FINAL

UNITS OF SERVICE FOR NON-MASTER METERED CUSTOMERS OF GREAT LAKES WATER AUTHORITY AND SYSTEM WATER AUDIT: PHASE TWO REPORT

GLWA PROJECT CS-039

B&V PROJECT NO. 195145

PREPARED FOR

Great Lakes Water Authority

29 MARCH 2019

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Abbreviations and Definitions

The following acronyms and abbreviations are used in this document.

Acronym	Description
AL	Apparent Losses
AMI	Advanced Metering Infrastructure
AMR	Automated Meter Reading
AWG	Analytical Work Group
AWWA	American Water Works Association
AZP	Average Zone Pressure
B&V	Black & Veatch
Benesch	Previously Tucker, Young, Jackson, Tull, Inc.
CIP	Capital Improvement Plan
CMI	Customer Metering Inaccuracies
CMP	Critical Monitoring Points
CTA	Common-to-all
DB1	Dearborn DMA No. 1
DB2	Dearborn DMA No. 2
DET-D	City of Detroit DMA
DMA	District Metered Area
DWSD	Detroit Water and Sewerage Department
Gal/conn/day	Gallons per connection per day
GIS	Geographical Information Systems
GLWA	Great Lakes Water Authority
GPM	Gallons per Minute
HPZ	High Pressure Zone
ILI	Infrastructure Leakage Index
LP	Low Pressure
IMM	Insertion Magnetic Meter
IPZ	Intermediate Pressure Zone
IWA	International Water Association
KPI	Key Performance Indicators
M36	AWWA Manual M36 (Water Audits and Loss Control Programs)
Mag	Electromagnetic
MDD	Maximum Daily Demand
MGD	Million Gallons per Day
MNF	Minimum Night Flow
NMMC	Non-Master Metered Communities

NRW	Non-Revenue Water
NW	City of Detroit DMA
PHD	Peak Hourly Demand
PS	Pump Station
PSI	Pounds per Square Inch
RH1-X	City of Detroit DMA
RL2	City of Detroit DMA
SA&MO	System Analytics and Meter Operations
SCADA	Supervisory Control and Data Acquisition
SDHE	Systematic Data Handling Errors
UARL	Unavoidable Annual Real Loss
UoS	Units of Service
VFD	Variable Frequency Drive
WADI	Water Audit Data Initiative (AWWA Water Audit Benchmark Data)
WAMR	Wholesale Automated Meter Reading
WL	Water Losses
WMPU	Water Master Plan Update
WRF	Water Research Foundation
WTP	Water Treatment Plant
WWP	Water Works Park

Executive Summary

The Phase 1 Report on the Units of Service for Non-Master Metered Customers of Great Lakes Water Authority (GLWA) and System Water Audit, produced by Black & Veatch on December 8th, 2017, was the basis for variables used in FY 2019 charges for the non-master metered communities (NMMCs). This Phase 2 Report is intended to provide updated information and new data to enable recalculation of charges for these NMMCs for FY 2020. The emphasis of Phase 2 has been to improve the best available data for GLWA and the NMMCs through field measurements. The field measurements were primarily conducted through the implementation of District Metered Areas (DMAs) in the City of Dearborn (Dearborn), City of Detroit (Detroit) and the ongoing temporary metering of the City of Highland Park (Highland Park).

The information presented here represents an improvement in understanding and quantifying water losses, although it is no substitute for the greater confidence that would come with fully implemented master metering.

District Metered Areas

District Metered Areas (DMAs) were conducted specifically to refine the estimate of real water loss (i.e., physical water loss through the pipe network) in Dearborn and Detroit. As part of Phase 2, two DMAs were completed in Dearborn and two DMAs were completed in Detroit. Two additional DMAs were planned for Detroit, and equipment was installed; however, the commissioning of the DMAs was not completed prior to the development of this report due to challenges of implementation in the field.

Significant planning and field work are required to successfully implement DMAs in any utility setting. The level of effort was increased further for this project as multiple parties have inter-related responsibilities and extra scrutiny is required as the DMA results are used for determining cost allocation.

- Results from the two DMAs in Dearborn were extrapolated across the full Dearborn system, and combined with an estimated water loss from water main breaks, for a total real water loss of 20 gallons per connection per day. This represents a significant reduction from the level of real loss estimated during Phase 1 (66 gallons per connection per day).
- Results from the two DMAs in Detroit, plus the DMA detailed in Phase 1 from northwest Detroit were extrapolated across the full Detroit system, and combined with an estimated water loss from water main breaks, for a total real water loss of 102 gallons per connection per day. This represents a slight reduction from the level of real water loss estimated in Phase 1 (106 gallons per connection per day).

Water Treatment Plant Metering Upgrades and Pump Testing

Phase 1 uncovered the need for a more accurate assessment of the input volume from the water treatment plants (WTPs) into the GLWA system. Without a clear understanding of the volume of water entering the transmission and distribution systems, GLWA cannot reliably calculate and analyze water usage and total system non-revenue water (NRW) and measure improvements in efficiency. Finished water metering upgrades are currently being implemented by GLWA; the Northeast WTP has recently had renovations completed on the Venturi meters with the goal of using these to measure finished water entering the transmission and distribution system rather than the use of pump curves which is typical for several of the plants.

Pump testing was completed at four of the WTPs in October 2018 on selected pumps at each WTP. The data has been reviewed and approximate maximum flow rates have been determined for each of the tested pumps. Additional information on valve positions and discharge header pressure will be required to confirm pump curve accuracy. Additional testing of pumps in combination would also improve accuracy measurements.

Transmission Main Leakage and Blow-Off Valve Assessment

Phase 1 determined a need for additional work on understanding the frequency and size of issues with the blow-offs on the GLWA transmission mains. A program of inspection of the blow-off valves was instigated and by the time of writing approximately one-third of the sites had been investigated with only small leaks identified at 5 locations out of 395 inspected. A second methodology for the estimation of transmission mains losses is reviewed in the Phase 2 report; however, no changes to the estimated volume for Transmission losses is recommended.

Process for Annual Wholesale Meter Audit

The Wholesale Automated Meter Reading (WAMR) Communities are the largest system usage when considered as a group. Therefore, the accuracy of these meters is paramount for equitable charges. A plan has been included as part of Phase 2 to test these meters more effectively. This plan will enable an increased level of validation of the accuracy of these meters. The testing program recommends annual verification and electronic calibration of all differential pressure and electromagnetic meters, and physical flow testing of all mechanical meters. One-third of all differential pressure and electromagnetic meters should be physically flow tested each year as well and a prioritized approach should been identified. As an alternative approach, or if physical flow testing is not feasible, GLWA should conduct a screening level water audit comparing wholesale volumes with customer retail sales following the basic principles of the AWWA Water Audit methodology.

Long-term Water Audit

A methodology for calculating the water audit long-term has been established and reported upon herein. This includes annual updates of demands and NRW calculations. Many of the calculation methods noted in this section will be removed if master metering of Dearborn and Detroit is implemented.

Volumetric Units of Service FY2020

Units of Service for Non-Master Metered Customers have been updated as a result of field-based measurements collected during Phase 2. Primarily, the estimates of real loss have been updated through the DMAs conducted in Dearborn and Detroit, the results of which have been extrapolated to the respective systems. In Highland Park, flow monitoring of the entire system has continued through the use of three insertion meters. Estimates of projected FY2020 sales volumes have been updated for Dearborn and Detroit along with revised estimations of the associated apparent losses (metering inaccuracies other than data reporting), by applying data generated as part of Phase 1 (e.g., customer metering accuracy values). Max Day and Peak Hour demand estimates have been updated for FY2020 using the same approaches as Phase 1, with data updates where available. FY2020 recommended volumetric Units of Service are presented in Table E 1. These values do not include operational buffers.

Table E 1 FY2020 Units of Service for Non-Master Metered Customers

TOTAL VOLUMES ASSIGNED BY ENTITY	AVG. DAY (MGD)	MAX DAY (MGD)	PEAK HOUR (MGD)
Dearborn	12.7	21.8	30.3
Detroit	90.9	111	131
Highland Park	2.18	2.79	2.86

As part of the process to update FY2020 charges a new GLWA system water balance has been developed as presented in Table E 2. The projected FY2020 values have been utilized for the NMMC demand values along with 2017 demands for lines 1 and 7. The inconsistency between these dates is inconsequential for this high-level water balance. Additional clarifications on the data are provided below:

Table E 2 GLWA System Water Balance

TOTAL VOLUMES ASSIGNED BY ENTITY	AVG. DAY (MGD)	MAX DAY (MGD)	PEAK HOUR (MGD)
WAMR / Wholesale	281	475	591
Dearborn	12.7	21.8	30.3
Detroit	90.9	111	131
Highland Park	2.18	2.79	2.86
Transmission (incl. open blow offs)	26.5	26.5	26.5
GLWA / Common-to-all (CTA)	40.1	42.8	
Adjusted System Pumpage (Total)	453	680	769

- WAMR/Wholesale (Line 1) Max Day and Peak Hour demands corresponding with GLWA system Max Day (7/31/2017) and Peak Hour (7/31/2017 5-6AM EST).
- Estimated Transmission Losses (Line 5) are consistent with Phase 1 estimated values and are assumed constant across all demand scenarios

- GLWA/Common To All (Line 6) is the residual value of line 7 minus the sum of lines 1-5. This is the volume of water that has not been assigned to any other water balance item. This value is not presented for the Max Hour value as the residual is negative. Possible explanations include system pumpage is under reported at the Peak Hour, or all the peak hour components of the water balance are not coincident.

Adjusted System Pumpage (Total) (Line 7) is the volume pumped from the five water treatment plants adjusted for changes in storage during Max Day (7/31/2017) and Peak Hour (7/31/2017 5-6AM EST). The numbers reflect a 5.8% reduction from the reported plant Pumpage as developed and applied in Phase 1.

1 Introduction

The Phase 1 Report, produced by Black & Veatch (B&V) on December 8th, 2017, was the basis for variables used in FY 2019 charges for the non-master metered communities (NMMCs). This Phase 2 Report is intended to provide updated information to enable recalculation of charges for these NMMCs for FY 2020.

Phase 2 of this water audit has been focused on improving available data through field measurements. The project teams have actively reviewed and discussed methodology and fieldwork results through weekly and bi-weekly meetings. The One Water Partnership Analytical Work Group (AWG) has served in an advisory role on the Phase 2 methodology and has been kept up-to-date with progress on approximately a monthly basis throughout 2018. However, due to the extensive collaborative planning efforts and challenges in the field, a significant portion of the fieldwork has been conducted in the fall of 2018; therefore, most of the data and the analysis has only been presented immediately prior to this draft report being provided for review.

The areas to be addressed in the Phase 2 Report include:

- District Metered Areas (DMAs)
- Water Treatment Plant Testing and Metering Upgrades
- Transmission Blow-Off Valve assessment
- Wholesale Automated Meter Reading (WAMR) Meter Testing Protocols
- Identification of Data Gaps
- Develop Long-term Water Audit Approach
- Develop Process for Annual Wholesale Meter Audit

2 District Metered Areas

The most imperative recommendation to come out of the Phase 1 work was the need for additional field-based data to provide a more data-driven analysis of non-revenue water (NRW) for both Dearborn and Detroit. While the two DMAs in Dearborn and the proposed four in Detroit are still a small amount of the total system, within the context of the schedule, it was determined that these DMAs would add a further level of system-specific and field-based data to inform the overall NRW values. These DMAs also represent a step along the way to master metering the two communities, and as field work continues to be undertaken, a greater understanding of the system will be realized, such as improved knowledge of system operating pressures and interconnectivity. The following subsections outline the main sequences involved in the development of these DMAs and the results generated.

2.1 USING DMAS FOR NRW EXTRAPOLATION

One of the key goals for Phase 2 was to derive field-based values for the real loss of both Dearborn and Detroit. Extensive and frequent collaboration was conducted between GLWA, B&V, Dearborn, and Detroit (generally separately) in order to develop an approach that could be agreed upon. Significant effort went into developing the process that would identify, develop, and implement the DMAs with the aim of having a clear understanding of how the data would be collected and used in the estimation of NRW. These discussions took several months, and during this time, updates were provided to the GLWA's AWG for their feedback into the process. Key points from the discussions are summarized in the following sections.

2.1.1 Purpose of DMAs within Non-Master Metered Communities

The data obtained from the DMA activity will provide estimates of Water Losses for the DMAs within the NMMCs. This step is achieved by measuring the inflow to the DMA (through a source meter or meters) and comparing this value to the cumulative consumption by customers within the DMA over a given period of time. Based on the measured volumes within each DMA, it is possible to determine the water balance of the DMA, where:

$$Water\ Losses = DMA\ input - DMA\ Customer\ Consumption$$

A review of AWWA's Water Audit Methodology is useful to highlight how the results of the DMA fit in to the overall water balance.

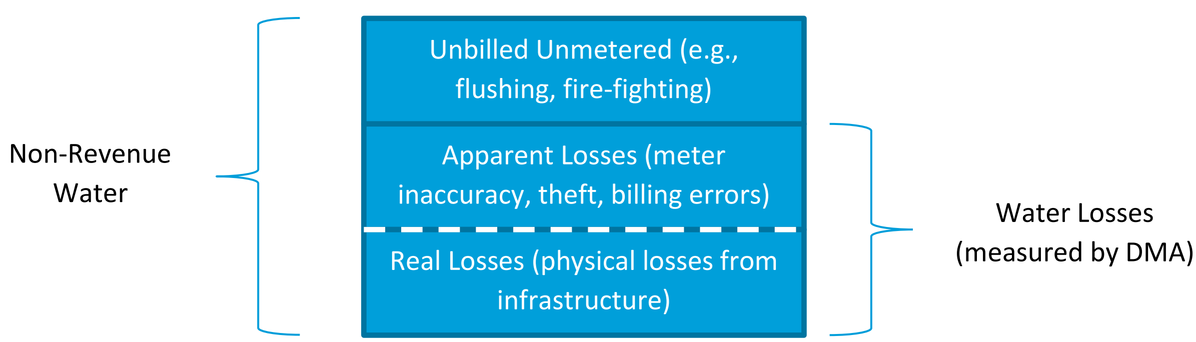

Figure 2-1 DMAs and Non-Revenue Water

The dashed line in Figure 2-1 indicates that apparent losses cannot be easily separated from real losses based on DMA monitoring alone; therefore, the DMA measures both types of losses together with an unknown split between these two pieces of the water balance. The Unbilled Unmetered component represents authorized use that generally represents unusual or infrequent uses of water. Since the DMAs were operational for a short period of time (typically ten to fourteen days) it is recommended that the DMAs are utilized to represent Water Losses and not total NRW, because the shorter duration is unlikely to capture a representative sample of flushing and fire-fighting activity. It is recommended that regular flushing activity in the DMA area is not conducted while it is being monitored. If fire-fighting or specific flushing is necessary during the study period, the event should be reviewed, and the volume of water used should be estimated and adjusted in the DMA balance (either added to consumption or removed from the input volume).

2.1.2 Method for DMA Implementation

Careful planning is required to avoid unintended consequences, such as supply restriction or adverse water quality effects. Thousands of distinct zones and DMAs have been successfully implemented by water utilities in many countries, helping to provide highly efficient water service. The DMAs will be designed and implemented in accordance with best current Water Industry practice. The methodology from the AWWA Manual M36 is instructive and includes key concepts that are applicable for the GLWA project.

2.1.3 Flow Metering Technology

A significant area of discussion focused on the use of metering technology to measure flow into the DMAs. Insertion magnetic meters (IMMs) are relatively economical and relatively easy to install compared to inline full-bore mag-meters. There is a history of usage of these meters in the GWLA system, and they are currently in use for metering the Highland Park. Although they are not expected to be as accurate as inline meters, IMMs can be applicable for temporary metering applications. At the outset of Phase 2, it was generally accepted that the DMAs would be temporary. Of course, the underlying project objective is related to charging; therefore, accuracy of metering carries a high significance. These issues were discussed by the collective project team (NMMC's and their consultants, GLWA and B&V) in the context of both DMA development and the path towards Master Metering. To achieve the objectives of Phase 2 and meet the project schedule it was agreed that IMMs would be used in the DMAs.

As part of the deliberations on metering technology several other water utilities were contacted[1] that have direct experience in the use of IMMs for DMA monitoring. Although the use of DMAs in the other systems were not for billing purposes, their experience was still valuable and provided the following key inputs based on their experience:

- The use of IMMs allows valuable insight into the system operations where traditional flow metering is not practical or cost-effective.

[1] Knoxville Utilities Board, TN; Metro Water Services, Nashville TN.

- A straight-run of pipe with a minimum of 10 upstream and five downstream diameters is recommended.
- The accuracy of IMMs at low flow rates is less than the accuracy of traditional metering. Because the meter is measuring velocity, it is important to understand expected flow rates and convert to a velocity in order to assess the likely accuracy. The same flow rate in terms of gallons per minute will have a faster velocity (which is generally preferred) in a smaller pipe compared to a larger diameter pipe.

2.2 DMA PLANNING & DESIGN

2.2.1 Size of DMAs

In most water systems 1,500 customer accounts represents an optimum size, but DMAs can be expanded to 2,500. This target range typically provides a DMA of manageable size and recognizes that DMAs may have to be modified depending on valve condition and other field conditions. The upper range is specified as this typically constrains flows to a level where the incremental flow rate from a burst watermain will show up as an unexpected increase in flow minimum night flow; therefore, the DMA can be used as a real loss management tool and an early warning system for a pipe break that does not surface.

Due to the relatively small overall coverage of the DMAs relative to the entire water systems, an extrapolation technique was needed to produce an estimate of Water Losses for the entire NMMC water systems.

It is proposed that the values of Water Losses are computed in terms of gallons per connection per day, consistent with AWWA recommended best practice. In order to project the Water Loss values from the DMAs to the wider system, the representativeness of each DMA relative to the overall water system was considered.

Discussions were conducted between the consultant groups, GLWA, Dearborn, and Detroit to determine feasible DMA areas that could be evaluated for more detailed investigation. Multiple factors influenced the initially identified areas; these factors included:

- Overlap with potential sewer district metering (in Detroit)
- High probability of isolation (e.g., areas on the perimeter of the systems, or with natural hydraulic boundaries to minimize the number of required valve closures)
- Areas that would be representative of the broader system, or areas that would capture different characteristics (e.g., high connection density / low connection density) and could be extrapolated across the system using available data

2.3 DEARBORN DMA SELECTION

Three potential DMA areas were reviewed in Dearborn as shown in Figure 2-2. After discussion with the project team it was determined that two DMAs would be developed for Dearborn and that DB1 and DB2 were the preferred locations as these provided a contrast of newer and older pipe material.

Figure 2-2 DMA Areas Evaluated for the City of Dearborn

There was concern about the number of valves required for isolation in DB3, so this DMA was excluded from further consideration. No DMAs were considered in predominantly commercial or industrial areas of Dearborn for the following reasons:

- There is a higher probability of critical customers in commercial and industrial areas and isolating DMAs in areas of critical customers can be problematic in temporary DMAs due to service level requirements (e.g., pressure and redundancy).
- Commercial and industrial customers have more unpredictable night flows which makes interpretation of minimum flows more problematic.
- The primary reason for the DMAs is to refine estimates of real water loss, and physical condition of the pipe can be extrapolated to commercial and industrial areas.

The area covered by the two selected DMAs represents 3.2% of Dearborn's total area, and nearly 7% of total connections (Table 2-1).

Table 2-1 Characteristics for City of Dearborn DMAs

DMA ID	AREA (SQ. MI)	LENGTH OF MAINS (MILES)	NUMBER OF CONNECTIONS
DB1	0.25	6.3	805
DB2	0.52	11.7	1,349

2.3.1.1 Dearborn Pipe Age

Based on a review of Dearborn's GIS data and the hydraulic model during Phase 1, there is minimal information on pipe condition using variables such as pipe material and pipe age. Based on discussions with Dearborn, approximately 60% of the system is cast iron and approximately 40% is ductile iron with a minimal amount of concrete and HDPE pipe. During Phase 2, additional data was provided by Dearborn to document the extent of mains replacement over the past several decades. A map showing the replaced pipe is included in Appendix 9.1, and a time series chart showing mains replacement over the past 32 years is shown in Figure 2-3.

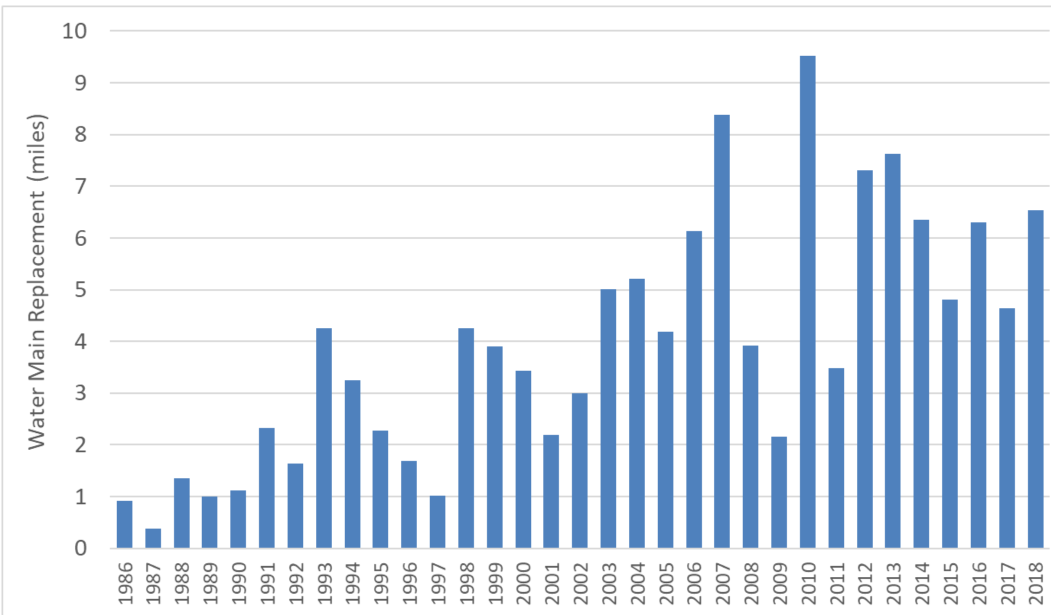

Figure 2-3 Miles of Water Main Replaced per Year in Dearborn

In the 2008 Master Plan prepared for Dearborn by OHM Advisors, an analysis of the frequency of water main breaks by approximate pipe age noted the frequency of breaks increased significantly in pipes 40 years or older, as can be seen in Figure 2-4 (annotation in light blue added by B&V).

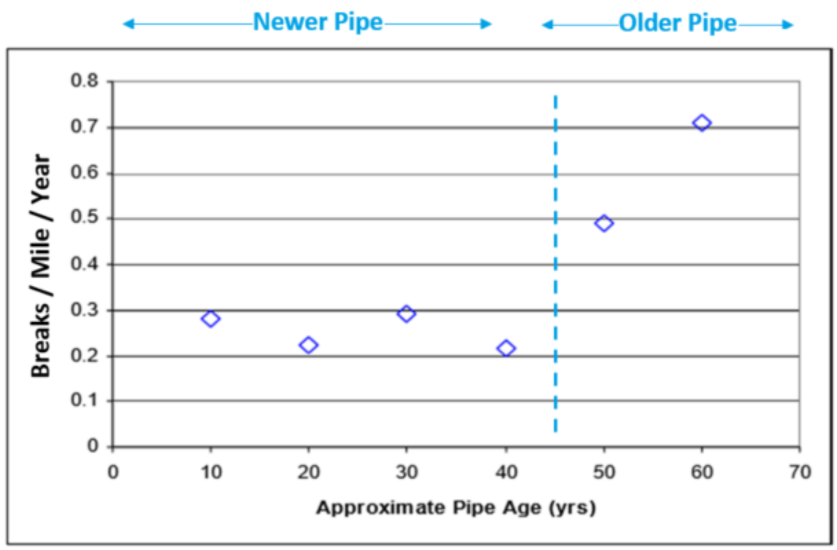

Figure 2-4 Variation in Number of Breaks with Pipe Age. Source: 2008 Master Plan (OHM)

A detailed evaluation of pipe age in each DMA area was conducted by B&V. The results of this analysis are shown in Figure 2-5.

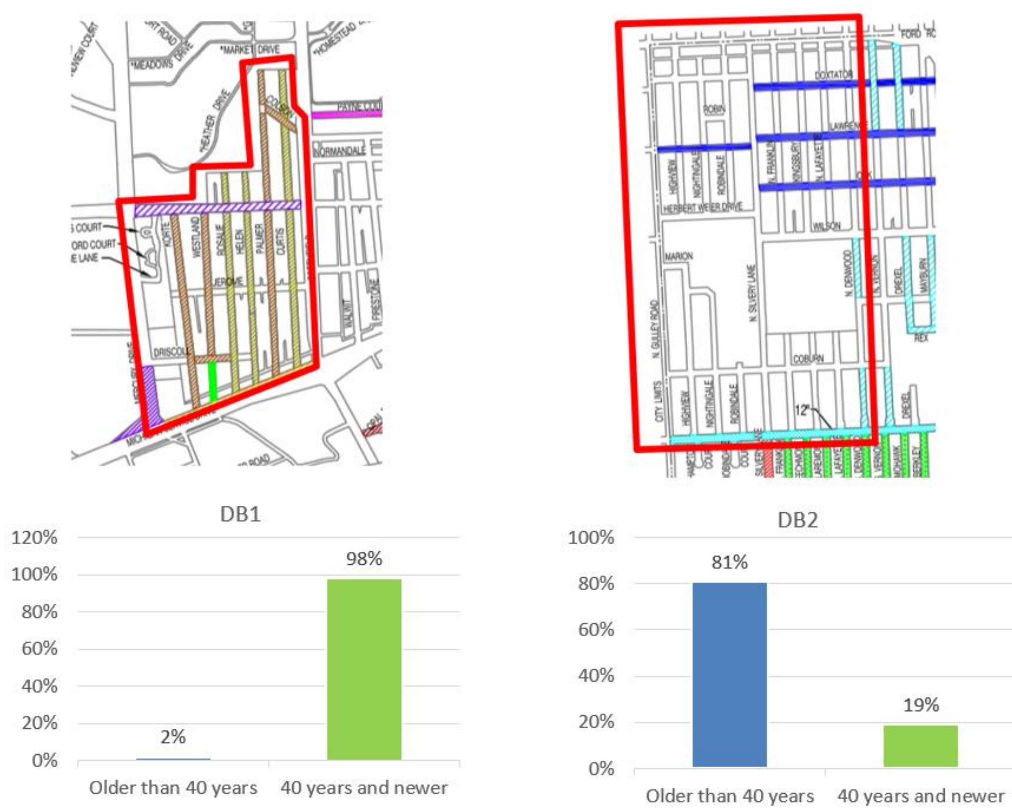

Figure 2-5 Analysis of Age of Pipe in Dearborn DMAs

2.3.1.2 Dearborn System Pressure

DMA area DB1 is located in an area of relatively high pressure as compared with the rest of the Dearborn system, and DB2 is located in an area of relatively low pressure. Given that pressure is not uniform across Dearborn and that the pressure influences real water loss (see Section 2.3.1.2.1), the relative pressure between the DMA and the average system pressure is used to normalize and extrapolate the two DMA results across the entire Dearborn system. This extrapolation requires an assumption of the relative proportion of real and apparent water loss within the DMA, because the pressure adjustment will only apply to real loss.

2.3.1.2.1 Leakage-Pressure Relationship

As documented in AWWA M36, leakage flow rate (L) (volume/unit time) varies with pressure (P^{N1}). The higher the assumed value for N1, the more sensitive leaks are to pressure; for example, N1 is higher (~2.5) for systems with plastic pipe. Assuming minimal plastic pipe in the systems, it would be reasonable to assume a leakage-pressure relationship consistent with that advocated by AWWA M36 (page 178) where it is noted that it is common to assume a power (N1) of 1.0 for most systems. In other words, leakage (of all forms) is assumed to vary approximately linearly with pressure. This assumption arises from the fact that the leakage rate for bursts is proportional to the square root of pressure, and for background leakage, it is proportional to 3/2 pressure due to flexing of joints. Therefore, the exponent of 1 (i.e., a proportional relationship) is an assumed average. In other words, the relationship between pressure and leak flow rate for Areas 1 and 2 is $L_1/L_2 = P_1/P_2$.

2.3.2 Configuration of DMAs

Once the DMA areas were determined in concept, hydraulic modeling was conducted using the available hydraulic model[2]. The modeling was performed under max day / fire flow and peak hour conditions to determine approximate meter location(s) and identify required valve closures. No DMA area was chosen with more than two inlet meters.

Once the DMAs passed the initial requirements, critical customers were identified and Critical Monitoring Points (CMPs) were located. Pressures were monitored at each input location and at the Low Pressure (LP) and Average Zone Pressure (AZP) locations in each DMA. Both available fire flows and post-isolation pressures were evaluated to make sure the theoretical analyses did not show any areas of concern. The project teams participated in the review of the DMA configurations and provided input to the DMA design for further review and consideration by B&V. Examples included relocating the input meters to take advantage of newer pipe within the DMA to minimize the impact of tuberculation on the insertion meter location. In addition, the GIS information and hydraulic model used by B&V did not always reflect on the ground conditions (e.g., missing or additional pipe sections and valves) and modifications has to be made to DMA configurations.

[2] City of Dearborn Hydraulic Model (Dearborn_MaxDay_WaterModel_7-12-17) provided to B&V by OHM Advisors.

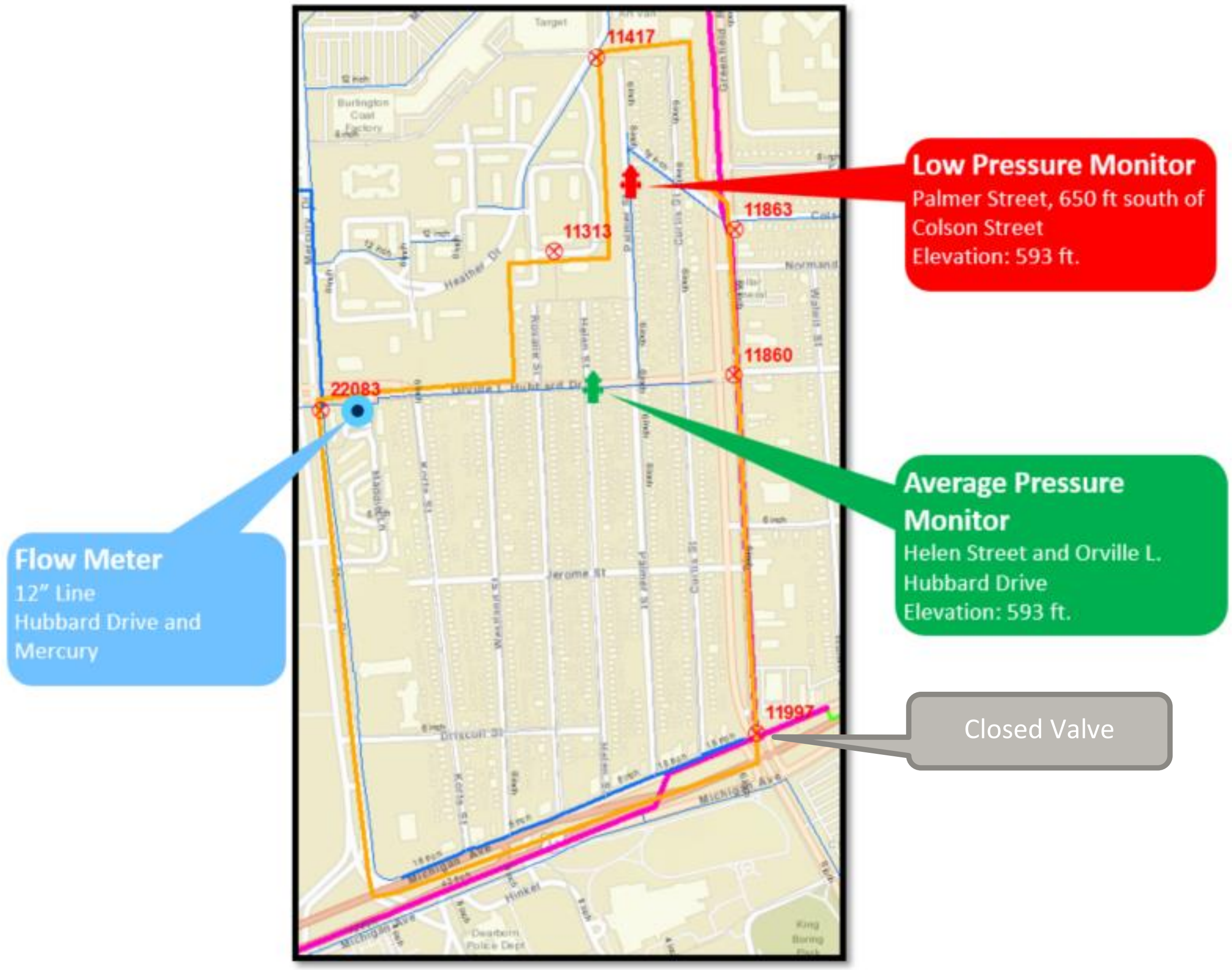

Figure 2-6 Configuration of Dearborn DMA DB1

2.3.2.1 DMA DB1

DB1 required a single flow meter and the closure of six valves to achieve isolation. Dearborn opted to install a new chamber to take advantage of a newer section of pipe and ensure sufficient straight run of pipe up and downstream of the meter location. Two pressure monitors were located within the DMA (Figure 2-6):

- IMM Flow Meter on 12" line on Hubbard Dr. and Maddie Lane.
- Average Pressure Location: Helen Street and Orville L. Hubbard Drive
- Low Pressure Location: Palmer Street and Colson Street

2.3.2.2 DMA DB2

DB2 is located on the western boundary of Dearborn in an area of lower pressure, and based on the model results, it required two flow meters to provide adequate fire flows within the DMA. Two pressure monitors were located within the DMA (Figure 2-7):

- IMM Flow Meter on 12” line on Oak Street, east of Denwood Street
- Inline 8” electromagnetic (mag) meter on Gulley Road and Cherry Hill Street
- Average Pressure Location: Herbert Weier Drive and North Gulley Road
- Low Pressure Location: Cherry Hill Street and Denwood Street

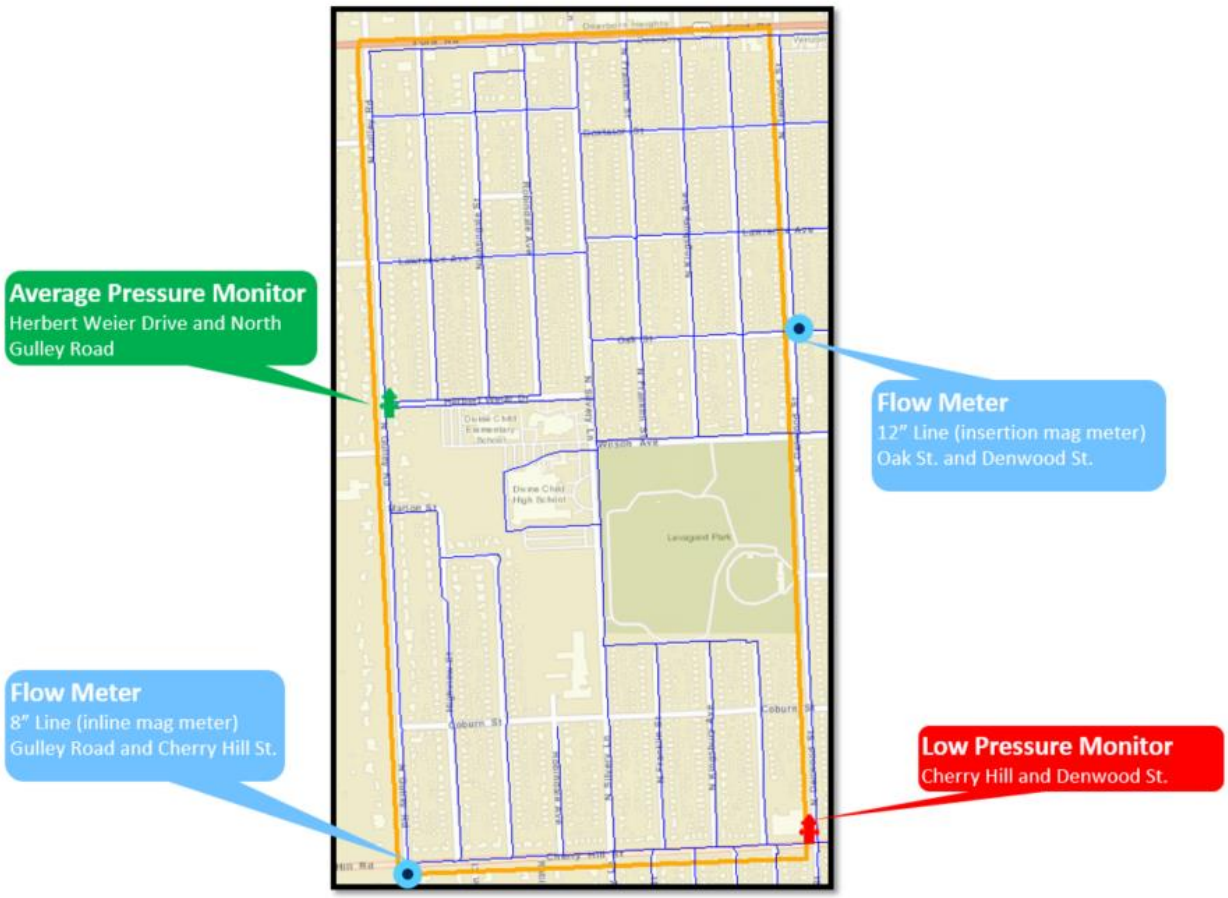

Figure 2-7 Configuration of DMA DB2

2.3.3 System Data

Within each DMA, the number of connections, type of customer, length of mains etc. was determined and recorded. An assessment of anticipated flow rates, velocities, and meter accuracy was also conducted for each of the areas.

2.4 DETROIT DMA SELECTION

Multiple potential DMA areas were reviewed in collaboration with Detroit as shown in Figure 2-8. After discussion with the project team it was determined that four DMAs would be developed for Detroit. Two of the DMAs (RH1-X and RL2) overlap with the Wastewater Master Plan’s DMAs, so it may be possible to use the data collected to refine estimates of how much real water loss is entering the sewer system. The primary considerations in the final selection were that the average age of pipe in the DMAs (average install year is 1929) was reflective of the average system age (average install year of 1925), the areas represented a mix of different pressure zones, and a contained a cross-section of different customer demographics (e.g., variations in the density of connections and number of vacant properties).

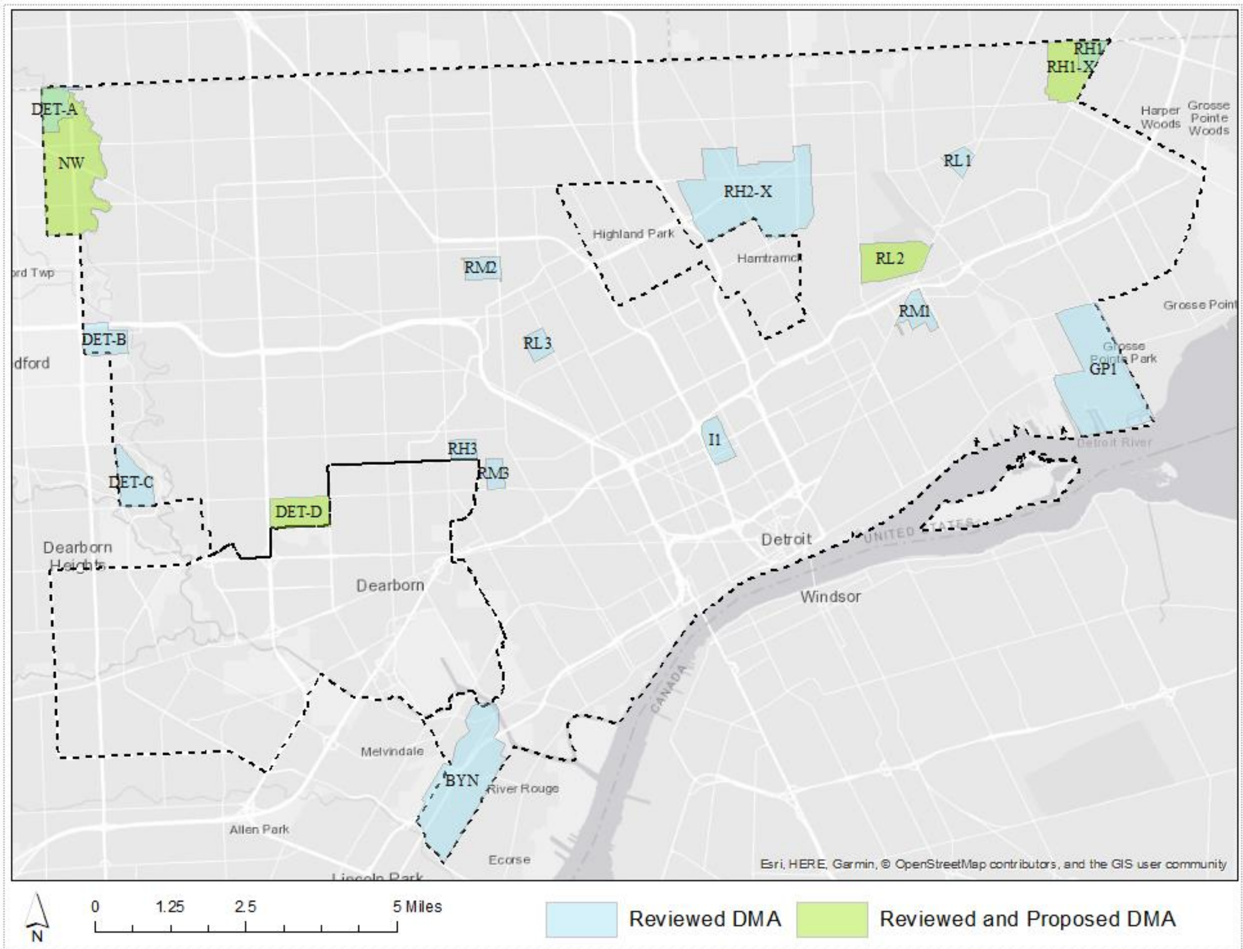

Figure 2-8 Reviewed and Proposed Detroit DMAs

No DMAs were considered in predominantly commercial or industrial areas of Detroit (such as Boynton) for the following reasons:

- There is a higher probability of critical customers in commercial and industrial areas, and isolating DMAs in areas of critical customers can be problematic in temporary DMAs due to service level requirements (e.g., pressure and redundancy).
- Commercial and industrial customers have more unpredictable night flows which makes interpretation of minimum flows more problematic.

- The primary reason for the DMAs is to refine estimates of real water loss, and the physical condition of the pipe can be extrapolated to commercial and industrial areas.

The area covered by the four selected DMAs represents approximately 3% of Detroit's total area and approximately 3% of pressurized connections (Table 2-2).

Table 2-2 Proposed Detroit DMAs Statistics

NAME	VALVE CLOSURES	MILES (DISTR.)	AVG. PIPE INSTALL YR.	TOTAL CONNS.	CONN. DENSITY	PRESSURE ZONE
DET-D	8	9.3	1925	1,507	162/mile	Springwells Int.
RH1-X	14	15.1	1932	1,924	127/mile	Northeast High
RL2	20	13.2	1919	2,725	206/mile	Waterworks Park Int.
NW	9	34.3	1940	3,074	90/mile	Springwells High

2.4.1.1 Detroit System Pressure

The DMAs were selected in different pressure zones as pressure influences real water loss (see Section 2.3.1.2.1). The relative pressure between the DMAs and the average system pressure is used to normalize and extrapolate the DMA results across the entire DWSD system. Pressure adjustment will only apply to real loss.

2.4.2 Configuration of DMAs

Once the DMA areas were determined in concept, hydraulic modeling was conducted using the available hydraulic model[3]. The modeling was performed under max day / fire flow and peak hour conditions to determine approximate meter location(s) and identify required valve closures. No DMA was chosen with more than two inlet meters. These criteria match the ones used for the determination of the Dearborn DMAs.

Once the DMAs passed the initial requirements, critical customers were identified, and Critical Monitoring Points (CMPs) were located. Pressures were monitored at each input locations and at the Low Pressure (LP) and Average Zone Pressure (AZP) locations in each DMA. Both available fire flows and post-isolation pressures were evaluated to make sure the theoretical analyses did not show any areas of concern. DWSD staff participated in the review of the DMA configurations and provided input to the DMA design for further review and consideration by B&V. In addition, the GIS information and hydraulic model used by B&V did not always reflect on the ground conditions (e.g.,

[3] GLWA Transmission and Distribution System Hydraulic Model (Transmission_and_Distribution_System.net)

missing or additional pipe sections and valves). Section maps were reviewed by B&V and DWSD, and overlays were developed that showed the DMA valve closures as determined by the hydraulic modeling superimposed on the section maps as this provided the most useful format for inspection and operations of valves by DWSD field crews (e.g., Figure 2-9).

