65.0	59.0	640
J-267	625	65.0	59.0	1,100
J-268	625	65.0	59.0	2,310
J-269	625	65.0	59.0	6,000
J-270	635	61.0	54.0	4,440
J-271	625	65.0	59.0	5,500
J-272	635	61.0	54.0	1,710
J-273	625	65.0	59.0	2,360
J-274	625	65.0	59.0	6,000
J-278	635	60.0	54.0	1,530
J-279	635	60.0	54.0	1,610
J-280	625	65.0	59.0	6,000
J-281	635	60.0	54.0	1,710
J-282	625	65.0	59.0	6,000
J-283	635	61.0	54.0	1,020
J-286	625	65.0	59.0	6,000
J-287	625	65.0	59.0	5,930
J-288	625	65.0	59.0	5,570
J-290	635	56.0	54.0	6,000
J-293	635	55.0	54.0	4,450

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH RECOMMENDED IMPROVEMENTS

Label	Elevation (ft)	Pressure (psi)		Available Fire Flow (gpm)
		Avg Day	Max Day	
J-294	635	55.0	54.0	740
J-296	625	64.0	59.0	6,000
J-297	625	65.0	59.0	1,670
J-298	635	57.0	54.0	6,000
J-299	635	55.0	54.0	6,000
J-302	625	65.0	58.0	3,580
J-303	625	65.0	59.0	5,200
J-304	625	65.0	59.0	6,000
J-305	615	68.0	63.0	6,000
J-311	635	55.0	54.0	6,000
J-314	635	61.0	54.0	1,170
J-316	635	60.0	54.0	5,390
J-319	625	65.0	59.0	110
J-323	625	65.0	59.0	1,580
J-325	635	60.0	54.0	5,840
J-329	625	65.0	59.0	670
J-331	615	69.0	63.0	1,870
J-332	625	69.0	65.0	6,000
J-333	625	71.0	67.0	6,000
J-334	635	55.0	54.0	6,000
J-335	625	66.0	62.0	6,000
J-337	635	60.0	54.0	1,290
J-338	625	(N/A)	(N/A)	#VALUE!
J-339	625	64.0	59.0	6,000
J-345	615	68.0	63.0	6,000
J-347	615	68.0	63.0	6,000
J-349	615	68.0	63.0	4,880
J-351	635	55.0	54.0	6,000
J-352	635	55.0	54.0	6,000
J-354	630	63.0	56.0	2,350
J-356	615	68.0	63.0	6,000
J-359	635	61.0	54.0	4,490
J-363	640	59.0	53.0	1,190
J-367	625	65.0	59.0	1,650
J-368	625	65.0	59.0	6,000
J-374	625	65.0	59.0	430
J-375	625	65.0	59.0	6,000
J-376	625	65.0	59.0	6,000
J-377	625	65.0	59.0	2,210
J-378	635	61.0	54.0	1,550
J-379	635	61.0	54.0	1,650
J-380	635	61.0	54.0	4,910
J-382	630	63.0	57.0	460
J-383	625	65.0	59.0	1,530
J-384	625	65.0	59.0	1,950
J-385	625	65.0	59.0	5,540

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH RECOMMENDED IMPROVEMENTS

Label	Elevation	Pressure (psi)		Available Fire Flow
	(ft)	Avg Day	Max Day	(gpm)
J-387	625	65.0	59.0	5,550
J-388	625	65.0	59.0	2,260
J-389	625	65.0	59.0	5,660
J-390	625	65.0	59.0	1,860
J-391	625	65.0	59.0	3,400
J-393	625	65.0	59.0	690
J-395	625	65.0	59.0	1,580
J-396	625	65.0	59.0	170
J-398	640	59.0	54.0	5,510
J-399	640	59.0	53.0	5,400
J-402	640	60.0	55.0	6,000
J-403	640	60.0	55.0	6,000
J-407	625	66.0	62.0	6,000
J-409	625	66.0	61.0	6,000
J-410	625	66.0	61.0	6,000
J-411	625	65.0	59.0	4,560
J-412	625	65.0	59.0	320
J-413	625	65.0	59.0	1,820
J-414	625	65.0	59.0	6,000
J-415	625	65.0	59.0	6,000
J-416	625	65.0	60.0	5,700
J-417	625	65.0	59.0	990
J-418	625	65.0	59.0	1,050
J-419	625	65.0	59.0	2,040
J-421	625	63.0	60.0	6,000
J-423	625	66.0	62.0	6,000
J-424	625	65.0	59.0	2,170
J-425	625	65.0	59.0	2,440
J-426	625	65.0	59.0	1,920
J-427	625	65.0	59.0	1,520
J-428	625	65.0	59.0	5,560
J-429	625	65.0	59.0	2,040
J-430	635	61.0	54.0	600
J-431	635	61.0	54.0	880
J-432	635	61.0	54.0	1,360
J-433	635	61.0	54.0	1,090
J-434	635	61.0	54.0	1,080
J-435	635	61.0	54.0	1,060
J-436	635	61.0	54.0	820
J-437	635	61.0	54.0	620
J-438	635	61.0	54.0	680
J-439	635	61.0	54.0	4,320
J-440	635	61.0	54.0	1,950
J-441	635	61.0	54.0	4,260
J-442	635	61.0	54.0	2,190
J-443	625	65.0	59.0	5,870