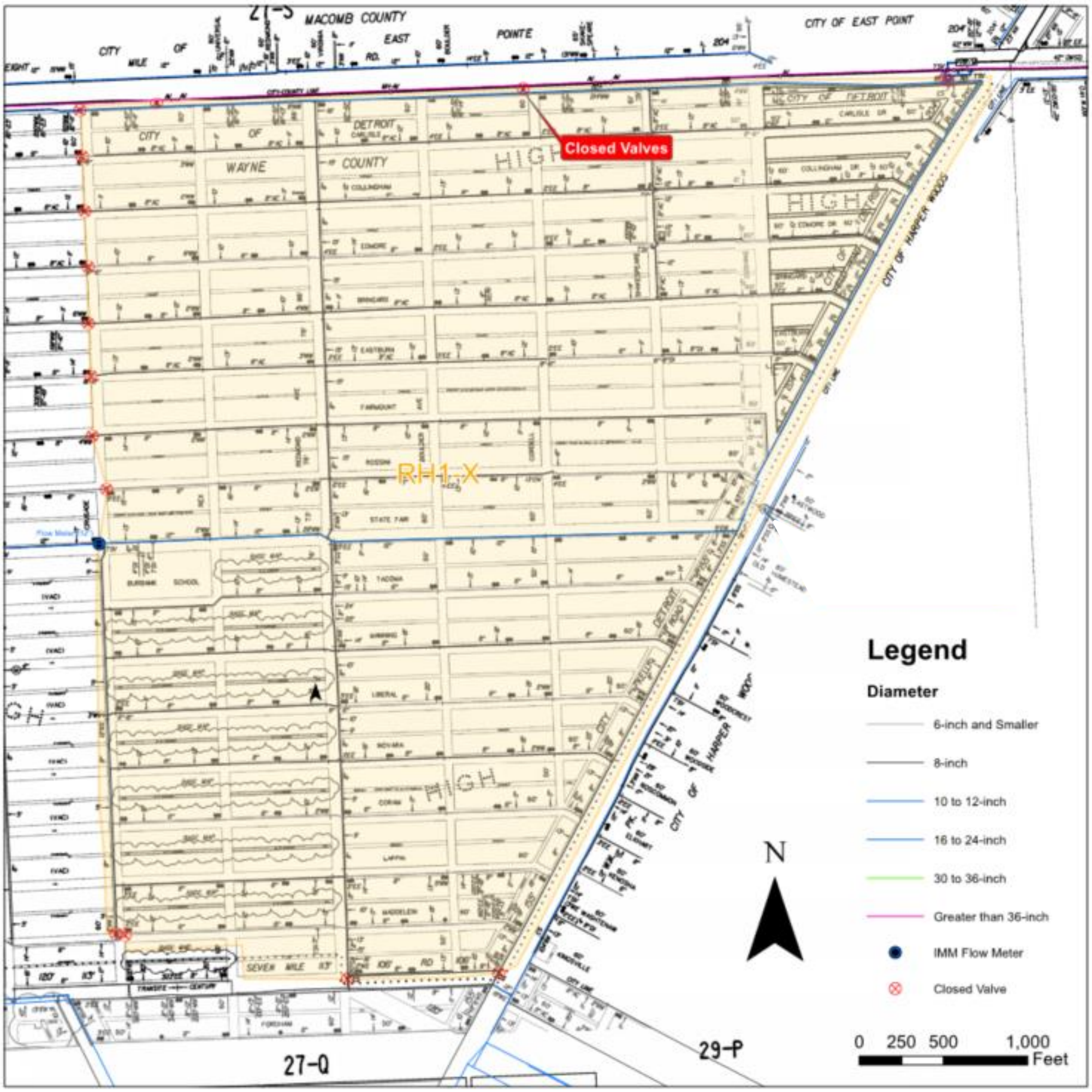

Figure 2-9 Section Maps showing Required Valve Closures for DMA Isolation

2.4.2.1 DMA DET-D

Detroit DMA DET-D is situated in the Springwells Water Treatment Plant (WTP) Intermediate pressure zone on the boundary of Detroit and Dearborn with the Southfield Freeway defining the Western edge of the DMA. The DMA is densely developed with approximately 1,500 retail connections; most of the meters are small with four retail meters 2” and larger. It is mostly residential with some commercial connections on Warren Avenue. In order to provide for sufficient fire flows, two input locations were identified for the DMA. The locations of the two flow meters and two pressure monitors are listed below and are shown in Figure 2-10:

- Flow Meter on 8” line at Southfield Freeway Exit and Warren Avenue
- Flow Meter on 8” line at Greenfield Road and Paul Street
- Average Pressure Location: Warren Avenue and Woodmont Avenue
- Low Pressure Location: Whitlock and Rutherford Street

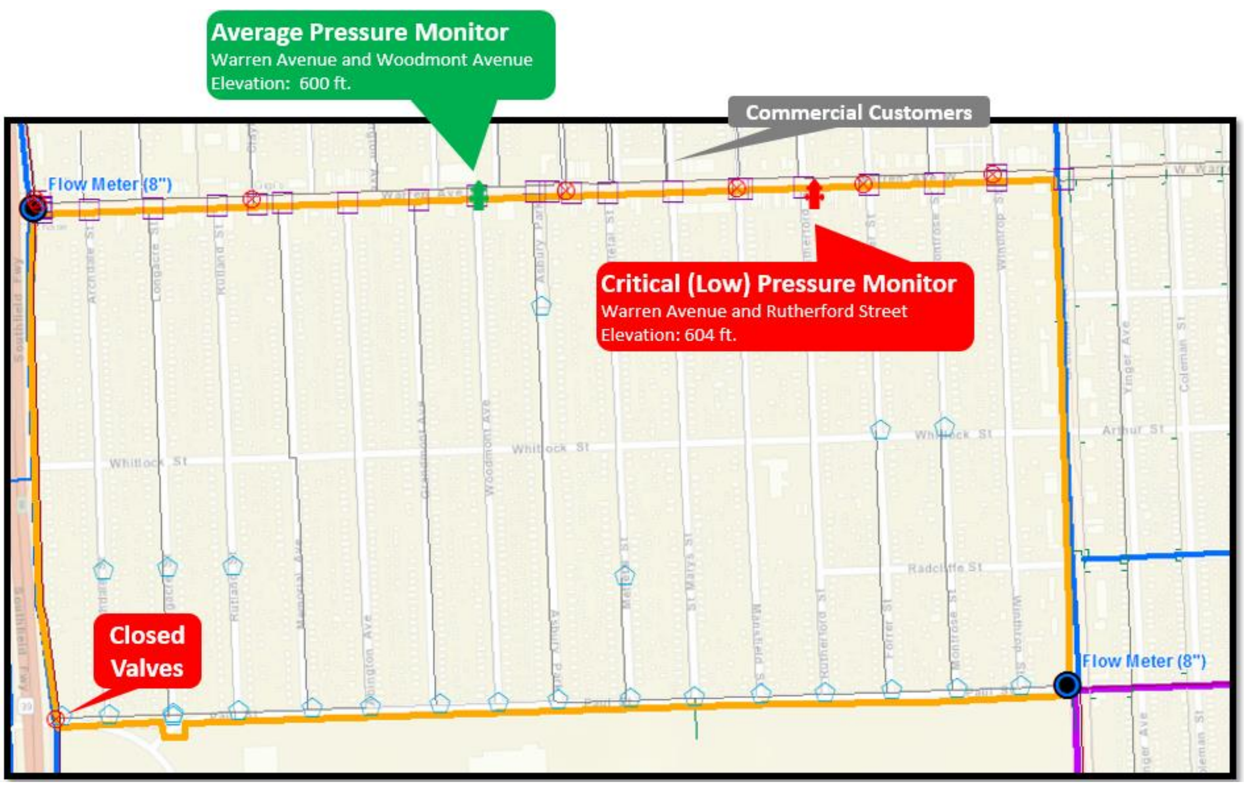

Figure 2-10 DET-D DMA Flow meters and Pressure Monitors

2.4.2.2 DMA RH1-X

This DMA is situated in the high-pressure supply zone from the Northeast treatment plant and is situated in the northeast corner of Detroit. The DMA is densely developed with approximately 1,900 retail connections. It is mostly residential with seven retail connections 2” and larger. Based on the fire flow analysis, it was determined that the DMA could be served by a single flow meter on a 12” pipe on the western side of the DMA. The flow meter and two pressure monitor locations are listed below and shown in Figure 2-11:

- Flow Meter on 12” line at State Fair and Crusade Street
- Average Pressure Location: Bringard Drive and Shakespeare Street
- Low Pressure Location: Novara Street and Kelly Road.

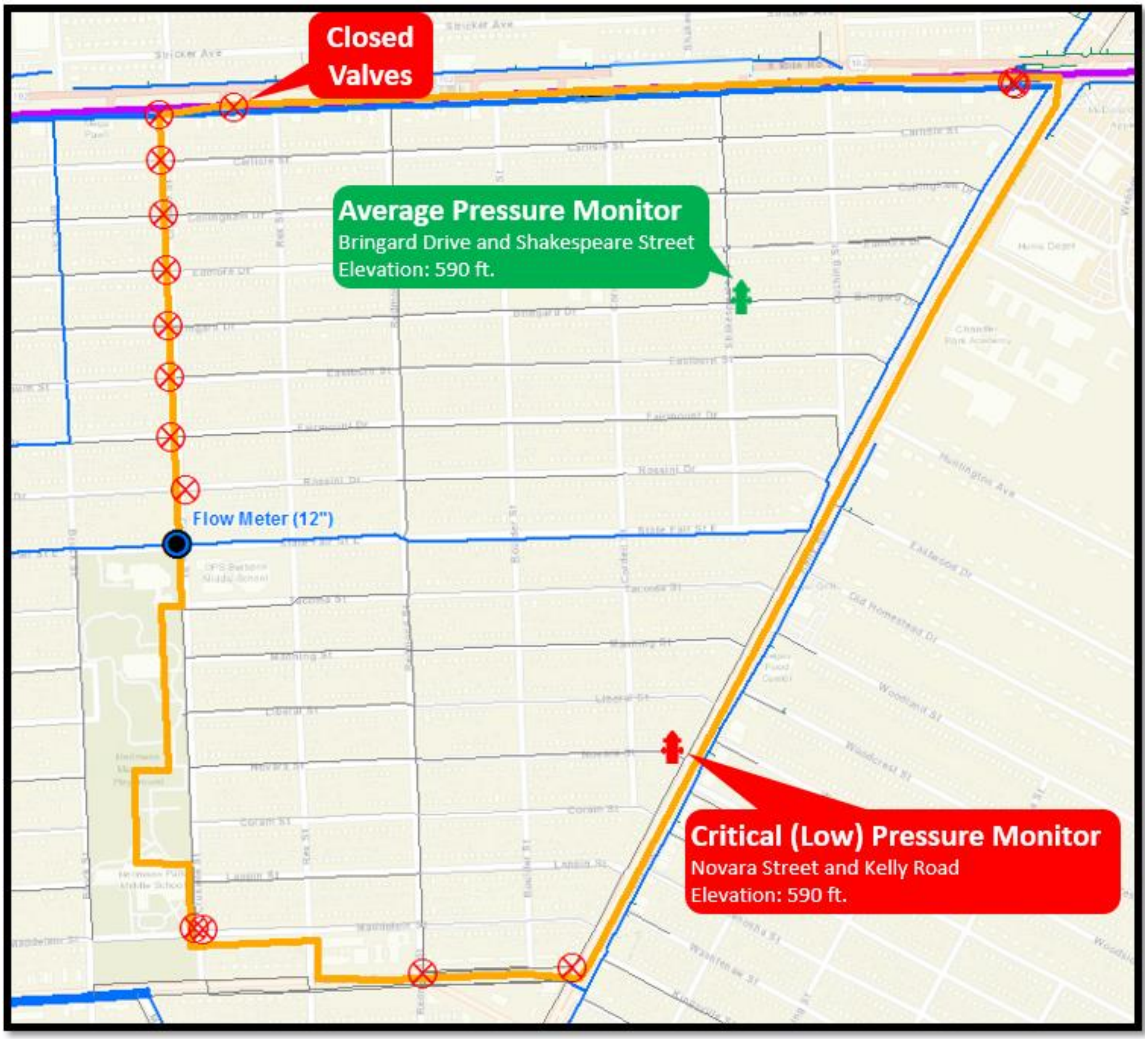

Figure 2-11 RH1-X DMA Flow Meter and Pressure Monitor Locations

2.4.2.3 DMA RL2

This DMA is situated in the Water Works Park Intermediate pressure supply zone. It has a potentially high number of connections; however, the area has a lot of vacant lots and properties. It also has the oldest pipe of the four DMAs (average install year 1919). There are some commercial and industrial customer demand nodes in the hydraulic model that require this DMA to be fed by two sources of supply to support fire flows. The locations of the two flow meters and two pressure monitors are listed below and are shown in Figure 2-12:

- Flow Meter on 12” line at Van Dyke Street and Woodlawn Street
- Flow Meter on 12” line at French Road north of Grinnell Street (alteration to plan)
- Average Pressure Location: Raymond Avenue and Traverse Street
- Low Pressure Location: Grinnell Avenue and Van Dyke Street

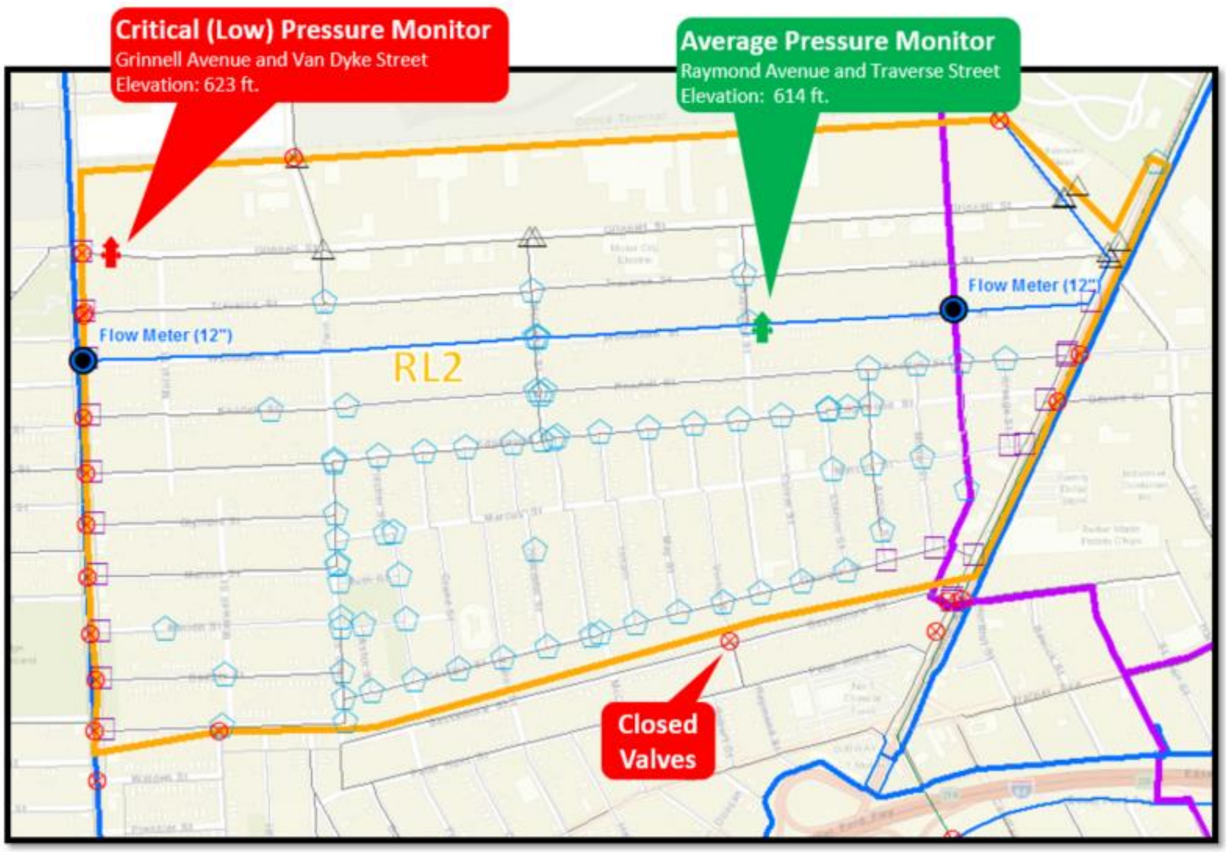

Figure 2-12 RL2 DMA Flow Meter and Pressure Monitor Locations

2.4.2.4 DMA NW

This DMA is situated in the Springwells high pressure zone in the northwestern corner of Detroit. It is the largest of the four DMAs with 34 miles of pipe but has a lower than average connection density. It also has the newest pipe of the four DMAs (average install year 1940). It is a primarily residential DMA with commercial customers concentrated on Grand River Avenue. The hydraulic modeling for this DMA indicated two sources of supply would be required to support fire flows. The locations of the two flow meters and two pressure monitors are listed below and are shown in Figure 2-13:

- Flow Meter on 12” line at 7 Mile Road and Berg Road
- Flow Meter on 12” line at Telegraph Road and Puritan Avenue
- Average Pressure Location: Winston Street and 7 Mile Road
- Low Pressure Location: Norfolk Street and Five Points Street

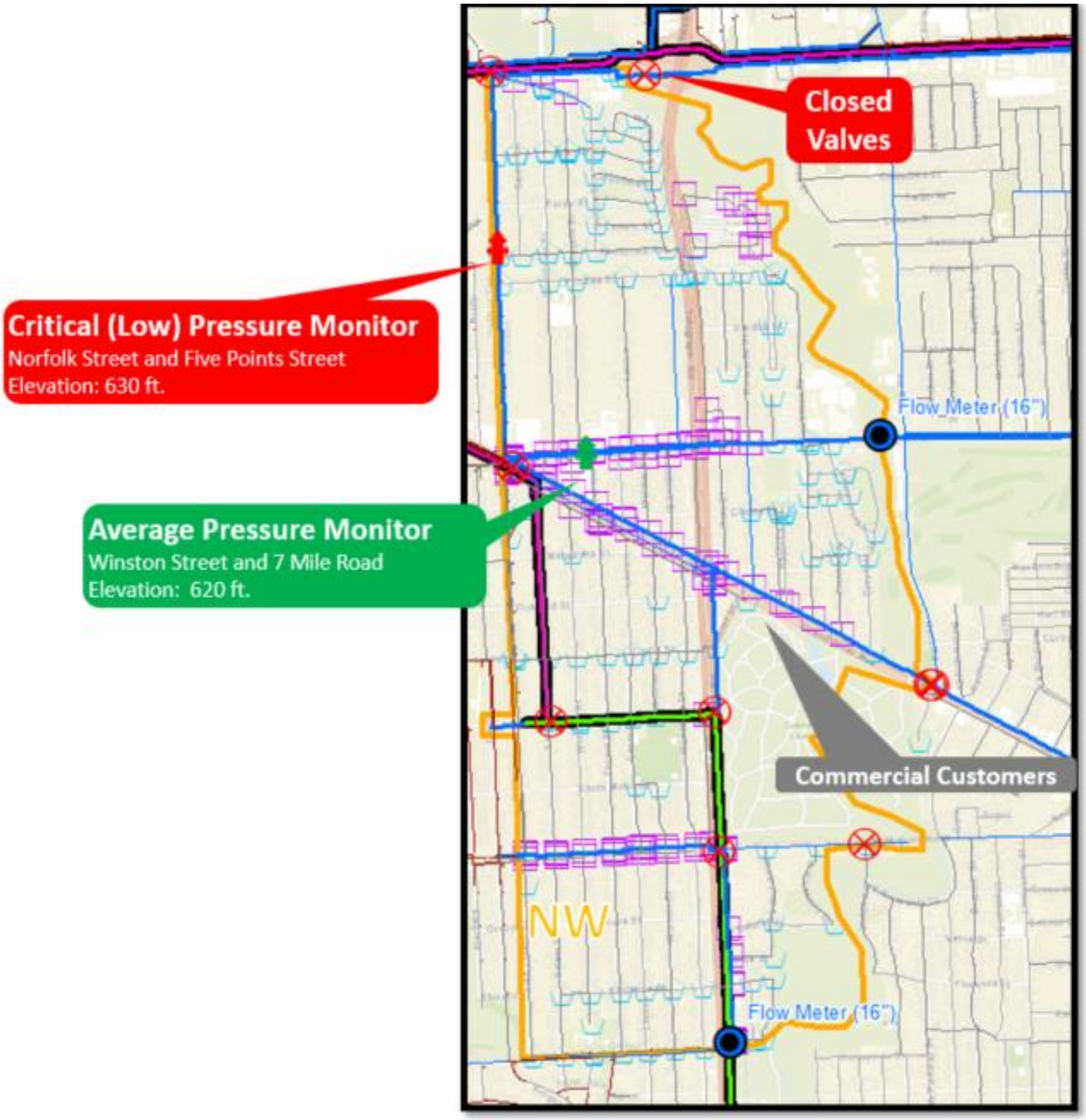

Figure 2-13 NW DMA: Flow Meter and Pressure Monitor Locations

2.5 EQUIPMENT

To measure the flow and pressure within the district metering areas, the following key equipment was utilized.

2.5.1 Technolog Cello 4S Pressure Loggers

The Technolog Remote Monitoring Cello 4S Data Logger (Figure 2-14), can be used to measure multiple data series, such as flow rate, pressure (minimum, maximum, and mean), transients, and water temperature. In total, each logger can be programmed to observe 2 separate pressure readings and 8 programmable digital or analogue inputs. The logger connects to the pipeline via a 1/8" or 1/4" valved tapping. All parts, including the battery and antenna, are located within the logger. If needed, external antennas can be purchased through a third party and were utilized in this project. Each logger is equipped with a replaceable SIM card that transmits on 2G or 3G frequencies to any available cell network. The battery typically lasts for about 5 years but will depend on how often data is transmitted to WaterCore, the online portal that allows access to near real-time data (depending on data upload frequency). Data for all communication lines can be obtained at any point via direct connection to the logger.

Figure 2-14 Technolog Cello 4S Pressure Logger (Source: Technolog)

2.5.2 ABB AquaProbe FEA200 Insertion Flowmeter

The AquaProbe FEA200 insertion flowmeter (Figure 2-15) is a cost-effective alternative to full bore flowmeters. It is designed for installation in existing pipelines, greater than 8-inch diameter, via a small valved tapping, 1-inch or larger. No excavation is needed if a valve is already attached to the pipeline. It contains no moving parts which reduces the maintenance and increases reliability. It provides measurement of water velocity through a small electromagnetic flow sensor attached to the end of the insertion rod. Flow is typically measured at the center of the pipeline where velocities are the most consistent and accurate as opposed to closer to the pipe wall. The meter should be completely vertical to get the most accurate readings. The flow meter will be cabled to the Technolog Cello 4S which will allow the flowmeter data to be viewed in the same online database (WaterCore) in near real time.

Figure 2-15 ABB AquaProbe FEA200 Insertion Flowmeter (Source: ABB)

2.6 FIELD RECONNAISSANCE

2.6.1 Insertion Meter Locations

Field review to finalize the locations of the IMM insertion points was conducted with the goal of ensuring a desired straight-run of pipe which is necessary to maintain a suitable level of accuracy of the IMMs. In accordance with the ABB insertion meter manual, at least ten diameters of straight pipe upstream, and five diameters downstream, of the insertion meter location are recommended to provide a stable and symmetrical flow profile in the pipe.

2.6.2 Flow Profiles

A flow profile for a pipe is determined by taking measurements of flow velocity at multiple intervals within the pipe to build a profile of the flow. Typically, velocity is greater at the center of the pipe and less at the edges of the pipe due to friction. Figure 2-16 shows the ideal conditions of a fully developed turbulent flow profile. Field investigations were performed to find the optimal insertion meter location for each DMA close to the modeled points. In the case of DB1, a clean run of pipe was tapped specifically for the insertion meter installation which also required the addition of an access chamber. In all other cases (for both Dearborn and Detroit), the insertion meters were located in gate wells and a 1" corporation stop was added to the pipe adjacent to the gate valve where necessary. Given that a fully opened gate valve will clear the internal diameter of the pipe, these locations were considered as straight pipe thus eliminating the need to create a new chamber.

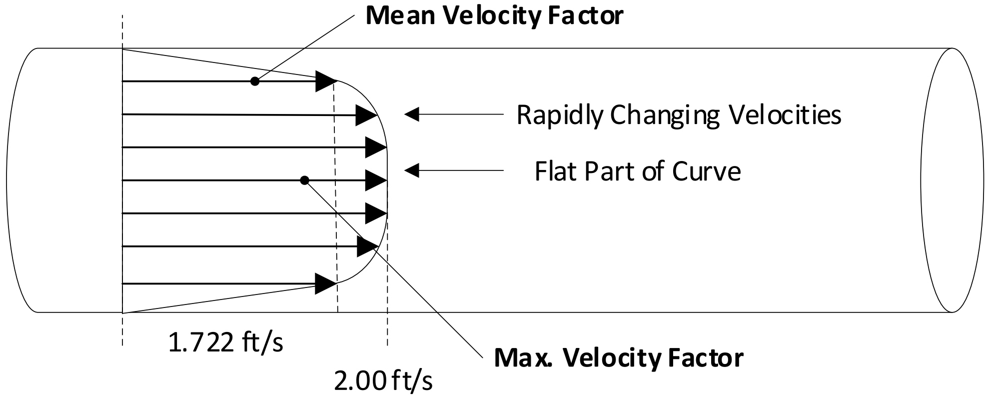

Figure 2-16 Turbulent Flow Profile

In order to confirm the suitability of the flow profile at each IMM location, the flow profile was estimated and developed by M.E. Simpson (contracted by B&V) by the use of a Pitot Rod. This additional test, using their specialized equipment, was conducted to validate that the proximity to the gate wells did not have a significant effect on the flow profile, and also to evaluate any other impacts on the flow profile such as pipe tuberculation. Figure 2-17 shows an example flow profile from the insertion meter location at DET-D at Warren Avenue and Southfield Freeway. The flow profile is rarely identical to the ideal turbulent flow profile but typically the center of the pipe is the flattest part of the curve with more stable and uniform velocities. This condition is desired as the insertion meter sensor is installed in the center of the pipe and therefore any slight variation from the center should have minimal impact on the accuracy of the flow measurement.

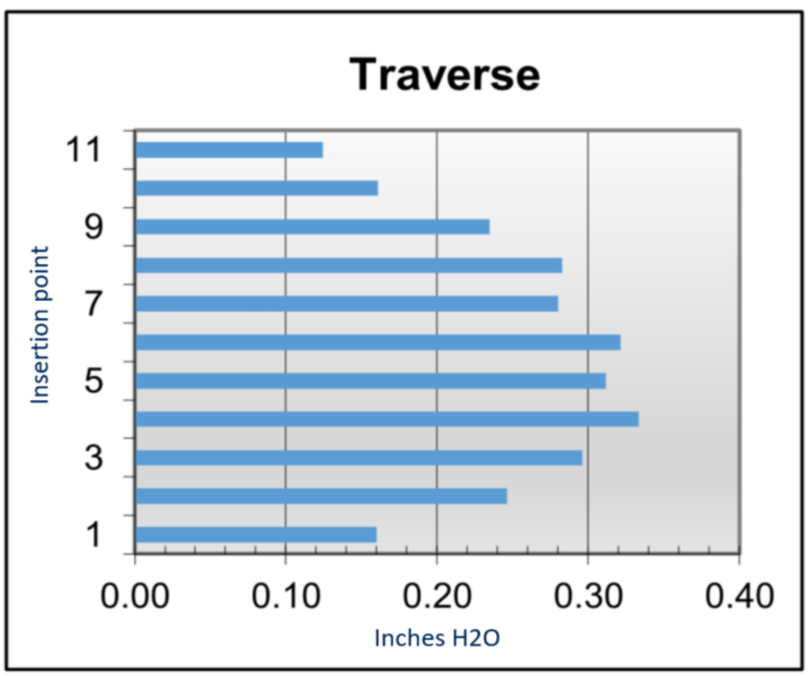

Figure 2-17 Flow Profile Result from Testing on Corporation Stop adjacent to a Gate Valve.

2.6.3 Valve Investigation and Closures

The water section maps were reviewed, and all the proposed boundary valves were inspected and exercised prior to isolation to ensure they were functional and could provide a watertight closure. Valves were sounded where necessary and defective valves were repaired as needed. In some cases, exercising the valves caused minor water quality issues and flushing was required to clear the lines.

2.7 BASELINE MONITORING

The pressure monitors (Technolog Cellos) were installed on connections in gate wells to obtain pressure profiles within the DMAs. Pressures were monitored at the inlets (i.e. IMM locations) and at the low pressure and average pressure locations. With the reduced interconnectivity of the DMA to the broader system, it is important to monitor system pressure in case a large water main break occurs. The data loggers chosen for this project had cell-based communication with the ability to configure customized alarms that would alert the system operators via text or email of a pressure or flow value out of the expected normal range. Due to the underground location of the logging units, cell signal strength had to be evaluated and tested. Each unit received an external antenna to ensure the signal was as close to ground level as possible, but the antenna remained within the gate well chambers. Prior to commissioning of the DMAs, signal strength was checked for several days to ensure communications were adequate. In most locations, a grated lid was necessary to allow the cellular device to communicate with the network.

The goal was to automate as much of the data logging and collection as possible; therefore, equipment with cell capability and an existing online visualization platform was chosen for the data capture and review. To benefit from these systems, the wireless signal needs to reach its collector or tower. The existing manhole covers needed to be replaced with the grate-style covers as shown in Figure 2-18. These covers were used throughout the DMAs in Dearborn and Detroit to allow the signals to consistently send to the cell towers from the gate well chambers.

Figure 2-18   Grated Manhole to Enable Cellular Communication of DMA data

2.8 BENCH TESTING

GLWA and DWSD share a large meter test facility (Figure 2-19) at the Central Services Facility which is used to test the accuracy of many types and sizes of meter within the GLWA service area. Each of the new ABB AquaProbe IMMs were tested on the GLWA test bench to verify operation and accuracy prior to installation. Each meter was tested in a 1” corporation stop tapped into the 12” line. Prior to meter testing, a flow profile was obtained by M.E. Simpson using a Polcon pitot rod for the insertion location. Testing was conducted using both the 10” inline Siemens mag meter and the calibrated tank. The tank volume and mag meter tracked closely (within 1-2%) in all initial tests; therefore, in subsequent tests, the inline mag was used as the test meter. The inline electromagnetic meter was calibrated the week prior to the IMM testing. The bench testing revealed a wide range of results and a lack of consistency was observed between each meter. M.E. Simpson measured the internal diameter of the pipe at the insertion location using a pipe caliper, and it was determined to be 311mm. This information was programmed into the AquaProbe and used to determine the required Insertion Factor and Profile Factor, which was also programmed.

Figure 2-19 GLWA Large Meter Testing Facility

A 1-inch corporation was installed within a segment of pipe to mimic what would be found in the field and all the meters tested in the same configuration as shown in Figure 2-20.

Figure 2-20 Insertion Flow Meter Test Bench Configuration

2.9 INSTALLATION & FIELD TESTING

In most cases, existing gate wells were used to house the monitoring equipment; however, in two locations, specialized chambers were constructed to house the monitoring and data logging equipment. A pipe tap for a corporation stop was generally required for the IMMs to be installed and were 1-inch in diameter. Once the meter was installed, in-situ testing by a downstream metered hydrant was conducted to verify flow meter measurement. In ideal circumstances, the hydrant test configuration involves the IMM and the hydrant test meter in close proximity without any customers drawing water. In some test locations, customer connections were included between the two measurement points. In those cases, an estimated volume used by the customers during the hydrant test was subtracted from the measured IMM flow value. An example test configuration is shown in Figure 2-21. The test was performed by pulling a known volume of water through a calibrated hydrant test meter across the range of anticipated flows for the site, typically six or seven flows rates were captured between 50 and 500 gpm. At these known flow rates, a timed test was performed on the IMM and the hydrant meter (typically 10 minutes per flow rate), and the results used to compare flow volumes were recorded. Prior to pulling flow through the hydrant the IMM flow rate was monitored to ensure there was no flow which could be indicative of a leak between the IMM and the hydrant meter.

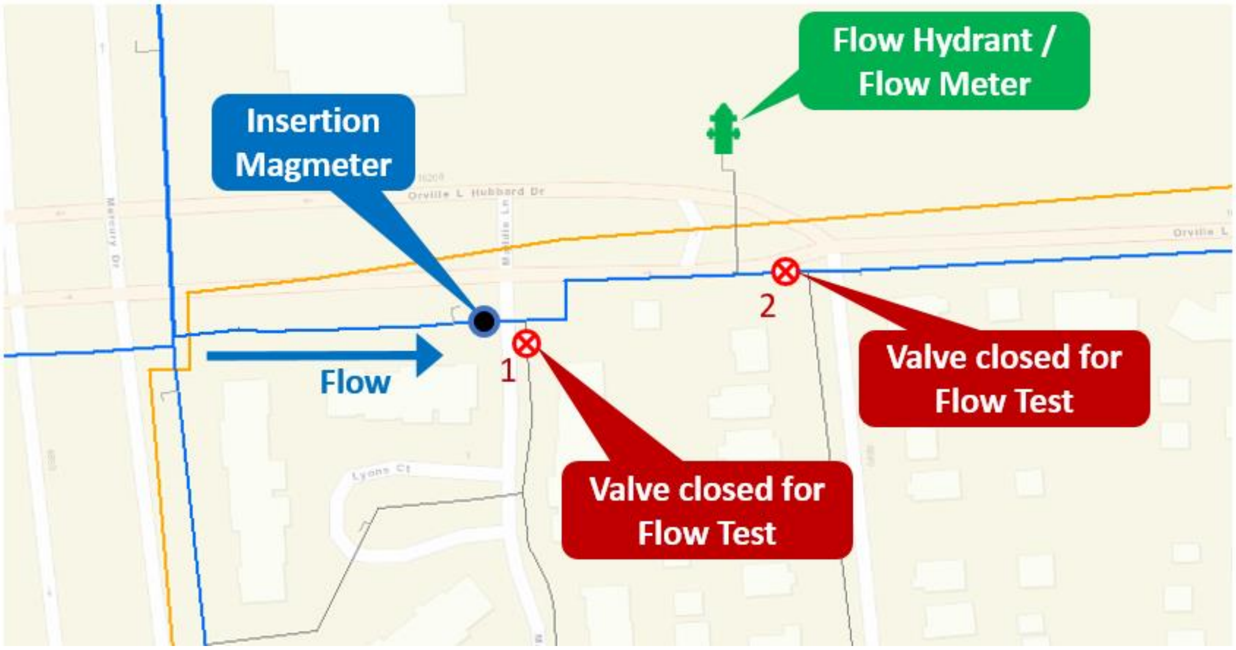

Figure 2-21 Hydrant Test Example Configuration

2.10 COMMISSIONING

Prior to commissioning the DMAs, each boundary valve that required closure was exercised to ensure that it seated correctly and was watertight in order to ensure the isolation and integrity of the DMA's hydraulic boundary. During the DMA commissioning process, a pressure drop test was conducted to confirm the integrity of the DMA. Once the DMA was deemed as being "tight" the boundary valves were marked, and DMA monitoring began.

2.11 DMA TEST PERIOD MONITORING & ANALYSIS

The data from each of the sites was actively monitored for large variations which may have suggested significant flushing, leakage, or abnormal customer usage. No flushing events were noted during the test periods, and therefore, it was assumed that unbilled authorized uses were zero in each of the DMAs. The retail meter reads were accessed from Dearborn and Detroit for the specific monitoring periods in the selected DMAs.

2.12 PRESSURE LOGGING & MONITORING

In order to determine the integrity of the DMA and to make sure that there are no issues during operation, pressure loggers were utilized to make sure that the pressures did not drop below specific thresholds. If these thresholds were breached, then automated alerts were sent via text and / or email to recipients for action. Actions could include further monitoring and observation of pressures, or if pressure levels warranted more significant action, valves could be opened to allow additional flow into the district to restore pressures. This would mean DMA operation would be suspended as the area would no longer be fully metered.

Figure 2-22 Example Installation of Pressure Logging Infrastructure

2.12.1 Flow Logging

All flow was measured through the IMM, except for one input into DB2 which was measured through an in-line mag meter. The internal logging system on the IMM was connected to the automated logging unit which sent the data via a cell-based system to the visualization platform noted previously. The in-line mag meter in DB2 was connected directly to GLWA's WAMR reporting system through their radio network.

Figure 2-23 Example Installation of Flow Logging Infrastructure (from DB1)

Figure 2-24 Insertion Mag Flow Meter Installation in Dearborn DB1

2.13 RETAIL CONSUMPTION DATA

Retail consumption within the DMA for the monitoring period is subtracted from the volume of measured input to the DMA as the key basis of the water balance; other adjustments are made to separate apparent and real water losses. Therefore, it is important to accurately identify those accounts served from the distribution network within each DMA. B&V provided the final DMA boundaries to Dearborn and Detroit who then returned GIS files containing customer and meter information to B&V for further review. In some cases, a customer metering location appeared outside of the DMA boundary. This can happen when a service line extends beyond the DMA spatial boundary but the source of supply to the customer is from within the DMA. In such cases, these metering points were discussed in more detail with Dearborn and Detroit. An example of the types of issues that were reviewed is shown in Figure 2-25.

Figure 2-25 Review of Customer Accounts within a DMA

2.13.1 Dearborn Retail Data

The Dearborn retail metering system normally reads its retail customer meters once every three months. For the duration of this project, Dearborn staff read the meters within the DMAs every business day. This process involved utilizing the drive-by AMR system for the 805 meters in DB1 and 1,349 meters in DB2.

Most of these meters register at 100 cubic feet (748 gallons) intervals; therefore, the reads require averaging over periods longer than one day to provide realistic representations of the retail usage recognizing that each meter will not turn every day. On average, a domestic retail meter will show increments of 100 cubic feet (cf) approximately five to six times per month. The number of meters within each DMA also influences the consumption patterns – the higher the number of meters the less sensitive the aggregate volume is to individual meter turns. Meters were read daily for a period of several days prior to isolation of the DMA to provide a baseline of retail consumption and to identify any discrepancies in the data such as stopped meters. Accounts for which meters that did not turn during the DMA period were investigated by Dearborn, but these accounts were determined to be legitimate zero consumption and no adjustments to the data were required. No meters were changed out during the DMA monitoring periods.

2.13.2 DWSD Retail Data

The retail metered data for DWSD is predominantly hourly readings provided through their Itron fixed-network AMR system. The meter inventory was provided to B&V with an account linkage to GIS (Premise Number) to identify customer meters served within each Detroit DMA.

The majority of AMR enabled meters in the DWSD system are capable of reporting at one cubic foot increments which provides greater granularity and reduces impacts of meter reading lag; however, some meters have a granularity of 100 cf.

2.13.2.1 Data Adjustments

In addition to the AMR reads a file of estimated reads was provided to B&V for each DMA. During the review and analysis of AMR data by B&V, it was observed that some recorded consumption data points were not plausible values. For example, one hourly value for a 5/8" meter was reported as 14,815 cf, which is not possible. Upon review with DWSD staff, it was determined that this value was the actual meter read and not a consumption value. B&V developed a data checking process which replaced data anomalies with more plausible data. Table 2-3 and Table 2-4 list the typical maximum flow rating for standard positive displacement and type II turbine water meters respectively. The capacity may vary slightly between manufactures and technologies used so standard data from the AWWA M22 manual was utilized for this purpose. During screening of the AMR data, if the hourly value exceeded the Max. Flow value in the tables below, the value was replaced with the Avg. Flow value which was determined based on an analysis of the average hourly consumption values by meter size from the Detroit DMA retail data.

Table 2-3 Typical Maximum Flow for Positive Displacement Meters

SIZE	MAX. FLOW GPM	MAX. FLOW CF/HR	AVG. FLOW CF/HR
5/8”	20	160	0.7
3/4”	30	240	0.8
1”	50	401	1.7
1.5”	100	802	2.4
2”	160	1,283	3.6

Table 2-4 Typical Maximum Flow for Type II Turbine Meters

SIZE	MAX. FLOW GPM	MAX. FLOW CF/HR	AVG. FLOW CF/HR
3”	435	3,489	5.9
4”	750	6,016	8.6

2.14 DMA IMPLEMENTATION AND RESULTS.

The results of the DMAs are described in the following sections. A greater level of detail is provided for Dearborn’s DB1 DMA in order to explain in more detail the steps that were taken to obtain and validate results. For subsequent DMAs, a more summarized description is provided with more detailed graphics and additional data included in the Appendix 10.2.

2.14.1 Dearborn DB1

Dearborn’s DMA DB1 was the first to be implemented. The meter was installed, and a hydrant test performed on 8/3/2018. The hydrant test was performed to provide an in-situ calibration of the IMM. Any discrepancy between the IMM measurement and the hydrant meter measurement could be addressed through an adjustment curve (as described below). Additional pressure monitoring equipment was installed and configured in the DMA. Issues related to the cell signal strength on the communications equipment were addressed by the use of external antennae (still within the gate well structure) and the use of grated manhole covers – this allowed near real-time data to be viewed remotely through Technolog’s online monitoring platform known as WaterCore. Alarms were configured on the pressure monitoring equipment and protocols for action in the event of a low-pressure alarm being triggered were put into place and tested. Retail meter reads were also initiated each business day starting 8/20/2018. The DMA was isolated, and a pressure drop test was performed on 8/30/2018 to confirm isolation (see Figure 2-26); monitoring began immediately after the successful pressure drop test. Pressures were dropped to approximately 15psi. Pressures in the DMA were highly sensitive to a 1/8 turn of the 12” supply valve to the DMA providing confidence that this was the only feed to the DMA.

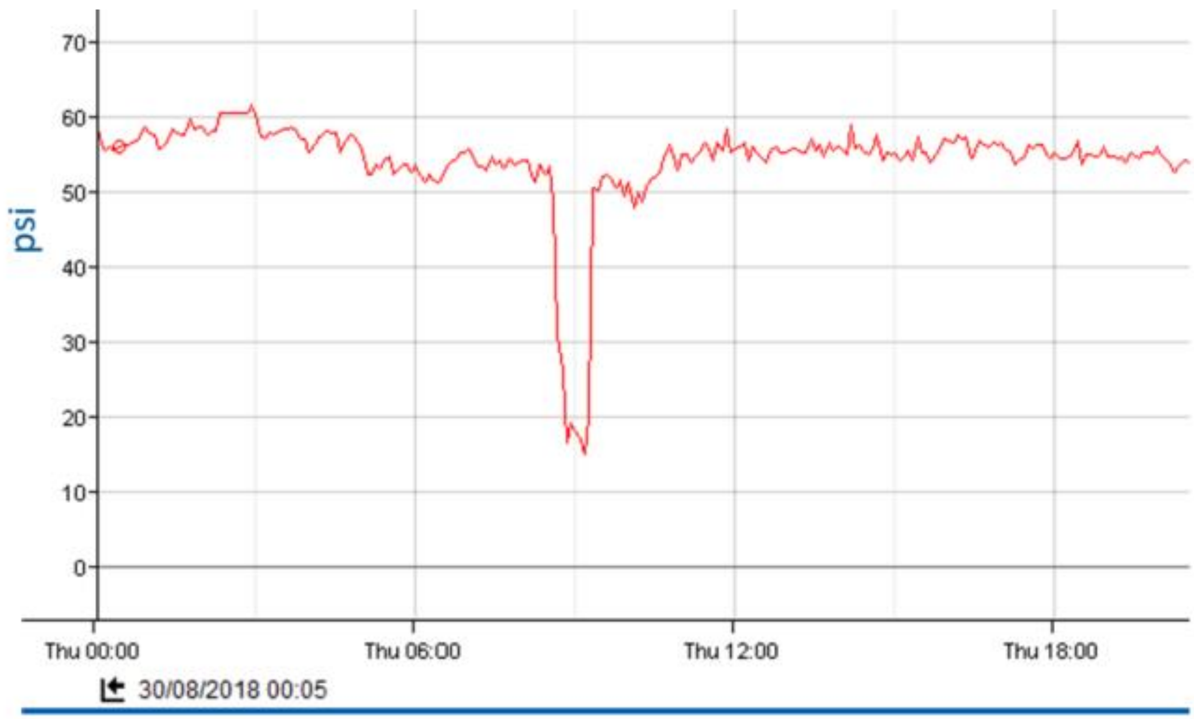

Figure 2-26 Pressure Drop Test in DB1 Confirming DMA Isolation

The initial water balance for DB1 indicated that more water was being sold through retail meters than was entering the DMA. The DMA water balance was performed several times during the 14-day monitoring period and each time the results were negative water loss. The project team (GLWA, Dearborn and its consultants, and B&V) reviewed the findings for possible reasons including a detailed review of the retail metering points and retail consumption data. No data anomalies or unexpected values were found during the retail data review. Customer retail data was reviewed for any high usage accounts, but none were found. The average water use per account was 151 gallons per day.

The flow rates entering the DMA, as measured by the IMM, are shown in Figure 2-29.

2.14.1.1 DB1 Low Flow Validation Test

The project team wanted to validate the accuracy of measuring low flow (i.e., minimum night flows) with the insertion mag meter. The minimum night flow as measured by the IMM was approximately 25 gpm, with sporadic data points below that level. This flow rate in a 12" pipe equates to a velocity of approximately 0.07 ft./sec. According to the manufacturer's specifications, accuracy of flow measurement may decrease at velocities below 0.33 ft./sec. In order to provide a validation point of low flows, a short-term flow augmentation was conducted after the 14 day DMA monitoring period had finished. This involved adding demand to the DMA by pulling additional water through a hydrant within the DMA for three days at a constant 100 gpm flow rate. The purpose of this test was to evaluate the low flows to see if they moved from approximately 25 gpm to approximately 125 gpm. If the variation was significantly different then this would imply that the 25 gpm low flow measurement may not be accurate. As can be seen in Figure 2-27, the test indicated that the known increase in flow was reflected in the measured (and adjusted) volume.

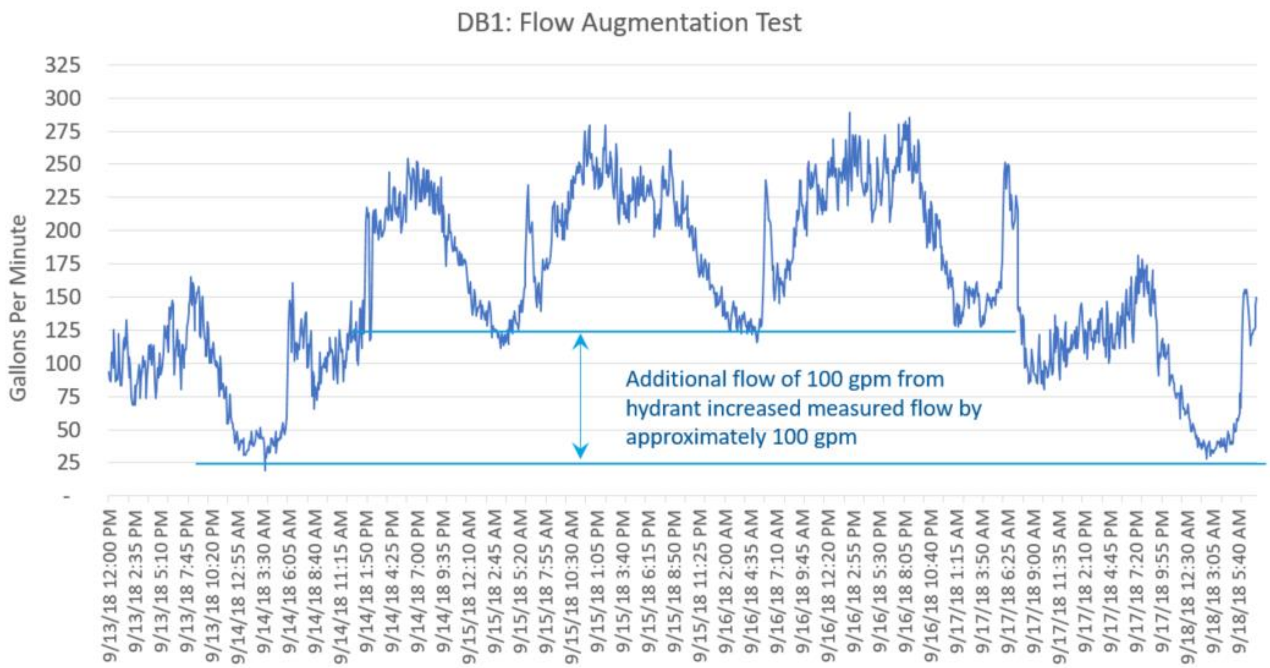

Figure 2-27 Flow Augmentation Test at DB1

2.14.1.2 DB1 Hydrant Tests

After the 14 days monitoring period a second hydrant test was conducted. The second test was conducted by M.E. Simpson (sub-contractor to B&V). The monitoring period had provided more insight into the range of flows and the second hydrant test collected additional data points that were more representative of the observed range of flows in the DMA. For example, 59% of the five-minute intervals during the 14 day monitoring period had flow rates less than the lowest test flow rate during the first hydrant test.

The second hydrant test required the de-isolation of the DMA. During the testing, it was observed that the flow meter orientation was not entirely colinear with the pipe, although photos taken during install indicated that it was colinear at time of installation.

The results of the two hydrant tests are shown in Figure 2-28. Test 2 (removal test) captured more data points with in the observed range of flows. For this reason, and because it appeared the meter may have moved slightly since installation, it was determined that the results of this second test would be used to adjust the flow meter data. The project team also agreed that it would be prudent to conduct a second DMA evaluation period using a second meter for an additional 14 days.

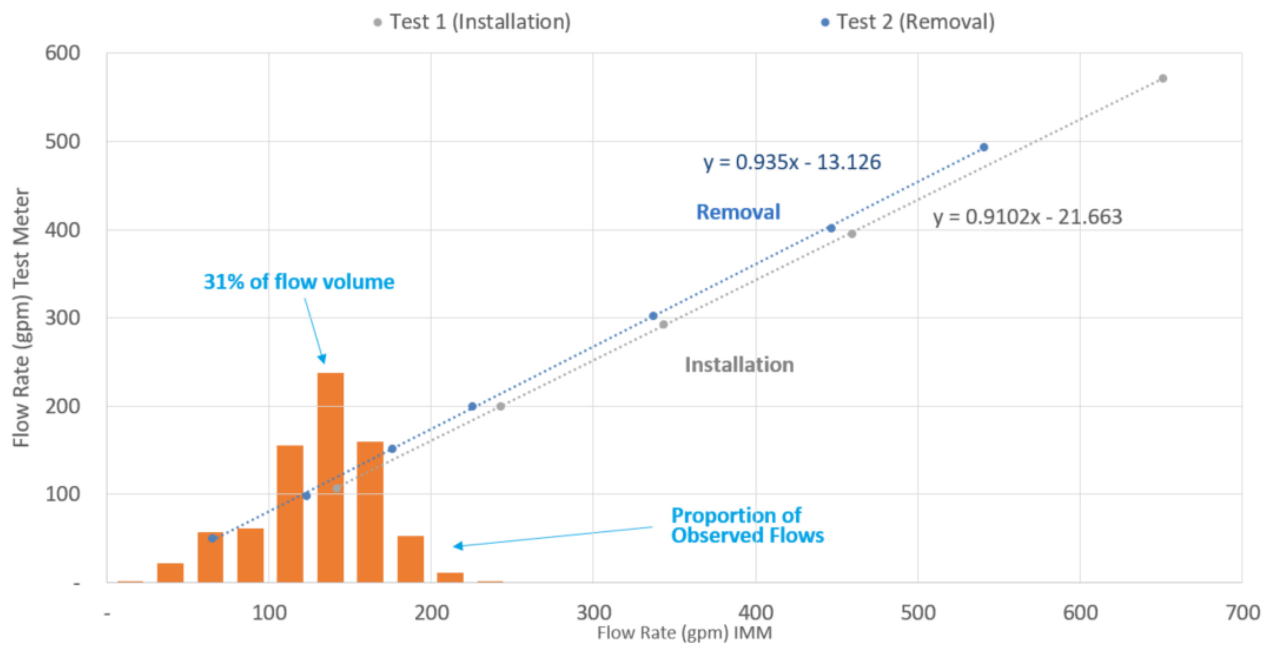

Figure 2-28 DB1 Meter 1 Hydrant Test Comparison

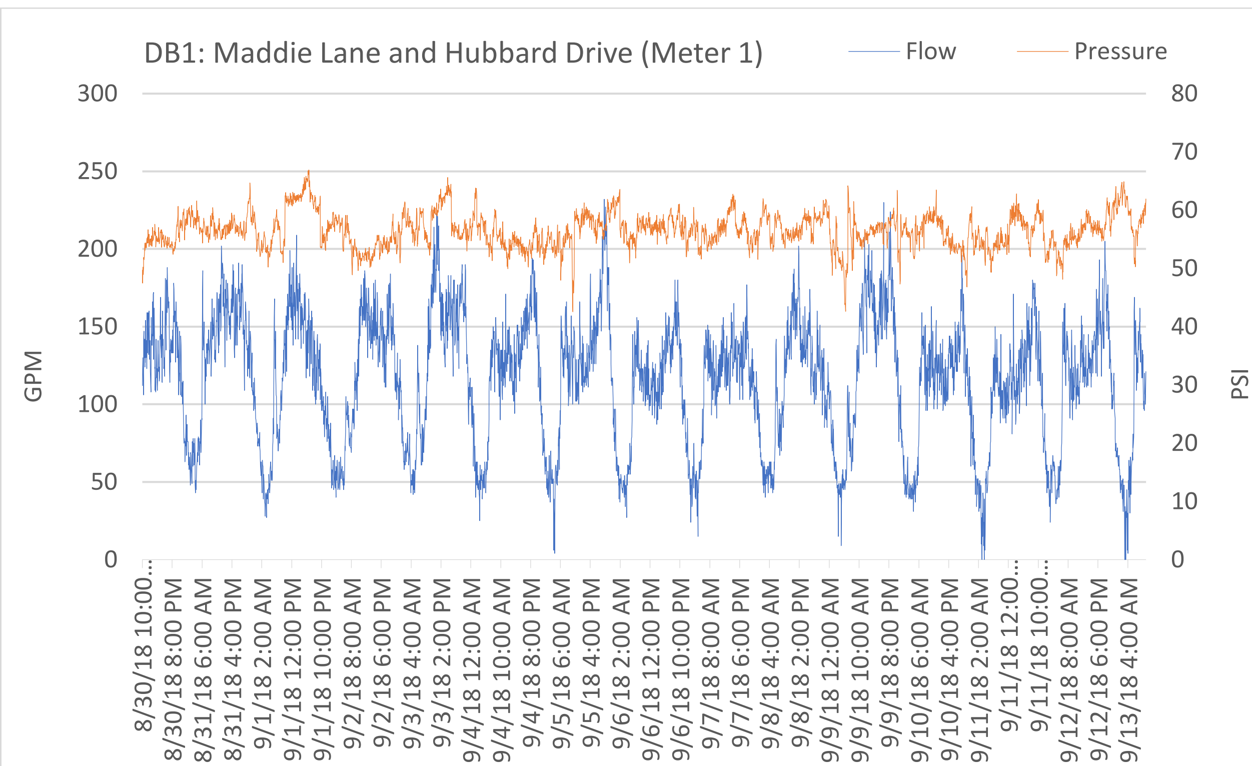

Figure 2-29 Flow and Pressure at DB1 Input Location (Meter 1)

A replacement meter (Meter 2) was installed in the same location in DB1 on 9/18/2018. The internal diameter of the pipe was measured, and the meter was calibrated in-situ using parameters recommended by M.E. Simpson. A new hydrant test was conducted, and the resultant calibration curve indicated that the meter matched the flows at the hydrant more closely than the first meter.

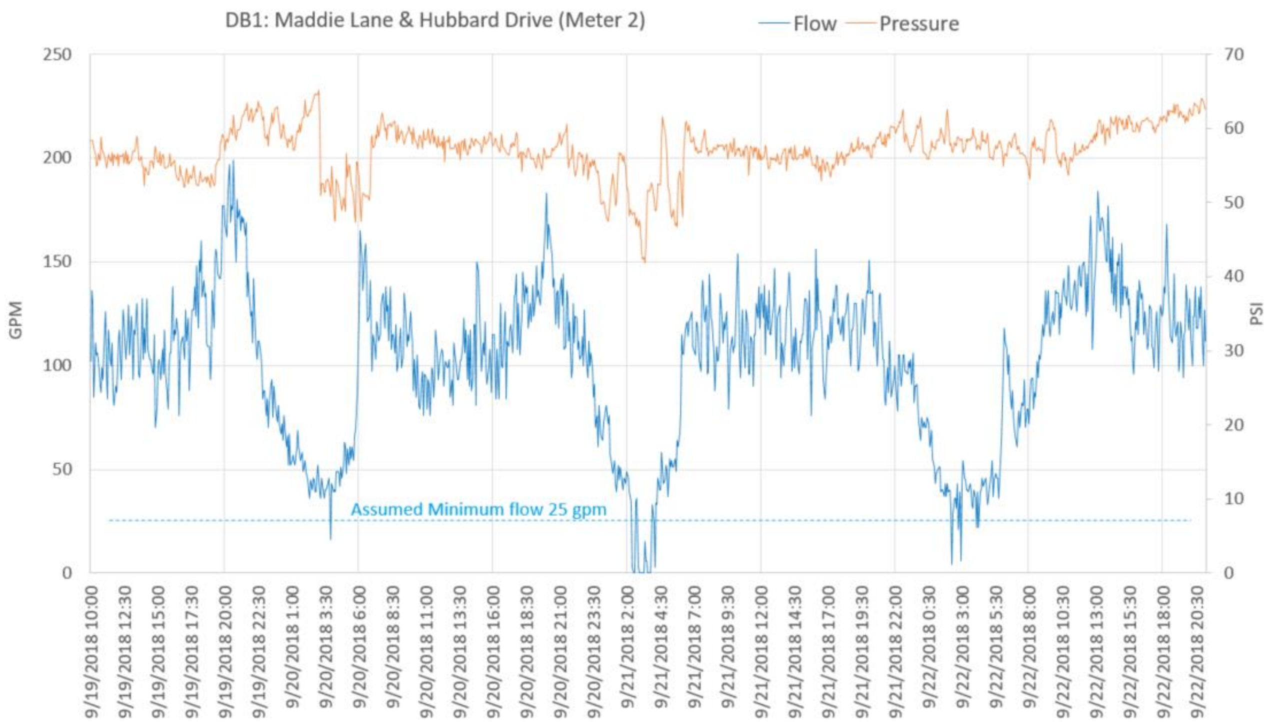

Figure 2-30 Low Flow Adjustment for DB1 Meter 2

This DMA was monitored for 14 days using this meter. A trend was observed that low flows during the night (i.e., 2-4 am) were generally declining. This occurrence is consistent with typical late summer trends and is likely attributable to less frequent lawn watering from automated sprinkler systems. The same trend was also observed in retail consumption. Flows sometimes dropped to zero as registered on the IMM which is not plausible for a single feed DMA. Zero flow is likely to be indicate that the velocity in the pipe is below the minimum level that the meter can detect; whereas in reality, some flow will be passing. Based on the general patterns observed within the DMA, B&V determined that a minimum flow of 25 gpm should be established, i.e., flows below 25 gpm would be replaced with 25 gpm. The total impact of replacing the data points for Meter 2 was an increase of 0.6% to the total volume of flow measured by the IMM.

2.14.1.3 DB1 Results

A water balance for each of the two monitoring periods was created and are shown in Table 2-5 and Table 2-6. The following explanatory notes relate to the table item numbers.

1. The totalized flow volume entering the DMA as measured by the insertion meter
2. The adjusted, or corrected, flow volume entering the DMA based on the correction factor applied from the hydrant test comparison

3. The consumption volume based on retail meter reads. There were no estimated reads in the DMA during the monitoring period in DB1.
4. Customer metering inaccuracies (CMI) reflect the potential for retail meters to under-record actual consumption. In Dearborn, this is based on 2.0% for meters 2" and smaller and 3.4% for meters 3" and larger. The value for the DMA reflects a weighted average of CMI based on consumption through small and large meters specific to this DMA.
5. Unauthorized Consumption (e.g., theft) based on AWWA recommended default value
6. Systematic Data Handling Errors (e.g., meter reading error) based on AWWA recommended default value
7. The aggregate volume of items 4, 5, and 6 is the apparent loss total expressed as gallons per connection per day
8. Net Real Loss in the DMA: Line 2 – Line 3 – (Line 4 + Line 5 + Line 6)
9. Net Real Loss in the DMA expressed as gallons per connection per day

Table 2-5 DB1 Meter 1 DMA Water Balance

	DB1 Meter 1	Total Volume (Gallons)	Gallons Per Day
[1]	Raw IMM Between 10:00AM 8/30/2018 and 10:00AM 9/13/2018:	2,323,110	165,936
[2]	IMM Adjusted Between 10:00AM 8/30/2018 and 10:00AM 9/13/2018:	1,926,768	137,626
[3]	Retail Reads	1,714,977	122,498
[4]	Customer Metering Inaccuracies (2.01% x [3])	34,471	2,462
[5]	Unauthorized Consumption (AWWA default) [0.25% x [2]	4,817	344
[6]	Systematic Data Handling Errors (AWWA default) [0.25% x [3]	4,287	306
[7]	Gallons per Connection* per Day Apparent Loss		**4**
[8]	Net Real Loss	168,216	12,015
[9]	Gallons per Connection* per Day Real Loss		**15**

* 805 Total connections

Table 2-6 DB1 Meter 2 DMA Water Balance

	DB1 Meter 2	Total Volume (Gallons)	Gallons Per Day
[1]	IMM Raw Between 10:00 AM 9/19/2018 and 10:25 AM 10/3/2018	1,881,115	134,232
[2]	IMM Adjusted Between 10:00 AM 9/19/2018 and 10:25 AM 10/3/2018	1,849,810	131,998
[3]	Retail Reads	1,655,327	118,120
[4]	Customer Metering Inaccuracies (2.01% x [3])	33,272	2,374
[5]	Unauthorized Consumption (AWWA default) (0.25% x [2])	4,625	330
[6]	Systematic Data Handling Errors (AWWA default) (0.25% x [3])	4,138	295
[7]	Gallons per Connection* per Day Apparent Loss		**4**
[8]	Net Real Loss	152,448	10,878
[9]	Gallons per Connection* per Day Real Loss		**14**

* 805 Total connections

The results from the two monitoring periods, using two different meters, were very similar. An average value of 14 gallons per connection per day of real loss was calculated for DB1 (rounded to the nearest gallon).

2.14.2 Dearborn DB2

This DMA is situated in the northwestern corner of Dearborn bordering Dearborn Heights. Based on fire flow requirements, two meters were installed for this DMA which is in an area of lower pressure within the Dearborn system. The insertion meter was installed on Oak Street east of Denwood, and a hydrant test was performed on 9/21/2018. An 8” inline insertion mag meter was borrowed from GLWA and installed on Gully Road and Cherry Hill. A temporary SCADA cabinet was set up for the inline mag meter, and communications were established to the WAMR system to monitor this meter. Alarms were configured on the pressure monitoring equipment and protocols for action in the event of a low-pressure alarm being triggered were put into place and tested. Retail meter reads were also initiated each business day starting 9/24/2018. The DMA was isolated, and a pressure drop test performed on 10/3/2018 to confirm isolation. Flow was turned off to the inline mag meter, and flow was controlled by the valve at the IMM location. Some difficulties were encountered before achieving isolation in DB2; several valves had to be exercised and hydrants were opened and closed as part of the effort to clear the valve seats. Following this activity, the boundary valves seated correctly, and no flow could be heard passing. Pressure dropped significantly within the DMA (see Figure 2-31) and was restored by opening the gate valve at the IMM location. Monitoring began immediately after the successful pressure drop test.

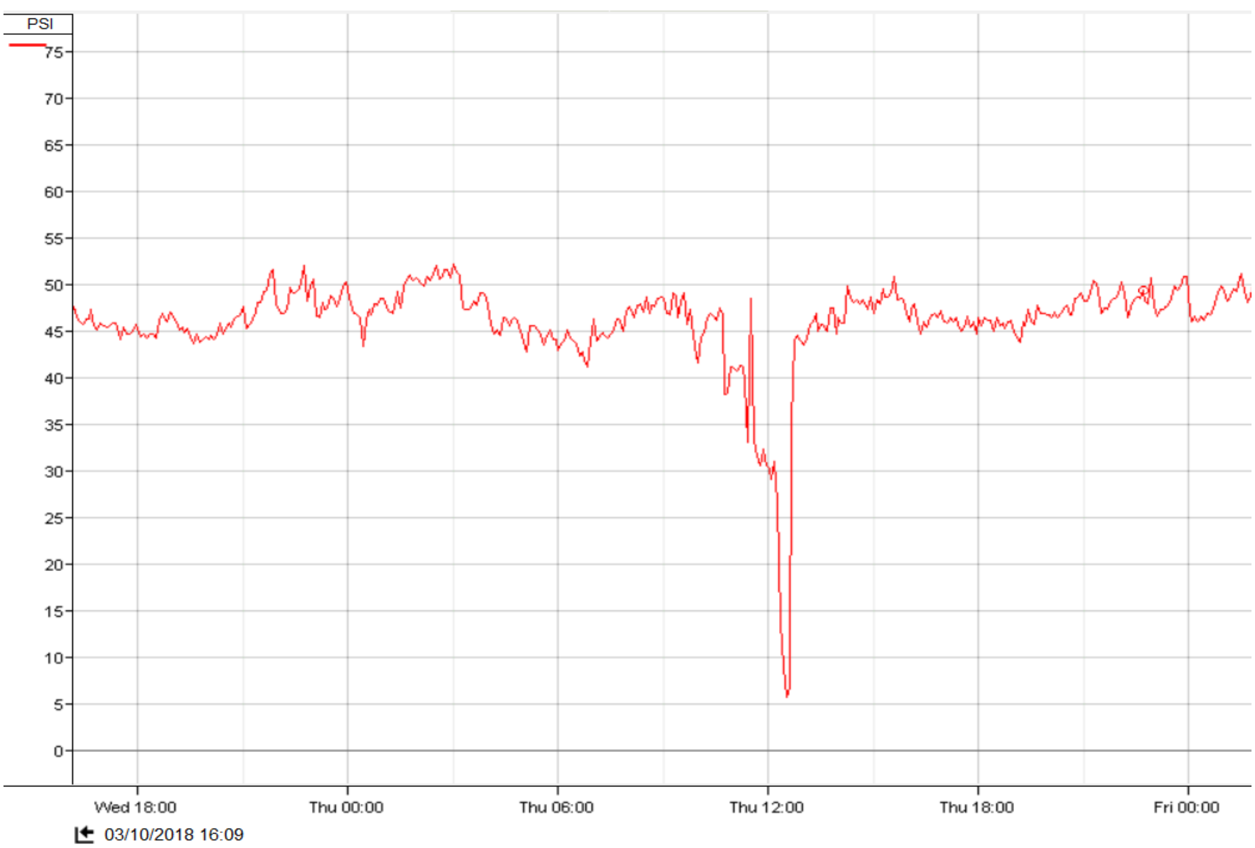

Figure 2-31 Pressure Drop Test to Confirm Isolation in DB2

During the first few days of operation of the DMA it was observed that flows not only entered the DMA, but also exited the DMA via the metering locations at certain times of the day. For example, during the night, flow through the inline mag meter in the southwest corner of the DMA would increase significantly, and flow would leave the DMA via the insertion meter location. The metering equipment is capable of logging and recording flow in both directions, but this adds complexity to the analysis. Based on a review of the observed flows into the DMA, Dearborn closed the feed through the inline mag meter, and therefore, the DMA was only fed through the IMM. Ideally, the inline meter location would have been used as the single feed; however, based on the maximum flow available during the hydrant test at this location (approximately 250 gpm), there was insufficient flow available to feed the DMA from this source only. Therefore, the IMM location was used as the single source to the DMA. After the DMA was converted to a single feed, monitoring of the DMA restarted on 10/8/2018.

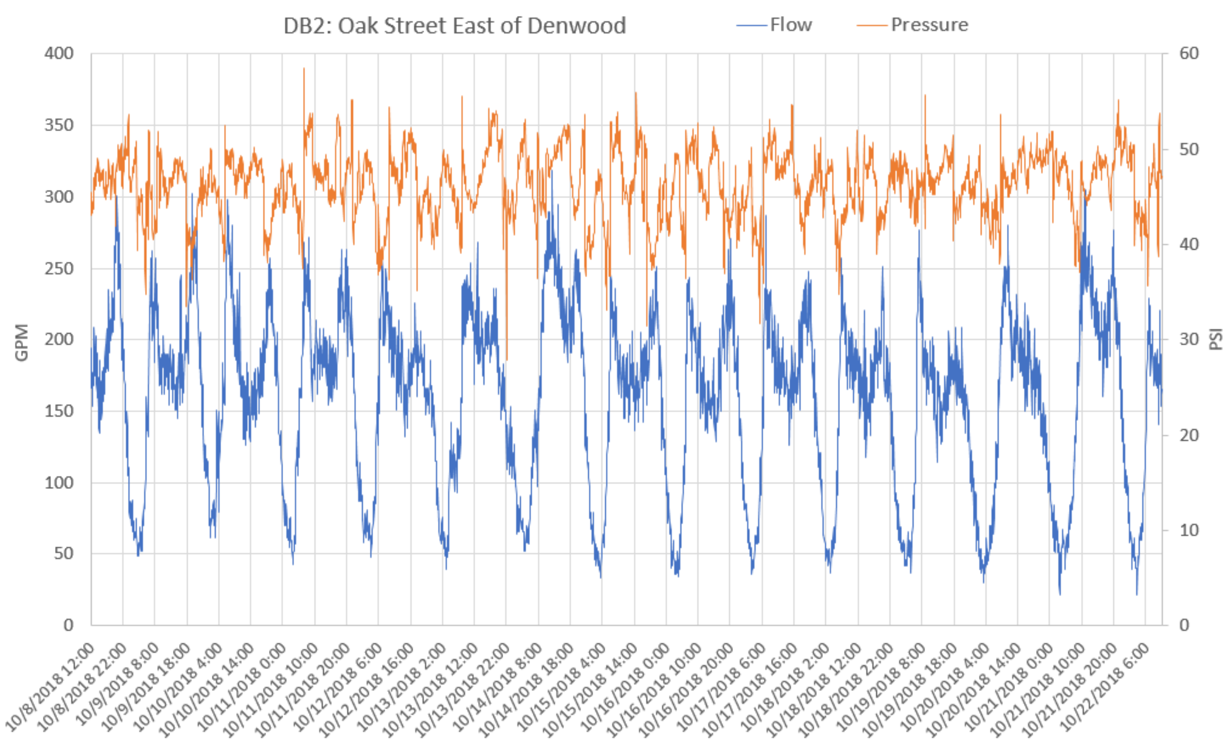

Figure 2-32 Flow and Pressure during DMA Monitoring in DB2

From Figure 2-32 it can be noted that night time flows in the DMA reduced noticeably in the middle of the monitoring period (10/15/2018). Lower consumption was also noted in the retail reads coinciding this with timeframe (Figure 2-33). This reduction in both input and consumption follows a weekend and one possible explanation is the turning off of automated sprinkler systems in the DMA.

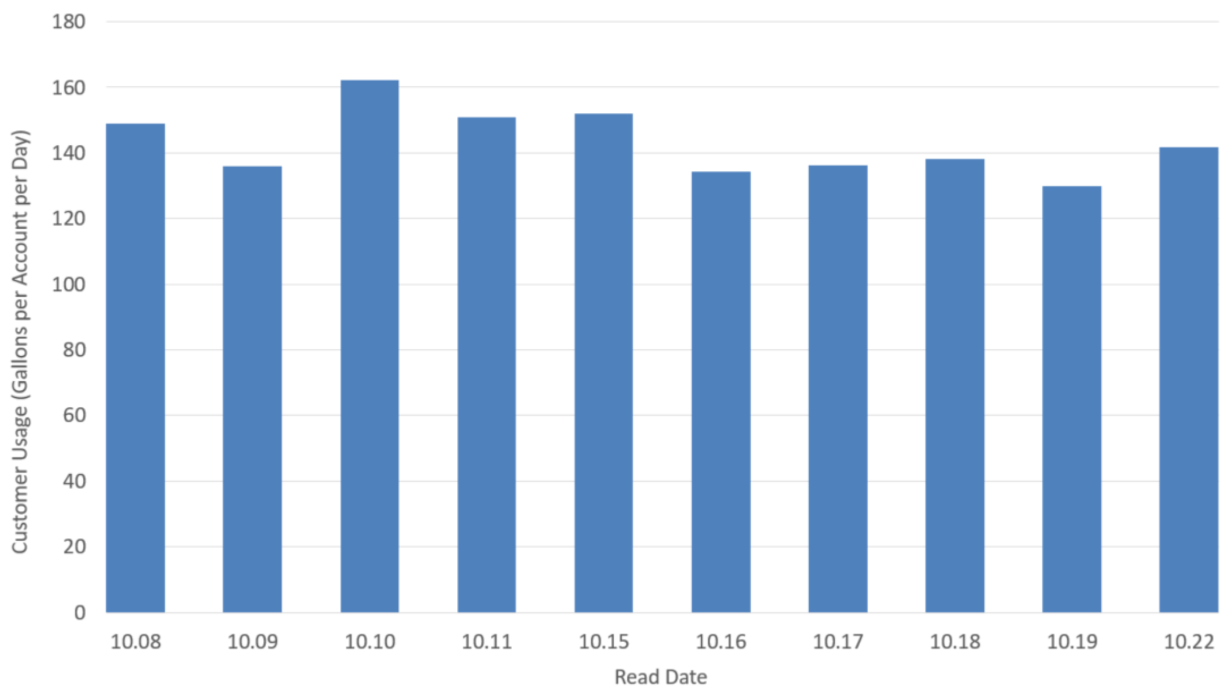

Figure 2-33 Retail Consumption in DB2 during DMA Monitoring

2.14.2.1 DB2 Hydrant Tests

The hydrant test configuration for DB2 is shown in Appendix 9.2.2. The isolated area included service to 28 properties. In such cases, an estimated flow volume associated with the properties during the time of the hydrant test (typically 10 minutes at each flow rate) is subtracted from the IMM totalized flow for the test recognizing that the IMM will include this flow but the hydrant meter will not. Based on an assumed average of 160 gallons per retail connection per day, the estimated additional flow per customer is 0.11 gallons per minute. Tests were typically performed mid-morning during the average portion of the diurnal curve. The estimated consumption associated with the 28 accounts equated to approximately 6.2% of the test volume at 50 gpm and 1.0% of the test volume at 300 gpm.

The installation test was completed on 9/21/2018, and the removal was completed on 11/1/2018; the test results and meter adjustment curves are shown in Figure 2-34. The test results matched closely at lower flows but deviated at higher flows. Due to some problems associated with the hydrant meter reported by the field crew during the removal test, the installation test was used as the basis for flow adjustment for the DMA.

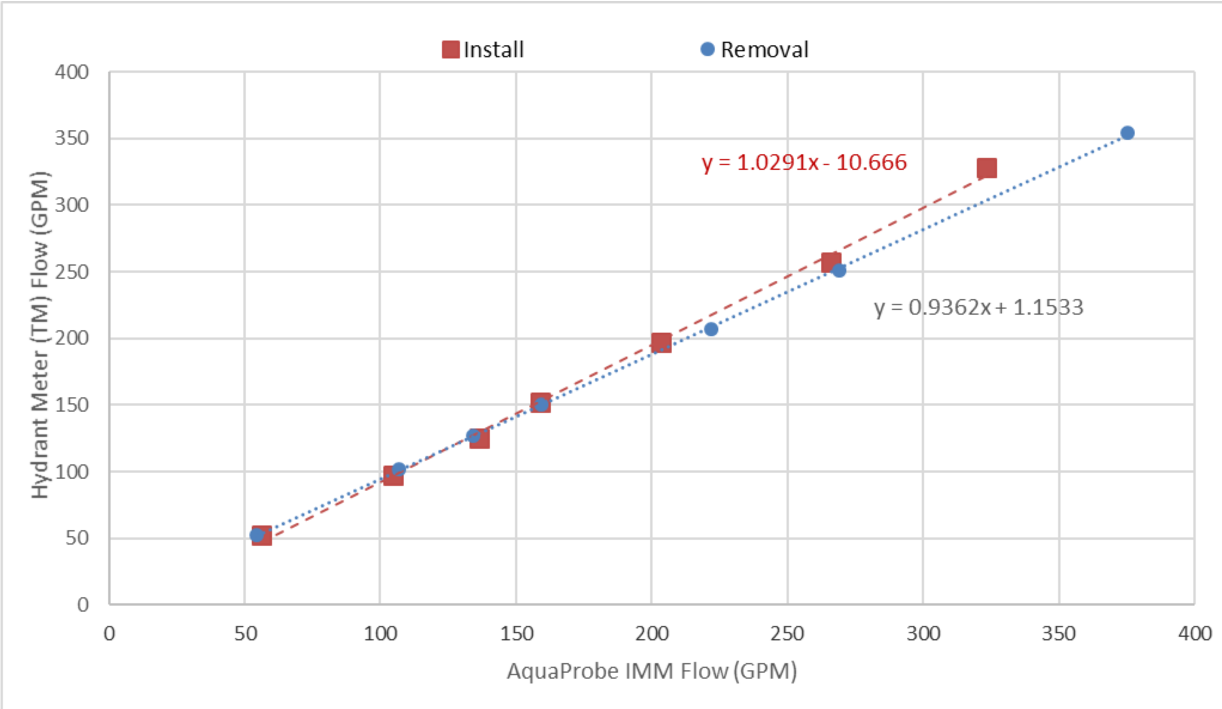

Figure 2-34 Hydrant Test Results for DB2

2.14.2.2 DB2 Results

A water balance for the 14-day DMA monitoring period was created and is shown in Table 2-7. The following explanatory notes relate to the table item numbers.

1. The totalized flow volume entering the DMA as measured by the insertion meter
2. The adjusted, or corrected, flow volume entering the DMA based on the correction factor applied from the hydrant test comparison. The consumption volume based on retail meter reads. There were no estimated reads in the DMA during the monitoring period in DB1.
3. Customer metering inaccuracies (CMI) reflect the potential for retail meters to under-record actual consumption. In Dearborn this is based on 2.0% for meters 2” and smaller and 3.4% for meters 3” and larger. The value for the DMA reflects a weighted average of CMI based on consumption through small and large meters specific to this DMA.
4. Unauthorized Consumption (e.g., theft) based on AWWA recommended default value
5. Systematic Data Handling Errors (e.g., meter reading error) based on AWWA recommended default value
6. The aggregate volume of items 4, 5, and 6 is the apparent loss total expressed as gallons per connection per day
7. Net Real Loss in the DMA: Line 2 – Line 3 – (Line 4 + Line 5 + Line 6)
8. Net Real Loss in the DMA expressed as gallons per connection per day

Table 2-7 DB2 DMA Water Balance

	DMA DB2	Total Volume Gallons	Gallons Per Day
[1]	IMM Raw Between 10/08/18 11:30 and 10/22/18 11:30	3,195,695	228,264
[2]	IMM Adjusted Between 10/08/18 11:30 and 10/22/18 11:30	3,082,500	220,179
[3]	Retail Reads	2,670,994	190,785
[4]	Customer Metering Inaccuracies (2.04% x [3])	54,488	3,892
[5]	Unauthorized Consumption (AWWA default) (0.25% x [2])	7,706	550
[6]	Systematic Data Handling Errors (AWWA default) (0.25% x [3])	6,677	477
[7]	Gallons per Connection* per Day Apparent Loss		**4**
[8]	Net Real Loss	342,634	24,474
[9]	Gallons per Connection* per Day Real Loss		**18**

* 1,349 Total connections

2.15 DETROIT DMA RESULTS

2.15.1 Detroit DMA DET-D

DET-D is situated between Southfield Freeway and Telegraph Road with Warren Avenue to the north and a boundary with Dearborn to the south. The first meter was installed at the Southfield Freeway and Warren Avenue location at the northwest corner of the DMA (hereinafter referred to as the DET-D NW flow meter) and flows tested against a hydrant on 9/25/2018. A second meter was installed in the southeast corner of the DMA at Greenfield Drive and Paul St. (hereinafter referred to as the DET-D SE flow meter) and flows tested against a hydrant on 9/27/2018. Additional pressure monitoring equipment was installed and configured in the DMA. Issues related to the cell signal strength on the communications equipment were addressed through the use of external antennae (still within the gate well structure) and the use of grated manhole covers – this allowed near real-time data to be viewed remotely through Technolog's online monitoring platform WaterCore. Low pressure alarms were configured on the pressure monitoring equipment and tested.

DMA isolation was attempted during the week of 10/15/2018; however, isolation was not achieved. B&V reviewed the section maps and identified an additional valve required for closure. In addition, 17 accounts previously considered to be a part of the DMA were identified for exclusion from the retail analysis as they are served from the 16" line along Telegraph Rd. on the east of the DMA; this line is not part of the DMA. Once the additional valve was closed, isolation was achieved on 10/21/2018. The valve at DET-D NW was closed completely for the isolation test and the valve at DET-D SE was throttled to control the feed to the DMA and reduce the pressure for the test (Figure 2-35).

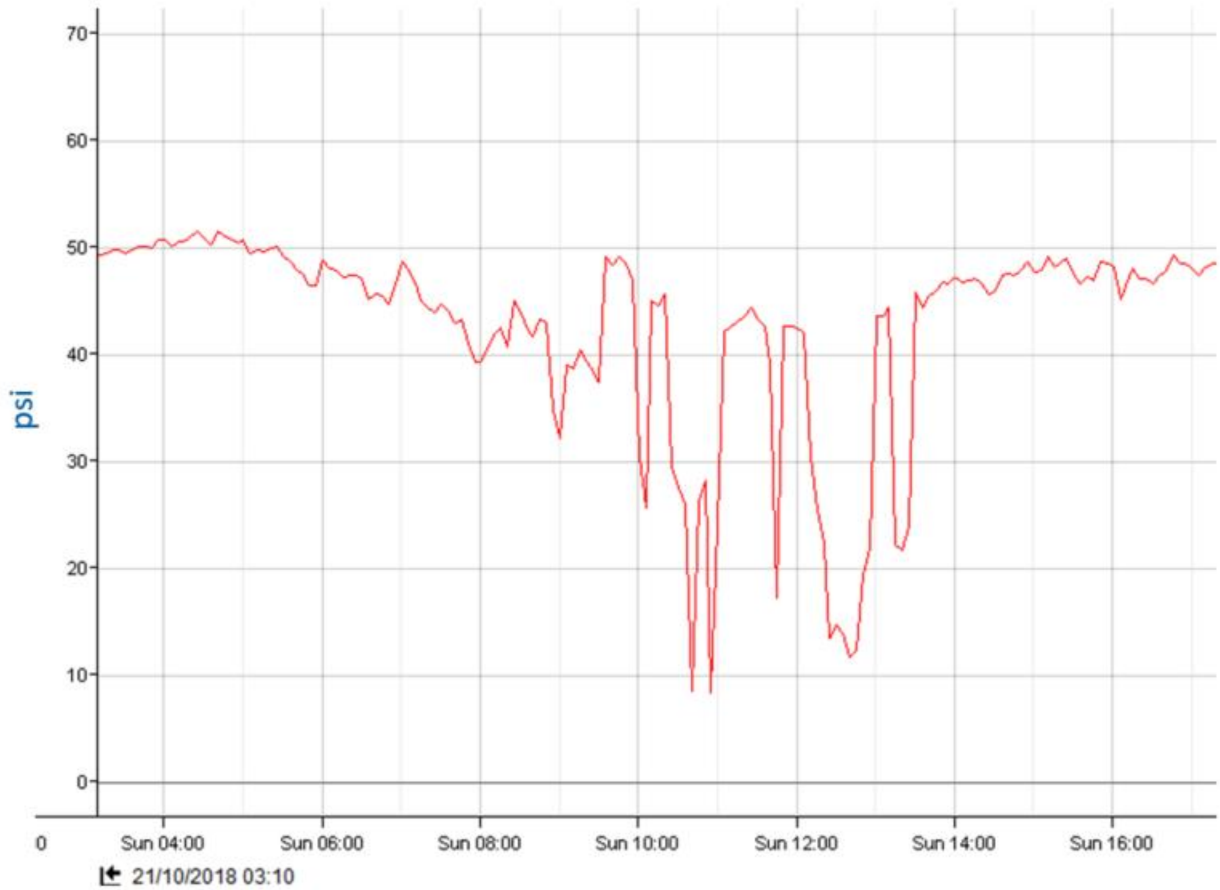

Figure 2-35 Pressure Drop Test at DET-D to confirm DMA Isolation

During the first few days of operation of the DMA, it was observed that flows not only entered the DMA but also exited the DMA via the metering locations at certain times of the day. Only minimal flow was observed entering the DMA at DET-D NW metering location. The low flows and potential for reverse flow means that velocities are very low, and this increases the uncertainty associated with the flow measurement. This situation was reviewed with the project team, and it was determined that DET-D NW could be closed providing a single feed to the DMA through DET-D SE flow metering location which was the dominant feed to the DMA and became the exclusive feed on 10/26/2018.

2.15.1.1 DET-D Hydrant Tests

The hydrant test configuration for DET-D SE is shown in Appendix 9.2.3. The test at the time of installation required the closure of three valves in order to isolate flow to the hydrant. The isolated area included service to 18 properties. In such cases, an estimated flow volume associated with the properties during the time of the hydrant test (typically 10 minutes at each flow rate) is subtracted from the IMM totalized flow for the test recognizing that the IMM will include this flow but the hydrant meter will not. Based on an assumed average of 98 gallons per retail connection per day (as calculated from the AMR data for these customers), the estimated additional flow per customer is 0.07 gallons per minute. The estimated consumption associated with the 18 accounts equated to approximately 2.5% of the test volume at 50 gpm and 0.4% of the test volume at 300 gpm.

For the hydrant test at the time of removal (after completion) of the DMA, DWSD added a hydrant and closed an additional valve to provide isolation for the new hydrant and a new test configuration that did not include the 18 properties. The results from the two hydrant tests were significantly different. Taking the 50 gpm test as an example, the IMM measured less flow relative to the hydrant meter during the installation test and measured more flow relative to the hydrant meter during the removal test. This is counter-intuitive as the new configuration eliminated customer demand from the test. The removal test was performed a second time and returned similar results to the first removal test. The project schedule did not allow for a new meter to be installed and a second monitoring period to be completed which was the preferred option. Therefore, the average adjustment value of these three tests (the installation test and both removal hydrant tests) was used to determine the flow volume into the DMA. The three test results can be seen in Figure 2-36.

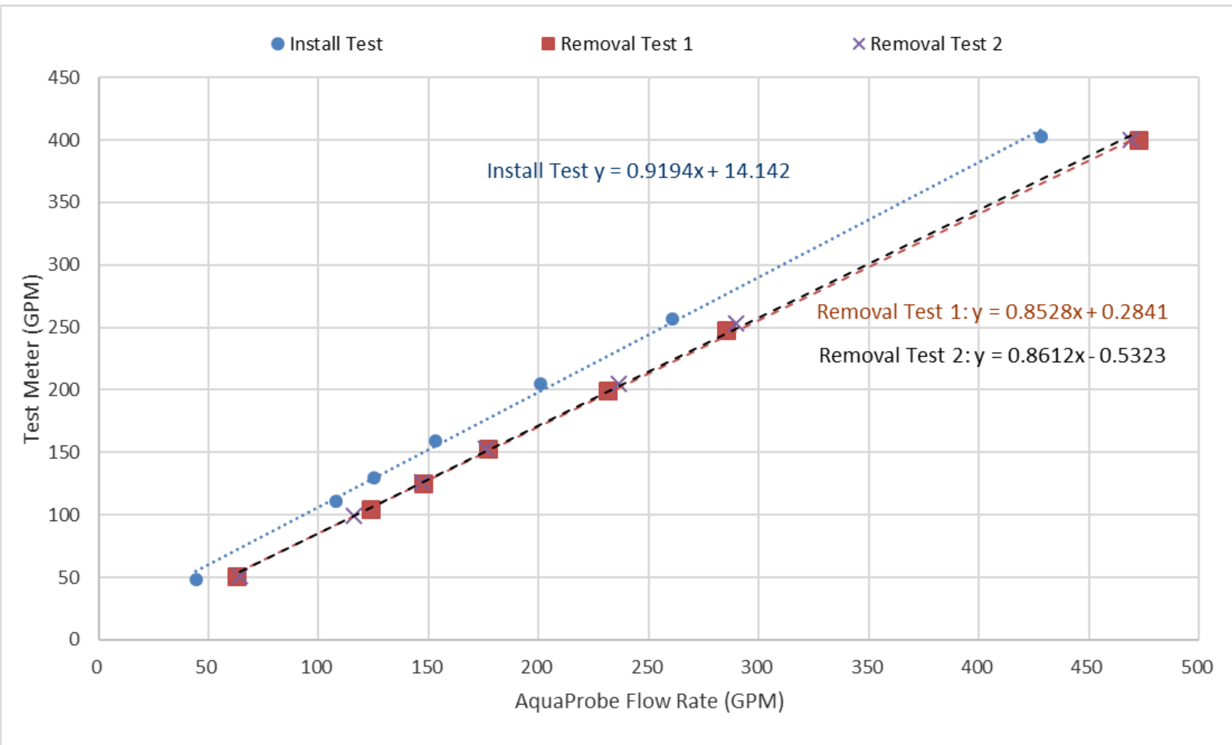

Figure 2-36 Hydrant Test Results for Meter at DET-D SE

The observed flow rates as measured at DET-D during the 11-day DMA monitoring period are shown in Figure 2-37. In the afternoon of 11/1/2018, flow spiked in the DMA to approximately 400 gpm which is not a typical pattern based on the observable data. DWSD indicated that this was related to MDOT filling a tanker truck from a hydrant. No specific information was available for review. This type of activity falls in the category of unbilled unmetered water use which is not part of the DMA analysis as described in 2.1.1, and therefore, the increased volume of water associated with the spikes in usage was removed from the analysis.

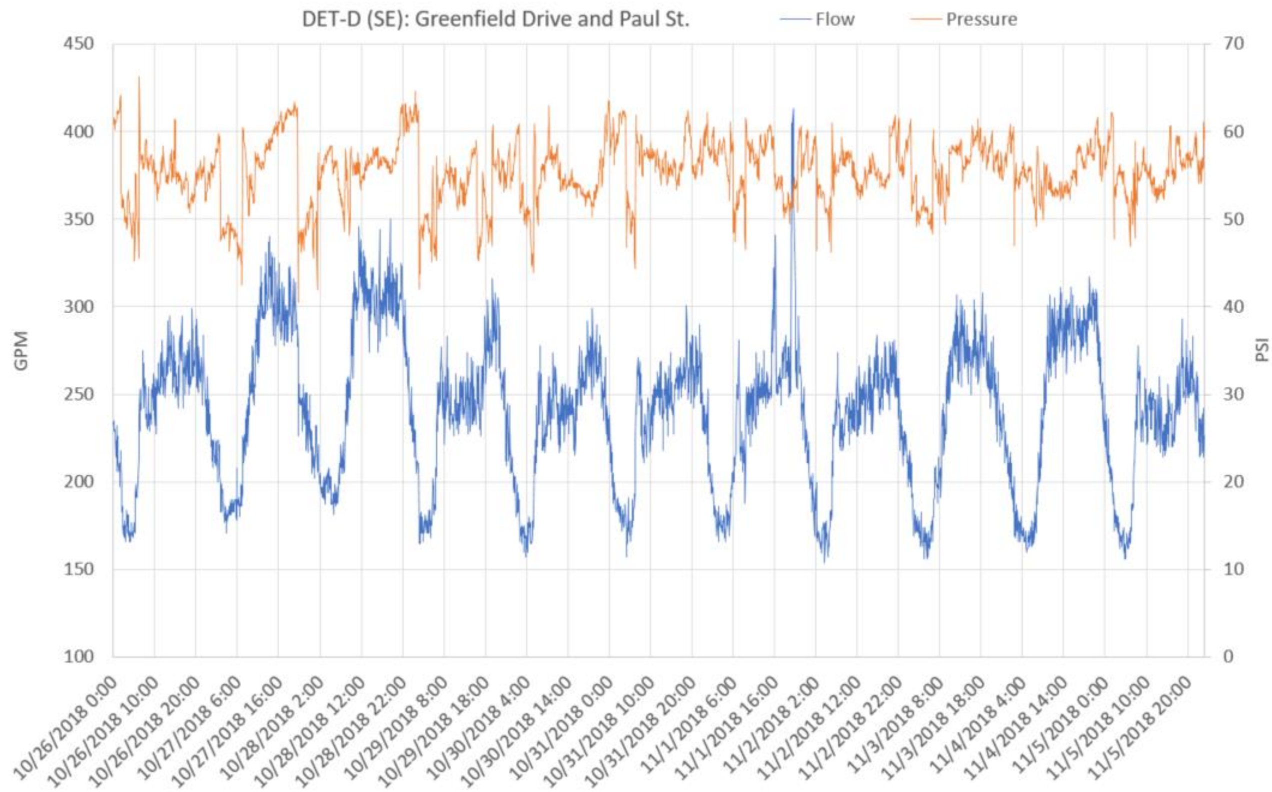

Figure 2-37 Flow and Pressure During DMA Monitoring in DET-D

2.15.1.2 DET-D Results

A water balance for the 11-day DMA monitoring period was created and is shown in Table 2-8. The following explanatory notes relate to the table item numbers.

1. The totalized flow volume entering the DMA as measured by the insertion meter.
2. The adjusted, or corrected, flow volume entering the DMA based on the correction factor applied from the hydrant test comparison (average of the installation and both removal tests). This includes a subtraction of 2,703 gallons related to the MDOT usage of water from hydrants.
3. The consumption volume based on retail meter reads. This includes estimated reads, provided by DWSD, for 74 accounts in DET-D which totaled 45,528 gallons for the monitoring period, or 2.3% of the total retail consumption value. This line item also includes adjustments to data for implausible consumption values reported in the AMR files (the process for identifying these values is noted in Section 2.13.2). The adjustment value was 53,903 gallons (subtracted from the DMA consumption) which is 2.7% of the total retail consumption value.

4. Customer metering inaccuracies (CMI) reflect the potential for retail meters to under-record actual consumption. In Detroit, this is based on Phase 1 results of 2.3% for meters 2" and smaller and 3.0% for meters 3" and larger. The value for the DMA reflects a weighted average of CMI based on consumption through small meters (98% of consumption) and large meters (2% of consumption) specific to this DMA.
5. Unauthorized Consumption (e.g., theft) based on AWWA recommended default value
6. Systematic Data Handling Errors (e.g., meter reading error) based on AWWA recommended default value
7. The aggregate volume of items 4, 5, and 6 is the apparent loss total expressed as gallons per connection per day
8. Net Real Loss in the DMA: Line 2 – Line 3 – (Line 4 + Line 5 + Line 6)
9. Net Real Loss in the DMA expressed as gallons per connection per day

Table 2-8 DET-D DMA Water Balance

	DET-D	Total Volume Gallons	Gallons Per Day
[1]	IMM Raw Volume Between 10/26/18 00:00 and 11/06/18 00:00	3,796,895	345,172
[2]	IMM Adjusted Vol.* Between 10/26/18 00:00 and 11/06/18 00:00	3,403,594	309,418
[3]	Consumption from Retail Reads**	1,994,956	181,360
[4]	Customer Metering Inaccuracies (2.32% x [3])	46,222	4,202
[5]	Unauthorized Consumption (AWWA default) (0.25% x [2])	8,509	774
[6]	Systematic Data Handling Errors (AWWA default) (0.25% x [3])	4,987	453
[7]	Gallons per Connection*** per Day Apparent Loss		**4**
[8]	Net Real Loss	1,348,919	122,629
[9]	Gallons per Connection*** per Day Real Loss		**81**

* Removes estimated volume from MDOT usage at hydrant (2,703 gallons)
** Includes estimated usage as provided by DWSD, and corrections to anomalies
***Total number of accounts (including estimates) = 1,506
Estimated accounts with usage = 17
Estimated accounts with zero usage = 57

2.15.2 Detroit DMA RH1-X

RH1-X is situated in the northeast corner of Detroit. The hydraulic model indicated that the DMA could be fed with one meter through a 12" line on the western side of the DMA. The meter was installed on 9/28/2018, and the internal diameter of the pipe was measured. A flow profile was attempted for this location; however, it was not successful as the pitot rod was unable to be inserted into the corp. During the hydrant test it was observed that flow was passing through the IMM when the hydrant meter was off. Seven properties were included in the hydrant test with an estimated combined flow of less than 1 gpm which would not have registered on the IMM, and therefore, it was concluded that some other significant demand was occurring within the isolated area. DWSD checked the valves and confirmed closure. M.E. Simpson used their acoustic leak detection devices on corporation stops at several houses and vacant lots. One corporation stop was found to be leaking to a vacant house and was shut off by DWSD. A hydrant test was conducted; however, the results indicated there was still additional flow passing through the IMM and further investigation and leak detection was required by DWSD. Pressure monitoring equipment was installed, configured, and tested in the DMA enabling near real-time data to be viewed remotely through Technolog's online monitoring platform WaterCore. Low pressure alarms were configured on the pressure monitoring equipment and tested.

DWSD made repairs to leaks found at an abandoned school in the area of the hydrant test, and a new test was conducted on 10/24/2018. The impact of leakage on the DMA calculations is discussed in Section 2.15.2.2. Isolation was achieved on 10/30/2018 (see Figure 2-38).

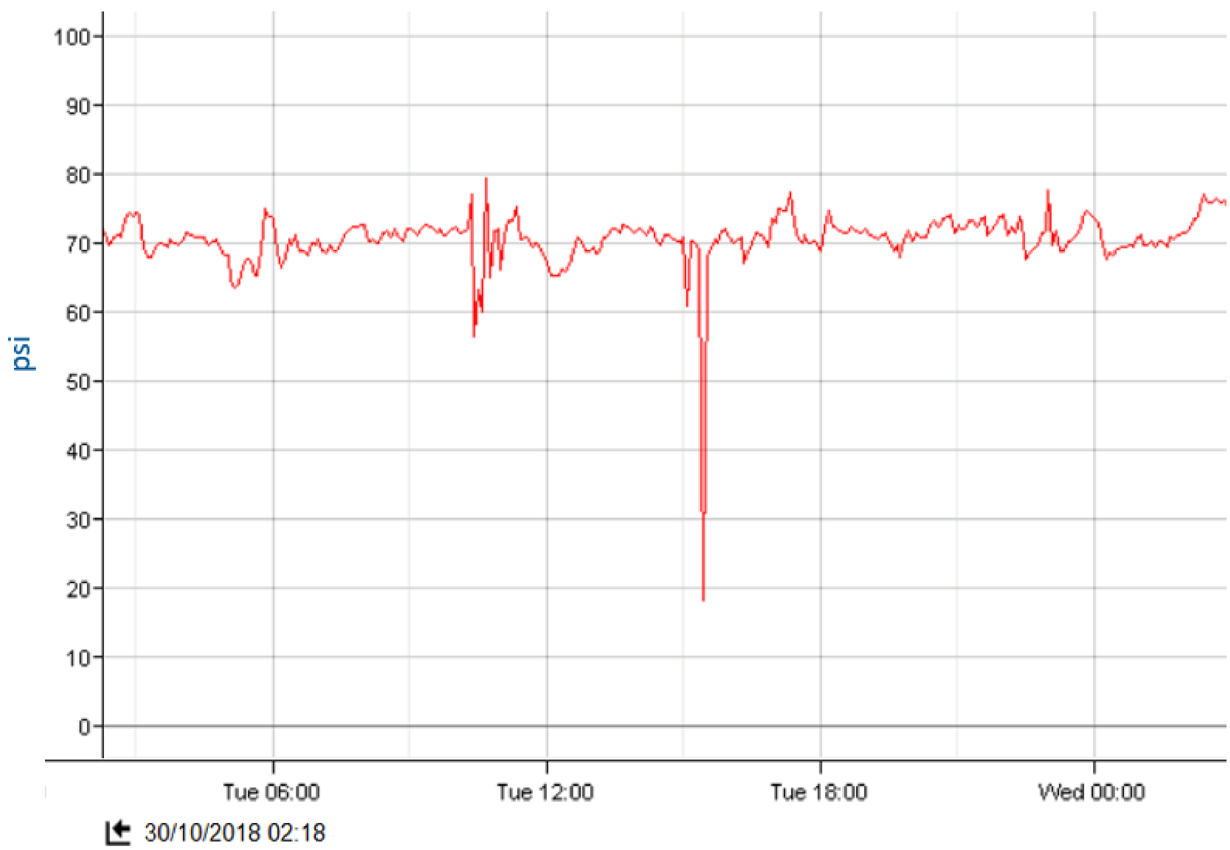

Figure 2-38 Pressure Drop Test to Confirm Isolation in RH1-X

2.15.2.1 RH1-X Hydrant Tests

The hydrant test configuration for RH1-X and detailed results of the tests are shown in Appendix 9.2.4. The test area included service to 7 inhabited properties. In such cases, an estimated flow volume associated with the properties during the time of the hydrant test (typically 10 minutes at each flow rate) is subtracted from the IMM totalized flow for the test recognizing that the IMM will include this flow but the hydrant meter will not. Based on an assumed average of 160 gallons per retail connection per day, the estimated additional flow per customer is 0.11 gallons per minute. Tests were performed mid-morning during the average portion of the diurnal curve. The estimated consumption associated with the 7 active accounts equated to approximately 1.6% of the test volume at 50 gpm and 0.3% of the test volume at 300 gpm.

The installation test was completed on 10/24/2018 and the removal was completed on 11/14/2018; the test results and meter adjustment curves are shown in Figure 2-39. The test results matched closely; the adjustment factor used to adjust flows in the DMA was based on the average of the two test results.