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH RECOMMENDED IMPROVEMENTS

Label	Elevation	Pressure (psi)		Available Fire Flow
	(ft)	Avg Day	Max Day	(gpm)
J-444	625	65.0	59.0	5,780
J-445	625	65.0	59.0	2,050
J-446	625	65.0	59.0	2,550
J-447	625	65.0	59.0	1,650
J-448	625	65.0	59.0	1,680
J-449	625	65.0	59.0	6,000
J-450	615	69.0	63.0	6,000
J-451	615	69.0	63.0	1,100
J-452	615	69.0	63.0	2,020
J-453	615	69.0	63.0	1,910
J-454	625	64.0	59.0	2,200
J-455	625	64.0	59.0	6,000
J-456	615	69.0	63.0	1,300
J-457	615	69.0	63.0	1,860
J-458	615	69.0	63.0	900
J-459	615	69.0	63.0	1,620
J-460	615	69.0	63.0	2,500
J-461	635	55.0	54.0	1,910
J-462	635	60.0	54.0	6,000
J-463	635	60.0	54.0	6,000
J-464	635	61.0	54.0	3,690
J-465	635	61.0	54.0	3,820
J-466	635	61.0	54.0	4,080
J-468	635	61.0	54.0	1,220
J-469	635	61.0	54.0	1,050
J-471	635	61.0	54.0	4,920
J-472	635	61.0	54.0	4,370
J-473	635	61.0	54.0	4,660
J-474	635	61.0	54.0	4,880
J-475	635	61.0	54.0	5,040
J-476	635	61.0	54.0	4,290
J-477	635	61.0	54.0	4,890
J-478	635	61.0	54.0	4,870
J-479	635	61.0	54.0	4,810
J-480	635	61.0	54.0	2,890
J-481	625	66.0	60.0	6,000
J-482	625	65.0	60.0	6,000
J-483	625	65.0	59.0	6,000
J-484	625	65.0	59.0	6,000
J-485	625	65.0	59.0	2,740
J-486	625	65.0	59.0	1,790
J-487	625	65.0	59.0	5,600
J-488	625	65.0	59.0	5,570
J-489	625	65.0	59.0	6,000
J-490	625	65.0	59.0	4,160
J-491	635	61.0	54.0	4,900

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH RECOMMENDED IMPROVEMENTS

Label	Elevation	Pressure (psi)		Available Fire Flow
	(ft)	Avg Day	Max Day	(gpm)
J-492	630	63.0	56.0	5,190
J-494	630	63.0	57.0	5,340
J-495	635	61.0	54.0	5,470
J-496	635	60.0	54.0	5,320
J-497	635	60.0	54.0	5,350
J-499	635	60.0	54.0	6,000
J-500	635	60.0	54.0	4,610
J-501	635	60.0	54.0	5,330
J-515	635	60.0	54.0	5,960
J-516	635	60.0	54.0	6,000
J-517	635	61.0	54.0	6,000
J-518	635	61.0	54.0	5,090
J-519	630	63.0	56.0	4,340
J-520	630	63.0	56.0	3,920
J-521	625	65.0	59.0	6,000
J-522	630	63.0	57.0	420
J-523	630	63.0	57.0	440
J-524	625	65.0	59.0	6,000
J-525	635	61.0	54.0	6,000
J-526	635	61.0	54.0	6,000
J-528	635	61.0	54.0	6,000
J-529	635	61.0	54.0	4,550
J-530	635	60.0	54.0	1,230
J-531	635	60.0	54.0	1,620
J-532	635	60.0	54.0	1,450
J-533	635	60.0	54.0	1,610
J-534	635	60.0	54.0	1,530
J-535	625	65.0	59.0	1,090
J-536	625	65.0	59.0	5,860
J-537	625	65.0	59.0	880
J-538	630	63.0	56.0	860
J-539	635	61.0	54.0	2,130
J-540	630	63.0	57.0	2,160
J-541	635	61.0	54.0	680
J-543	635	61.0	54.0	6,000
J-544	635	61.0	54.0	1,530
J-545	635	61.0	54.0	5,050
J-547	630	63.0	56.0	2,150
J-548	625	65.0	59.0	6,000
J-549	630	63.0	56.0	2,110
J-550	625	65.0	59.0	6,000
J-551	625	65.0	59.0	1,620
J-552	640	59.0	54.0	1,790
J-554	595	77.0	73.0	1,480
J-555	615	68.0	65.0	6,000
J-556	640	59.0	53.0	5,260