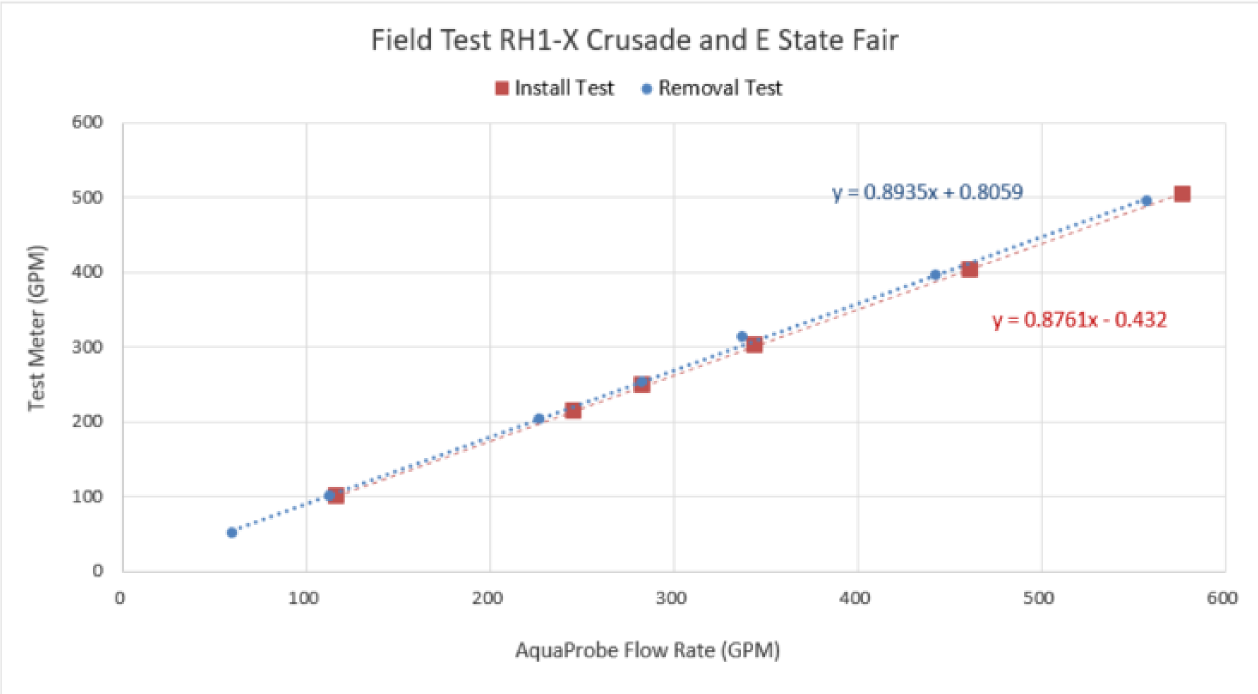

Figure 2-39 Hydrant Tests Results at RH1-X

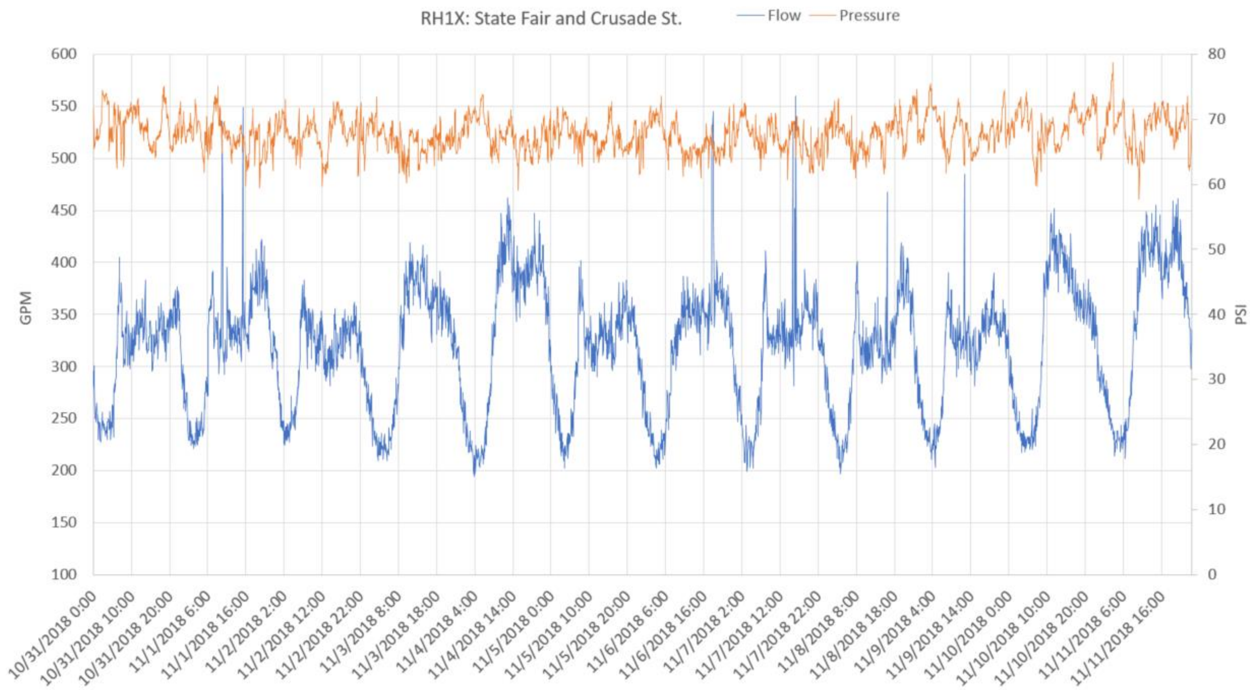

Figure 2-40 Flow and Pressure During DMA Monitoring in RH1-X

2.15.2.2 RH1-X Leakage

As noted above, specific leakage events were identified during DMA activities in RH1-X.

1. During the hydrant test, a service line was leaking into a vacant property and was closed prior to the initial test on 9/28/2018.

2. Two service line leaks were identified on an abandoned school in the area during the follow-up field investigation by DWSD.

The work required to establish the DMA led to the discovery of these leaks, and it was necessary to repair these before the DMA could become operational. Therefore, it is appropriate to make an estimation of the flow rates associated with these leaks, and this value should be added to the DMA flow volume as it would be reflective of baseline conditions or the state of the DMA immediately prior to the study.

An estimated flow rate of 12.8 gpm was assigned to the service line leak at the school. This rate is based on the difference in observed flow rates on the IMM between the hydrant test that was performed when the school leaks were present and the install test that was performed after the leaks were repaired.

An estimate of 8.1 gpm was assigned to the leak at the vacant property (single family home). This is based on a flow rate of 65 cubic feet/hour which was observed in the AMR data as a suspected customer side (metered) leak during the DMA monitoring period in RH1-X.

The sum of these two leaks equates to 20.9 gpm which was added to the flow rate in RH1-X.

2.15.2.3 RH1-X Results

A water balance for the 12-day DMA monitoring period was created and is shown in Table 2-9. The following explanatory notes relate to the table item numbers.

1. The totalized flow volume entering the DMA as measured by the insertion meter plus the assumed leakage that was corrected because of the DMA work as noted above.
2. The adjusted, or corrected, flow volume entering the DMA based on the correction factor applied from the hydrant test comparison plus the assumed leakage that was corrected because of the DMA work as noted above.
3. The consumption volume based on retail meter reads. This includes estimated reads, provided by DWSD, for 213 accounts in RH1-X which totaled 17,354 gallons for the monitoring period or 0.7% of the total retail consumption value. This line item also includes adjustments to data for implausible consumption values reported in the AMR files (the process for identifying these values is noted in Section 2.13.2). The adjustment value was 132,337 gallons (subtracted from the DMA consumption) which is 5.1% of the total retail consumption value.
4. Customer metering inaccuracies (CMI) reflect the potential for retail meters to under-record actual consumption. In Detroit, this is based on Phase 1 results of 2.3% for meters 2" and smaller and 3.0% for meters 3" and larger. The value for the DMA reflects a weighted average of CMI based on consumption through small meters (99% of consumption) and large meters (1% of consumption) specific to this DMA.
5. Unauthorized Consumption (e.g., theft) based on AWWA recommended default value
6. Systematic Data Handling Errors (e.g., meter reading error) based on AWWA recommended default value
7. The aggregate volume of items 4, 5, and 6 is the apparent loss total expressed as gallons per connection per day
8. Net Real Loss in the DMA: Line 2 – Line 3 – (Line 4 + Line 5 + Line 6)
9. Net Real Loss in the DMA expressed as gallons per connection per day

Table 2-9 RH1-X DMA Water Balance

	RH1-X	Total Volume Gallons	Gallons Per Day
[1]	IMM Raw Volume Between 10/31/18 00:00 and 11/12/18 00:00	5,507,975	458,998
[2a]	IMM Adjusted Vol. Between 10/31/18 00:00 and 11/12/18 00:00	4,876,687	406,391
[2b]	Estimated volume from leakage at 21.0 gpm	363,364	30,280
[2c]	Total Adjusted IMM Volume	5,240,051	436,671
[3]	Consumption from Retail Reads*	2,594,751	216,229
[4]	Customer Metering Inaccuracies (2.31% x [3])	59,890	4,991
[5]	Unauthorized Consumption (AWWA default) (0.25% x [2a])	12,192	1,016
[6]	Systematic Data Handling Errors (AWWA default) (0.25% x [3])	6,487	541
[7]	Gallons per Connection** per Day Apparent Loss		**3**
[8]	Net Real Loss	2,566,730	213,894
[9]	Gallons per Connection** per Day Real Loss		**110**

* Includes estimated usage as provided by DWSD, and corrections to anomalies

**Total number of accounts (including estimates) = 1,937

Estimated accounts with usage = 8

Estimated accounts with zero usage = 205

2.16 EXTRAPOLATION METHODOLOGY

This section outlines the methodologies used to extrapolate the relatively small datasets from the DMAs to the whole system in Dearborn and Detroit. Each community has slightly different data available from outside the DMAs; therefore, each extrapolation method is also slightly different but still based on similar key concepts.

2.16.1 Dearborn

Since the two DMAs chosen for the fieldwork were very different with respect to the age of pipe, a methodology of extrapolation from these DMAs to the rest of the system was necessary. The two variables which have relevance to the leakage and real losses that were available within the Dearborn data were age of pipe and pressure. Therefore, an extrapolation methodology as shown in Figure 2-41 was developed.

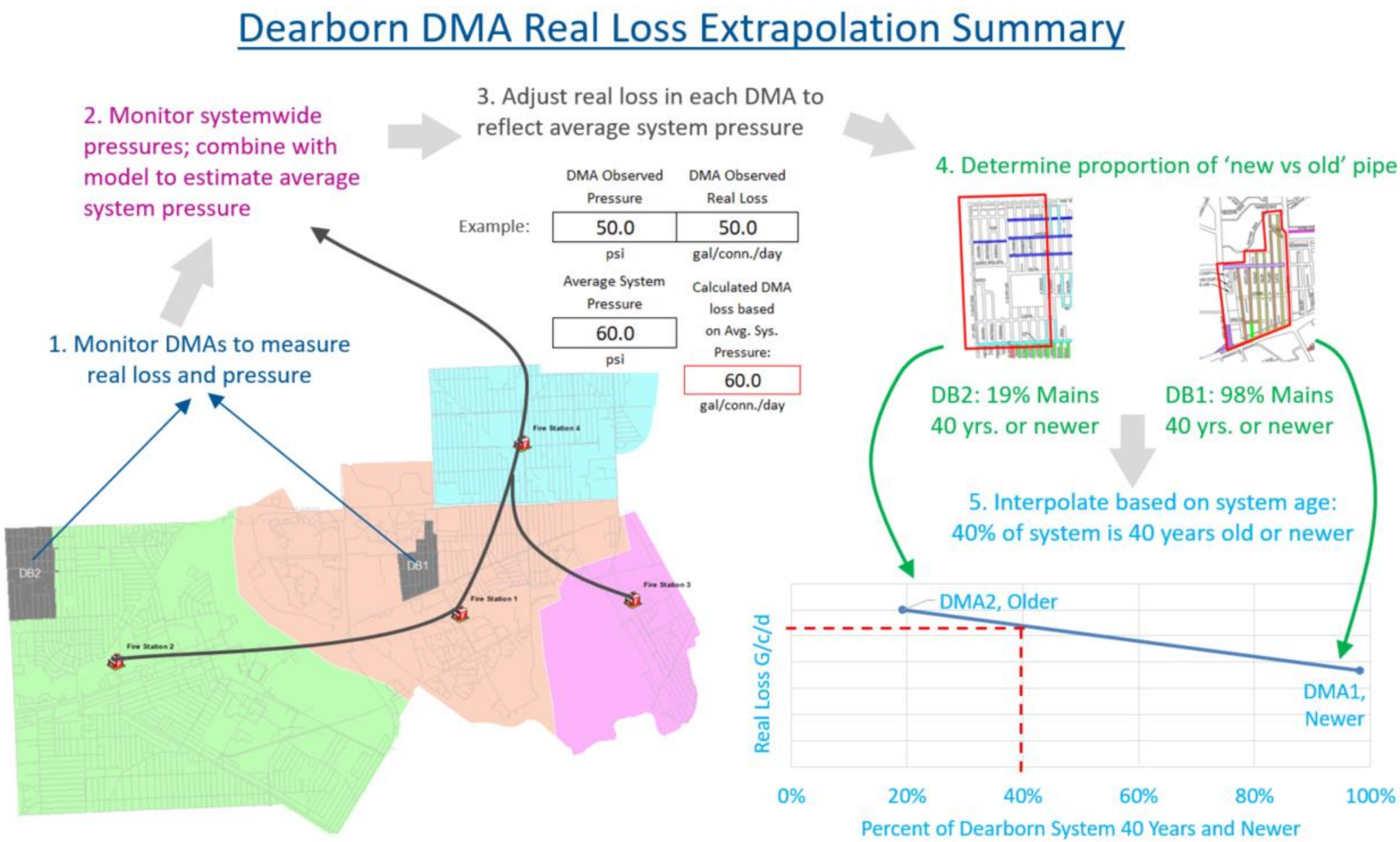

Figure 2-41 Dearborn Extrapolation Schematic

The steps required for the extrapolation of real loss from Dearborn's DMAs to the entire system are as follows:

1. Complete the monitoring and analysis of DMAs using a water balance approach to determine real loss within each of the DMAs. Assumptions of apparent loss are applied based on Phase 1 customer metering inaccuracy data and AWWA default estimations. The result of the DMA monitoring period determines a real loss and an average pressure for each of the DMAs.
2. Prior to the Phase 2 work, there was no pressure monitoring data available for Dearborn. Four temporary pressure monitoring locations were established at fire stations within Dearborn. The locations of the pressure monitors are shown in the map in Figure 2-41 along with assigned pressure zones (although Dearborn does not have distinct pressure zones). The available average pressure data was converted to average HGL for each pressure gage, and these HGLs were averaged for each pressure zone or area. The hydraulic model was used to determine the average elevation of each pipe and then determine the pressure at each pipe section based on the average HGL and the average pipe elevation. The length-weighted average pressure could then be calculated for the entire system. The methodology is subject to the following assumptions:
   a. The pressure monitoring locations are representative of average HGLs in each zone.
   b. The pressure monitoring period is representative of average pressures over the course of a year
   c. HGLs are constant across the entire zone under average conditions.

   Based on this analysis, the average system wide pressure for Dearborn is 53 psi.
3. Real loss in each DMA is adjusted based on the relative pressure between that observed in the DMA during the monitoring period and the estimate of average system pressure from Step 2. The relationship between Pressure (P) and Leak Flow Rate (L) for $L_{SYS}/L_{DMA} = P_{SYS}/P_{DMA}$; therefore, the leakage rate in the DMA at average system pressure is:

$$L_{SYS} = P_{SYS}/P_{DMA} \times L_{DMA}$$

4. The result of step 3 is that real loss in each DMA is now normalized to average system pressure. The two real loss values are plotted on a chart where the x-axis is the percentage of new pipe in the DMA, and the y-axis is the real loss in gallons per connection per day. A linear interpolation of the line at 40% newer pipe for Dearborn determines the average real loss in gallons per connection per day system-wide.

The results of the pressure monitoring are shown in Figure 2-42. The data was collected and shared with the project team by Benesch, consultant to the City of Dearborn. An issue was identified with the monitor at Fire Station 2. The monitor was replaced, and new data was collected as shown in Figure 2-42 as data series Fire Station 2B. Fire Station 2 data was not used in the pressure analysis.

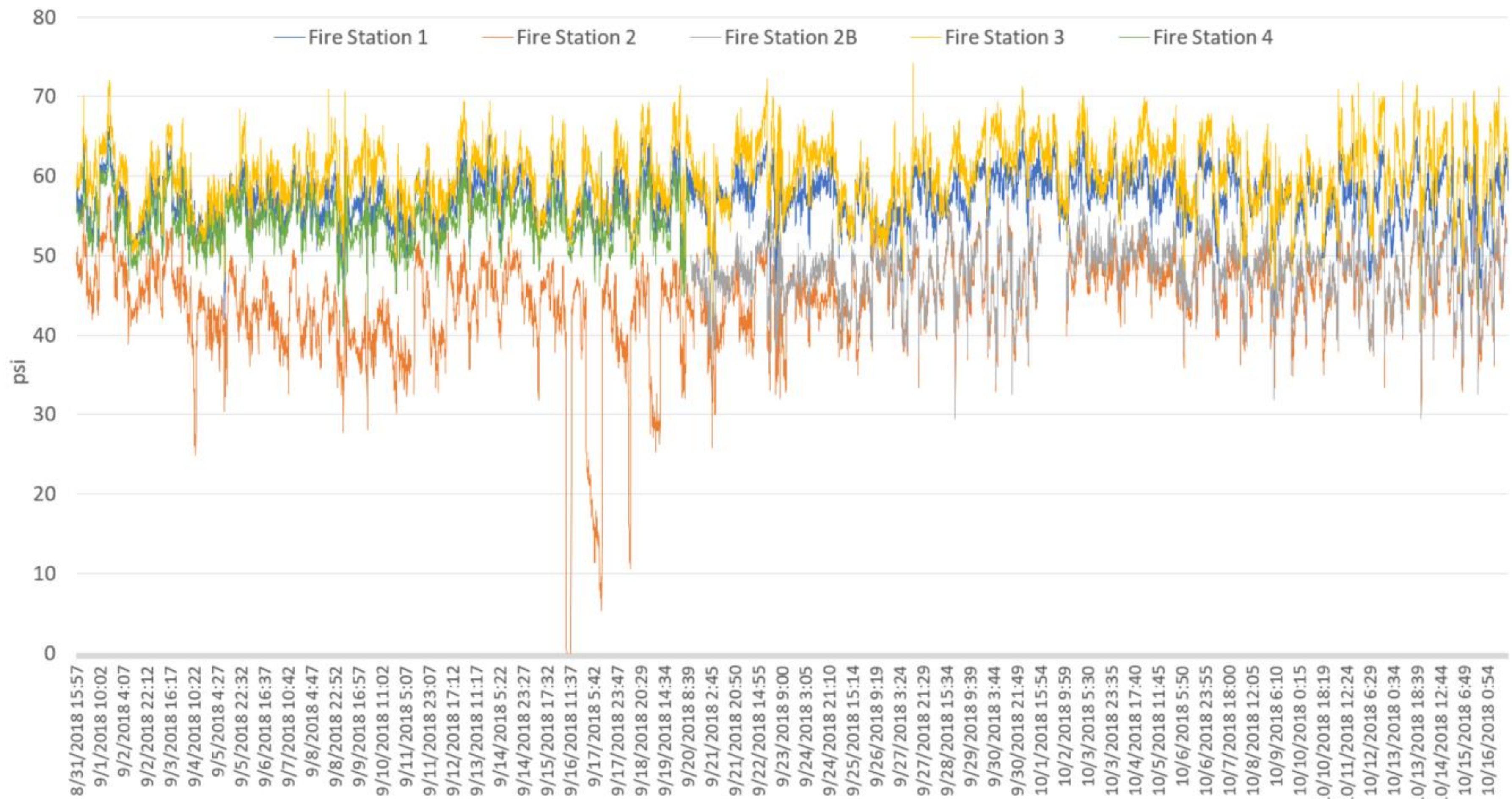

Figure 2-42 Pressure Monitoring Results at Fire Stations in Dearborn

The recorded DMA real losses, pressures, and pressure-adjusted DMA results are shown in Table 2-10.

Table 2-10 DMA Real Loss Values for Dearborn

DMA ID	REAL LOSS (GAL/CONN/DAY)	AVG. DMA PRESSURE (PSI)	AVG. SYSTEM PRESSURE	PRESSURE ADJUSTED REAL LOSS (GAL/CONN/DAY)
DB1	14	56.7	53.1	13
DB2	18	44.0	53.1	22

The interpolation step to arrive at a system-wide estimate of real loss is shown Figure 2-43. As 40% of Dearborn's pipe network is approximately 40 years or newer, the estimated system-wide real loss is 19.4 gallons per connection per day.

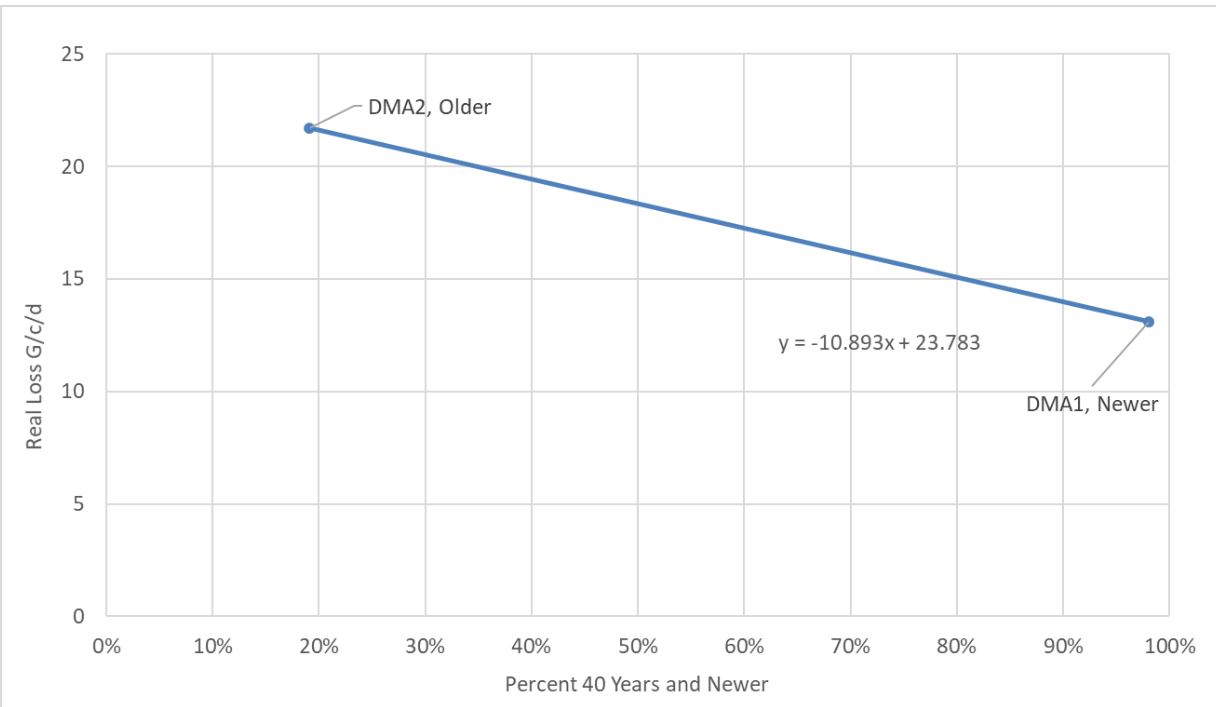

Figure 2-43 Interpolating Dearborn DMA results for System-wide Estimate of Real Loss

Because no mains breaks were identified during the monitoring period, an estimate of the water loss associated with mains break was added to the DMA real loss calculation. As determined by Phase 1, Dearborn has approximately 99 reported breaks / year based on available data. Assuming a response time to isolate the break of 24 hours and an average leakage rate of each break of 78 gpm, this equates to an estimated real loss of 0.9 gallons per connection per day associated with the response time to mains breaks. The 78 gpm is based on Water Research Foundation (WRF) data[4]

[4] Water Research Foundation 4372a Real Loss Component Analysis: A Tool for Economic Water Loss Control.

and a review of mains break by diameter for Dearborn which indicated 1% of breaks on 4” and smaller, 89% on 6-10”, and 10% on 12” and above. The WRF data are adjusted for average system pressure in Dearborn as shown in Figure 2-44.

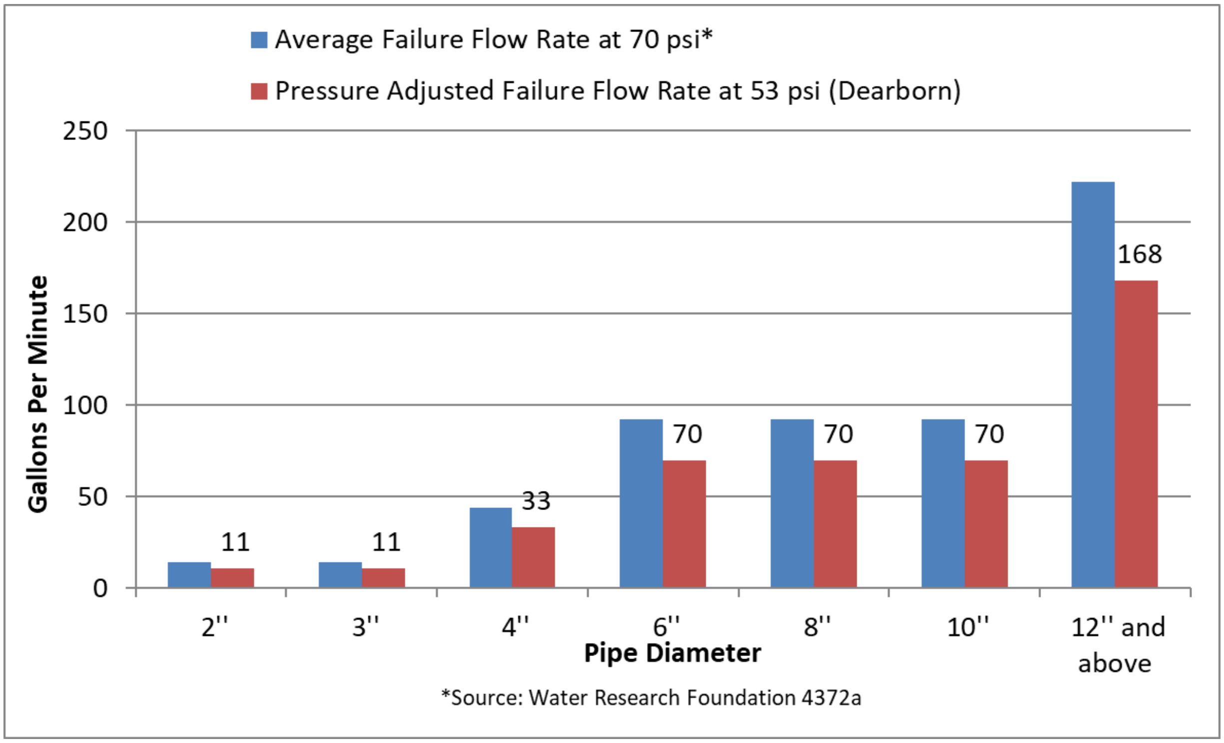

Figure 2-44 Pipe Failure Flow Rates: WRF and Dearborn

2.16.1.1 Dearborn Real Loss Summary

In summary, the Phase 2 estimated real loss for Dearborn is 20.3 gallons per connection per day. This is comprised of 19.4 gal/conn/day related to DMA monitoring reflective of background leakage and 0.9 gal/conn/day associated with mains breaks. When multiplied by total system connections of 32,566, this gives a system-wide real water loss value of 0.66 MGD.

2.16.2 Detroit

Detroit has slightly different data as compared to Dearborn, and this difference influences the method of extrapolation. The four selected DMAs have an average age (average installation year 1929) similar to the average age of the distribution system as a whole in Detroit (average installation year of 1925); therefore, the results of the DMAs were averaged. Available information in GIS did not allow for pipe material to be a consideration in the extrapolation methodology. At the time of writing of this report, the equipment for all four DMAs had been installed but only two of the four DMAs had been fully commissioned and monitored to provide results for the development of FY2020 charges. The NW DMA was studied previously in 2015 and was scheduled to be re-analyzed as part of Phase 2. The results from the previous DMA study in this area were used in Phase 1 as best available data. However, the procedures followed in the development and implementation of the Phase 2 DMAs were more robust; for example, Phase 2 work included a confirmation of isolation via a pressure drop test. This was not part of the procedure in the previous DMA work, and therefore, the confidence in the results generated are not as reliable as the results obtained from Phase 2.

Pressure adjustment of Detroit's DMAs was necessary as Detroit has multiple pressure zones (even though these are not truly discrete districts with boundary valves) based on proximity to water treatment plant supply, and the two DMAs completed were in different pressure areas. GLWA and DWSD maintain pressure monitors in Detroit. Data was provided for 12 monitoring locations in the City of Detroit as shown in Figure 2-45.

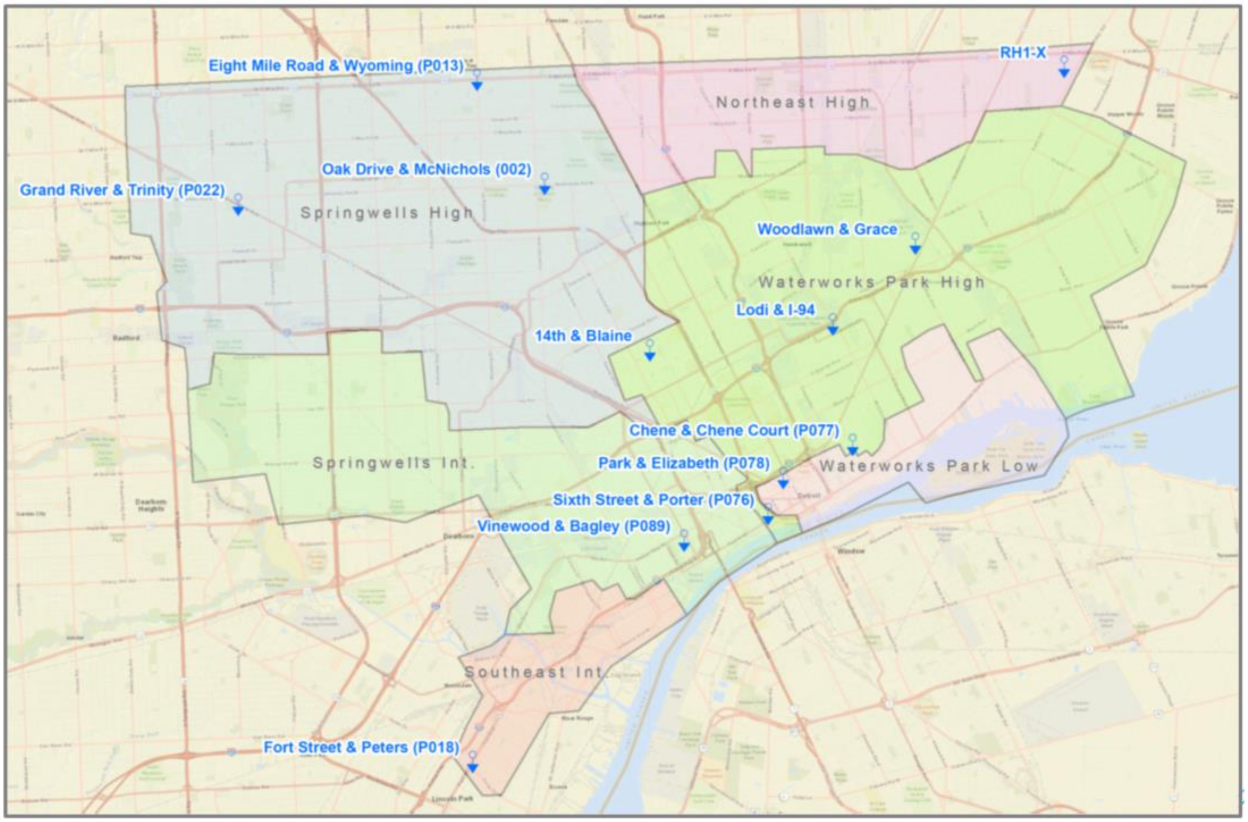

Figure 2-45 Pressure Monitoring Locations for Determining Detroit Average System Pressure

The steps required for the extrapolation of real loss from Detroit's DMAs to the entire system are as follows:

1. Complete the monitoring and analysis of DMAs using a water balance approach to determine real loss within each of the DMAs. Assumptions of apparent loss are applied based on Phase 1 customer metering inaccuracy data and AWWA default estimations. The result of the DMA monitoring period determines a real loss and an average pressure for each of the DMAs.
2. The available average pressure data was converted to average HGL for each pressure gage, and these HGLs were averaged for each pressure zone or area. The hydraulic model was used to determine the average elevation of each pipe and then determine the pressure at each pipe section based on the average HGL and the average pipe elevation. The length-

weighted average pressure could then be calculated for the entire system. The methodology is subject to the following assumptions:

a. The pressure monitoring locations are representative of average HGLs in each zone.
b. The pressure monitoring period is representative of average pressures over the course of a year
c. HGLs are constant across the entire zone under average conditions.

Based on this analysis the average system wide pressure for Detroit is 54 psi.

3. Real loss in each DMA is adjusted based on the relative pressure between that observed in the DMA during the monitoring period and the estimate of average system pressure from Step 2. The relationship between Pressure (P) and Leak Flow Rate (L) is $L_{SYS}/L_{DMA} = P_{SYS}/P_{DMA}$; therefore, the leakage rate in the DMA at average system pressure is:

$$L_{SYS} = P_{SYS}/P_{DMA} \times L_{DMA}$$

4. The result of step 3 is that real loss in each DMA is now normalized to average system pressure. For Detroit, the average value of the DMA results is used to determine a system wide average real loss in gallons per connection per day.

The recorded DMA real losses, pressures, and pressure-adjusted DMA results are shown in Table 2-11.

Table 2-11 DMA Real Loss Values for Detroit

DMA ID	REAL LOSS (GAL/CONN/DAY)	AVG. DMA PRESSURE (PSI)	AVG. SYSTEM PRESSURE	PRESSURE ADJUSTED REAL LOSS (GAL/CONN/DAY)
DET-D	81	46	54	95
RH1-X	110	70	54	85

Therefore, the average real loss value of the two pressure-adjusted DMA results is 90 gallons per connection per day.

Although the impact of one main break was recorded on the DMA monitoring equipment (in RH1-X), it was outside of the specific period of DMA data collection, and it was also not necessarily reflective of an average main break. Therefore, an estimate of the water loss associated with mains break was added to the DMA real loss calculation. As determined by Phase 1, Detroit has approximately 1,244 reported breaks / year based on available data. Assuming a response time to isolate the break of 60 hours[5] and an average leakage rate of each break of 78 gpm; this equates to an estimated real loss of 3.1 gallons per connection per day associated with the response time to mains breaks. The 78 gpm is based on WRF data[6] and a review of mains break by diameter for Detroit which indicated 1% of breaks on 4” and smaller, 92% on 6-10”, and 8% on 12” and above. The WRF data are adjusted for average system pressure in Detroit as shown in Figure 2-46

[5] Estimated from Cabinet Metrics file provided by DWSD 11/25/2018.
[6] Water Research Foundation 4372a Real Loss Component Analysis: A Tool for Economic Water Loss Control.

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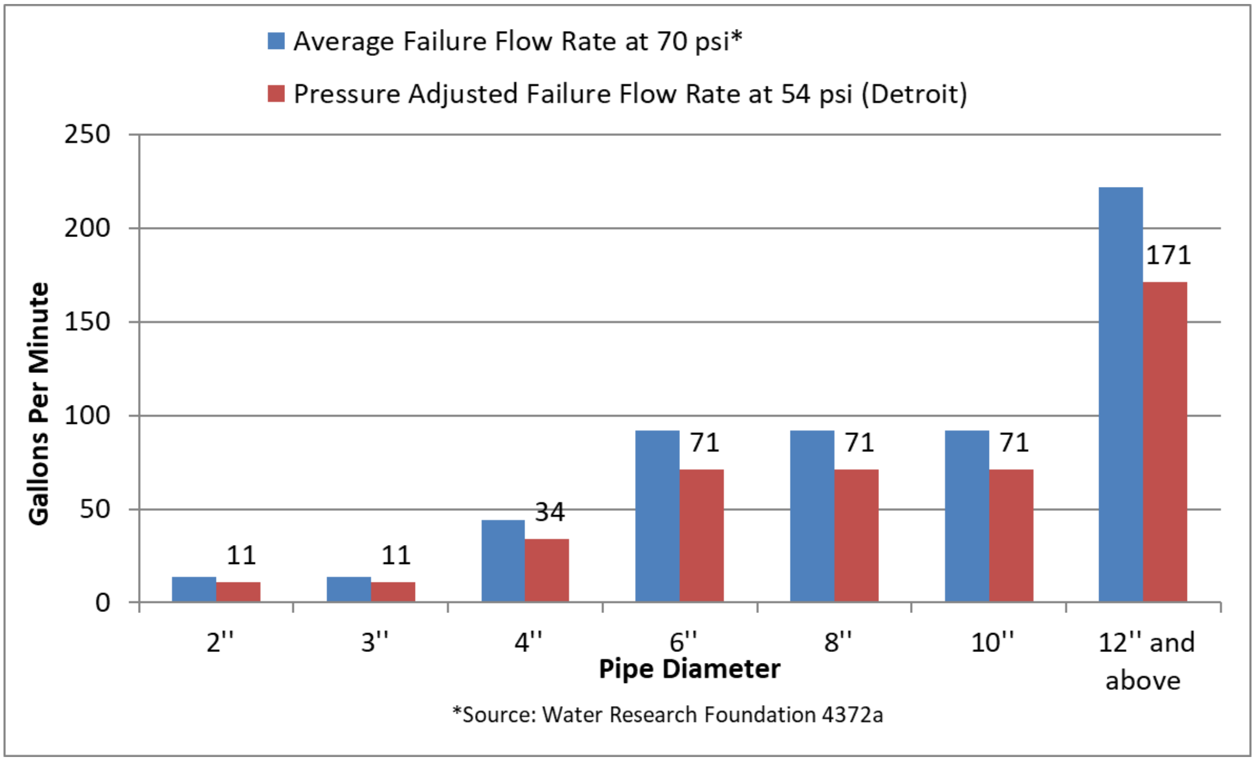


Figure 2-46 Pipe Failure Flow Rates: WRF and Detroit

The estimated response time is based on a review of four years of water mains breaks response data tracked by DWSD. DWSD has a goal of fixing mains breaks within four days. The data shows that over the last four years, 92% of leaks were fixed within four days as shown in Figure 2-47. Although the data provided does not allow a specific average response time to be calculated, it indicates that the majority of leaks are fixed within the target timeframe, and therefore, the average response time is less than four days. Based on a review of the data with DWSD staff, B&V recommended that a response time of 60 hours be utilized as the estimated response time for fixing (isolating) a mains break.

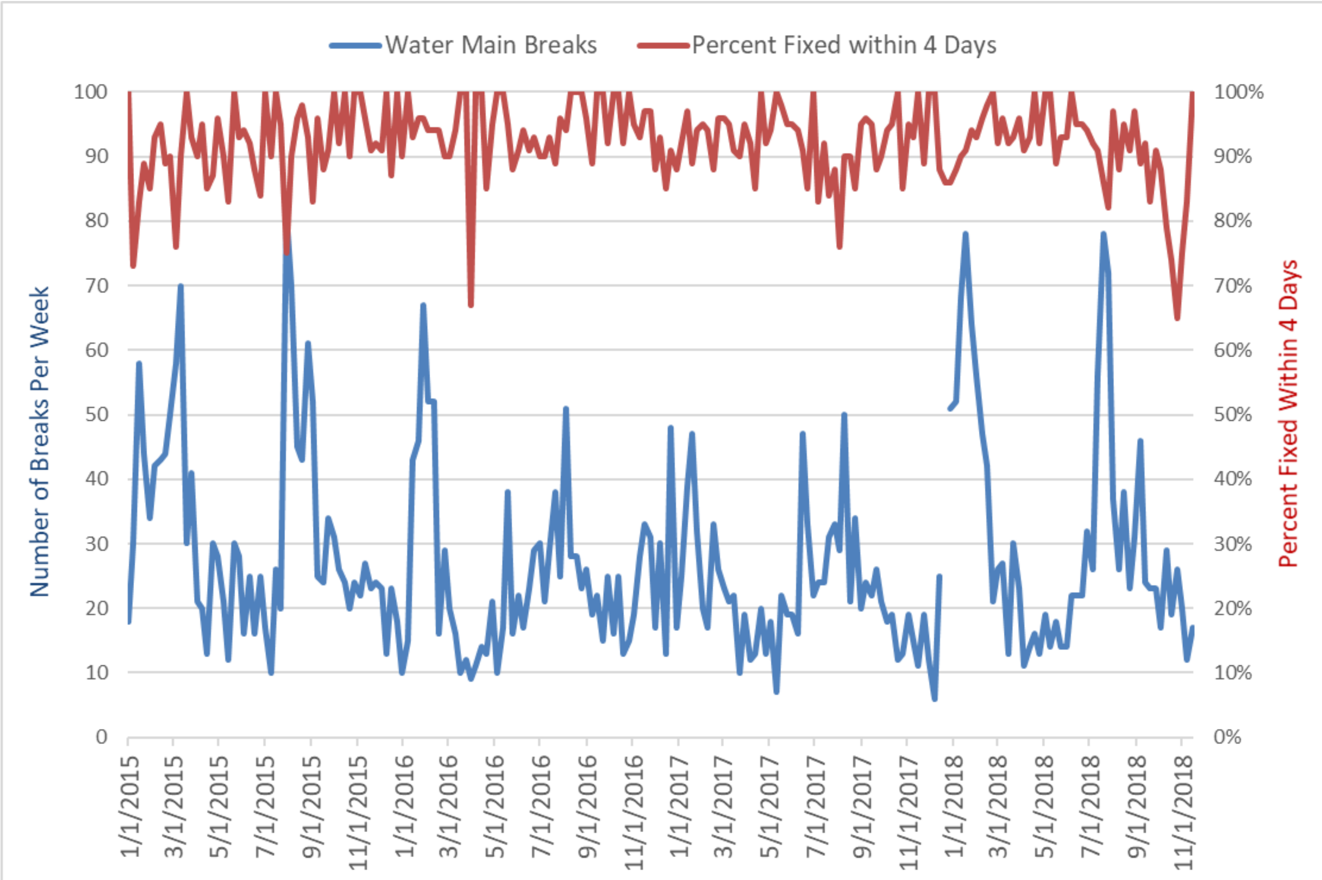


Figure 2-47 DWSD Water Mains Breaks Tracking Metrics

2.16.2.1 Detroit Real Loss Summary

In summary, the Phase 2 estimated real loss for Detroit is 93 gallons per connection per day. This value is comprised of 90 gal/conn/day related to DMA monitoring, reflective of background leakage, and 3 gal/conn/day associated with mains breaks. When multiplied by total system connections of 309,928, this gives a system-wide real water loss value of 28.8 MGD.

2.17 ISSUES AND SOLUTIONS RELATED TO DMAS

There were many aspects to this program which were first-of-a-kind both for the area and even in some cases for the water industry itself. This made the project very challenging, but the intensive collaborative nature of the planning and implementation over the last few months of installation, commissioning, and analysis enabled significant progress to occur. Some examples of issues encountered and their solutions are shown in Table 2-12 below.

Table 2-12 Issues and Solutions in Dearborn DMAs

	ISSUE	SOLUTION
1	Insertion Mag Meters did not consistently test within the expected range on the test bench or in the field.	The hydrant test provides a means of comparing the IMM flows against a calibrated test meter in the field, from which a calibration curve can be generated. This is preferred to transferring bench test results and assumptions to the field.
2	There were customer connections which could not be shut off when conducting the hydrant test.	An estimate of customer use was removed from the flow monitored at the IMM.
3	After the 14-day test period in DB1, the IMM appeared to be slightly off-center and not fully parallel to the pipe where it was set initially.	A second hydrant test was conducted, and a second meter was installed to re-check the flows over a second 14-day period.
4	The retail meters are normally read every three months.	Special meter recording runs were conducted on a daily basis (during weekdays).
5	Some meters only have a granularity of 100 cubic feet (CF).	Multiple days were used to calculate the retail volumes (14-days). Daily variation was typically 1-3%.
6	During initial installation, the cellular signals sending the pressure and flow data were intermittent at best.	Semi-open (grated) manhole covers were installed to allow the signal to propagate.
7	In DB1, the second IMM meter measured zero flow during some night time periods.	The IMMs are not as reliable at measuring low flows as billing meters. Analysis was conducted on all the logged data, and a minimum flow value was assigned as a proxy for the inconsistent readings at the very low-flows. This adjustment represented less than 1% of the total flow volume.
8	In DB2, isolation proved difficult.	A near pressure zero test was conducted to make sure that two valves (which were seen to be passing during the pressure drop test) were tight.
9	Once DB2 was isolated, it became obvious that flow conditions were altering at different times of the day. In the early morning, there was reverse flow through the IMM.	The second (metered) feed to the DMA was turned off, and only positive flow was observed with only one feed.

Table 2-13 Issues and Solutions in Detroit DMAs

	ISSUE	SOLUTION
1	Insertion Mag Meters did not consistently test within the expected range on the test bench or in the field.	The hydrant test provides a means of comparing the IMM flows against a calibrated test meter in the field, from which a calibration curve can be generated. This is preferred to transferring bench test results and assumptions to the field.
2	There were customer connections which could not be shut off when conducting the hydrant test.	An estimate of customer use was removed from the flow monitored at the IMM, and it was typically minimal compared to the total test volume. In DET-D, DWSD installed a new hydrant to allow for a test configuration that did not include customer consumption.
3	Detroit noted that pressures seemed to be rapidly fluctuating in some of the DMAs.	Up to 10 psi variation was noted (5-minute intervals of logging) across a daily cycle. This inconsistency is a recommendation for assessment into the future.
4	There were implementation constraints for the Detroit DMAs.	Field work did not get started until September 2018. Field investigation revealed insufficient straight-run of pipe in one of the planned metering locations and alternative locations had access issues or needed construction repairs. Hydrant testing attempts revealed leaks in the pipe and in the valves which delayed hydrant testing, as the area needs to be isolated and without leaks.
5	Only two DMAs, out of the planned four, were commissioned and produced results for Phase 2.	The best available data is being used which is the average of two DMAs in Detroit, implemented under Phase 2, and one DMA result set carried over from Phase 1.
6	Isolation proved difficult in DET-D.	Field conditions often vary from the available mapping and hydraulic modeling. Section maps were reviewed and merged with GIS information to provide information on valve closures and a cross-check of pipe interconnections in a format that worked best for DWSD field crews.
7	Service leaks were found during hydrant testing.	Leaks need to be repaired prior to a successful hydrant test. As the leaks represented the baseline conditions of the DMA and were only found and repaired due to the DMA work, an estimate of the leak flow rate was added to the DMA.

2.18 CITY OF HIGHLAND PARK

In mid-2016, the Highland Park system was isolated to three open connections, and all three connections began to be metered with IMMs. Highland Park has approximately 2,800 retail customer connections, and although it is not technically a DMA under the Phase 2 work, the size of the system and the available metering allows the system to be monitored similarly to a DMA.

The meters and associated data are managed by GLWA's System Analytics and Meter Operations (SA&MO) section. To support the analysis for this study, approximately thirty months of data were downloaded for Highland Park (June 2016 to October 2018) which reflected the total extent of the records at the time. Although these meters are not designed for permanent installation and billing purposes, they do provide measurements of current flow entering the Highland Park system and provide insights on the system. However, because the equipment is not designed and configured for long-term flow measurement, there are periods of time when all three meters are not operational, and therefore, total system demand is not being accurately tracked. Since installation, all three meters have been operational together about 50% of the time.

2.18.1 Highland Park Flow Data

The Highland Park flow data is stored in GLWA's WAMR system and was extracted for analysis using WAMR's standard exporting tools. Based on discussion with GLWA's System Analytics and Meter Operations staff, a conversion factor was applied to generate units of MGD[7]. Based on an analysis of the available data, the average system demand is 2.90 MGD.

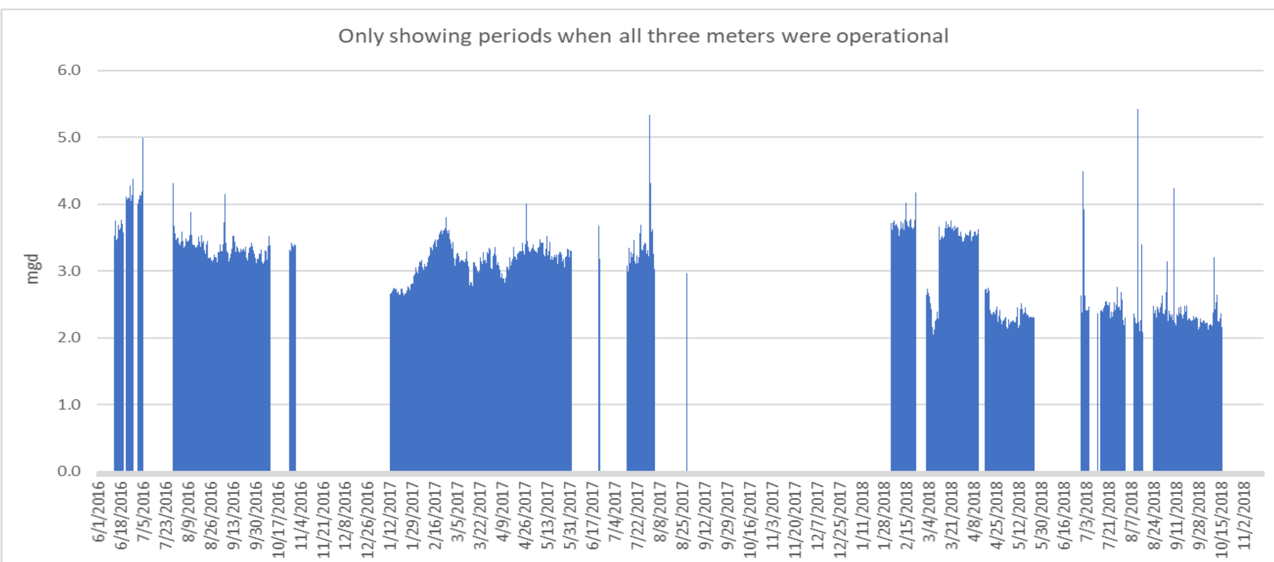


Figure 2-48 Hourly Data for Highland Park

[7] A known issue with the Highland Park meters is an incorrect conversion factor related to the configurations used to download the data. It was therefore necessary to adjust the values stored in WAMR to obtain the correct MGD values.

In April 2018, a significant change in the flow pattern was observed (see Figure 2-49). The meter at HP01 (Hamilton Ave. and Webb St.) showed a significant decline comprised of two separate step-changes in flow during mid-to-late April. In early April, HP01 was registering flow consistently over 0.5 MGD, and by late April, the meter was registering reverse flow. GLWA checked the boundary valves several times between May and July and reported finding no valves out of expected position.

GLWA is currently in litigation with the City of Highland Park. Leak detection and repair activity has been reported by the operators of the Highland Park system. In addition, the minutes of the regular meeting of the Highland Park City Council, July 2, 2018 (p10), note the following:

> First, Highland Park will continue to use State grants and internally generated funds to detect leaks in the water distribution system. On April 19, 2018, the City of Highland Park Water Department located and repaired a major leak at 330 Glendale Avenue, the Spectrum Juvenile Justice Calumet Center. This facility was constructed in the late 1990's/early 2000's and was supposed to be inspected by the State of Michigan during construction. However, it was believed to have never been inspected during the construction process. The Water Department eventually located this leak under a high grass berm on the property, to reach a solution for ongoing complaints of intermittent low water pressure in the area. Estimated leakage rate of up to 750,000 gallons a day was calculated. After completion of the repair, it was discovered this water leak had been ongoing for some extended period of time and had undermined the grass berm and steel guard rail in the area. The City of Highland Park eventually covered the cost of this repair.

The size of this documented leak, and the timing of the repair, is consistent with the change in flows that was observed in April 2018. Since April 26, 2018, flows have averaged 2.18 MGD. Several large spikes in demand have been observed during the summer of 2018 which appear to be mains breaks. These breaks also appear to have been resolved quickly. The three insertion meters were removed, cleaned, tested, and reinstalled by M.E. Simpson in August 2018. Flows have remained in a similar pattern after the reinstallation. It is recommended that these meters are removed and inspected every six months until permanent master meters are installed. If possible, a comparative hydrant test should be conducted on each of the insertion meters to provide an in-situ calibration.

Figure 2-49 Change in Flow Pattern at Highland Park, April 2018

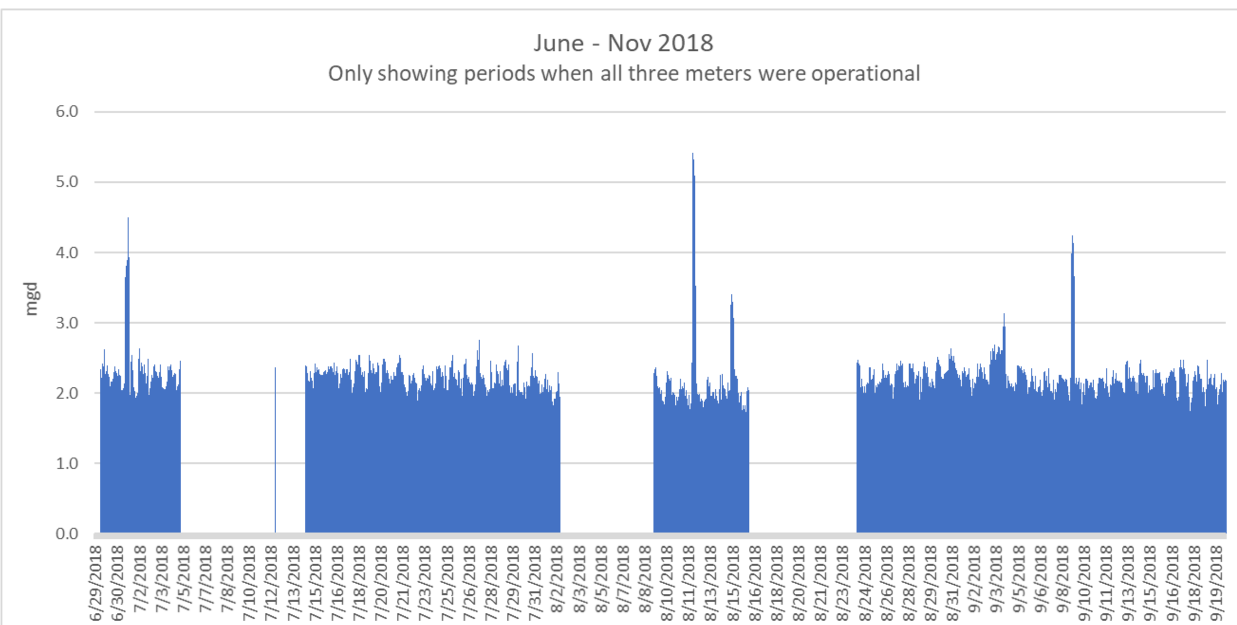


Figure 2-50 Flow Data for Highland Park Summer 2018

3 Water Treatment Plant Metering Upgrades & Pump Testing

3.1 FINISHED WATER METERING UPGRADES

Phase 1 uncovered the need for a more accurate assessment of the input volume into the GLWA system. Without a clear understanding of the volume of water entering the transmission and distribution systems, GLWA cannot reliably calculate and analyze water usage and non-revenue water and improve efficiency. The preferred solution is to implement finished water metering for all WTPs. Finished water metering upgrades are currently being implemented by GLWA; the Northeast WTP has recently had renovations completed on the Venturi meters with the goal of using these to measure flow rather than the use of pump curves.

The planned completion of the new or refurbished metering systems for all five WTPs is shown in Table 3-1.

Table 3-1 Water Treatment Plant Finished Water Metering Upgrades Status (Nov 2018) and Schedule

WTP	METERING RENOVATIONS STATUS	SCHEDULED COMPLETION DATE
Northeast	• Venturi Meters (VM) have been rehabilitated • SCADA work completed • Flow data is on Ovation	Complete, pending acceptance testing (AT).
Southwest	VM 4 & 5 • Rehab is complete • SCADA work underway VM 1,2, & 3 • VM 3 complete • VM 1 &2 & SCADA work	1/15/2019 3/30/2019
Springwells	Three phases of equipment shutdown and rehab planned • Phase 1 • Phase 2 • Phase 3	12/03/18 + SCADA work and AT 1/25/19 + SCADA work and AT 3/25/19 + SCADA work and AT
Lake Huron		2021
Water Works Park		2021

Upgraded and calibrated finished water metering will provide accurate and frequent knowledge of the flows entering the system, and they will allow for more accurate non-revenue water calculations.

3.2 PUMP TESTING

Phase 1 recommended coordinating WTP pump testing along with planned rehab or new finished water metering as pump curves are widely used as the basis of flow estimation. Alternative pump testing approaches have been reviewed by GLWA and B&V. These methods include thermodynamic, pitot tube, and ultrasonic testing.

Thermodynamic testing was the initial recommended approach. B&V provided case studies of this type of testing, performed by HydraTek, to GLWA for review. Initial planning identified the need for pipe disassembly and rework to install the necessary equipment. The thermodynamic testing was planned to be coordinated with pitot tube testing of the pumps under contract CS-103 (renovations at Springwells) and CS-052A (booster stations and other WTPs) conducted by CDM Smith. This would have provided multiple test methods to verify flow estimations. The pitot testing also required modifications to pump discharge piping. The planned work was scheduled for peak demand season and ultimately the necessary plant modifications and requirements to take pumps out of service were not considered prudent during peak demand season. The CDM Smith pump testing plan was modified and moved ahead focusing on vibration and impact testing which was required for CS-103.

- Water Works Park: Available pumps tested 10/2/2018
- Southwest – Available pumps tested 10/3/2018
- Springwells – Available pumps tested 10/15/2018
- Lake Huron Plan - Available pumps tested 10/18/2018

A third option of non-invasive ultrasonic testing went ahead as this could proceed without modifications to plant equipment. Flow testing was conducted by SW Controls for GLWA at each WTP and the data has been reviewed by B&V. Ultrasonic meter (Flexim) technology was used to conduct flow testing at four of the five plants. The data provided for each WTP is insufficient to determine plant production flow. Primary concerns with the testing results are summarized below (Table 3-2).

Table 3-2 Water Treatment Plant Flow Testing

WTP	TEST DATE	RESULTS
Water Works Park	10/2/2018	Data was not recorded for Pump Nos. 1, 2, 4, 6, and 9. Raw data was only provided for Pump Nos. 10 and 11.
Southwest	10/3/2018	Flow data was invalid on all pumps tested, except Pump No. 4, and data is insufficient to compare with the pump curve.
Springwells	10/15/2018	Flow data was invalid on all pumps tested, except Pump Nos. 19 and 23, and data is insufficient to compare with pump curves.
Lake Huron	10/18/2018	Discharge header pressures and valve positions were not recorded.

A more detailed analysis of the high lift pump testing data is provided in Appendix 9.3. In conclusion, the data collected is currently insufficient to determine production flow from the WTPs.

Of the five WTPs, Northeast is the only plant with functional production flow meters, and further improvements to the Northeast metering system, including calibration, are currently in progress. Flow metering improvements are planned at each WTP.

With additional testing and data collection, the theoretical production flow rates for each WTP can be estimated using pump curves until finished water metering is completed. When estimating flow using pump curves, accuracy can be significantly impacted by the condition of the pumps, as worn impellers will reduce pumping capacity. To accurately calculate flow rates using pump curves, the performance of each pump must be validated through testing of individual pumps and comparing results factory curves. Performance discrepancies could then be used to estimate a calibrated curve for each pump. Validation of pump curves will require substantial testing, data collection, and evaluation.

Alternately, pumps may be assumed to be in good condition based on favorable operating characteristics without history of cavitation, and pump curves may be used to estimate production flow without calibration. Reliable flow estimation requires a comprehensive understanding of each pumping system. Factory test curves (or factory design curves) must be available for each functional pumping unit. Plan and profile record drawings of each high lift pumping system must be reviewed, modeled, and calibrated with the system curve. Required drawings include pump suction header(s) (if applicable), pump suction piping, pump discharge piping, and discharge header piping. Detail must be adequate to understand the location and type of valves, meters, and pressure gauges used for testing and data collection. Minimum required data includes:

- Pumping units operated at the time of data collection with related speed and valve positions
- Suction pressure or well water surface level (elevation or depth & datum)
- Discharge pressure
- Variable Frequency Drive (VFD) % speed of test pump
- Valve positions of test pump and header(s)

Accuracy will be improved by collecting supplemental data, as available/applicable:

- Flow rate (total and/or individual pump)
- Suction header pressure
- Pump suction pressure
- Pump casing pressure
- Pump discharge pressure
- Discharge header pressure

Regardless of conducting additional testing to estimate production flow rates, it is still recommended to install production flow meters at each WTP. Meters will provide an accurate and continuous knowledge of the flows entering the GLWA system and would allow for more accurate non-revenue water calculations and greater confidence in the overall GLWA water balance.

3.3 RECOMMENDED WATER TREATMENT PLANT ADJUSTMENT

As the pump testing was not comprehensive B&V recommends applying the same correction factor to overall water treatment plan production volume as developed, and reported in detail, in the UoS Phase 1 report. The Phase 1 analysis looked at available data for each water treatment plant, including secondary sources of data validation such as the volumes associated with low lift or filter-bed Venturi meters within the plants. In Phase 1, B&V concluded that the overall reported volume of plant production should be decreased by 5.8%. This value is comprised of adjustments at each individual water treatment plant as shown in Figure 3-1.

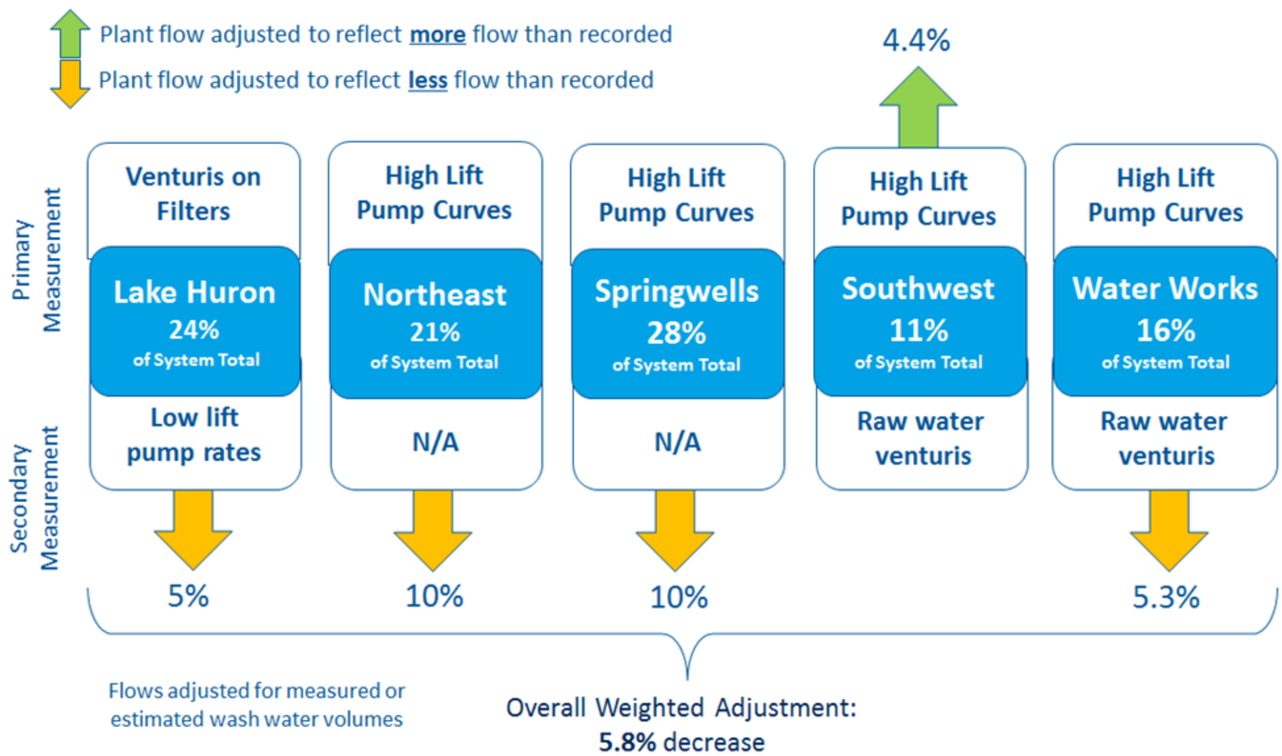


Figure 3-1 Summary of Adjustments to Reported Plant Production Volume

As shown in Figure 3-1, Venturi meters are available at Lake Huron, Southwest, and Water Works Park. In Phase 1, data was obtained from these meters to provide a secondary data point in addition to the volume of produced water estimated from pump curves. In each case an adjustment for backwash water was made based on the characteristics of the backwash system at each plant. During the data review, it was noted that very minimal information was available on calibrations of the differential pressure cells for the Venturi meters. It is recommended that electronic calibration is performed on the differential pressure cells every six months by a qualified technician. No secondary measurements were available for Northeast and Springwells, and therefore, it was assumed that the pump efficiency had deteriorated and an adjustment of 10% was applied.

4 Transmission Main Leakage and Blow-Off Valve Assessment

Transmission main leakage is currently a "common-to-all" (CTA) component of the water audit as derived in the Phase 1 report. The Phase 1 report estimated transmission leak rates using an approach which included a connections-based component plus an estimate to account for open blow-off valves. Transmission main leakage continues to be a CTA component in Phase 2, but additional analysis of transmission main leakage and blow-off valve assessments have also been completed to allow more accurate estimation of transmission main leakage. The additional analysis and discussion of near-term future planned and recommended activities are described in the following subsections. Note that this data does not have a direct effect on Units of Service for Non-Master Metered Customers under Phase 2.

4.1 TRANSMISSION MAIN SYSTEM DATA

The Phase 2 assessment utilized some additional data on the transmission mains and associated main breaks which is outlined in the subsections below. This includes more detailed age and material information.

4.1.1 GLWA Transmission Main Age and Material

There were two primary periods of transmission main installation, between 1910-1930 and 1950-1970. Figure 4-1 outlines the ages and related miles of main installed. The materials used are also shown on this Figure and show a change in material used from unknown (likely cast iron and steel) in the first period to concrete (initially reinforced moving to pre-stressed) in the second major development period. It should be noted that there may be changes in these values depending on the outcome of the arbitration between GLWA and DWSD.

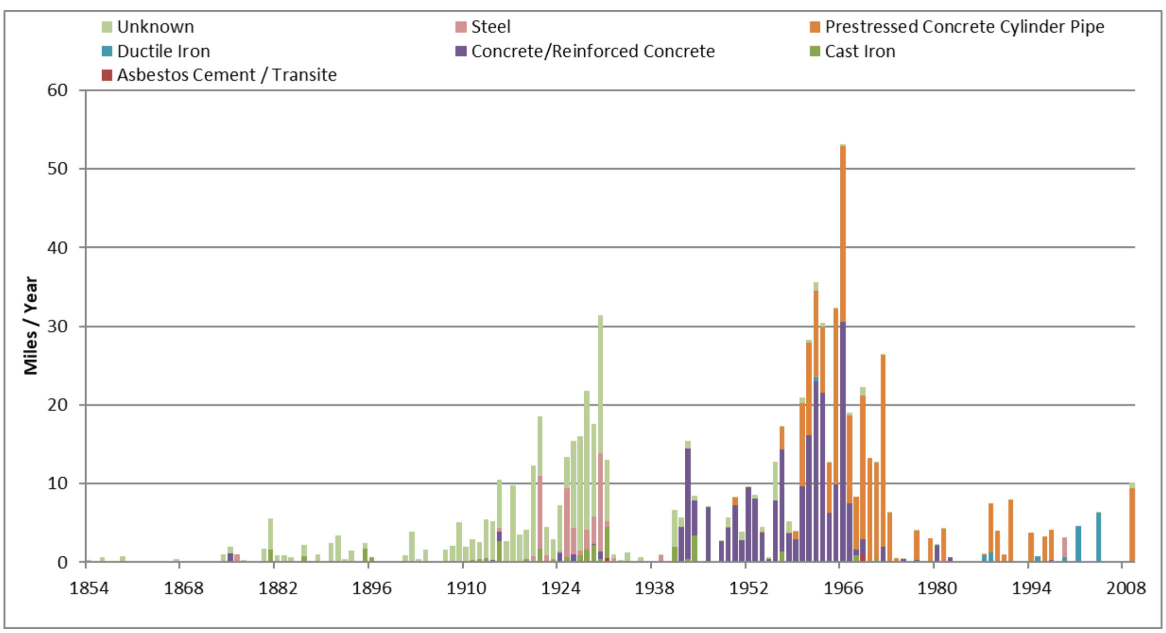


Figure 4-1 GLWA Transmission main age and material

The transmission main breaks themselves were also analyzed. As anticipated the very oldest pipe has the highest ratio of main breaks per hundred miles. However, the main installed during the 1940's has a higher break rate than the main in the earlier part of that century. This suggests that age alone is an imperfect measure of the failure potential of the transmission mains.

Install Age	n of Breaks	% of Breaks on Material	% Age in System	Ratio	Breaks / 100 mi /Yr
1850 - 1860	2	1.0%	0.4%	2.4	12.1
1860 - 1870	0	0.0%	0.2%	-	-
1870 - 1880	4	2.0%	1.0%	2.0	10.0
1880 - 1890	10	5.1%	3.2%	1.6	8.0
1890 - 1900	3	1.5%	3.1%	0.5	2.5
1900 - 1910	8	4.1%	4.0%	1.0	5.1
1910 - 1920	20	10.2%	12.5%	0.8	4.1
1920 - 1930	82	41.6%	32.6%	1.3	6.5
1930 - 1940	13	6.6%	11.5%	0.6	2.9
1940 - 1950	24	12.2%	7.2%	1.7	8.6
1950 - 1960	21	10.7%	13.9%	0.8	3.9
1960 - 1970	10	5.1%	8.8%	0.6	2.9
>1970	0	0.0%	0.5%		

Figure 4-2 Transmission Main Breaks by Age of Pipe Installation

Material	n of Breaks	Breaks on Material	% Material in System	Ratio	Breaks / 100 mi /Yr
Unknown	38	19%	56%	0.3	1.7
AC	1	1%	0%	2.5	12.4
Cast Iron	94	48%	7%	6.4	32.4
Steel	15	8%	10%	0.7	3.7
Reinforced Concrete	46	23%	22%	1.0	5.3
Ductile Iron	2	1%	1%	0.7	3.7
Prestressed Concrete	1	1%	2%	0.2	1.2

Figure 4-3 Transmission Main Breaks by Material

4.2 COMPONENTS OF TRANSMISSION MAIN WATER LOSS CONSIDERED FOR PHASE 2

The Phase 1 report estimated transmission main water loss based on a connections and breaks-based approach plus an additional estimate of water lost through open blow-offs. The connections and breaks-based method scaled water loss based on the average number of breaks during the three-year period 2014 – 2016, the number of connections in the system, WRF and AWWA data correlating water loss to break rates, and the number of system connections. Ultimately, a leakage rate of 16.4 MGD was estimated using this method. The second component included in transmission main losses in the Phase 1 report, losses due to open blow-offs, was estimated using flow data from two actual blow-offs identified to be open in 2017. The water loss due to open blow-offs was estimated to be 10.1 MGD. Total estimated transmission losses for the Phase 1 report were 26.5 MGD.

For the Phase 2 report, additional data in transmission main water loss sources was introduced. Transmission main water loss occurs from several main sources:

- Open blow-offs
- Unsurfaced or unreported leaks
- Breaks
- Flushing
- Unauthorized consumption

The Phase 1 report explicitly considered open blow-offs, as described above, and flushing, which was included in unbilled unmetered estimates for GLWA. In Phase 1, breaks were neglected as being relatively inconsequential to total water loss. This approach is supported by anecdotal experiences of the authors which estimate real loss from a typical high consequence transmission break in the range of 5 to 25 million gallons. Even at 25 million gallons per break, the corresponding daily water loss is a little over 0.1 MGD. Finally, in Phase 1, unsurfaced/unreported leaks and unauthorized consumption were assumed to be included in the connections and breaks-based estimation discussed above. The Phase 2 analysis considers alternate methods of estimating these components of water loss for transmission mains, including review of literature sources, analysis of data expected from future GLWA transmission main assessment projects, and methods for physical validation.

4.3 BENCHMARKING OF TRANSMISSION MAIN WATER LOSS FROM LITERATURE SOURCES

Transmission main leaks and breaks are generally accepted in most systems to occur less frequently than distribution leaks and breaks. For example, in the GLWA system an average of 40 transmission breaks occur per year, corresponding to a break rate of approximately 5 breaks/100 miles/year. Contrasting this to Dearborn and Detroit distribution break rates of approximately 30 and 45 breaks/100 miles/year, respectively, reported in Phase 1 demonstrates the significant disparity between transmission and distribution break rates in the GLWA service area. It can be assumed that each break was preceded by a leak of unknown duration and consequently a similar disparity exists between distribution and transmission leak rates.

Relatively little data on leak rates and water loss from transmission mains exists in the literature. Historically, water leak detection used acoustic methods focused on distribution mains. Such methods rely on the acoustic leak sound either traveling to the surface directly above the leak or to an above-ground appurtenance such as a valve stem, where it can be detected using acoustic correlators. Several factors complicate the application of such methods to transmission mains. Sound travels less readily through transmission-sized pipe than through distribution-sized pipe and fewer above-ground appurtenances tend to be installed on transmission mains than on distribution mains. Further transmission mains tend to be buried more deeply than distribution mains, lessening the likelihood of leaks surfacing or being detected from the surface by acoustic methods.

An empirical analysis of transmission losses based on system age, size, and type of pipe was presented by Laven (2012)[8]. This analysis aggregated data from unreported transmission leaks where the above information was available. It is important to note that the actual leak size was not physically validated in all instances and the length of pipe included in the study was not published. The data presented by Laven were used for high-level validation of the Phase 1 approach to unreported/unsurfaced water loss estimations. Using the methods presented by Laven and calculating the average age of the GLWA distribution system to be approximately 69 years, length to be approximately 780 miles and average breaks to be 40 per year.

The GLWA break rate was significantly less than those from the other utilities presented in the Laven analysis. Therefore, the Unavoidable Annual Real Loss component was used from Table 4 in this document with a multiplier for the difference in pressure. Assuming an average of 80 psi in the transmission main (this equates with just above 50 meters (56m) head line in the Laven report), The average pressure of 80 psi was calculated as an average of all the upstream pressures at all the WAMR meters (on the GLWA side). This results in an overall water loss estimation of approximately 24 MGD. The calculation is outlined below:

Average age of pipe	= 69 years
Average transmission pressure	= 80 psi
From Laven (2012)	= 3 m^3 per hour per km
	= 792 gallons per hour per km
	= 1,275 gallons per hour per mile
Length of transmission main	= 780 miles
Leakage Estimation	=23.9 MGD

[8] What Do We Know About Real Losses On Transmission Mains? K. Laven, A.O. Lambert. Conference Publication – IWA Water Loss, 2012, Manila.

This estimation is slightly higher, but in the same order of magnitude as the Phase 1 estimation. Given the data available, it cannot be determined whether estimation based on the method set forth by Laven should be assumed to include the open blow-offs found during Phase 1 investigations or not. For the sake of this analysis we will assume that the open blow offs were included in the Laven study.

The Phase 2 investigations of open blow-offs have not found any new open blow offs to date (only small leaks have been identified), and therefore, this is estimated to partially offset the increases estimated in overall transmission main leakage.

4.4 WATER LOSS ESTIMATION USING PHYSICAL TESTING

This section discusses methods available to estimate water loss in the transmission system using physical testing.

4.4.1 Inline and Correlator Methods to Estimate Transmission Water Loss

Transmission main leaks can be physically detected through two basic approaches: inline tools and correlators which acoustically detect leaks from appurtenances providing water column access. The sensitivity to identifying leaks increases as the proximity of the sensor to the leak decreases, meaning that inline tools tend to be more sensitive and accurate in detecting leaks.

Inline tools bring the sensor to within one pipe diameter of the leak. Such tools can be tethered or free-swimming. Tethered tools have the advantage of allowing the operator to stop the sensor near the leak, obtaining higher certainty that the acoustic signal corresponds to an actual leak. Tethered tools have the disadvantage of limited deployment distances, typically significantly less than one mile per deployment, due to pulling forces of the water flow not being able to overcome friction associated with the data cable. Free-swimming tools have the advantages of being simpler to deploy and being able to traverse longer distances of pipe. Survey lengths are limited by battery life of the tool and availability of a retrieval appurtenance. Free-swimming tools have the disadvantages of slightly reduced certainty in detecting leaks and the requirement that the tool be successfully retrieved for data to be collected. Vendors of free-swimming tools acknowledge that tools pass the retrieval appurtenances with some regularity but tend not to report the frequency at which this happens. Both tethered and free-swimming tools are commercially available from multiple technology vendors.

Correlators for leak detection typically require sensors spaced at approximately 2,500-foot intervals or less. Direct water column access is preferred. Highly sensitive sensors and advanced signal filtering and processing are used to locate leaks. This technology is commercially available from multiple technology vendors.

If inline or correlator methods were used in the GLWA system, the primary purpose would be not just identifying leak locations but also attempting to quantify the volume of water lost. It is important to note that none of the methods described in this section claim to make highly accurate reports of water loss quantities. While methods have been used to estimate the volume of water loss based on the acoustic signature of each leak, leak size is generally qualitatively reported (small, medium, etc.). Additional field verification would be required to excavate each leak and estimate the quantity of water loss.

4.4.2 Metering to Estimate Transmission Water Loss

Metering between water treatment plants and master metered areas may be an option to estimate transmission main losses. For this option to be viable, candidate transmission mains would need to be identified and an evaluation of the feasibility of this approach would need to be completed taking into consideration:

- Feasibility of isolating the candidate mains from other non-metered production supply sources and non-metered customers
- Meter accuracy with respect to the volume of transmission main losses expected to occur along the candidate mains during the test
- Whether the data gained would be sufficient to allow extrapolation to the balance of the transmission system
- Ability to capture a diverse population of transmission mains with respect to locations, pipe material, and age (may not be a critical factor in the feasibility evaluation)

4.4.3 Future Plans for Assessments of GLWA Transmission Mains

GLWA has both near and long-term plans for assessment of its transmission system. Short-term plans are well-defined and specific to the 14 Mile Road Transmission Main which experienced a catastrophic failure in 2017. The portion of the assessment plan relevant to the Units of Service project is leak detection on 7.8 miles of PCCP main that comprises the 14 Mile Road Transmission Main. A free-swimming tool is planned to be deployed to acoustically detect leaks by Spring of 2019 at the latest. No specific plans for physically validating the leak locations and sizes have been made.

GLWA plans additional transmission main assessments, including leak detection, as part of its upcoming transmission system integrity program. This program is expected to begin in 2019 and develop plans for assessment of all of GLWA's transmission mains. It is widely acknowledged by GLWA staff that the transmission system integrity program has an implementation schedule reaching into decades, not years, and will prioritize assessment type and schedule according to pipe risk. Not all transmission mains will undergo leak detection and the schedule for deploying tools into those mains for which leak detection is a part of the recommended protocol may be many years out.

4.5 REFINING BLOW-OFF VALVE WATER LOSS ESTIMATIONS

Phase 2 evaluation of blow-offs was conducted by GLWA staff for those valves deemed to be connected directly to sewer systems. The GLWA Investigation Summary of the work conducted in the Phase 2 analysis period was as follows:

- Total GLWA valves 990 (395 tied to sewer)
- 393 of 395 valves located (99.5%)
- Two valves found partially open

- Seven discharge points within the 393 reviewed were estimated to be leaking 0 - 5 gpm

As a conservative estimate this data was equated to 35 gpm of leakage. No fully open sites were found or any sites leaking water in the ranges found (up to 10 MGD) during the Phase 1 analysis of sewer flow data. Considering this evaluation was only on approximately 1/3 of the total valves it is expected that at least 100 gpm would be a reasonable assumption (0.14 MGD).

4.6 DISCUSSION & RECOMMENDATIONS

This analysis reviewed the Phase 1 approach to the main components of transmission main water loss:

- Open blow-offs
- Unsurfaced or unreported leaks
- Breaks
- Flushing
- Unauthorized consumption

No modifications are recommended from the Phase 1 report to the approach for estimating breaks or flushing losses for transmission mains. This section discusses recommendations for modifications to the remaining components.

While the primary intent of this review was to analyze feasibility of estimating transmission main losses, the primary benefit of identifying transmission main losses is early intervention to repair previously undetected leaks before they surface as leaks or catastrophic main breaks. Loss quantification is the primary goal for the System Water Audit. However, loss identification benefits the overall transmission main system by identifying leaks which are part of the failure mode for all pipe materials in GLWA's system. Early identification of leaks prevents future catastrophic breaks.

4.6.1 Water Loss Estimation for Open Blow-off Valves

This section includes recommendations for further activities focused on water loss estimation for open blow-offs.

4.6.1.1 Continuation of Blow-off Valve investigation

It is proposed that GLWA continue the investigation of its blow-offs to encompass all 990 locations.

4.6.1.2 Blow-offs Valves within the DWSD System

There are a number of blow-offs within the DWSD system which are generally on smaller mains. These will affect the water losses within the DWSD system and should be reviewed in a similar manner to the work conducted by GLWA. The volume of loss from these blow-offs (if any) has not been further studied in Phase 2.

4.6.2 Water Loss Estimation for Unsurfaced/Unreported Leaks and Unauthorized Consumption on Transmission Mains

This section discusses options for refining the unsurfaced/unreported leak and unauthorized consumption components in the future, beyond Phase 2. Three main options have been identified for estimating water loss for unsurfaced/unreported leaks and unauthorized consumption:

1. Deploy leak detection on a representative subset of GLWA transmission mains. Excavate leaks identified to estimate quantity of water loss. Extrapolate results to remaining transmission system.

2. Develop and implement a plan to meter between plant(s) and master metered areas to estimate transmission losses.

3. Over time, incorporate the results of transmission leak detection activities already planned as part of the 14 Mile Road Transmission Main inspection and the upcoming transmission main integrity program.

Option 1 is essentially an accelerated version of Option 3. Based on the scheduling and logistics which have been required to implement leak detection in the 14 Mile Road Transmission Main, it is not currently realistic to expect transmission main leak detection to be implemented according to a faster schedule specific to the Units of Service project. Similar to GLWA, most utilities in the early stages of implementing programmatic condition assessment tend to have logistical challenges which diminish over time. Option 1 is not currently recommended, but instead, should be reserved for use if urgency in quantifying transmission main water loss increases.

Option 2 is complicated by the nature of the GLWA transmission system. The mains are located both within and outside City limits of Detroit. Arbitration of the ownership of certain pipes in Detroit city limits is expected, and significant challenges will be met in attempting to separate portions of the system to estimate or measure water loss. Option 2 should not be discarded, but instead should be reserved for use in the event another more straightforward option cannot be implemented.

Finally, option 3 makes good use of GLWA's existing plans to allocate budget and resources to transmission main inspection projects. The recommended approach is to first evaluate the results of the 14 Mile Road Transmission Main leak survey expected to be available by Spring 2019. This survey will include 7.8 miles or nearly 1% of GLWA's transmission system. A reevaluation of the GLWA water balance specific to transmission losses should occur after the 14 Mile Road Transmission Main leak inspection results are available. Excavation in select locations will be required to estimate water loss quantity. As the transmission system integrity program develops and begins to be executed, the results of leak surveys completed as part of that program should be incorporated into the estimation of water loss for transmission mains. If the 14 Mile Road Transmission Main inspections do not occur as currently planned, or the transmission system integrity program is delayed, Options 1 and 2 should be revisited.

4.6.3 Update to Estimated Leakage from GLWA Transmission Mains

A desktop review has estimated a range of transmission losses which can be used for the Units of Service. In Phase 1, transmission losses were estimated to be 26.5 MGD, including 16.4 MGD for unsurfaced/unreported leaks and 10.1 MGD for open blow-offs. The Phase 2 evaluation has identified a different methodology which estimated open blow offs to now be only 0.14 MGD and transmission losses to be 23.9 MGD, without certainty as to whether this value should include blow-offs. It is recommended that transmission main losses continue to be reported as 26.5 MGD until additional information on blow-offs and volumes from transmission main leaks can be identified.

5 Develop Process for Annual Wholesale Meter Audit

There is additional work that needs to be performed by GLWA related to flow testing of WAMR meters, or other means of verifying reported volumes. GLWA's wholesale meters (WAMR) deserve scrutiny that is commensurate with their contribution to the overall system demand; on an average day, the WAMR meters measure approximately 300 MGD of sales to GLWA communities.

5.1 WAMR METERS

A wholesale meter audit is specifically called for in the GLWA lease agreement. Phase 1 indicated that GLWA performs regular meter testing on wholesale WAMR meters. Key aspects of the current program include:

- A work-order management system that ensures calibrations and meter testing are generally performed on schedule with few exceptions.
- A WAMR dashboard that allows visual analysis of trends and the provides data comparison tools to help capture data anomalies, available to customers and GLWA staff for analysis.
- A staff of 34 who manage both the water and sewer metering systems and provide data analytics to ensure the quality of the data. Staff includes analysts, engineers, field service crews and instrumentation technicians.

Key recommendations from Phase 1 included the potential to improve the analytical capabilities of the WAMR portal and the need for physical flow testing of WAMR meters in addition to electronic calibration.

5.1.1 WAMR Meter Testing

There are 290 WAMR meters supplying GLWA's customers. Physical flow testing of wholesale water meters is recommended by AWWA as part of the water audit methodology. A complete audit of all WAMR meters requires a long-term program that will likely take several years to implement. B&V reviewed WAMR meter data to identify those meters that supply the largest amount of volume to GLWA's customers. Table 5-1 indicates how much volume is supplied by the largest WAMR meters and shows how a prioritized approach could be taken to flow testing the largest WAMR meters and verifying the volumes recorded.

Table 5-1 WAMR Meter Test Scenarios Ranked by Highest Flow Volume

LARGEST N METERS	% WAMR CONSUMPTION	DIFFERENTIAL PRESSURE METERS	MAG METERS	MECHANICAL METERS
n = 5	19%	4	1	0
n = 10	26%	7	3	0
n = 20	38%	16	4	0
n = 30	46%	17	11	2
n = 40	53%	24	14	2
n = 50	60%	30	18	2

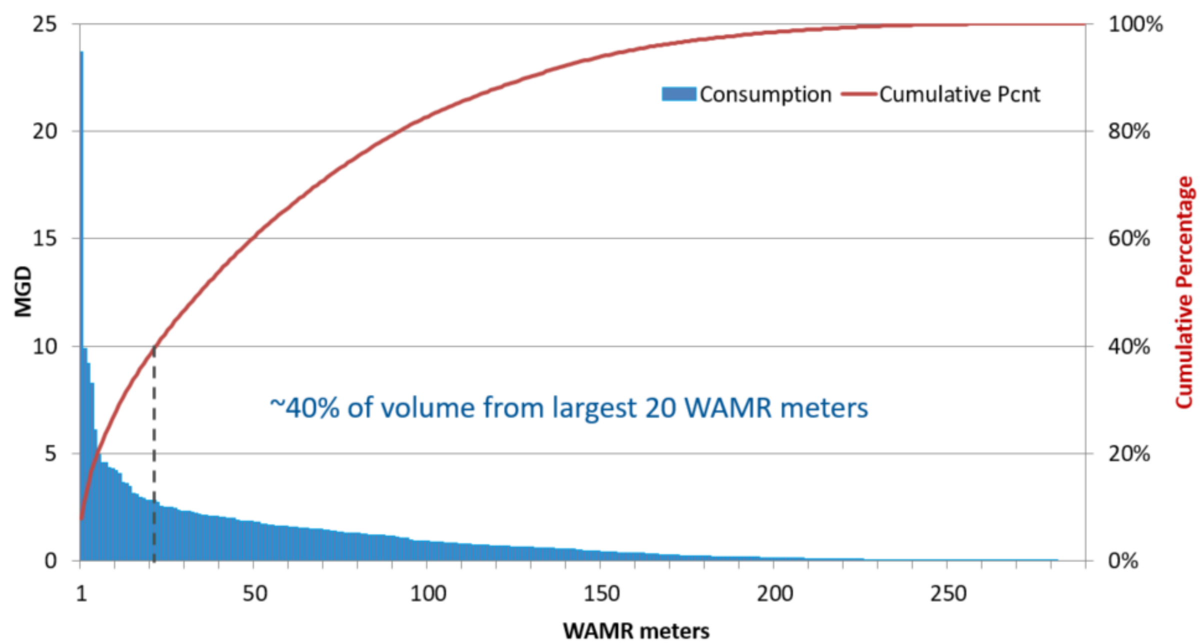


Figure 5-1 Ranking of WAMR Meters by Volume and Cumulative Percent of Total Volume

As part of Phase 1, B&V reviewed the data from approximately 700 meter tests and/or calibrations and used this data to estimate a level of meter error. GLWA's SA&MO group uses a work order system to schedule meter testing on the wholesale customers twice per year, at approximately six-month intervals. Additional testing and calibration is performed on an as-needed basis as issues are identified. B&V's review found that meters are generally tested per this schedule, and only a few deviations from this schedule were found and were typically related to site access issues.

The following excerpt from the UoS Phase 1 Report explains how each type of meter is tested:

- Mechanical Meters: Tested by GLWA staff. Most of these meters are compound meters. Larger meters are tested in-situ, and smaller meters are tested on the meter test bench at the Central Services Facility. The tests record as-found and as-left accuracy values across a range of flows (typically four to six flow rates according to the size of the meter).
- Electromagnetic (Mag) Meters: Tested by GLWA staff in-situ using dedicated testing equipment. The electronics are tested, but flow verification is not performed. However, ABB mag meters allow a specific flow rate through the meter from which the technician can compare the totalizer against a timed test to calculate percentage accuracy.
- Differential Pressure Meters: The pressure cells and electronic signal are tested and calibrated by GLWA staff in-situ. Flow verification is not performed. The tests record as-found and as-left accuracy values across a range of flows (typically four different flow rates according to the size of the meter).

In addition to the electronic calibration that is currently performed on differential pressure and mag meters, a secondary method of flow verification can be achieved through inline testing with a Pitot rod or other insertion probe. B&V recommends that flow testing via Pitot rod of the top 20 largest volume meters is conducted initially and results reviewed to determine next steps. This testing would provide flow verification for approximately 38% of the recorded WAMR volume. Mechanical meters are flow verified during the testing procedure which adds another 10% to this volume, and therefore, nearly half of total WAMR volume would be flow verified under this scenario.

5.1.2 WAMR Meter Upgrades

GLWA's SA&MO group is upgrading wholesale water meters under Contract GWLA-CON-285. Fifty meters have been identified for replacement under this program and the program began with the first meter replacements in the fall of 2018. All new meters will be Siemens Magnetic flow meters ranging between 6" and 36". 31 of the replacement meters are smaller than the existing meter reflecting the fact that flow rates in general have trended downwards since the existing meters were placed into service. Only one meter scheduled for replacement is a larger size than the existing meter.

In Phase 1, B&V reviewed the flow rates through the existing differential pressure meters. In Phase 2, B&V conducted an additional review focused on the lowest flow rates, which were the lowest 5% of the reported flow range. This review confirmed that most of the meters with the majority of flow rates in the lowest 5% of the reported flow range were scheduled for replacement under CON-285. The exceptions were those meters where the total flow volume was relatively small; therefore, these meters were not prioritized for replacement.

5.2 WHOLESALE CUSTOMER WATER AUDITS

An additional approach to the wholesale meter audit is to cross validate each customer's wholesale volume against retail sales as a high-level validation using basic AWWA water audit principles. In the Phase 1 Report, B&V recommended that each community system connected to GLWA conduct an annual AWWA water audit as this is a recommended best practice. The water audit process can be simplified, and as long as basic data validation principles are adhered to, the data will provide a screening level assessment that can identify any major discrepancies between purchased water by the wholesale communities and their retail sales. B&V understands that GLWA's Best Practices Workgroup is considering advancing this concept with GLWA's customers. The WRF has published a guidance manual for Level 1 Water Audit Validation[9] that could serve as a starting point for communities interested in developing a valid water audit. A data collection protocol has been included in Appendix 9.5.

5.3 WHOLESALE METER TESTING METHODOLOGY

The objective of this program is to manage the meter assets and maintain a high degree of accuracy in GLWA's WAMR meter population by periodically testing meters of all sizes and refurbishing or replacing meters. For the purposes of the meter asset management, there are four types of meter in the GLWA system:

- Large mechanical (3-inch to 12-inch meters)
- Differential Pressure
- Electromagnetic

It is important to ensure that the meters are functioning accurately to prevent inequities between customer communities and to have confidence in the overall water balance.

5.3.1 Meter Asset Data

GLWA has a sound work order management system to schedule WAMR meter testing and record results. The system should capture the following data:

a) Location ID
b) Customer ID
c) Meter Size
d) Model
e) Manufacturer
f) Meter Body / Measuring Element Serial Number
g) Volume Throughput (Reading)
h) Age / Initially Manufactured
i) Previous Test and / or Calibration Results

If available:

a) Age Refurbished (if applicable)
b) Recent Usage Profile
c) Photos of Chamber / Configuration
d) Pressure at Service Connection (where removed)

[9] Water Research Foundation. Level 1 Water Audit Validation: Guidance Manual. 2016. Project #4639A

5.3.2 Develop the Testing Plan

The usage of each meter should be considered prior to testing/replacement to determine priority. The AWWA M6 manual states that it is necessary to know the typical accuracy curve of the meter before testing. This information can be obtained from the manufacturer's literature.

Testing plans need to be developed for each size, manufacturer, and type of meter within the system. While these testing plans may be similar, it is necessary to break the testing and analyses down into each category to allow GLWA to fully understand the metering infrastructure.

5.3.3 Testing Protocol

Different types of meters have different characteristics so that their frequency and method of testing differs. The period of time over which a meter retains its accuracy is determined by the characteristics, quality, and volume of water delivered.

All test results should be collected and reported into a managed electronic database for future reference and to be able to determine the most efficient replacement protocol. If a consistent trend is found in the early testing data, then it can be extrapolated to the full group of meters. However, extrapolations across different types and manufacturers should not be made. While the overall tested accuracy, as determined by Phase 1, is relatively minor, these protocols are still very important to improve accountability and the longevity of accuracy across the system.

5.3.4 Meter Test Flow Ranges

With most meters, there are three test flow ranges. The number of flow ranges may increase to five for the larger meters. In almost all cases, the low flow range will be the first to degrade. Therefore, in order to evaluate the meters as efficiently as possible, the low flow ranges should be evaluated first to determine any trends or anomalies.

5.3.5 Test Unit Calibration

Meter field test units and test benches should be calibrated annually (at a minimum). Calibrated tanks are integral to the successful volume calculations necessary for meter accuracy evaluations. Calibration certificates should be prominently displayed on the relevant tanks and field test equipment and the last test date written on the certificate.

5.3.6 Meter Test Validation

Since meter testing is still considered a luxury rather than a necessity by many utilities, there is not a standardized network of meter testers or meter testing protocols to validate or evaluate the meter test results. It is rare that a tester provides results of their most recent calibration or standardized testing of their own equipment.

Test validation is very important as even an error of 1% in the test results can have a significant impact on budget decisions with respect to metering infrastructure. To validate the meter test results, a small number of secondary tests need to occur. This process is modeled on the water quality use of field blanks and duplicates to provide quality control on the data. In this case, the blanks would be new meters, and duplicates would be the same meter tested twice by different meter testers. This would include testing a small proportion of the meters out to a second tester in order to gain a level of validation of the data. This method is an important step toward understanding the meter accuracy and the associated testing. There will always be some variation (between 1 to 2%) between different testers, but any variations outside of this range should be evaluated and discussed with the testing company.

5.3.7 Meter Sampling

The WAMR meters should continue to be electronically calibrated (where appropriate) on a bi-annual basis. The goal for flow testing should be to conduct tests once per year until a history of accuracy is built up so that better decisions on annual accuracy can be obtained. This objective will not be an easy process as almost all of the WAMR sites were not set up with flow testing in mind.

5.3.8 Large Mechanical Meters (4-inch to 12-inch)

Large retail meters should also be considered in testing protocols. Most of the testing of these meters is conducted by a dedicated testing team and a truck-mounted test rig. The testing is conducted through the test port on the downstream side of each of the meters, and the recordings are compared between the two meters running the same volume. This procedure will be conducted at differing flow rates which should be similar to bench test flow rates (although the two are generally not the same due to the variations with in-field testing). The test rig should also be tested and calibrated regularly to make sure it is accurate.

An example of the testing flow rates for inline turbine meters is outlined in Table 5-2 .

Table 5-2 Meter Test Flow Rates for In-line Turbine Meters (AWWA Manual M6)

METER SIZE (INCHES)	LOW FLOW (GPM)	INT. FLOW (GPM)	HIGH FLOW (GPM)
4	15	-	630
6	30	-	1,400
8	50	-	2,400
10	75	-	3,800

The large meter analysis should also include a pre-test on-site survey if one has not been previously conducted. The purpose of this step is to evaluate the valve locations and condition and record any pre-test information that was not available prior to the visit. Test and operate valves to allow the test site to be ready for testing. If any infrastructure is not fully-functioning, then a work order should be created to get the infrastructure into working condition as soon as possible.

Analyze the usage of each meter prior to testing/change out to determine priority. Also, conduct a visual inspection, take photos of the meter and surrounding pipework. This separate visit can be included in the testing program itself during subsequent rounds of testing if all the data has been collected and a test has already been successfully conducted within the last three years (i.e. only one visit may be required rather than two).

5.3.8.1 Testing Methods for Mechanical Meters

Tests can be conducted using the volumetric method with volumetric tanks or the gravimetric method using weight scales. Accuracy standards for new meters are contained in the latest revisions of the following AWWA standards: C700, C701, C702, C703, C704, C708, C710, C712, and C713.