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH RECOMMENDED IMPROVEMENTS

Label	Elevation	Pressure (psi)		Available Fire Flow
	(ft)	Avg Day	Max Day	(gpm)
J-558	640	59.0	53.0	5,170
J-559	640	59.0	53.0	5,170
J-560	625	65.0	60.0	5,760
J-561	625	65.0	60.0	5,790
J-562	625	65.0	60.0	5,770
J-563	625	65.0	59.0	1,300
J-564	625	65.0	59.0	5,290
J-565	625	65.0	59.0	5,390
J-566	625	65.0	59.0	2,510
J-567	615	69.0	63.0	1,840
J-568	615	69.0	63.0	2,020
J-569	615	69.0	63.0	2,100
J-571	625	65.0	59.0	1,310
J-572	625	65.0	59.0	6,000
J-573	625	65.0	59.0	6,000
J-574	625	65.0	59.0	6,000
J-575	625	65.0	59.0	6,000
J-576	625	65.0	59.0	6,000
J-577	625	65.0	59.0	4,320
J-578	625	65.0	59.0	1,850
J-579	625	65.0	59.0	790
J-580	625	65.0	59.0	6,000
J-581	625	65.0	59.0	6,000
J-582	625	65.0	59.0	6,000
J-583	625	65.0	59.0	6,000
J-584	625	65.0	59.0	6,000
J-585	625	65.0	59.0	5,520
J-586	625	65.0	59.0	5,240
J-588	625	65.0	59.0	3,330
J-589	625	65.0	59.0	1,100
J-590	625	65.0	59.0	1,690
J-591	625	65.0	59.0	1,980
J-592	625	65.0	59.0	1,550
J-593	625	65.0	59.0	790
J-595	625	65.0	59.0	4,010
J-596	625	65.0	59.0	5,890
J-597	625	65.0	59.0	5,850
J-598	625	64.0	59.0	4,630
J-599	635	57.0	54.0	3,500
J-600	625	61.0	59.0	930
J-601	625	61.0	59.0	920
J-602	635	57.0	54.0	890
J-603	635	57.0	54.0	1,030
J-604	635	56.0	54.0	1,750
J-605	635	56.0	54.0	1,660
J-606	635	56.0	54.0	2,300

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH RECOMMENDED IMPROVEMENTS

Label	Elevation	Pressure (psi)		Available Fire Flow
	(ft)	Avg Day	Max Day	(gpm)
J-607	635	56.0	54.0	1,040
J-608	635	56.0	54.0	1,030
J-609	635	56.0	54.0	1,160
J-610	635	56.0	54.0	1,140
J-611	635	55.0	54.0	2,410
J-612	635	55.0	54.0	2,540
J-622	625	64.0	60.0	980
J-623	625	64.0	60.0	900
J-624	610	70.0	67.0	500
J-626	615	64.0	63.0	350
J-627	625	71.0	68.0	6,000
J-628	615	68.0	65.0	6,000
J-629	615	68.0	65.0	6,000
J-630	615	68.0	65.0	2,710
J-631	615	68.0	65.0	1,140
J-632	625	65.0	59.0	6,000
J-633	625	65.0	59.0	6,000
J-634	625	65.0	59.0	6,000
J-635	625	65.0	59.0	6,000
J-636	630	63.0	56.0	5,200
J-637	625	65.0	59.0	1,160
J-639	625	65.0	59.0	1,640
J-640	635	56.0	54.0	730
J-641	635	60.0	54.0	1,480
J-642	625	65.0	59.0	890
J-644	635	61.0	54.0	4,830
J-646	635	60.0	54.0	1,500
J-649	625	65.0	59.0	1,170
J-651	625	65.0	59.0	1,310
J-652	625	65.0	59.0	2,460
J-655	640	59.0	54.0	5,270
J-657	625	65.0	60.0	1,410
J-659	635	58.0	54.0	6,000
J-660	625	65.0	59.0	1,180
J-662	640	58.0	52.0	2,060
J-664	640	58.0	52.0	3,390
J-665	625	65.0	59.0	5,040
J-671	635	60.0	54.0	5,710
J-672	635	60.0	54.0	5,660
J-673	625	65.0	59.0	3,140
J-674	625	63.0	59.0	5,560
J-675	635	60.0	54.0	550
J-676	635	60.0	54.0	5,830
J-677	625	65.0	59.0	1,030
J-678	625	65.0	59.0	1,080
J-679	625	65.0	59.0	410

CITY OF MUSKEGON HEIGHTS
2014 WATER SYSTEM RELIABILITY STUDY

MODEL OUTPUT - 2034 DEMANDS WITH RECOMMENDED IMPROVEMENTS

Label	Elevation	Pressure (psi)		Available Fire Flow
	(ft)	Avg Day	Max Day	(gpm)
J-680	625	65.0	59.0	1,050
J-681	630	63.0	56.0	1,030
J-684	630	63.0	56.0	1,130
J-686	630	63.0	56.0	6,000
J-687	630	63.0	56.0	6,000
J-688	635	61.0	54.0	2,660
J-689	635	60.0	54.0	5,690
J-690	635	60.0	54.0	920
J-691	635	60.0	54.0	1,160
J-692	635	60.0	54.0	5,680
J-693	635	60.0	54.0	1,030
J-694	635	60.0	54.0	1,160
J-695	625	65.0	59.0	1,210
J-696	625	65.0	59.0	1,200
J-697	625	65.0	59.0	1,330
J-698	625	66.0	60.0	6,000
J-699	625	65.0	60.0	870
J-700	640	59.0	53.0	820
J-701	640	59.0	53.0	950
J-702	640	59.0	53.0	990
J-703	640	59.0	53.0	1,010
J-704	640	59.0	53.0	1,010
J-705	640	59.0	53.0	1,050
J-706	640	60.0	55.0	6,000
J-707	640	59.0	54.0	1,240
J-708	640	59.0	53.0	1,190
J-709	640	59.0	53.0	1,190
J-710	625	64.0	59.0	1,470
J-711	625	64.0	59.0	1,560
J-712	625	65.0	59.0	5,850
J-713	625	65.0	59.0	1,220
J-714	625	65.0	59.0	380
J-715	635	60.0	54.0	1,900
J-716	625	65.0	59.0	3,800
J-717	625	65.0	59.0	680
J-718	625	65.0	59.0	1,550
J-720	640	61.0	57.0	6,000
J-721	610	70.0	67.0	1,780

Appendix E

City of Muskegon Heights Water System - Primary Asset

APPENDIX E - WATER SYSTEM ASSETS

Infrastructure	ID	Year Installed	Notes
High Service Pump	HSP 1	1965	150 hp, permit capacity - 4.5 mgd, Constant Speed
High Service Pump	HSP 2	1965	250 hp, permit capacity - 6.0 mgd, Constant Speed
High Service Pump	HSP 3	1973	100 hp, permit capacity - 2.0 mgd, Constant Speed
High Service Pump	HSP 4	2002	250 hp, permit capacity - 5.0 mgd, Variable Speed
High Service Pump	HSP 5	2002	250 hp, permit capacity - 5.0 mgd, Variable Speed
High Service Pump	HSP 6	2002	250 hp, permit capacity - 5.0 mgd, Variable Speed
High Service Pump	HSP 7	2002	250 hp, permit capacity - 5.0 mgd, Variable Speed
High Service Pump	SH 1	1965	100 hp, permit capacity - 3.0 mgd, Constant Speed
High Service Pump	SH 2	1940	200 hp, permit capacity - 6.0 mgd, Constant Speed
High Service Pump	SH 3	1965	75 hp, permit capacity - 2.2 mgd, Constant Speed
High Service Pump	SH 4	1940	150 hp, permit capacity - 4.0 mgd, Constant Speed
High Service Pump	GB 1	2002	30 hp, permit capacity - 0.3 mgd, Variable Speed
High Service Pump	GB 2	2002	30 hp, permit capacity - 0.3 mgd, Variable Speed
High Service Pump	GB 3	2002	30 hp, permit capacity - 0.3 mgd, Variable Speed
Generator	WTP		800 kW, diesel fuel , 1350 hp, 10 mgd capacity
Generator	Shorewell LSP		505 kW, diesel fuel , 765 hp, 10 mgd capacity
Storage Tank	Sherman Blvd (West)	1940	500,000 gal vol, ground storage - last inspection: 2005
Storage Tank	Sherman Blvd (East)	1940	1,000,000 gal vol, ground storage - last inspection: 2005
Storage Tank	Getty Street	1964	750,000 gal vol, multileg elevated - last inspection: 2007
Water Main	NA	1900-1930	140,618 ft
Water Main	NA	1931-1959	6,300 ft
Water Main	NA	1960-1979	152,732 ft
Water Main	NA	1980-1999	11,853 ft
Water Main	NA	2000-2014	4,381 ft