5.3.8.2 Mechanical Meter Testing Schedule

AWWA Manual M6 recommends conducting meter testing on the following schedule:

- Retail meters of 6-inch and larger – Test every year
- Retail meters of 3-inch and 4-inch – Test every three years
- Fire Service/Detector Check meters – inspect check valve functioning, conduct testing on low flow meter only if above warranty volume

However, it is suggested that GLWA evaluates its billing data to determine the highest users within each category and tests these meters on a more frequent time step. In some locations, the smaller meters may have the greatest volumes of throughput. If true, they should be checked every year too, and then, meter-sizing may also be a consideration to downsize the larger meters or upsize the smaller ones.

5.3.9 Flow Testing for Differential Pressure and Electromagnetic Meters

Differential Pressure and electromagnetic (mag) meters should be flow tested using a mobile test rig, insertion flow meter, or pitot rod depending on the size of the meter, and complexity of the pipework configuration or site access.

Based on a review of a sample of site and chamber drawings, there will likely be some difficulties with flow verification using a secondary flow meter for some of the differential pressure and Venturi and mag flow meters. A separate analysis will need to be conducted to determine the feasibility of test locations for each of these meters. The goal should be to physically flow test one third of the Venturi and electromagnetic flow meters annually, and test different ones each year so that every meter is flow tested at least once every three years.

Field assessment will be required to determine testing infrastructure needs, associated costs, and practical scheduling. Those sites which are immediately ready for testing should be prioritized. GLWA’s pressure monitors at WAMR locations use a 1” corporation tap that could be used for insertion testing. Any redevelopment of meter pits should be designed to accommodate a suitable access location where a secondary meter could be introduced to measure flow in a location that has sufficient straight run of pipe. Additional information on the methodology of testing with a Pitot Rod is included in Appendix 9.4.

6 Identify Data Gaps

As part of the review of the available data for this project, B&V has identified gaps in the available data. The data gaps have been categorized as either high, medium, or low as they relate to the criticality of the data needed for a typical water audit of a system the size of GLWA and how they relate to the expense of obtaining the data. A summary table of all the identified data gaps is shown in Table 6-1. Discussion of each data gap is conducted in the following subsections.

Table 6-1 Data Gaps

	DATA GAP	OWNERSHIP	CRITICALITY OF DATA NEED	EXPENSE OF OBTAINING DATA
1	Finished Water Production Metering	GLWA	High	High
2	Regular calibration and recordkeeping for WTP Venturi meters	GLWA	High	Medium
3	Ensure secondary metering method is established for each WTP	GLWA	High	Low
4	Monitoring and reporting of backwash and plant uses	GLWA	High	Medium
5	Automated anomaly analysis / trend breaks for WAMR	GWLA	Medium	Low
6	Highland Park Permanent Master Meters	GLWA / Highland Park	Medium	High
7	Flow Testing of WAMR meters	GLWA	Medium	High
8	Meter sizing for WAMR meters	GLWA	Medium	Medium
9	Updated Hydraulic Model	GLWA	Medium	Medium
10	Pressure transducer calibration for each WTP	GLWA	Medium	Low
11	Pressure data within the NMMCs	Detroit / Dearborn / Highland Park	Medium	High
12	Time for Awareness, Location, and Repair for breaks	Detroit / Dearborn	Low	Low
13	Length of mains field validation	Detroit / Dearborn	Low	High
14	Number of connections, including field validation	Detroit / Dearborn	High	Medium
15	Unauthorized consumption	Detroit / Dearborn	Medium	Medium
16	Systematic Data Handling Errors	Detroit / Dearborn	Medium	Medium
17	Retail meter sizing	Detroit / Dearborn	Medium	Low
18	Retail Meter accuracy testing (large and small)	Detroit / Dearborn	Medium	Medium
19	Dearborn Peaking Data	Dearborn	High	Medium

	DATA GAP	OWNERSHIP	CRITICALITY OF DATA NEED	EXPENSE OF OBTAINING DATA
21	Meter Age	Dearborn	Medium	Low
22	Unbilled unmetered	All	Low	Medium

Some of the priority gaps include:

- Finished water production metering (GLWA)
- Number of connections (Detroit)
- Retail meter testing (Dearborn and Detroit)
- Peaking Data (Dearborn)

All of the data gaps are described in more detail in the following subsections. This is structured by the relevant entity associated with collecting the data, in the following sections.

6.1 GLWA

The water audit data gaps related to GLWA are outlined below.

6.1.1 Finished Water Production Metering

The finished water production metering has been considered as an infrastructure gap for a number of years. However, this Units of Service project highlighted the issue that this data gap created. A water balance for the system cannot be developed with any sufficient level of certainty without metering (and calibrating) the water treatment plants. Therefore, this infrastructure rehabilitation and replacement was prioritized and has been expedited. Section 3 explains the current schedule for completion of the metering of all the treatment plants.

6.1.2 Regular Calibration and Recordkeeping for WTP Venturi Meters

Many years prior to the re-instatement of the Venturi metering at the water treatment plants, there were working Venturi meters. However, over time these systems degraded and were not maintained. It is important that any existing metering systems and the new ones about to be commissioned are actively reviewed at least twice per year and calibrations conducted at least at the same frequency. Records of the calibrations should be kept electronically and be reported annually.

6.1.3 Ensure Secondary Metering Method is Established for Each WTP

One validation check on the WTP meters is to assess them against a secondary meter. This is generally to determine if there are any significant issues rather than to tweak the accuracy values. There are a number of secondary systems already available for use (filter Venturi's at Lake Huron, raw water Venturi's at Water Works Park as examples). These secondary systems also need to be kept in prime condition through active calibration, testing, and replacement when necessary. The analyses of primary versus secondary metering systems should also be automated and alerting created to immediately report when one of the systems starts to go out of normal range.

6.1.4 Monitoring and Reporting of Backwash and Plant Uses

As part of the secondary validation checks on the finished water meters, the mass balance within the water treatment plants can be used to provide a check the overall accuracy of the main meters. However, this requires good monitoring of the in-plant uses such as the volume of backwash water. The methods of secondary calculations should be developed for each plant and the relevant process or backwash volumes monitored and reported along with the secondary calculations.

6.1.5 Automated Anomaly Analysis / Trend Breaks for WAMR

Automated anomaly detection has recently been added to the functionality of the WAMR online portal. All customers should utilize this functionality to its fullest potential. This should be available for Highland Park, but Dearborn and Detroit will need to install master meters before they will be able to utilize the WAMR system fully.

6.1.6 Highland Park Permanent Master Meters

The current temporary master metering system requires a manual download of data from the three flow metering sites. This increases the risk of anomalies and breakdowns in the data provided (if there are any issues, they are not determined until after the data is downloaded and analyzed). Automated logging units should be incorporated at these location until standard master meters are installed. This will allow active monitoring and troubleshooting of the data.

6.1.7 Flow Testing of WAMR Meters

All the WAMR meters (with a small number of exceptions) are calibrated every year. The mechanical meters are also flow tested annually. However, the Venturi and electromagnetic meters are not currently flow tested. This needs to be conducted in order to provide the highest level of certainty for the WAMR meter accuracy. It is not a simple task as many of the WAMR meter configurations do not allow a test port or enough straight pipe to conduct valid testing. Installation of test chambers is also expensive and so further analysis of this gap should be conducted in the future. All new chambers should consider secondary flow testing.

6.1.8 Meter Sizing for WAMR Meters

A basic analysis of flow ranges for the WAMR meters was conducted in Phase 1. This suggested that there were a significant number of meters which were operating only in their low-flow range. This would increase the risk of inaccurate reporting. Additional specialized meter sizing analysis should be conducted on these meters. In many cases, these meters are being replaced with newer infrastructure that is more appropriately sized.

6.1.9 Updated Hydraulic Model

There are three hydraulic models that are of interest in this data gap. These are the GLWA transmission main and the Detroit and Dearborn distribution main models. Each of these needs to be updated with more recent demands and re-calibrated. The most value would be gained out of joining the models so that the boundaries between Detroit and Dearborn are more accurately connected.

6.1.10 Pressure Transducer Calibration for Each WTP

The current methodology for calculating the volumes supplied to the system uses pump curves which are manually input from a look-up table. This table uses a pressure variable which is monitored from a single point in each plant. These pressure sensors need to be tested and calibrated at least annually and the calibration information reported.

6.2 DETROIT

6.2.1 Pressure Data within Detroit

One portion of the methodologies used for calculating the real loss within Detroit is the distribution of leakage by pressure. So, average pressure within the DMAs is matched to average pressure in the whole system and a factor set to recalculate the losses at average system pressure. The average pressure within the DMAs is well understood as pressure monitors were installed for that purpose. However, the measurements from the Detroit system as a whole were not as well understood. Therefore, more detailed and extensive logging of pressure data within Detroit's distribution system is recommended to prove out this average system value.

6.2.2 Time for Awareness, Location, and Repair for Breaks

Location and repair times are reasonably well documented in Detroit. However, the awareness (time between when the leak actually started to when it was found/reported) is uncertain. Not all leaks immediately surface and it is the non-surfacing leaks which run to the sewers or groundwater that need to be considered in this value. District metering can provide answers to this, but they are set up to reduce the awareness time.

6.2.3 Length of Mains Field Validation

Length of mains is one of the system data points within the audit. It is used as a multiplier in the unavoidable annual real losses component. It is not a priority variable in the units of service calculations, but it does have influence on the Infrastructure Leakage Index (ILI) which can be used by the utilities to understand and manage their own leakage reduction programs. Field validation of the GIS information is necessary in order to ground-truth the location and length of distribution and transmission mains in the systems.

6.2.4 Number of Connections, including Field Validation

The number of connections is an important value, especially for Detroit, because there are a large number of vacant or unused properties in Detroit which may or may not have a service line. There are conflicting reports on the timing of crimping the service lines versus a full "kill" of the service line back to the corporation on the main. These have quite different leakage potential and the crimped lined are especially susceptible to leakage.

No further work was conducted on the distinction between service lines within the Phase 2 work. However, it is recommended that this analysis is considered once again in 2019 after Phase 2 is completed.

6.2.5 Unbilled Unmetered

Unbilled unmetered uses include flushing, fire-fighting, etc. These are part of the non-revenue water volume that is assigned on top of Detroit's billed metered data. A value of 1.25% of water supplied will continue to be assessed until either more detailed reporting of these uses is documented or Detroit is master metered.

6.2.6 Unauthorized Consumption

Unauthorized consumption is realistically theft of service. This is part of the non-revenue water volume that is assigned on top of Detroit's billed metered data. A value of 0.25% of water supplied will continue to be assessed until either more detailed reporting of these uses is documented or Detroit is master metered.

6.2.7 Systematic Data Handling Errors

Since Detroit's Units of Service are currently calculated from their retail metered demand, the metering and billing systems need to be thoroughly vetted and this value calculated as accurately as possible. Data handling errors are those which occur between the meter being read and the customer receiving the bill. All the minutia that could possibly affect the retailed billed volume reporting need to be assessed and reported upon annually. Once Detroit is master metered, this annual requirement will not be necessary.

6.2.8 Retail Meter Sizing

Meter sizing is an issue for retail meters in a similar manner to production meters. The larger meters can be oversized or with respect to compound meters, the cross-over range can be problematic. Therefore, data on testing of the large meters should also be incorporated into future apparent loss analyses for determining if sizing could be an issue. If it is determined to be an issue, then a separate sizing analysis (requires a higher frequency logging period) should be conducted on selected meters.

6.2.9 Retail Meter Accuracy Testing

Retail meter testing of mechanical meters is a concern across all of the NMMC's. Detroit conducts a small number of retail meter tests annually, but the methods and protocols did not follow AWWA M6 guidelines until Phase 1 was completed. It has been reported that the AWWA guidelines have now been utilized and the retail test bench is annually calibrated to provide more certainty of accuracy. This protocol needs to change for all NMMC's with a relevant number of meter tests used to guide the changeout patterns and needs for each utility.

In Phase 2, the DMA's include a level of apparent and real loss which are not specifically distinguished. In future years, it is recommended that retail meter testing is conducted and updated accuracy curves developed and incorporated into the audit.

6.2.9.1 Large Meter Testing

For meters three-inches in diameter and larger the in-situ field testing trucks should continue to be utilized. The data from many of the tests is currently managed on paper. This reduces the ease of transfer of data, and so DWSD should move to an electronic method of reporting and calculation.

6.2.9.2 Small Meter Testing

For meters of two-inch diameter and smaller the test benches at the Huber facility should continue to be used. Updated calibration data should be recorded and reported at least annually. All tests should follow the AWWA guidelines as noted in Manual M6. Data recording and transfer should be conducted electronically and reports of meter tests reported at least quarterly. Additional third-party testing of a selection of small meters should be conducted to validate the Huber test bench results.

6.3 DEARBORN

6.3.1 Peaking Data

Phase 2 did not provide any additional direct data other than updating the existing methodology which included the peer utilities and an evaluation against the whole WAMR community. Dearborn is reportedly considering advanced metering for their retail connections, but this will provide only a certain level of understanding of the peak demands. The best way to access more accurate maximum day and peak hour will be to complete master metering. This could be phased in through adding areas with better data available until the whole system is master metered. The DMAs are too small to consider for peak demand analysis, so larger areas would be required.

6.3.2 Pressure Data within Dearborn

During the Phase 2 DMA analysis Dearborn monitored four fire stations which were spread through the distribution system. Since average pressure within the DMAs is matched to average pressure in the whole system and a factor set to recalculate the losses at average system pressure. Therefore, if DMAs are used in the future these sites should be re-measured to provide the necessary data to enable the real loss calculations.

6.3.3 Time for Awareness, Location, and Repair for Breaks

Location and repair times are reasonably well documented in Dearborn. The awareness (time between when the leak actually started to when it was found/reported) is uncertain and is reported to be very short. Not all leaks immediately surface and it is the non-surfacing leaks which run to the sewers or groundwater that need to be considered in this value. Data relating to awareness times beyond need to be recorded and reported annually.

6.3.4 Length of Mains Field Validation

Length of mains is one of the system data points within the audit. It is used as a multiplier in the unavoidable annual real losses component. It is not a priority variable in the units of service calculations, but it does have influence on the ILI which can be used by the utilities to understand and manage their own leakage reduction programs. Field validation of the GIS information is necessary in order to ground-truth the location and length of distribution and transmission mains in the systems.

6.3.5 Number of Connections, including Field Validation

The number of connections in Dearborn is relatively well understood. However, further cross-referencing between billing and GIS should be conducted to fine-tune the results. No further work was conducted on the distinction between service lines within the Phase 2 work.

6.3.6 Unauthorized Consumption

Unauthorized consumption is realistically theft of service. This is part of the non-revenue water volume that is assigned on top of Dearborn's billed metered data. A value of 0.25% of water supplied will continue to be assessed until either more detailed reporting of these uses are documented, or Dearborn is master metered.

6.3.7 Systematic Data Handling Errors

Since Dearborn's Units of Service are currently calculated from their retail metered demand, the metering and billing systems need to be thoroughly vetted and this value calculated as accurately as possible. Data handling errors are those which occur between the meter being read and the customer receiving the bill. All the minutia that could possibly affect the retailed billed volume reporting need to be assessed and reported upon annually. Once Dearborn is master metered this annual requirement will not be necessary.

6.3.8 Retail Meter Sizing

Testing of Dearborn's large meters should also be incorporated into future apparent loss analyses for determining if sizing could be an issue. If it is determined to be an issue, then a separate sizing analysis (requires a higher frequency logging period) should be conducted on selected meters.

6.3.9 Retail Meter Accuracy Testing

Retail meter testing of mechanical meters is a concern across all of the NMMC's. Dearborn does not currently conduct standardized meter testing of any of its meters. This protocol needs to change for Dearborn with a relevant number of meter tests used to guide the calculations of meter accuracy, changeout patterns and needs for each utility.

In Phase 2, the DMA's include a level of apparent and real loss which are not specifically distinguished. In future years, it is strongly recommended that retail meter testing is conducted annually and updated accuracy curves developed and incorporated into the audit. Once Dearborn is master metered this annual requirement will not be necessary

6.3.9.1 Large Meter Testing

For meters three-inches in diameter and larger, in-situ field testing trucks should be utilized. The data from the tests (as-found and as-left test results) should be provided in electronic format for ease of analysis and incorporation into the apparent loss analysis.

6.3.9.2 Small Meter Testing

For meters of two-inch diameter and smaller the DWSD test benches at the Huber facility or at a third party could be used. Updated testing data should be recorded and reported at least annually and all tests should follow the AWWA guidelines as noted in Manual M6. Data recording and transfer should be conducted electronically.

6.3.10 Meter Age

Meter age information was not available for Dearborn's meter inventory. This data would enable more informed analysis of the accuracy of the meters and would allow age degradation curves to be developed once the meter testing program is put in place.

6.3.11 Unbilled Unmetered

Unbilled unmetered uses include flushing, fire-fighting, etc. These are part of the non-revenue water volume that is assigned on top of Dearborn's billed metered data. A value of 1.25% of water supplied will continue to be assessed until either more detailed reporting of these uses are documented, or Dearborn is master metered.

6.4 HIGHLAND PARK

6.4.1 Highland Park Permanent Master Meters

There are three flow metering locations to Highland Park. The current system of utilizing Insertion Mag Meters is a reasonable short-term plan, but these three metering locations do not provide the full suite of data expected and should be changed to standard master metering chambers as soon as is feasible. This will improve the analysis of average and peak demands for Highland Park and better enable water loss reduction for the City.

6.4.2 Pressure Data within Highland Park

While Highland Park does not require pressure monitoring for analysis of real losses, it will be of value for the proper operation of the master metering locations. It would be part of any permanent master metering infrastructure.

7 Develop Mid-Term & Long-term Water Audit Approach

AWWA Manual M36 (Water Audits and Loss Control Programs) states that, "it will take three to six years for most water systems to obtain a mature level of validity in their water audit approach". This consideration is important when planning and implementing the long-term water audit approach. This approach also needs to be managed with the master metering programs in mind; as whenever a NMMC becomes fully metered, then it will pass from one part of the water audit (billed metered), to another (exported water / WAMR).

The key components of the long-term water audit are:

- Treatment Plant Finished Water Metering
- Wholesale Water Metering
- Billed Metered (currently includes Detroit and Dearborn retail metering)
- Metering Accuracy
- Non-revenue Water
- System Data and Key Performance Indicators

In order to provide a reasonable level of accountability for the water audit and losses in all of the communities (master metered and non-master metered) continued water loss monitoring, control, and reporting is required. In the case of master metered communities this is driven by the WAMR data provided to the communities and this also helps drive the review by GLWA staff if there are any anomalies which could suggest a rise in leakage. The NMMCs are more complicated and so a long-term water audit approach beyond the standard methods is necessary until all the utilities are fully metered. Note that we are assuming that Highland Park will continue to be master metered into the future and so they are not discussed further here and are considered in the same sections as the other WAMR customers.

This long-term water audit approach should be put into action for FY2021. All the methods annotated here follow procedures from the AWWA Water Audit and the methodologies described in Phase 1 and/or Phase 2 of this project. Note that the long-term water audit does not include any peaking factor information or discussion as this is a separate conversation to the long-term water audit and should be calculated separately.

7.1 TREATMENT PLANT FINISHED WATER METERING

It is anticipated that all the water treatment plants will be fully metered by FY 2021. Therefore, the focus on this section is on the validation of that data. Even though the meters will almost all be relatively new, calibration and validation are still important on an annual basis. The current protocols of electronic verification and calibration should continue to be conducted at least twice per year and the accuracies as-found and as-left reported. The calibration accuracies should be used to calculate the overall meter accuracy for each plant.

Validations using secondary flow meters should be used as an extra gross validation step. For example, the raw water Venturis at Water Works Park should be used to provide an overall validation of the flow volumes of finished water. As long as the volumes are within 2 percent after removal of any plant water uses then the finished water meters can be assumed to be accurate.

7.2 WHOLESALE WATER METERING

The Wholesale (WAMR) meters are another area which need to be evaluated annually for accuracy. Since there are three types of meter (mechanical, Venturi, and electromagnetic) there need to be some slightly different methodologies for calculation and evaluation of accuracy. These are discussed in more detail in the WAMR metering section. However, they still need to go through similar calibration (Venturi and electromagnetic) and flow testing (mechanical, plus secondary flow testing for Venturi and electromagnetic).

The mechanical meters should be tested at least annually with a mobile test rig. Differential pressure and electromagnetic meters may be tested using a mobile test rig, insertion flow meter or pitot depending on their size, and complexity of the pipework configuration. Calibration and testing of the mechanical meters should be conducted at least annually and as-found and as-left accuracy values reported. There will likely be some difficulty with a selection of the Venturi and mag flow meters to allow them to be tested using a secondary flow meter. A separate analysis will need to be conducted to determine the feasibility of test locations for each of these meters. The goal should be to physically flow test at least 33% of the Venturi and electromagnetic flow meters annually and different ones each year.

Any meters that are tested against insertion electromagnetic or pitot flow tubes should be within five percent of the insertion flow meter. If they are then the electronic calibration accuracy should be used, if they are outside this range then the in-line meter should be retested and considered for removal and replacement.

7.3 RETAIL BILLED METERED

Retail billed metered volumes from the NMMCs will continue to be required from Dearborn and Detroit until they are fully master metered and as such is a mid-term water audit option. These need to continue to be validated and reported upon annually. Any waivers, estimated, and altered bills should be summarized, recorded and reported to make sure that the usage volumes billed are as accurate as possible.

7.4 RETAIL METERING ACCURACY

Retail meter accuracy testing will be required from Dearborn and Detroit until they are fully master metered and as such is a mid-term water audit option. Metering accuracy is a significant concern the longer that master metering is not operational. Meters will degrade over time and with the amount of water that has passed through them. These need to be assessed on an annual basis and degradation curves established so that an in-system meter accuracy can be calculated. This weighted average should be used to update the water balances for Dearborn and Detroit annually. The following subsections outline a suggested methodology for testing these meters.

7.4.1 Dearborn.

1. Test a sample of 1% of small meters annually (this equates to approximately 330 small meters currently) using AWWA guidelines from Manual M6. Develop a spreadsheet of the

low, intermediate and high flow meter accuracies for all the meters and provide to GLWA annually for the previous years' tests. From this data GLWA will develop a weighted average small meter inaccuracy.

2. It is recommended that these tests for meters of 2-inches diameter and smaller, include the following;
    a. A selection of ages of meters, but with a focus on older meters
    b. A selection of meters with significant throughput (as an example – for 5/8-inch meters – those with more than 2,000 CCF or 1.5 million gallons throughput)
3. Test at least 25% of the approximately 250 large meters (3-inch and larger) annually and provide this data in a similar format to GLWA on an annual basis. As found test results for large meters are required for this reporting. From this data GLWA will develop a weighted average large meter inaccuracy. Prioritizing the meters with the largest consumption is recommended.

7.4.2 Detroit.

1. Test a sample of 0.5% of residential meters annually (this equates to approximately 1,000 small meters currently). Develop a spreadsheet of the low, intermediate and low flows for all the meters and provide to GLWA in January of each year for the previous years' tests. From this data GLWA will develop a weighted average small meter inaccuracy.
2. It is recommended that these tests for meters of 2-inches diameter and smaller, include the following;
    a. A selection of ages of meters, but with a focus on older meters
    b. A selection of meters with significant throughput (as an example – for 5/8-inch meters – those with more than 2,000 CCF or 1.5 million gallons throughput)
3. Test at least 25% of the approximately 1,500 large meters (3-inch and larger) annually and provide this data in a similar format to GLWA on an annual basis. As found test results for large meters are required for this reporting. From this data GLWA will develop a weighted average large meter inaccuracy. Prioritizing the meters with the largest consumption is recommended.

7.5 NON-REVENUE WATER

Non-revenue water components will change over time just like production demand and usage. Therefore, these need to be assessed on an annual basis also.

7.5.1 Unbilled Unmetered

The default (1.25% of water supplied) will continue to be used for the foreseeable future for unbilled unmetered consumption unless Dearborn or Detroit provides GLWA with well documented and valid information to prove otherwise.

7.5.2 Apparent Losses

The metering accuracy from the previous subsection will be incorporated into the water audit as customer metering inaccuracies. A weighted average accuracy should be assessed against the billed metered numbers (separately for Dearborn and Detroit) and aggregated for the final water balance. The defaults will continue to be used for the foreseeable future for unauthorized consumption and systematic data handling errors unless Dearborn or Detroit provides GLWA with well documented and valid information to prove otherwise.

7.5.3 Real Losses

Since leakage increases as pipes degrade and a small number of leaks can lead to large amounts of loss if left unchecked. Without master metering, large leaks that do not surface, such as noted for the Village of New Haven at the AWG meeting on November 1st 2018, may go undetected. Additional examples of water loss incidents that have been identified through master metering are included in Appendix 9.6. The non-master metered communities need to continue to show a proactive investigation and review of losses until master metering data is available instead. If the master meters are not installed by the next Units of Service cycle (FY2021) the format conducted as part of Phase 2 should be conducted annually until a time where at least a portion of the area is master metered, and this data can be used instead. Since leakage detection and reduction is recommended after any DMA analysis is completed and shows leakage, new areas should be chosen each year. It is recommended that at least one new DMA for Dearborn and two new DMAs for Detroit are conducted annually.

7.5.3.1 DMAs

The DMAs should be used as a methodology to determine the level of leakage in the NMMCs, but also as a tool to reduce leakage which will improve the situation for all the communities and continue to drive down the total demand on the system.

All the work noted above can be conducted by GLWA and the relevant NMMC staff with review from the Analytical Work Group (AWG). It does not necessarily require consultant assistance due to the procedures that have been developed and implemented as part of Phase 2 of this study.

7.5.3.2 Number of Main Breaks

Since the number of main breaks reported by Dearborn and Detroit are currently part of the real loss calculation, this value needs to be updated annually and the supporting data reported. The same methodology as described in Phase 1 and Phase 2 should be utilized for the calculations. Once the systems are master metered this data will not be required.

7.5.3.3 Time to Find and Fix Main Breaks

Within the real loss calculation, the number of main breaks reported annually are multiplied by the average time to find and fix the breaks in order to provide a value for real loss from reported main breaks. This calculation needs to be updated annually and the supporting data reported.

7.6 SYSTEM DATA AND PERFORMANCE INDICATORS

System data is part of the long-term water audit because it affects the performance metrics and non-revenue water calculations. The values of interest are the number of miles of main, number of connections and system pressure.

7.6.1 Number of Miles of Main

The number of miles of distribution main does not have a large influence on the audit values for the NMMCs due to the complex nature of the calculations which utilize connections as the multiplier to estimate real losses in this analysis. However, the length of transmission mains may have an effect depending on whether any of these mains get transferred from GLWA to Detroit, or Dearborn, or vice-versa. Currently the common-to-all component includes a value for transmission main losses which will likely be affected if there are any changes in inventory length for each agency. This will only need to be addressed after any transfer is finalized.

7.6.2 Number of Connections

The number of connections are another important set of system data to actively update. In Dearborn any new (or completely removed) connections will need to be added or subtracted to the calculation (real losses from the DMAs are multiplied by the number of connections). This should be updated and reported annually until the system is master metered. In Detroit the number of pressurized service connections is still not well understood due to the vacant properties and uncertainty regarding the number of service lines that have been crimped or totally removed back to the distribution main. These should be evaluated as new validated data becomes available. The data updates should be reported annually by the respective utility and validated by GLWA.

7.6.3 System Pressure

The system pressure is used to recalculate both Dearborn and Detroit's real losses determined in the DMAs. An average system pressure is used in concert with the average pressures within the DMAs. This will continue to need to be calculated until these customers are master metered. The hydraulic models for the two communities have been utilized to prepare an average day, average system pressure for each. These should be updated on a medium-term basis (suggested every three years) to account for system and operational changes. This should be completed by calibrating the pressure portions of the models using field-based pressure data. In Dearborn this can likely be done by logging data from the four fire stations spread around the system. Within Detroit, a plan of monitoring would need to be designed with Detroit to allow the most effective analysis of pressure across the distribution system to provide valid input into their hydraulic model. It is expected that the current values (for average system pressure – any DMA would still need monitoring actively) could be utilized until FY2021 and new pressures would be analyzed in FY2022 if master metering has not been conducted by then.

7.7 COMMON-TO-ALL COMPONENTS

The CTA components within the water audit water balance are focused on transmission main loses and the remainder is uncertain due to the possible inaccuracies in any of the variables that build up the balance. The one variable that can be further assessed is the volume of leakage from leakage on the transmission mains and the related open blow offs. The blow offs should be annually inspected to make sure that there are no more open or leaking. This data should be reported annually, and a volume assigned to blow offs. The future transmission main condition assessment and leak detection programs should be incorporated into the CTA balance as appropriate. A value of gallons per mile of transmission main should be built up as the data becomes available and the variable updated annually.

7.8 TIMELINE

In order to construct an overall timeline for the long-term water audit, Table 7-1 below outlines the variables required, the update frequency and recommended first year to consider updating.

Table 7-1 Long Term Water Audit: Actions and Indicators

VALUE/VARIABLE	UPDATE FREQUENCY	FIRST UPDATE
Treatment Plant Meter Calibration	Annual	FY2021
Treatment Plant Secondary Flow tests	Annual	FY2021
WAMR Meter Testing (mechanical)	Annual all meters	FY2021
WAMR Meter Calibration (Mag and Venturi)	Annual all meters	FY2021
WAMR Meter Flow Testing (Mag and Venturi)	1/3 of meters each year	FY2021
Billed Metered Volume validation*	Annual	FY2021
Retail Meter Accuracy*	Annual	FY2021
Unauthorized Consumption*	Annual	FY2021
Systematic Data Handling Errors*	Annual	FY2021
Number of Connections*	Annual	FY2021
Number of miles of main*	Annual	First year after arbitration complete
System Pressure*	Three years	FY2022
DMAs*	Annual (1 Dearborn, 2 Detroit)	FY2021
Number of leaks*	Annual	FY2021
Time to Find and Fix Leaks*	Annual	FY2021
Transmission Main Losses and Open Blow offs*	Annual Updates where appropriate	FY2021

* Mid-Term Water Audit until Master Metered

7.9 REPORTING

It is recommended that the data developed in the table above should be annually updated and reported through the AWG. The changes should be noted between years and Units of Service recalculated annually with the new demand datasets.

8 Units of Service for FY 2020

This section presents the recommended volumetric Units of Service (UoS) for Fiscal Year 2020 using data generated from Phase 1 and Phase 2 of the project. A water balance approach is used to develop all the components of average day demand using the AWWA Water Audit format and principles.

Data for maximum day and peak hour are derived from the best available data for each Non-Master Metered community.

8.1 DEARBORN

The demand variations of average day, maximum day and peak hour were developed for all three of the NMMCs in Phase 1. The methodology for the city of Dearborn has not been changed, but the relevant data from representative communities has changed due to the contract negotiations. This information has been used to develop updated UoS for Dearborn.

8.1.1 Average Day Demand

The water balance for Dearborn is shown in Figure 8-1 and the sources of data are summarized in Table 8-1

Table 8-1 Water Balance Inputs for City of Dearborn

WATER BALANCE INPUT	DATA SOURCES
Billed Metered Consumption	This value was provided by GLWA Finance and reflects the projected FY2020 retail sales based on 36 months of sales data through September 2018. The value is projected using the same methodology as applied to master metered customers. This value includes billed unmetered customers that receive estimated bills
Billed Unmetered Authorized Consumption	
Unbilled Metered Authorized Consumption	No unbilled metered customers exist, or their consumption is negligible in the water balance
Unbilled Unmetered Consumption	AWWA Water Audit recommended default value of 1.25% of Water Supplied
Customer Metering Inaccuracy	From Phase 1, meters 2” and smaller @ 2.00% inaccuracy and meters 3” and larger at 3.37% inaccuracy. Volume weighted average of 2.69% inaccuracy
Unauthorized Consumption	AWWA Water Audit recommended default value of 0.25% of Water Supplied
Systematic Data Handling Errors	AWWA Water Audit recommended default value of 0.25% of Billed Authorized Consumption
Real Losses	Updated based on DMA field work in Phase 2 and estimates of real losses associated with mains breaks

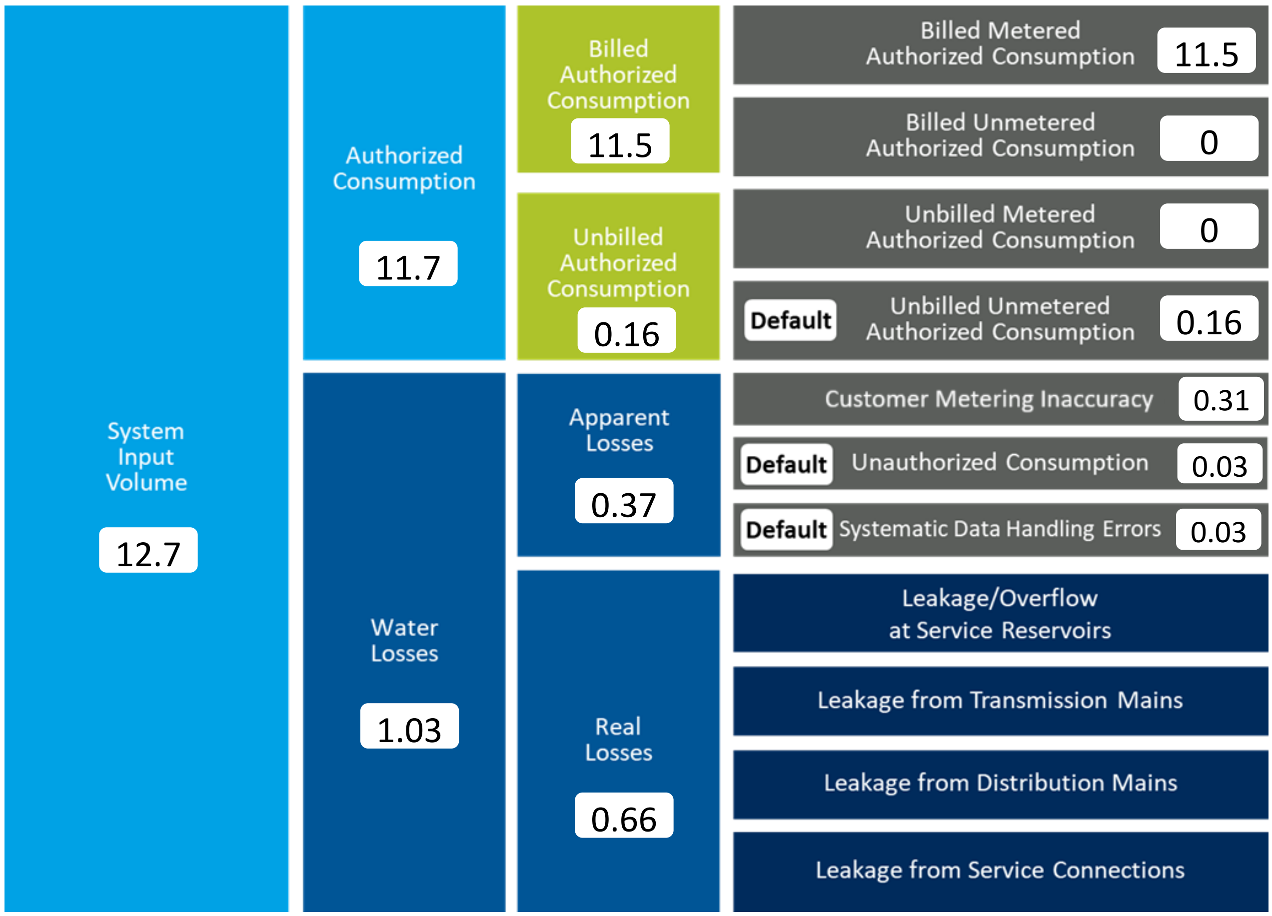


Figure 8-1 Dearborn Water Balance (Average Day)

8.1.2 Maximum Day Demand and Peak Hour Demand

Meter reading and billing for each customer in Dearborn occurs on a quarterly basis which presents a challenge in developing the max day and peak hour factors. The methodology for developing Dearborn's system peaks is the same as presented in Phase 1; it utilizes two different methods as summarized below and averages the results of each method:

Method 1a). Residential peaking factors have been developed based on comparisons to surrounding communities using attributes of housing age, household income, and proportion of single vs multi-family housing. Matching communities for these attributes are Lincoln Park, Garden City, and Taylor City respectively; the peaking factors for these communities were averaged and applied to the proportion of residential sales in Dearborn (estimated as 69.5% of total sales in Phase 1).

Method 1b). Non-residential peaking factors have been developed based on communities known to have a large non-residential component. Matching communities were identified as Ecorse and River Rouge. The peaking factors for these communities were averaged and applied to the proportion of residential sales in Dearborn (estimated as 30.5% of total sales in Phase 1).

Method 2). Comparison of Dearborn's monthly peaks (developed from quarterly data) relative to overall wholesale monthly peaks. This methodology uses the available seasonal data from Dearborn to provide insight into the relative seasonality of Dearborn compared to surrounding communities. Dearborn's monthly peaking factors were 87.1% of the wholesale monthly peaking factor and therefore under the method the max. day and peak hour peaking factors for Dearborn were established at 87.1% of the max day and peak hour peaking factors for all wholesale customers.

Dearborn's peaking factors were assigned as the average of the results of Method 1 and Method 2 above as shown in Table 8-2. The values do not include operational buffers.

Table 8-2 Inputs to Dearborn Peaking Factors

METHOD	MAX DAY FACTOR	PEAK HOUR FACTOR
1a) Residential Peers (weight 69.5%)	1.65	2.45
1b) Non-Residential Peers (weight 30.5%)	1.32	1.67
1) Peers (Weighted Avg.)	**1.55**	**2.21**
2) WAMR Monthly Peak Comparison	**1.89**	**2.55**
Dearborn Peaking Factors Average of Method 1 and Method 2	1.72	2.38

8.2 DETROIT

8.2.1 Average Day Demand

The water balance for Detroit is shown in Figure 8-2 and the sources of data are summarized in Table 8-3.

Table 8-3 Water Balance Inputs for City of Detroit

	WATER BALANCE INPUT	DATA SOURCES
1	Billed Metered Consumption	This value was provided by GLWA Finance and reflects the projected FY2020 retail sales based on 36 months of sales data through September 2018. The value is projected using the same methodology as applied to master metered customers. This value includes billed unmetered customers that receive estimated bills
2	Billed Unmetered Authorized Consumption	
3	Unbilled Metered Authorized Consumption	No unbilled metered customers exist, or their consumption is negligible in the water balance
4	Unbilled Unmetered Consumption	AWWA Water Audit recommended default value of 1.25% of Water Supplied
5	Customer Metering Inaccuracy	From Phase 1, meters 2" and smaller @ 2.30% inaccuracy and meters 3" and larger at 3.00% inaccuracy. Volume weighted average of 2.51% inaccuracy

	WATER BALANCE INPUT	DATA SOURCES
6	Unauthorized Consumption	AWWA Water Audit recommended default value of 0.25% of Water Supplied
7	Systematic Data Handling Errors	AWWA Water Audit recommended default value of 0.25% of Billed Authorized Consumption
8	Real Losses	Updated based on DMA field work in Phase 2 and estimates of real losses associated with mains breaks

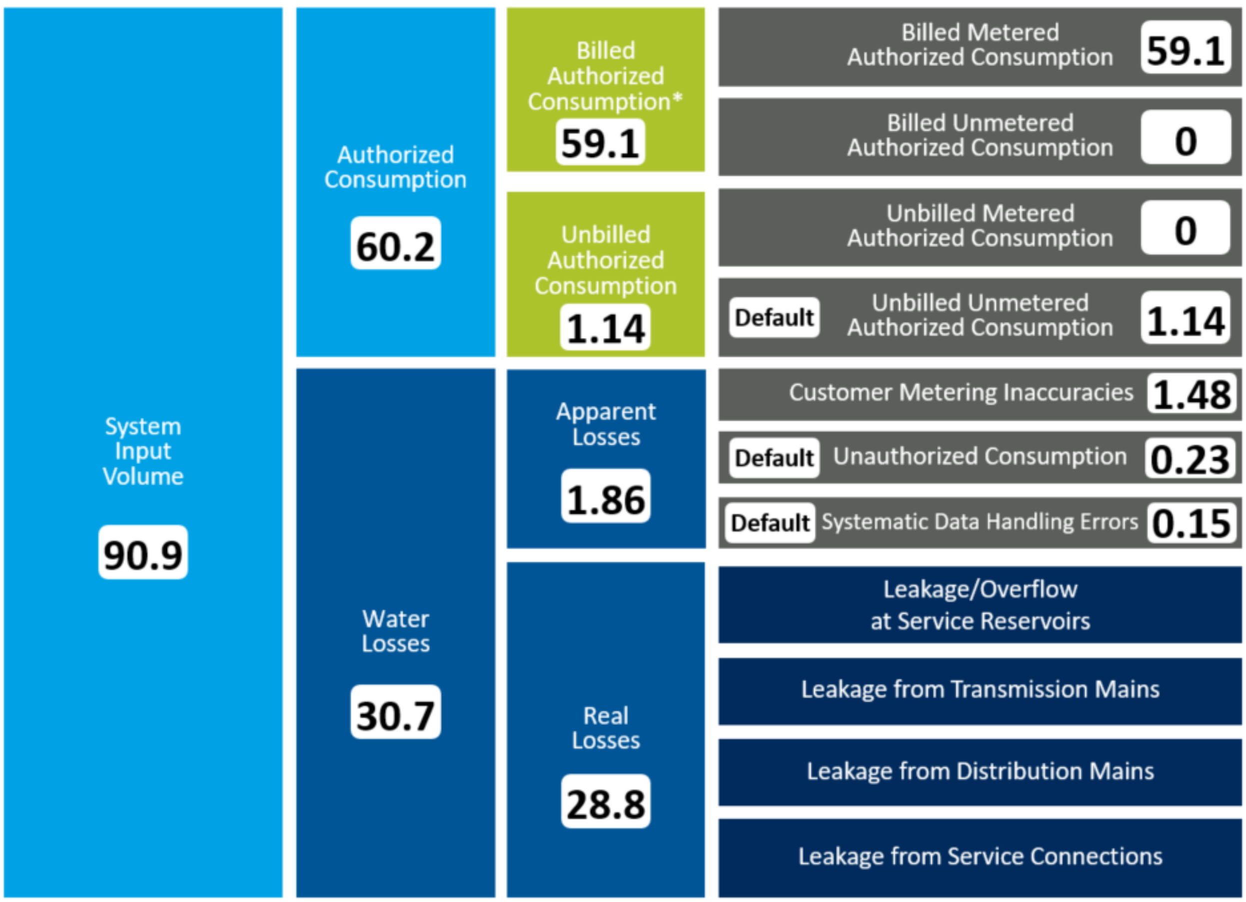


Figure 8-2 Detroit Water Balance (Average Day)

8.2.2 Maximum Day Demand and Peak Hour Demand

DWSD uses a fixed network AMR system to read the majority of their customer meters. This allows for the capture of hourly interval consumption data, and therefore, the maximum day and peak hour demands can be calculated using this data. In Phase 1, the AMR data was analyzed in detail at the daily and hourly level which allowed a peaking analysis to be conducted. DWSD daily and hourly consumption data for June through August of 2016 and 2017 was used in a scatter plot to compare the DWSD demands against the GWLA system demands for daily and hour time periods. Although the daily and hourly data is for the retail data only, a scatter plot can also be created for system demands by adding other water balance components, namely i) Unbilled Authorized Consumption, ii) Customer Metering Inaccuracies, iii) Unauthorized Consumption, iv) Systematic Data Handling Errors, and v) Real Loss. All of these components are added as constant values and are assumed not to peak. It important to recognize that the AMR data is not a complete record of retail consumption as not all customers have AMR meters and some customers receive estimated bills. Therefore, an adjustment must be made to increase the AMR data to reflect the total sales or billed authorized consumption. In 2016 and 2017, the average AMR recorded volume was 57.0 MGD. The billed authorized consumption value is 61.4 MGD. Therefore, the AMR data represents 93% of the billed authorized volume, and it is assumed that the non-AMR customers peak similarly to the AMR customers, and therefore, the AMR data is proportionally adjusted for the daily and hourly intervals to simulate the billed authorized consumption value.

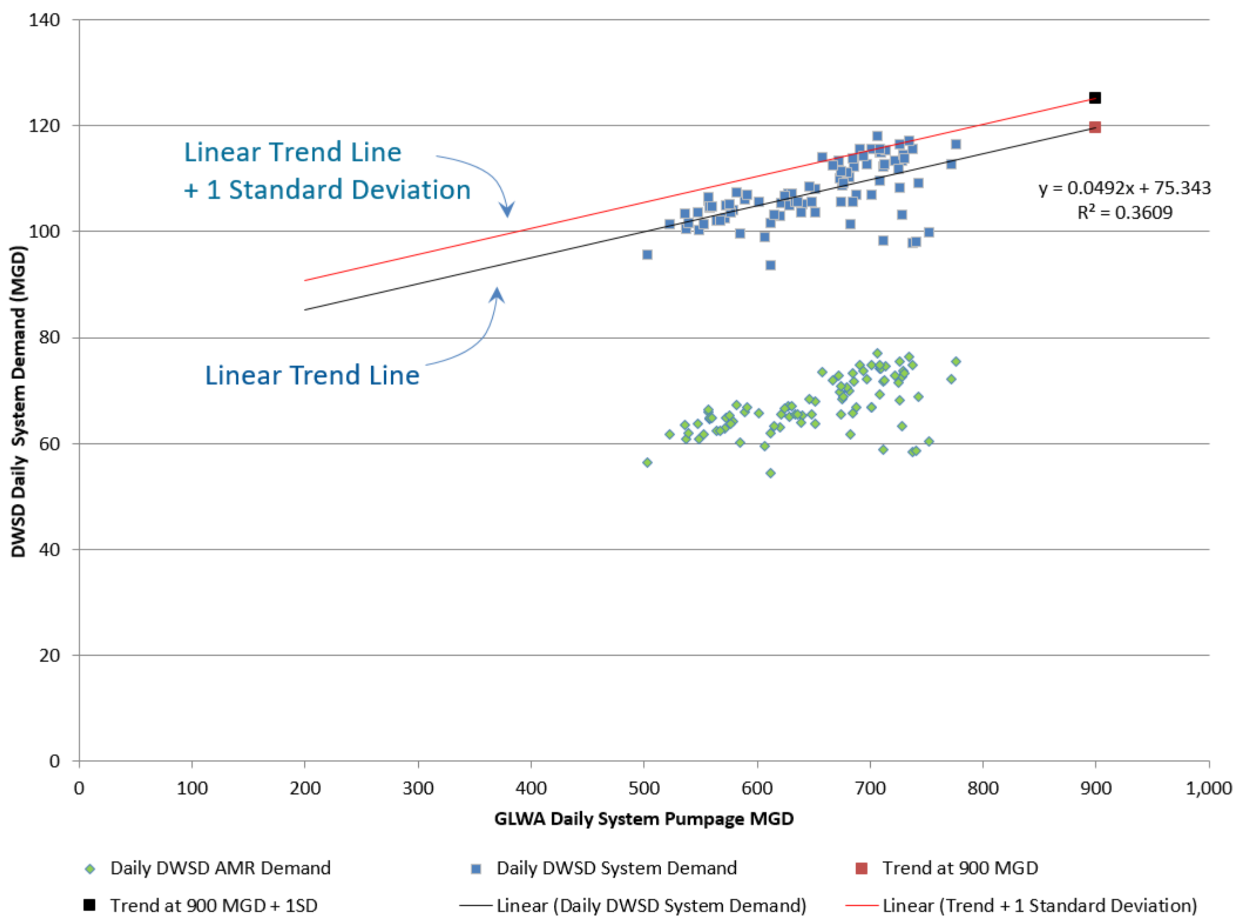


Figure 8-3 Scatterplot to Calculate DWSD Max Day Demand at 900 MGD System Pumpage

Figure 8-4 Scatterplot to Calculate DWSD Peak Hour Demand at 900 MGD System Pumpage

In Phase 1, the scatter plots were used to develop Max Day and Peak Hour Demand for FY2019 charges. From this data, peaking factors were developed for DWSD. For FY2020 charges, the same peaking factors will be applied to new Average Day demands that reflect projected FY2020 sales and the results of the NRW analysis conducted in Phase 2. This is summarized in Table 8-4. The values do not include operational buffers.

Table 8-4 Peaking Factors and FY2020 updated Units of Service for DWSD

	AVG. DAY	MAX DAY	PEAK HOUR
FY2019 MGD	98.1	120	141
Peaking Factors		1.22	1.44
FY2020 MGD	90.9	111	131

8.3 HIGHLAND PARK

8.3.1 Average Day Demand

Data for Highland Park is reviewed in 2.18.1. The insertion meters used to measure input at the three open connections were re-installed in August 2018 and found to be consistent with measured flow values since April 2018. Valves at connection points have reportedly been examined and found to be correct; therefore, the average flow rate of 2.18 MGD appears to be reflective of a recent average day demand conditions and this is recommended as the basis for Average Day Demand in FY2020 charges. More information form Highland Park on any recent improvements or changes to their system would be beneficial to help to understand the current flow rates and build confidence around the changes in flow observed in 2018.

8.3.2 Maximum Day Demand and Peak Hour Demand

In Phase 1, the scatter plots were used to develop Max Day and Peak Hour Demand for FY2019 charges. From this data, peaking factors were developed for Highland Park. For FY2020 charges, the same peaking factors will be applied to new FY2020 Average Day demand value of 2.18 MGD. This is summarized in Table 8-5.

Table 8-5 Peaking Factors and FY2020 updated Units of Service for Highland Park

	AVG. DAY	MAX DAY	PEAK HOUR
FY2019 MGD	3.07	3.94	4.03
Peaking Factors		1.28	1.31
FY2020 MGD	2.18	2.79	2.86

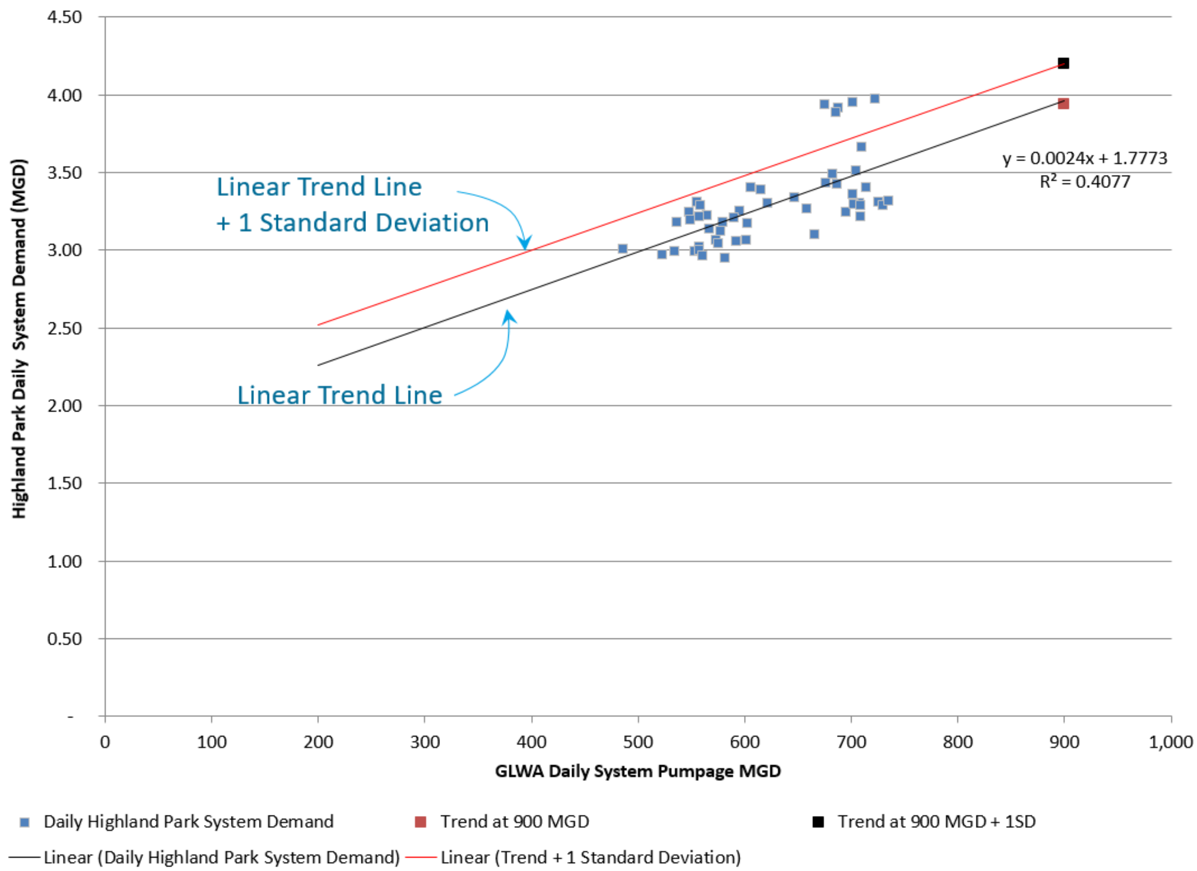


Figure 8-5 Scatterplot to Calculate Highland Park Max Day Demand at 900 MGD System Pumpage

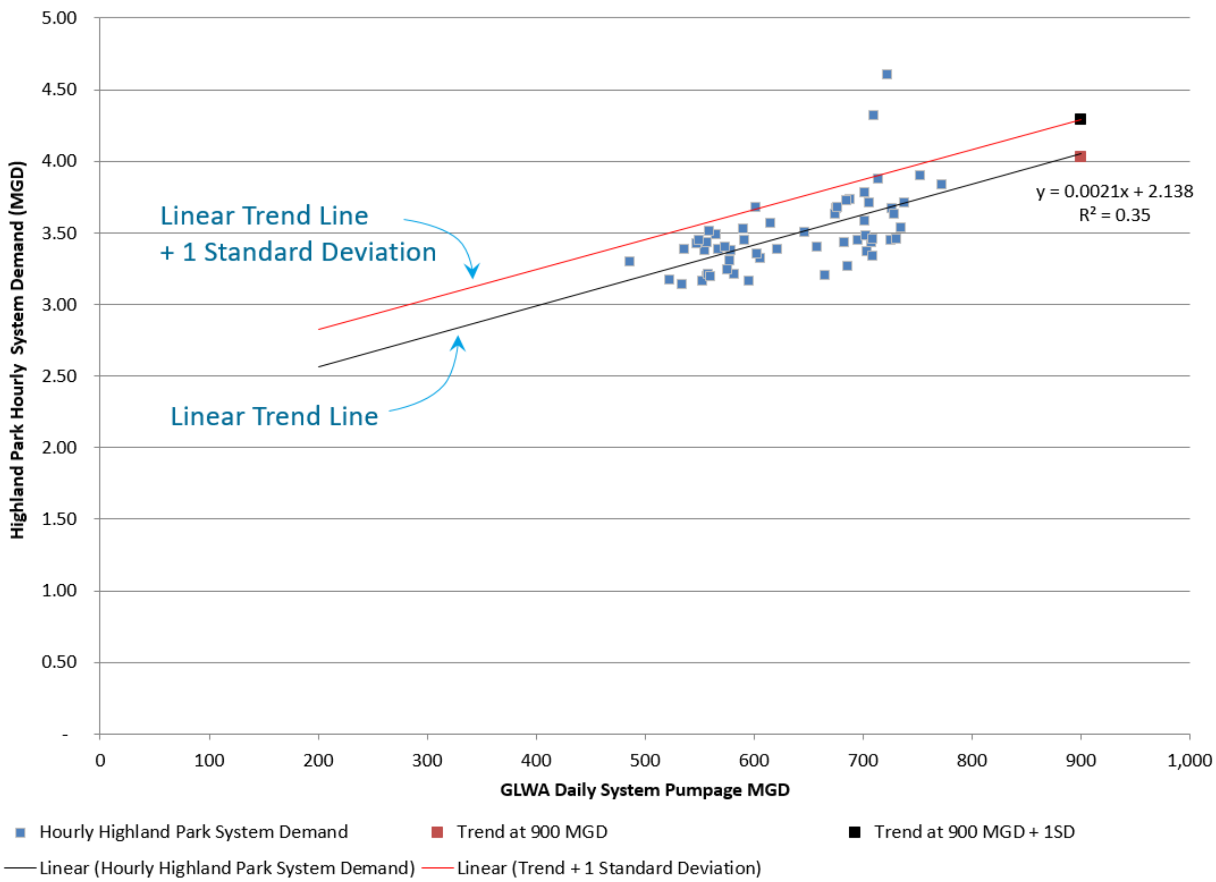


Figure 8-6 Scatterplot to Calculate Highland Park Peak Hour Demand at 900 MGD System Pumpage

8.4 NON-MASTER METERED COMMUNITIES UNITS OF SERVICE FY2020

The final recommended units of service for review and discussions during contract negotiations between the GLWA Contracts Negotiations team and the individual Non-Master Metered Customers are presented in Table 8-6. The values do not include operational buffers.

Table 8-6 Recommended Units of Service FY2020

TOTAL VOLUMES ASSIGNED BY ENTITY	AVG. DAY (MGD)	MAX DAY (MGD)	PEAK HOUR (MGD)
Dearborn	12.7	21.8	30.3
Detroit	90.9	111	131
Highland Park	2.18	2.79	2.86

8.5 GLWA WATER BALANCE

The GLWA System Water Balance, as calculated in Phase 2, is comprised of the components and values listed in Table 8-7. The projected FY2020 values have been utilized for the NMMC demand values along with 2017 demands for lines 1 and 7. The inconsistency between these dates is inconsequential for this high-level water balance. Additional clarifications on the data are provided below:

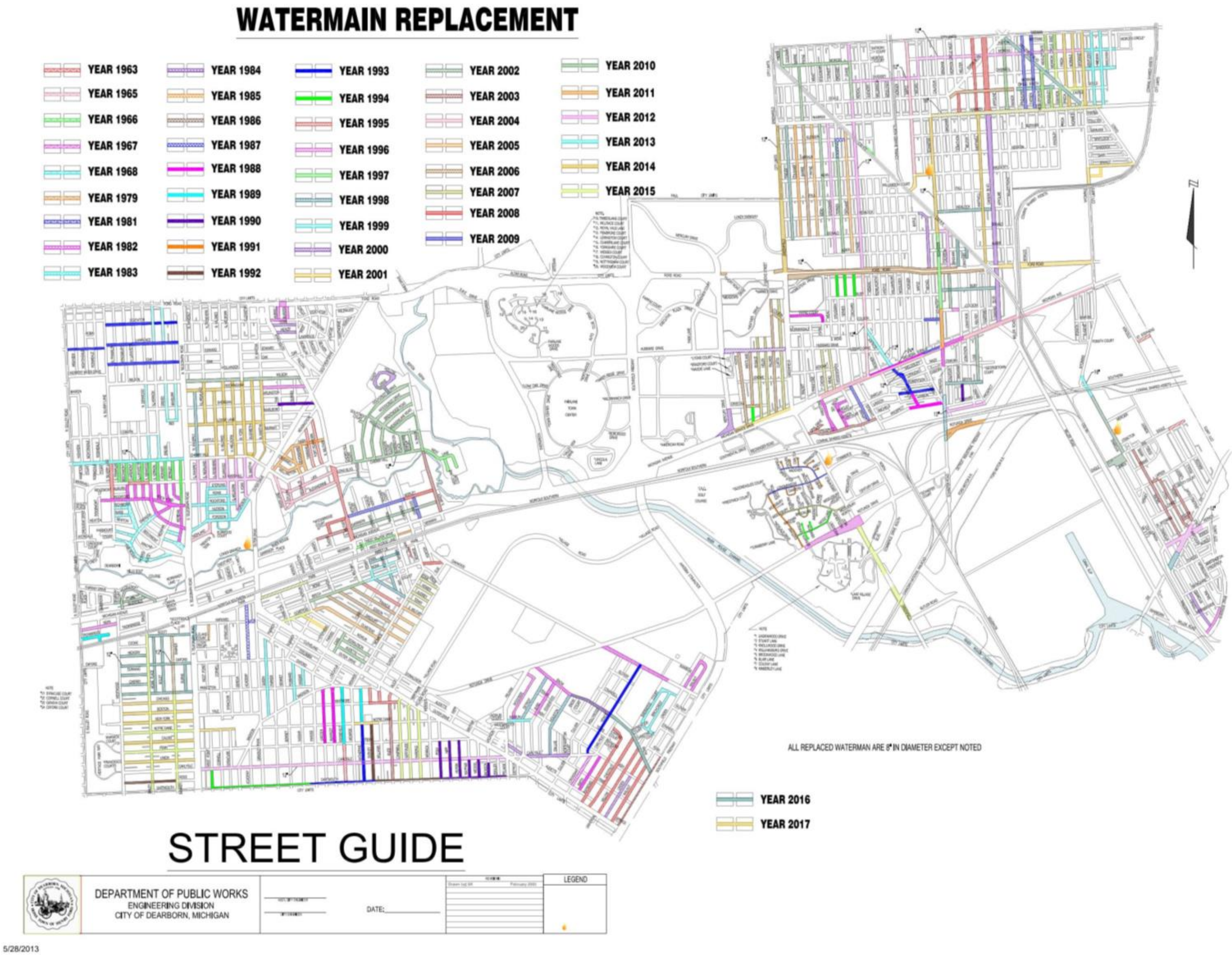
Table 8-7 Phase 2 Water Balance

	TOTAL VOLUMES ASSIGNED BY ENTITY	AVG. DAY (MGD)	MAX DAY (MGD)	PEAK HOUR (MGD)
1	WAMR / Wholesale	281	475	591
2	Dearborn	12.7	21.8	30.3
3	Detroit	90.9	111	131
4	Highland Park	2.18	2.79	2.86
5	Transmission (incl. open blow offs)	26.5	26.5	26.5
6	GLWA / CTA	40.1	42.8	
7	Adjusted System Pumpage (Total)	453	680	769

- WAMR/Wholesale (Line 1) Max Day and Peak Hour demands corresponding with GLWA system Max Day (7/31/2017) and Peak Hour (7/31/2017 5-6AM EST).
- Estimated Transmission Losses (Line 5) are consistent with Phase 1 estimated values and are assumed constant across all demand scenarios.
- GLWA/Common-To-All (Line 6) is the residual value of line 7 minus the sum of lines 1-5. This is the volume of water that has not been assigned to any other water balance item. This value is not presented for the Max Hour value as the residual is negative. Possible explanations include system pumpage is under reported at the Peak Hour, or all the peak hour components of the water balance are not coincident.
- Adjusted System Pumpage (Total) (Line 7) is the volume pumped from the five water treatment plants adjusted for changes in storage during Max Day (7/31/2017) and Peak Hour (7/31/2017 5-6AM EST). The numbers reflect a 5.8% reduction from the reported plant Pumpage as developed and applied in Phase 1.

9 Appendices

9.1 DEARBORN WATERMAIN REPLACEMENT MAP



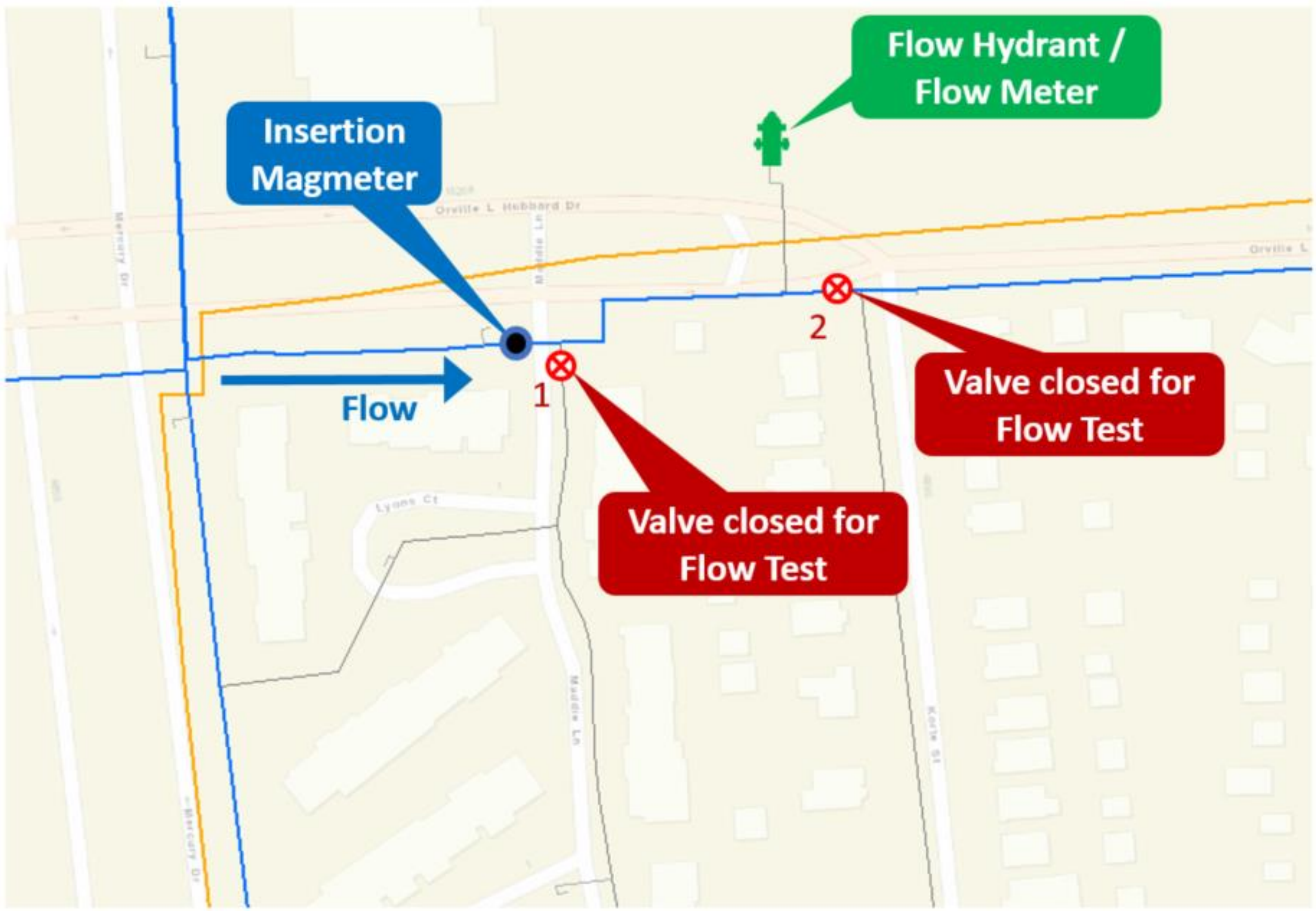
9.2 ADDITIONAL DMA GRAPHICS

The following DMAs are listed in this Appendix:

- DB1
- DB2
- DETD
- RH1X
- RL2
- NW

9.2.1 DB1 DMA

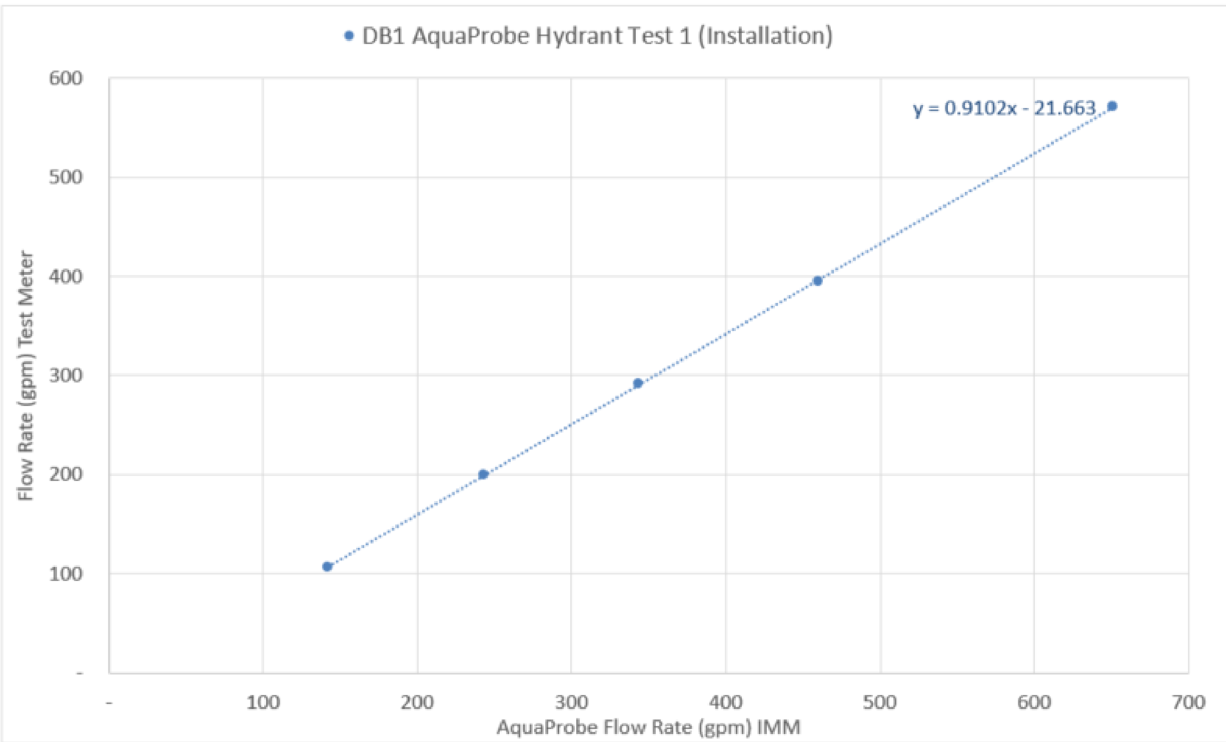
Hydrant Flow Test Configuration:



Hydrant Flow Test Results Meter 1 Install:

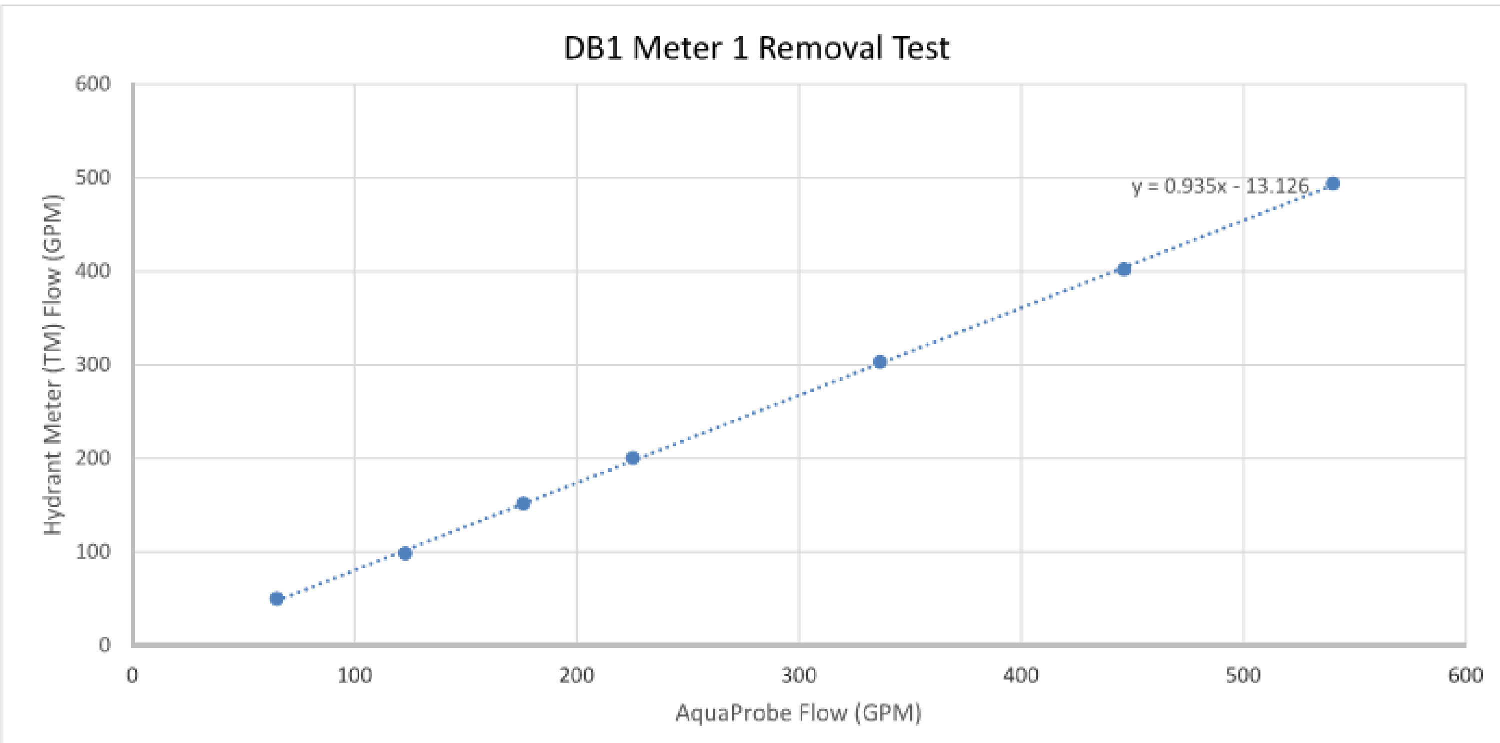
Date: 8/3/2018
Meter Number: 3K220000439959
Location: Maddie Ln & Hubbard Dr.

TEST (GPM)	IMM Gallons	SENSUS Gallons	Test Duration	IMM Flow Rate (gpm)	SENSUS Hydrant Meter Flow Rate (gpm)
100	1,182	886	8 min 20 sec	141.8	106.3
200	2,006	1,652	8 min 16 sec	242.7	199.8
300	2,815	2,398	8 min 12 sec	343.3	292.4
400	3,777	3,251	8 min 13 sec	459.7	395.7
580	5,296	4,643	8 min 8 sec	651.1	570.9



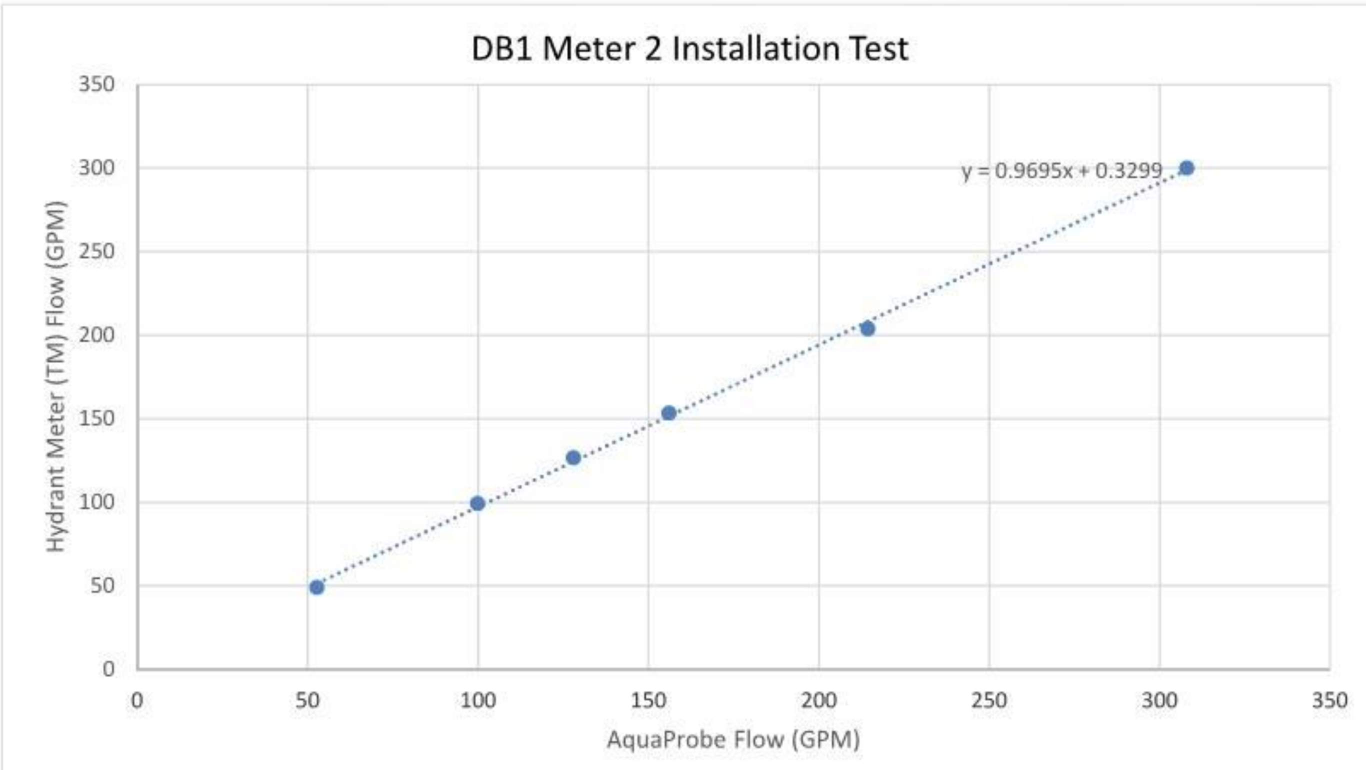
Hydrant Flow Test Results Meter 1 Removal:

DB1 Maddie Lane / Hubbard Drive (Meter 1 - Removal Test)							
Date:	9/18/2018	Time	9:30	S/N	3K220000439958		
Performed timed tests resetting both TM and AquaProbe							
Insertion Bore number used is 12.4" (315mm). Measurement from bottom of pipe 4 13/16" to center. Pf= 0.855							
Target Rate (GPM)	50	100	150	200	300	400	492 (max)
Test Time (mins)	8	8	5	5	5	5	5
IMM Observed (gallons)	521	984	880	1127	1683	2232	2702
TM Total (gallons)	399	784	756	1000	1514	2008	2467
IMM GPM	65	123	176	225	337	446	540
TM GPM	50	98	151	200	303	402	493



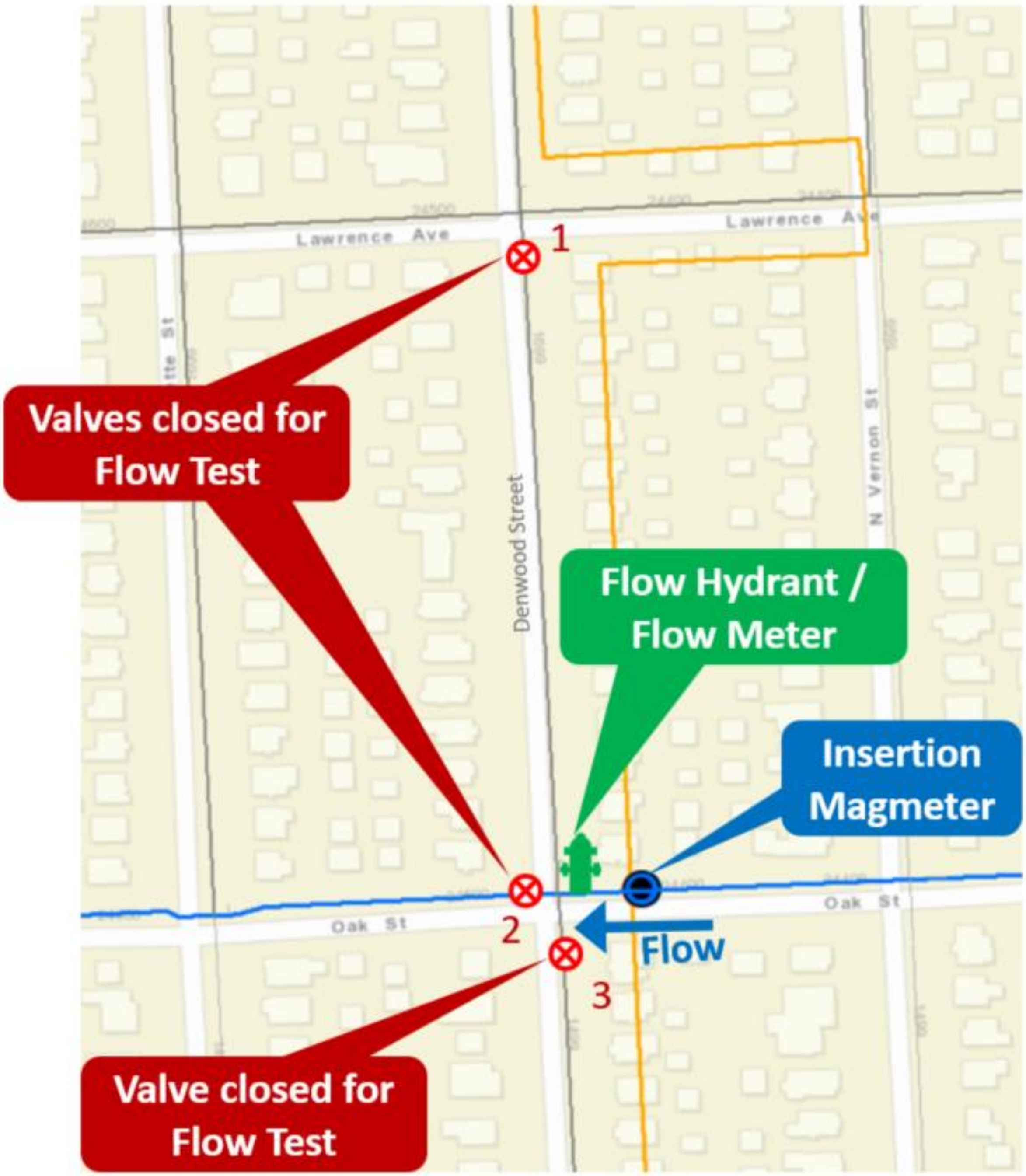
Hydrant Flow Test Results Meter 2 Installation:

DB1 Maddie Lane / Hubbard Drive (Meter 2 - Installation Test)						
Date:	9/18/2018	Time	14:30	S/N	3K220000439959	
Performed timed tests resetting both TM and AquaProbe						
Insertion Bore number used is 12.4" (315mm). Measurement from bottom of pipe 4 13/16" to center. Pf= 0.81						
Target Rate (GPM)	50	100	125	150	200	300
Test Time (mins)	8	8	5	5	5	5
IMM Observed (gallons)	422	799	640	780	1072	1540
TM Total (gallons)	391	793	633	767	1019	1500
IMM GPM	53	100	128	156	214	308
TM GPM	49	99	127	153	204	300



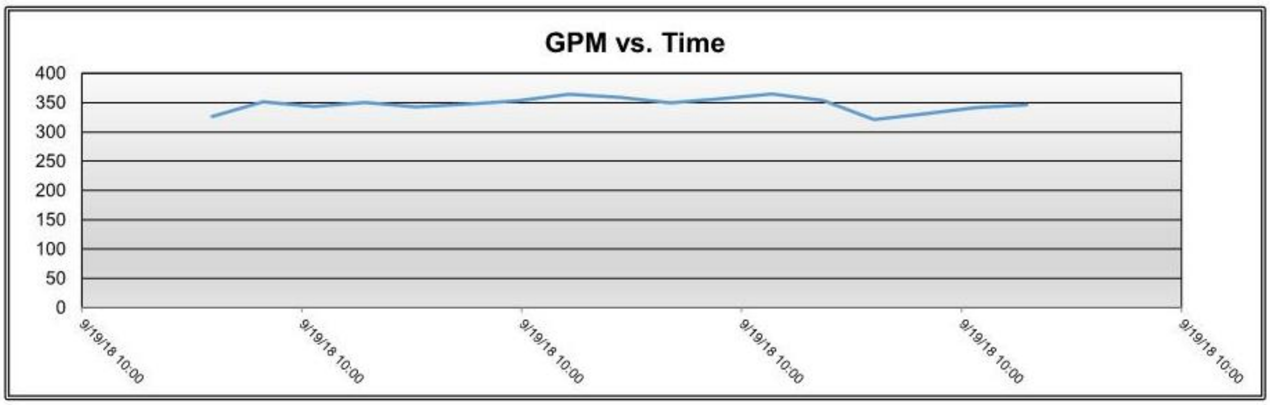
9.2.2 DB2 DMA

Hydrant Flow Test Configuration:



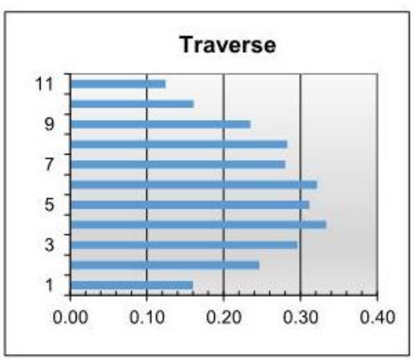
M.E. Simpson Company, Inc. - Polcon® Pitot Testing

Client:	Black &Veatch - GLWA			Emerg. Phone #:	911		
Contact Person:	David Sayers	Title:	Engineer			Phone:	(609)947-4161
Test Supervisor:	Asher Budka	Title:	Project Manager			Phone:	(219)405-2364
Account Name:	DB2 IMM Denwood and Oak Site Profie and Flow Check						
Building Name:	N/A			Address:	Denwood and Oak Dearborn,MI		
Meter Location:							
Confined Space:		O^2 Level:		Gas Present:		OK to Enter:	
Fall Protection?:		Pumped Vault?:				Ventilation Required?:	
Test Date:	9/19/2018	Time:	10:00:40 AM	Technicians:	Blake Winland	Supervisor:	Asher Budka
Meter Brand:		Type:		S/N:		Model:	
Size:		Meter Coeff:		Venturi Coeff:		Meter Range:	
Sensor 1 Brand:	N/A	Sensor Scaling:		S/N:		Model:	
Sensor 2 Brand:	N/A	Sensor Scaling:		S/N:		Model:	
Location:							
Confined Space:		O^2 Level:		Gas Present:		OK to Enter:	
Tap Location:	12" Gate Valve Vault in Sidewalk NE corner			Address:	Same as meter		
Confined Space:	Yes	O^2 Level:	20.9%	Gas Present:	None	OK to Enter:	Yes
Fall Protection?:	No	Pumped Vault?:	No			Ventilation Required?:	No
Corp Size:	1.00 in	Pipe Material:	Cast Iron	Nom. Diameter:	12 in	Measured Diameter:	12 in
Corp Adaptors:	None	Dir. of Flow:	West			Area Tested:	.767 sq.ft
Rod Length:	4.0 ft	Recorder #:	20155108	File Name:	DB2.Profile.091918		



Pipe Factor: **0.877**

Test Start Time: 9/19/18 10:00
Test End Time: 9/19/18 10:00



Metered Volume:	**99**	Gallons
Flow Rate:	**350**	GPM
	0.50	MGD

Pitot Volume:	**98**	Gallons
Flow Rate:	**347**	GPM
	0.50	MGD
	0.98	ft/s

METER READINGS

9.2.3 DETD DMA

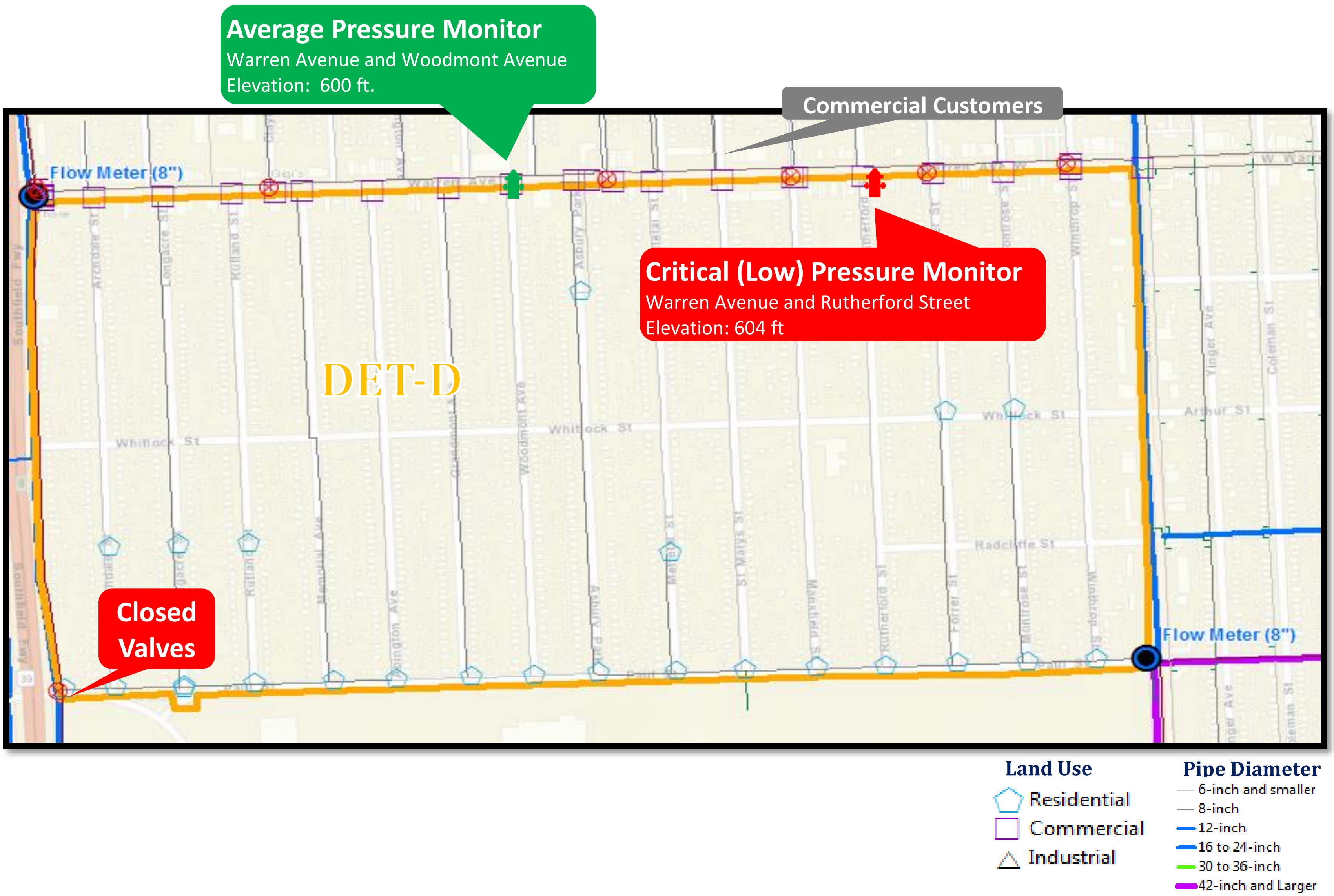


Figure 9-1 DET-D Overview

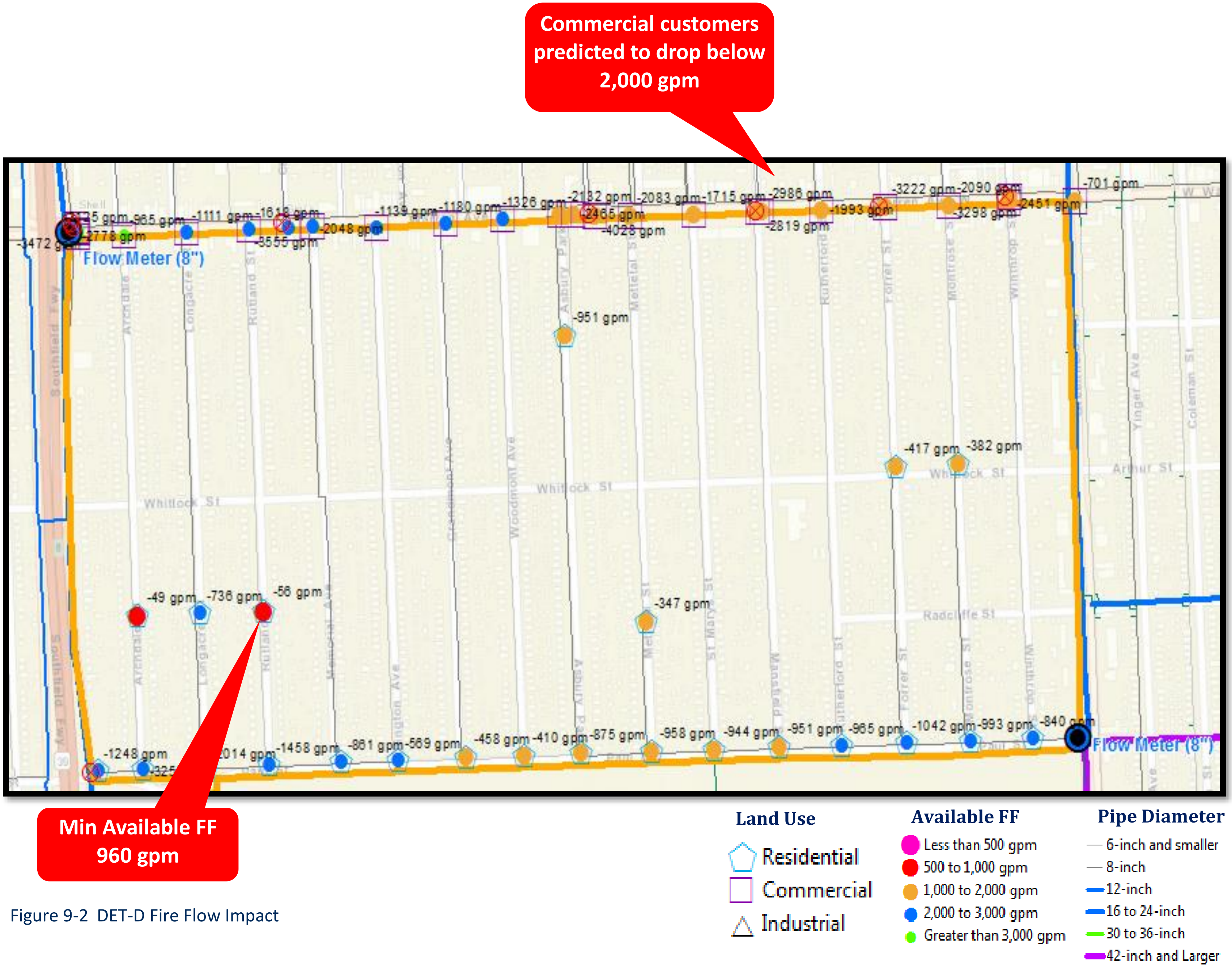


Figure 9-2 DET-D Fire Flow Impact

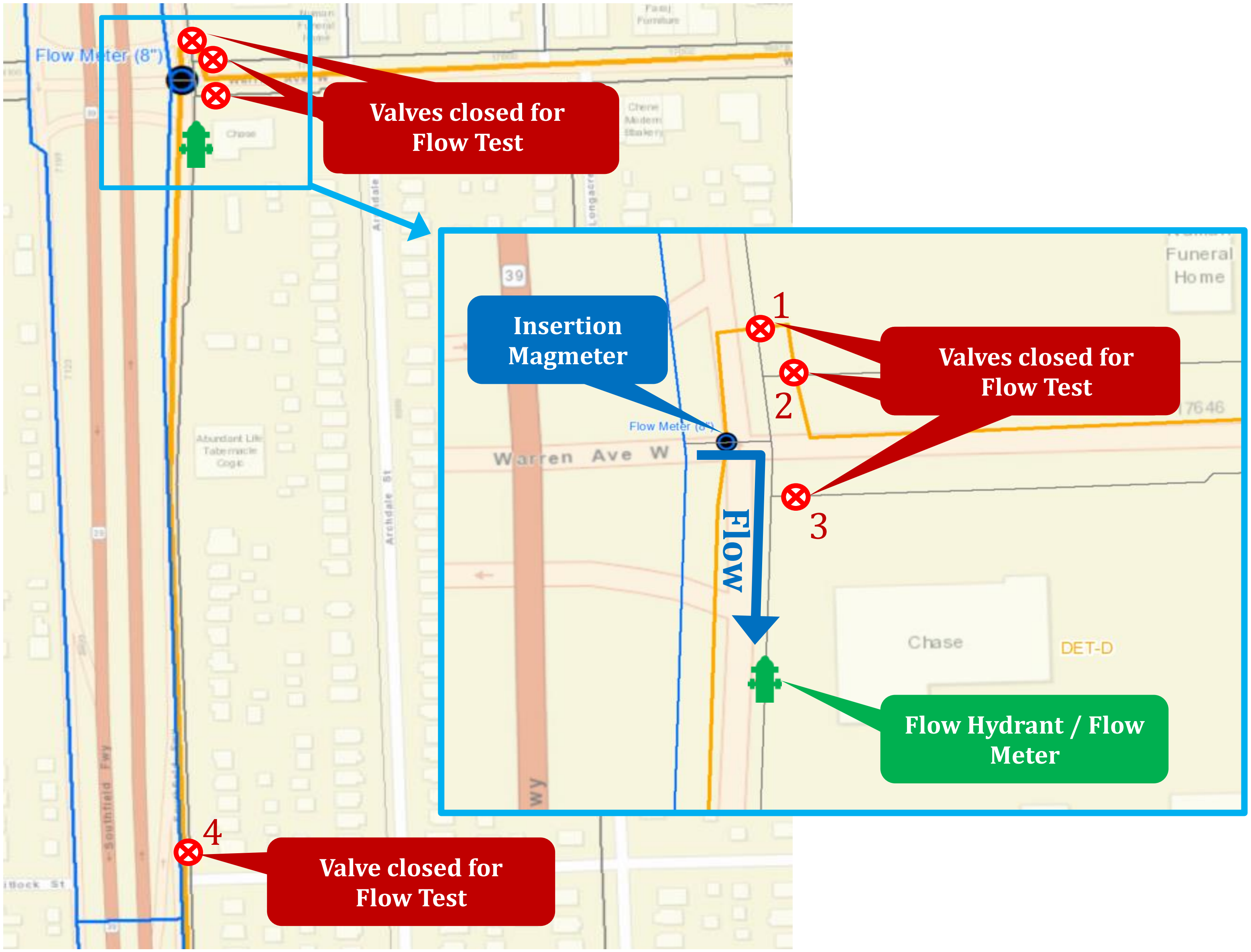


Figure 9-3 In-Situ Flow Test on Warren Ave. West Meter

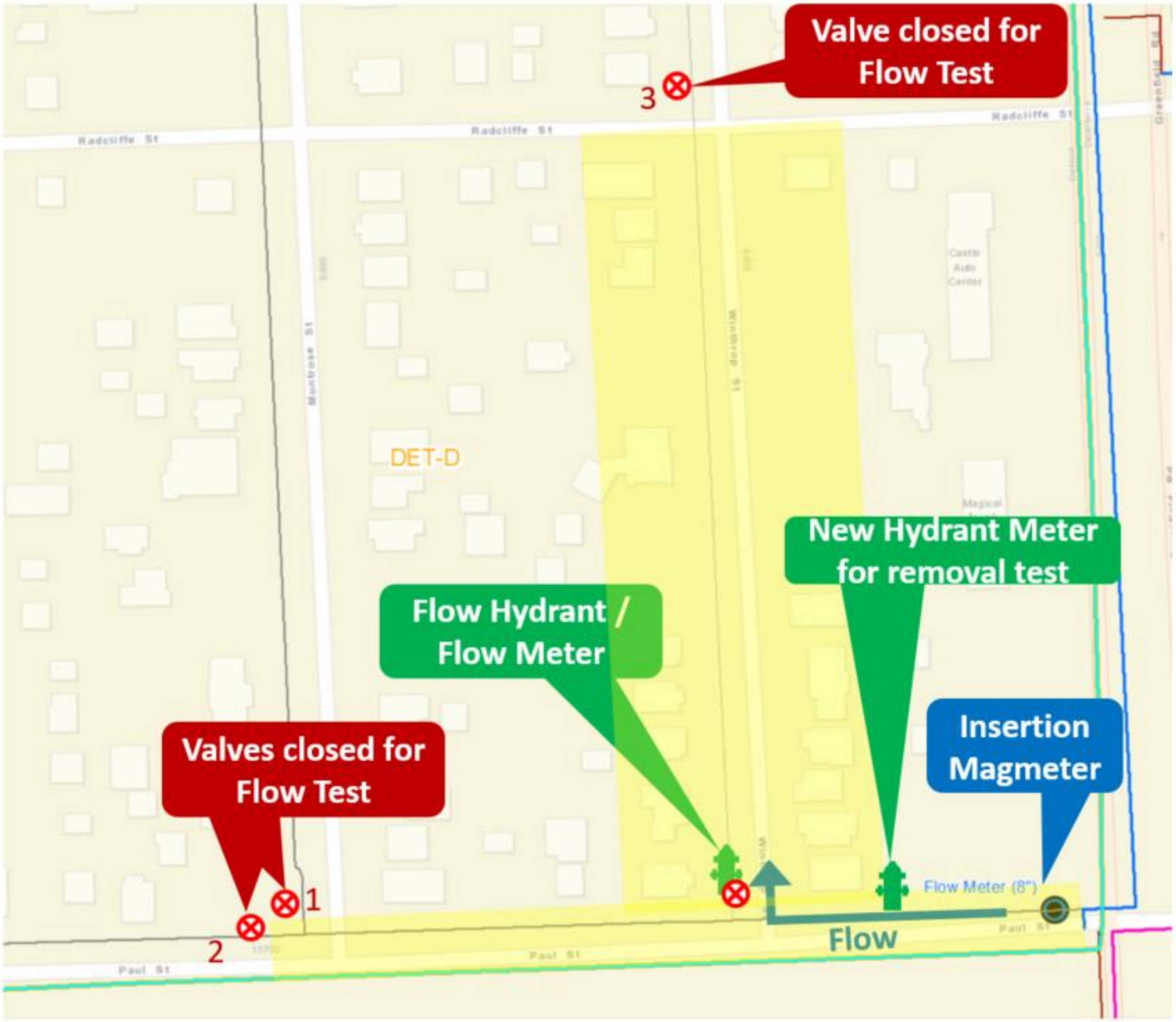
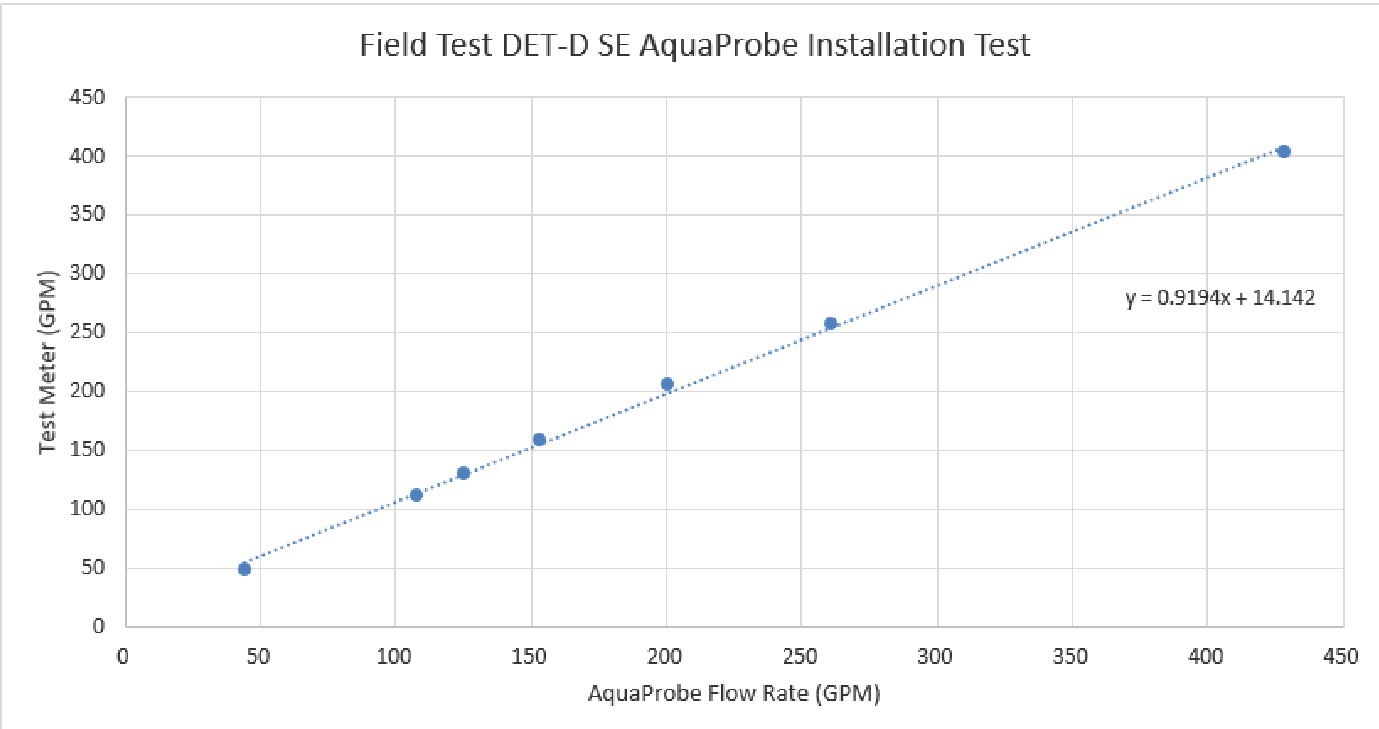


Figure 9-4 In-Situ Flow Test on Paul St. Meter

DET-D IMM SE Site (Greenfield Rd and Paul Ave)							
Date:	9/25/2018	Time	13:00	S/N	3K220000487698		
Performed 10 min time test @ resetting both Test Meter and AquaProbe							
Insertion Bore number used is 7 9/16" (192.088mm). Measurement from bottom of pipe 2 10/16" to center. Pf= 0.83. Ins.Factor=1.06720							
Target Rate (gpm)	50	100	125	150	200	250	400
Test Time (mins)	10	10	10	10	10	10	10
Estimated Cust. Usage gpm	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Cust. Usage (total gallons for test)	12	12	12	12	12	12	12
IMM Total Gallons Observed	456	1090	1263	1545	2021	2620	4297
IMM Total Gallons (minus cust. usage)	444	1078	1251	1533	2009	2608	4285
TM Total Gallons	485	1110	1300	1588	2049	2570	4030
IMM (gpm)	44	108	125	153	201	261	428
TM (gpm)	49	111	130	159	205	257	403



M.E. Simpson Company, Inc. - Polcon® Pitot Testing

Client: Black &Veatch - GLWA | **Emerg. Phone #:** 911

Contact Person: David Sayers | **Title:** Engineer | **Phone:** (609)947-4161

Test Supervisor: Asher Budka | **Title:** Project Manager | **Phone:** (219)405-2364

Account Name: DET-D IMM NW Site Profie and Flow Check

Building Name: N/A | **Address:** East side of Southfield Fwy and Warren Ave

Meter Location: 4" Sensus TM @ 2nd Hyd south of Intersection on Southfield Fwy Frontage Rd

Confined Space: No | **O^2 Level:** N/A | **Gas Present:** N/A | **OK to Enter:** N/A

Fall Protection?: N/A | **Pumped Vault?:** N/A | **Ventilation Required?:** N/A

Test Date: 9/27/2018 | **Time:** 11:29:20 AM | **Technicians:** Blake Winland | **Supervisor:** Asher Budka

Meter Brand: | **Type:** | **S/N:** | **Model:**

Size: | **Meter Coeff:** | **Venturi Coeff:** | **Meter Range:**

Sensor 1 Brand: N/A | **Sensor Scaling:** | **S/N:** | **Model:**

Sensor 2 Brand: N/A | **Sensor Scaling:** | **S/N:** | **Model:**

Location:

Confined Space: | **O^2 Level:** | **Gas Present:** | **OK to Enter:**

Tap Location: In 8" Gate Valve Vault in Center of Intersection | **Address:** East side Southfield Fwy and Warren Ave

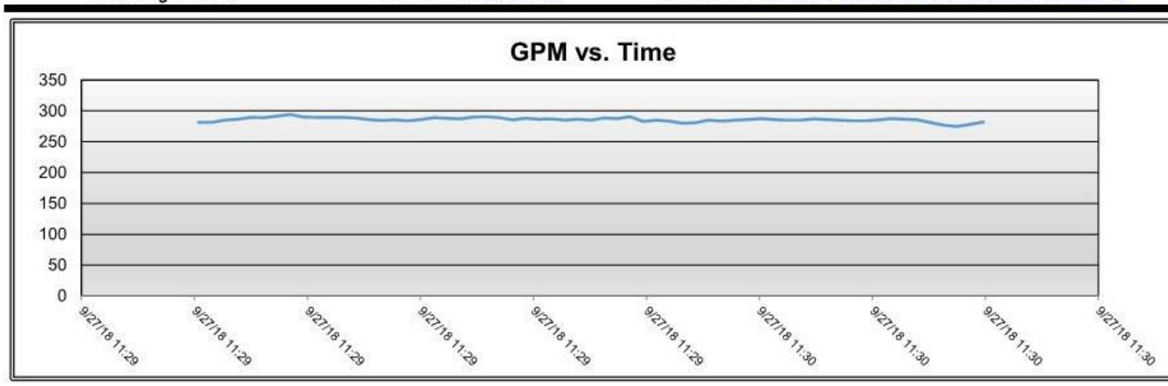
Confined Space: Yes | **O^2 Level:** 20.9% | **Gas Present:** No | **OK to Enter:** Yes

Fall Protection?: Yes | **Pumped Vault?:** Yes | **Ventilation Required?:** No

Corp Size: 1.00 in | **Pipe Material:** Cast Iron | **Nom. Diameter:** 8 in | **Measured Diameter:** 7 8/16 in

Corp Adaptors: None | **Dir. of Flow:** East | **Area Tested:** .295 sq.ft

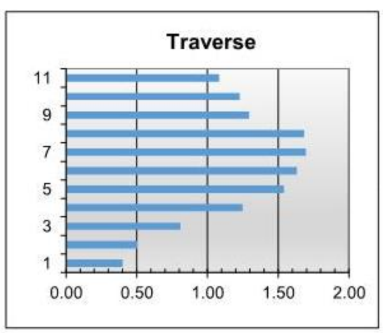
Rod Length: 4.0 ft | **Recorder #:** 20155108 | **File Name:** Profile.DET-D.Warren.Southfield.IMM.NW.092718



Pipe Factor: **0.839**

Test Start Time: 9/27/18 11:29

Test End Time: 9/27/18 11:30



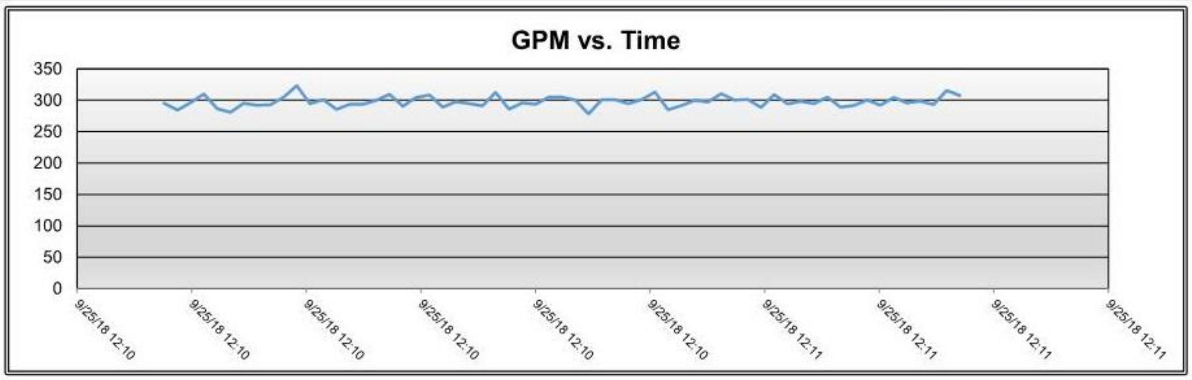
Metered Volume:	**293**	Gallons
Flow Rate:	**288**	GPM
	0.41	MGD

Pitot Volume:	**291**	Gallons
Flow Rate:	**286**	GPM
	0.41	MGD
	2.07	ft/s

METER READINGS

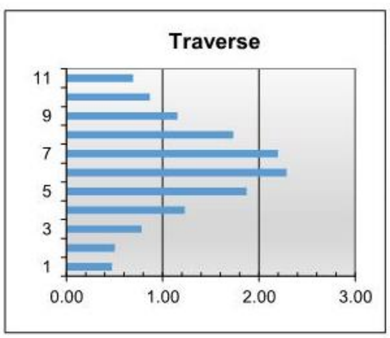
M.E. Simpson Company, Inc. - Polcon® Pitot Testing

Client:	Black &Veatch - GLWA			**Emerg. Phone #:**	911		
Contact Person:	David Sayers	**Title:**	Engineer			**Phone:**	(609)947-4161
Test Supervisor:	Asher Budka	**Title:**	Project Manager			**Phone:**	(219)405-2364
Account Name:	DET-D IMM SE Site Profie and Flow Check						
Building Name:	-----			**Address:**	Greenfield Rd and Paul Ave		
Meter Location:	8" Gate Valve Vault NW corner of Greenfield Rd and Paul Ave						
Confined Space:	Yes	**O^2 Level:**	20.9%	**Gas Present:**	No	**OK to Enter:**	Yes
Fall Protection?:	Yes	**Pumped Vault?:**	Yes			**Ventilation Required?:**	No
Test Date:	9/25/2018	**Time:**	12:10:20 PM	**Technicians:**	Blake Winland	**Supervisor:**	Asher Budka
Meter Brand:		**Type:**		**S/N:**		**Model:**	
Size:		**Meter Coeff:**		**Venturi Coeff:**		**Meter Range:**	
Sensor 1 Brand:	N/A	**Sensor Scaling:**		**S/N:**		**Model:**	
Sensor 2 Brand:	N/A	**Sensor Scaling:**		**S/N:**		**Model:**	
Location:							
Confined Space:		**O^2 Level:**		**Gas Present:**		**OK to Enter:**	
Tap Location:	In 8" Gate Valve Vault			**Address:**	Same as meter		
Confined Space:	Yes	**O^2 Level:**	20.9%	**Gas Present:**	No	**OK to Enter:**	Yes
Fall Protection?:	Yes	**Pumped Vault?:**	Yes			**Ventilation Required?:**	No
Corp Size:	1'	**Pipe Material:**	Cast Iron	**Nom. Diameter:**	8 in	**Measured Diameter:**	7 9/16 in
Corp Adaptors:	None	**Dir. of Flow:**	West			**Area Tested:**	.3 sq.ft
Rod Length:	4'	**Recorder #:**	20155108	**File Name:**	DET-D.IMM.SE.GreenfieldRd.PaulAve.092518		



Pipe Factor: **0.714**

Test Start Time: 9/25/18 12:10
Test End Time: 9/25/18 12:11



Metered Volume:	310	Gallons
Flow Rate:	305	GPM
	0.44	MGD

Pitot Volume:	303	Gallons
Flow Rate:	298	GPM
	0.43	MGD
	2.13	ft/s

METER READINGS

9.2.4 RH1-X DMA

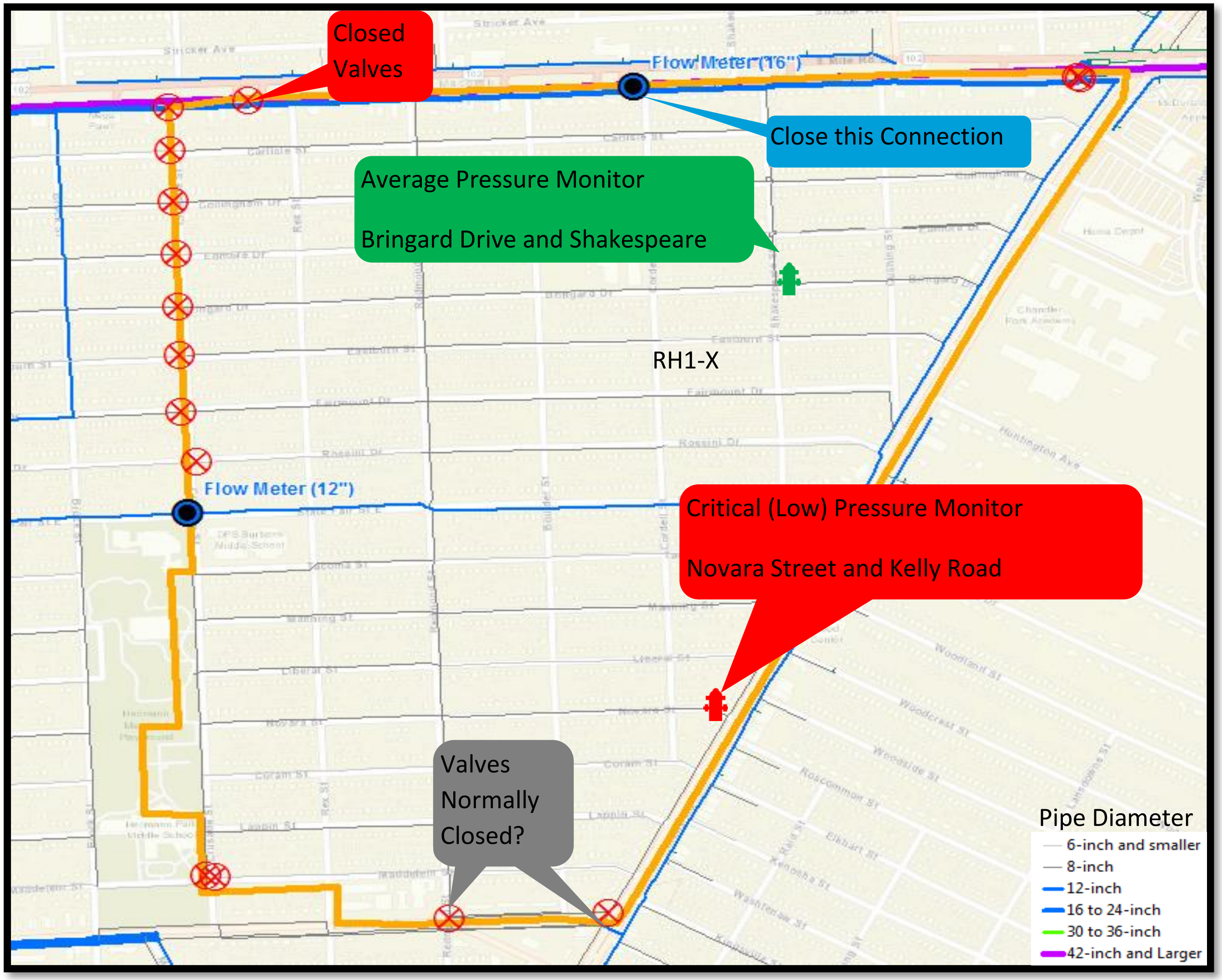


Figure 9-5 RH1-X Overview

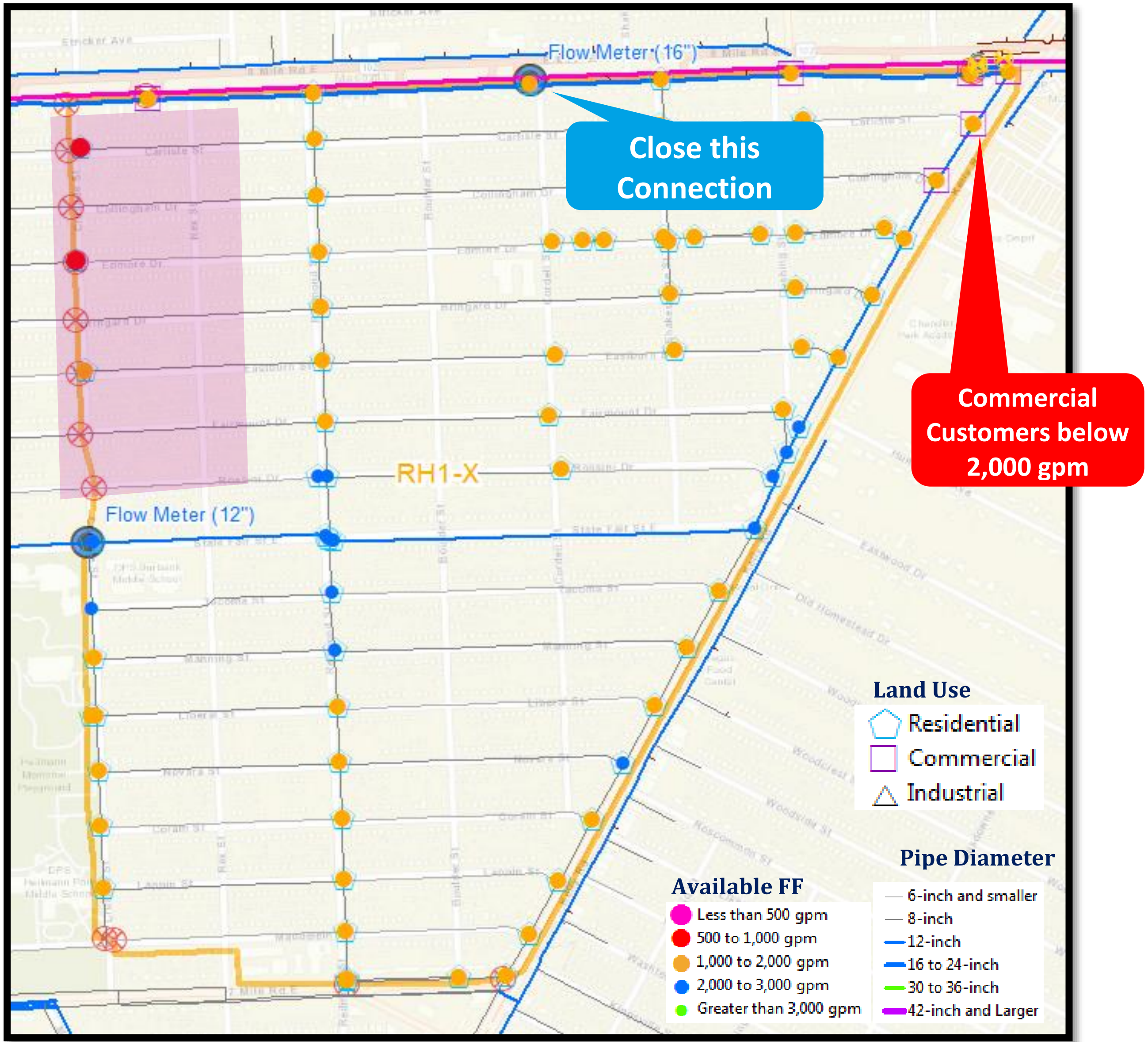


Figure 9-6 RH1-X Fire Flow Planning (One Input Scenario)

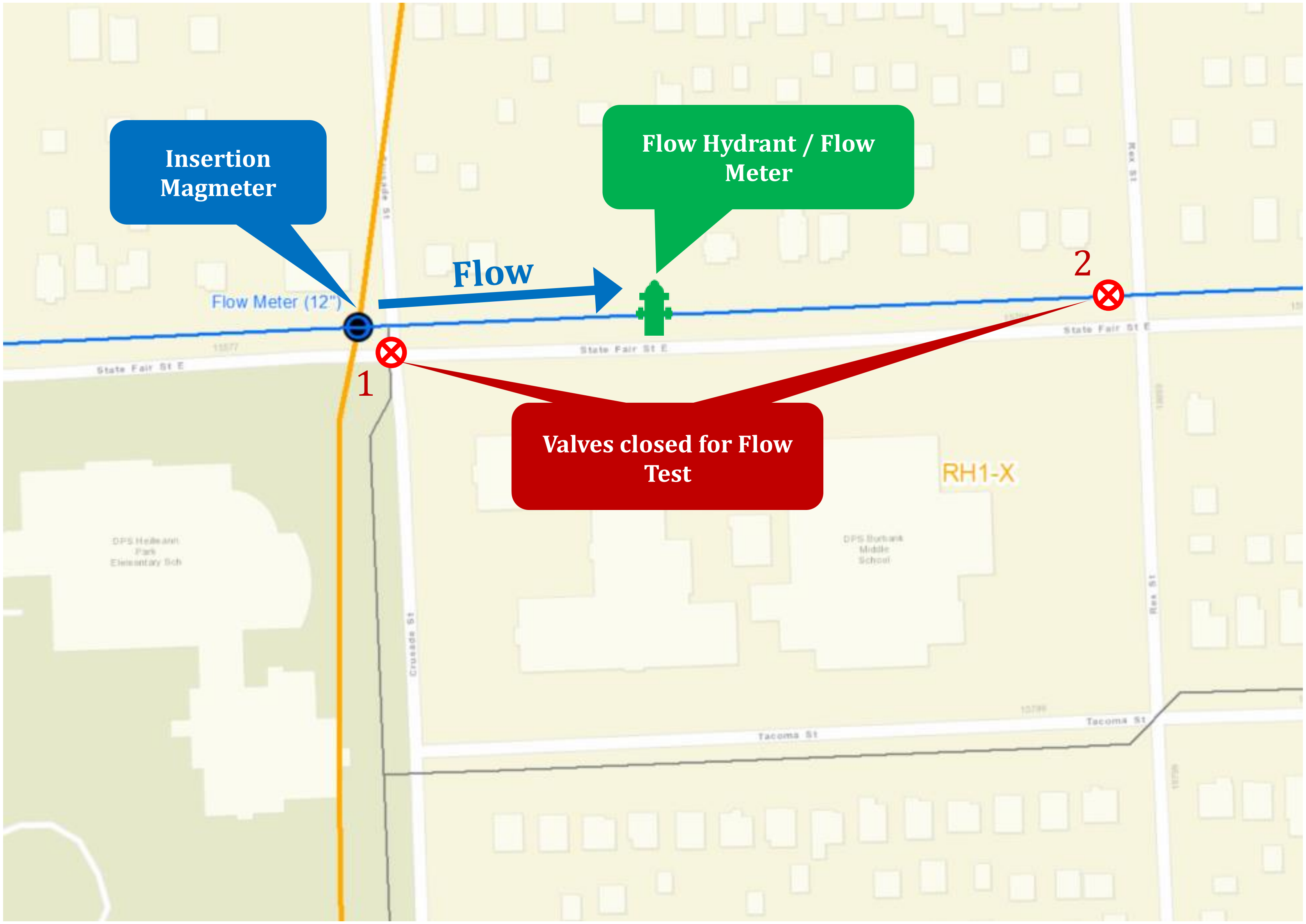
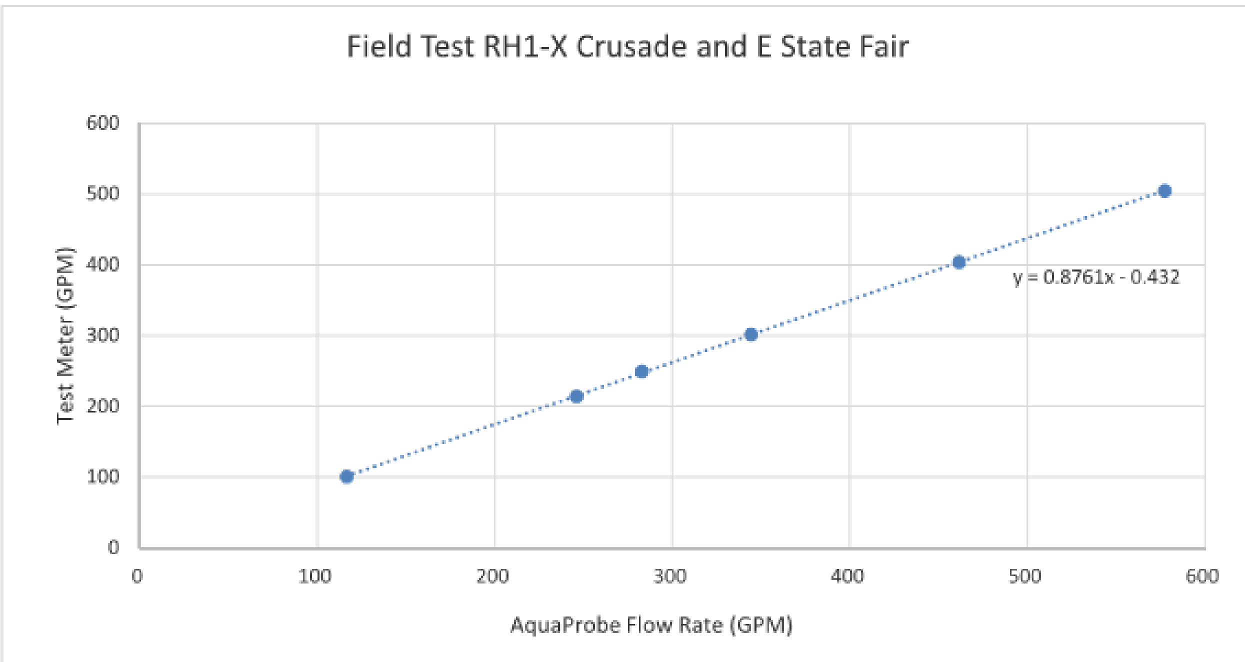


Figure 9-7 In-Situ Flow Test on State Fair St. E Meter

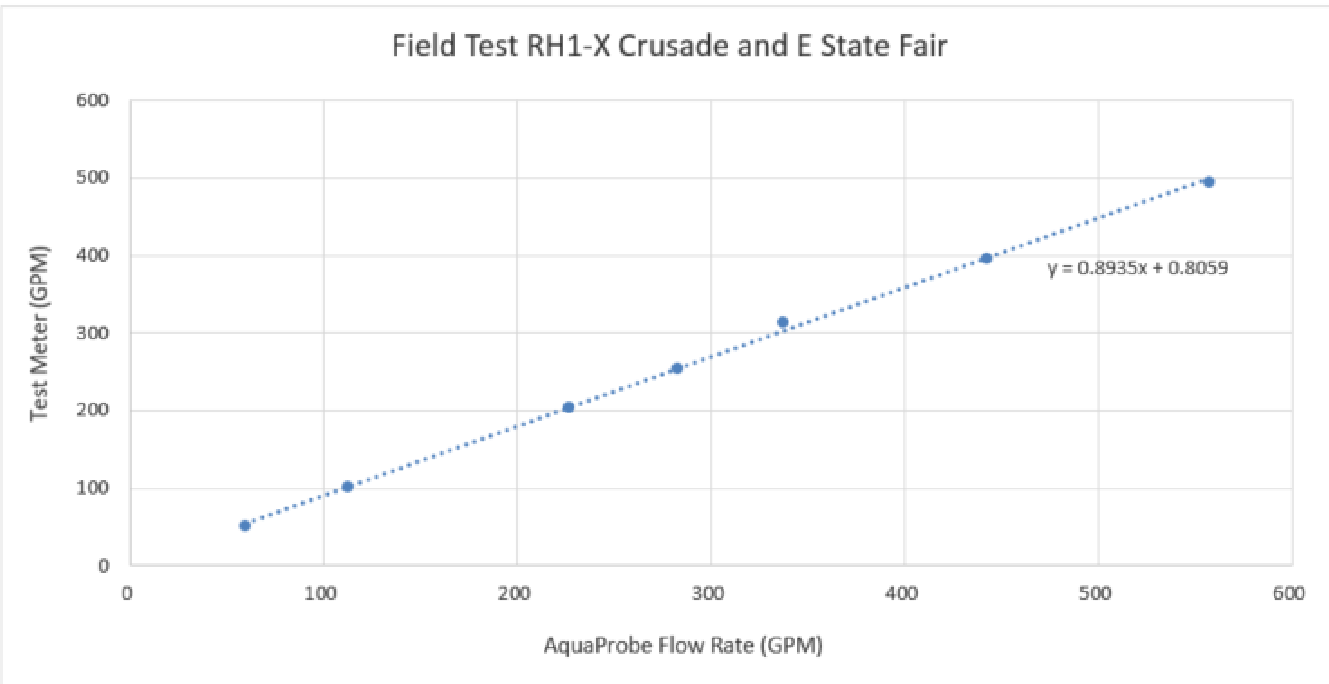
Hydrant Flow Test Results (Install Test)

RH1X-Detroit- Crusade and E State Fair						
Date:	10/24/2018	Time	9:30	S/N	3K220000487695	
Performed 10 min time test @ resetting both TM and AquaProbe						
Insertion Bore number used is 11 8/16" (292.10 mm). Measurement from bottom of pipe 4 9/16" to center. Pf= 0.8540. Ins.Factor=1.04320						
Target Rate (gpm)	100	200	250	300	400	500
Test Time (mins)	10	10	10	10	10	10
Estimated Cust. Usage (gpm)	0.8	0.8	0.8	0.8	0.8	0.8
IMM Total Gallons Observed	1,173	2,468	2,836	3,450	4,622	5,781
IMM Total Gallons (minus usage)	1,165	2,460	2,828	3,442	4,614	5,773
TM Total Gallons	1,009	2,140	2,494	3,016	4,038	5,047
IMM (gpm)	117	246	283	344	461	577
TM (gpm)	101	214	249	302	404	505



Hydrant Flow Test Results (Removal Test)

RH1X-Detroit- Crusade and E State Fair							
Date:		11/14/2018	Time	11:30	S/N	3K220000487695	
Performed 10 min time test @ resetting both TM and AquaProbe							
Insertion Bore number used is 11 8/16" (292.10 mm). Measurement from bottom of pipe 4 9/16" to center. Pf= 0.8540. Ins.Factor=1.04320							
Target Rate (gpm)	50	100	200	250	300	400	500
Test Time (mins)	10	10	10	10	10	10	10
Estimated Cust. Usage (gpm)	0.8	0.8	0.8	0.8	0.8	0.8	0.8
IMM Total Gallons Observed	605	1,140	2,282	2,843	3,384	4,435	5,586
IMM Total Gallons (minus usage)	597	1,132	2,274	2,835	3,376	4,427	5,578
TM Total Gallons	514	1,008	2,032	2,537	3,129	3,962	4,941
IMM (gpm)	60	113	227	284	338	443	558
TM (gpm)	51	101	203	254	313	396	494



9.2.5 RL2 DMA

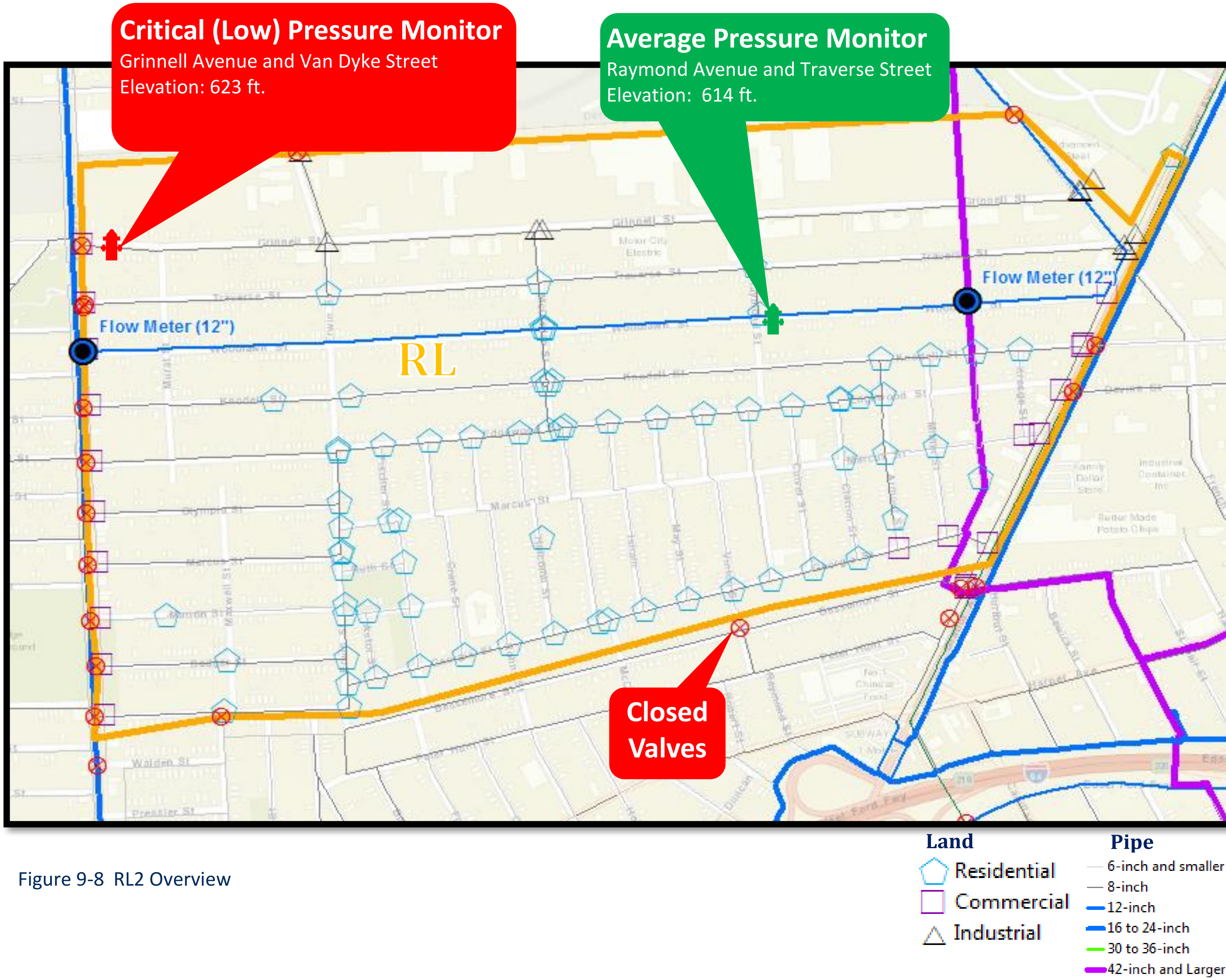


Figure 9-8 RL2 Overview

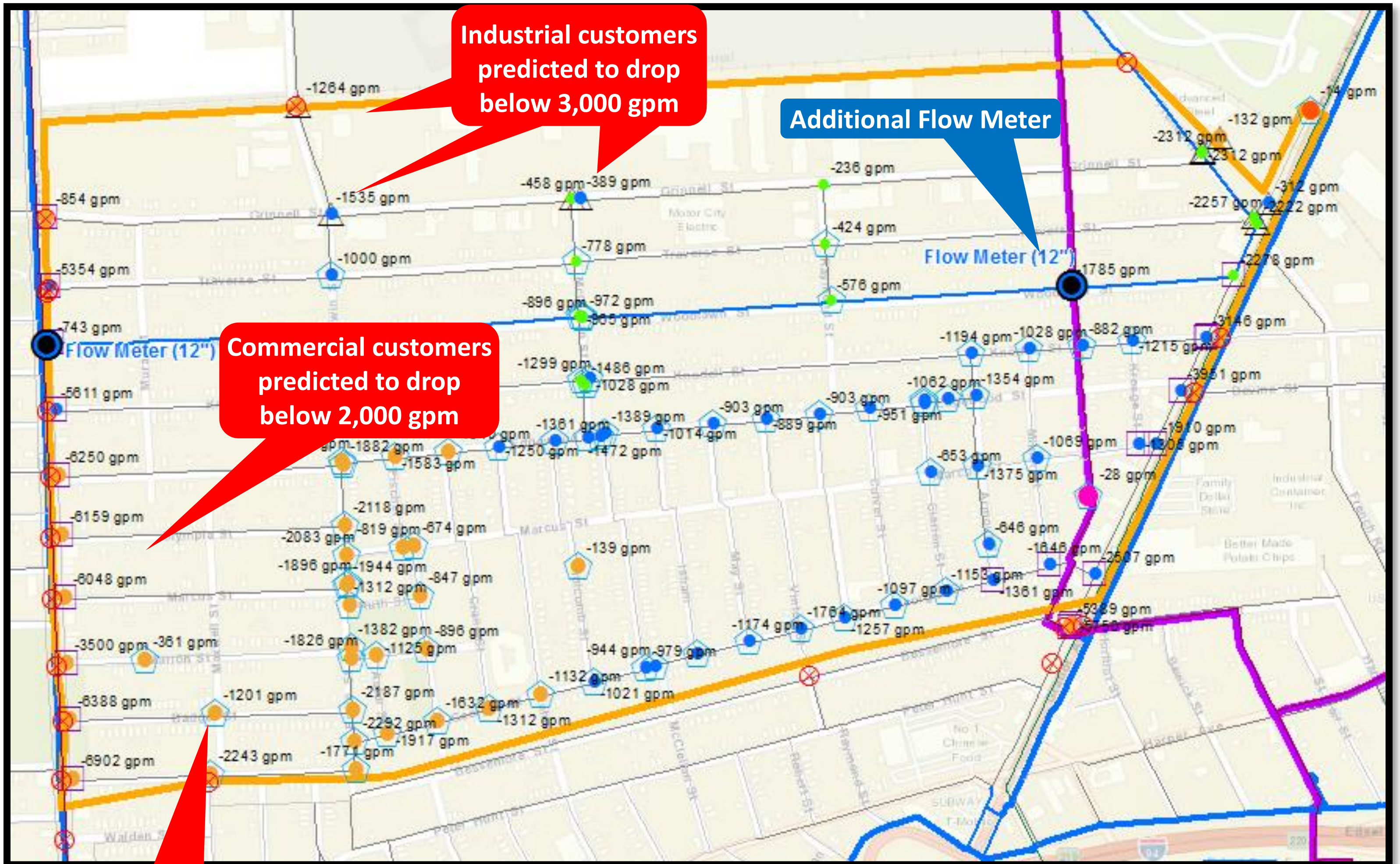


Figure 9-9 RL2 Fire Flow Impacts (Two Input Scenario)

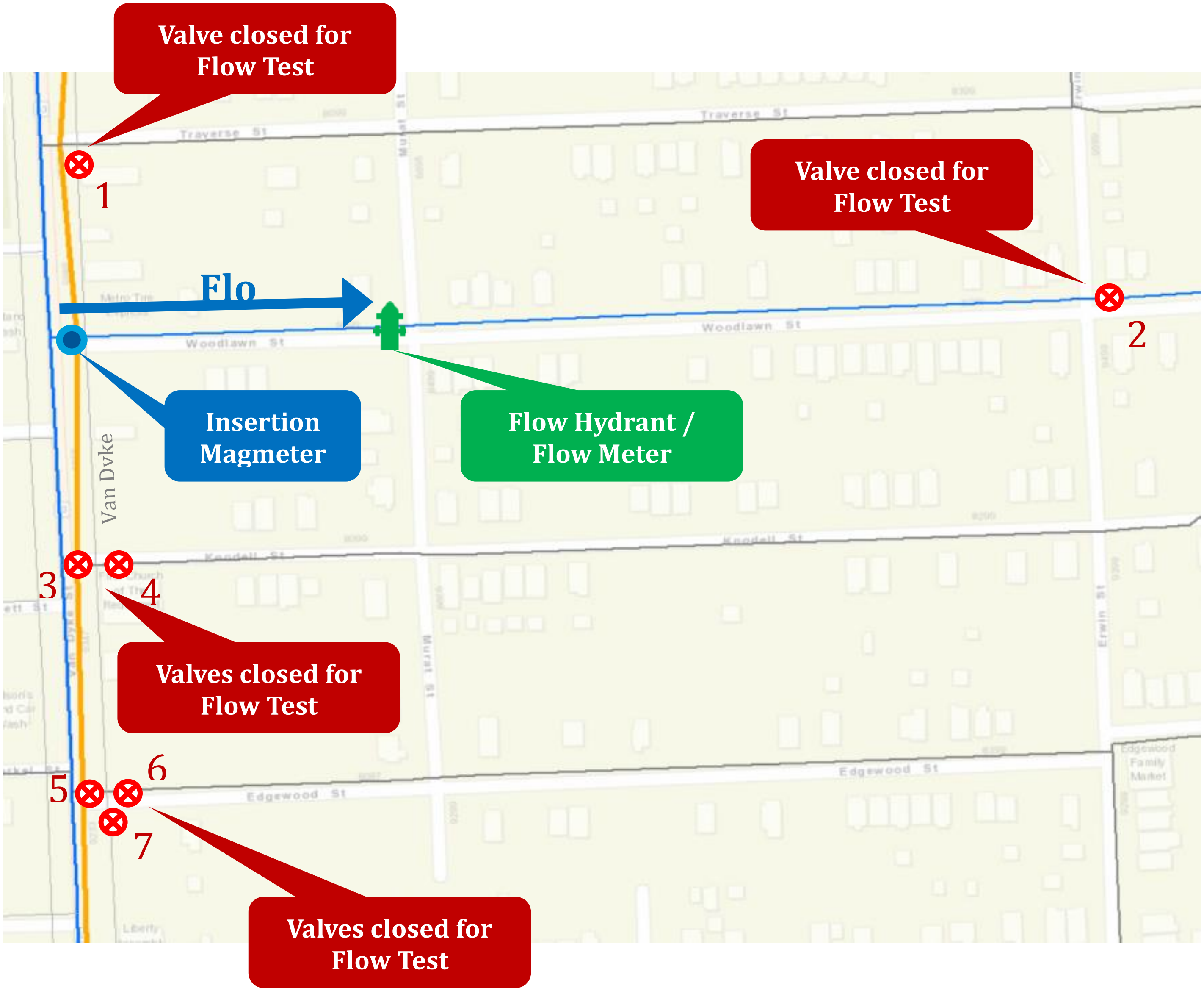
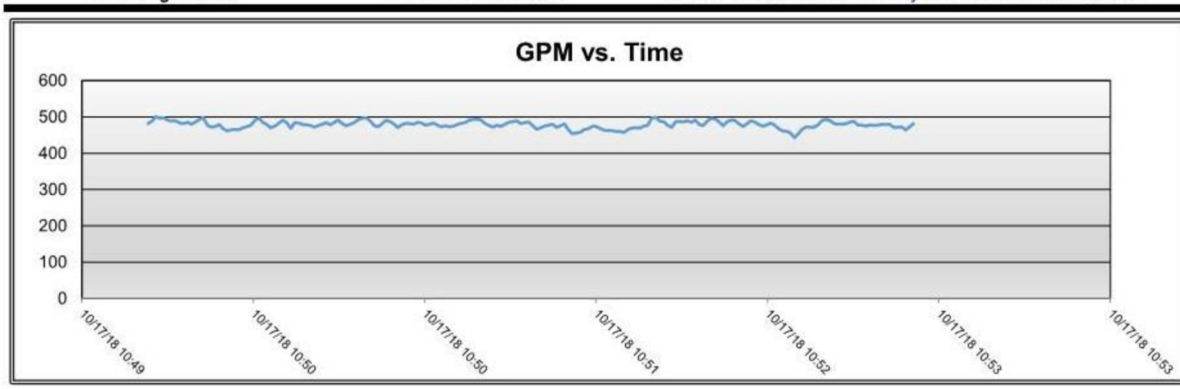


Figure 9-10 In-Situ Flow Test on Woodlawn St. (RL-2 DMA)

Figure 9-11 In-Situ Flow Test on French Rd. Meter (RL-2 DMA)

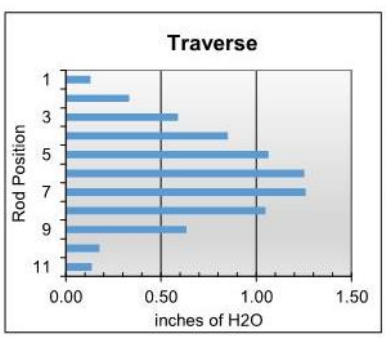
M.E. Simpson Company, Inc. - Polcon® Pitot Testing

Client: Black &Veatch - GLWA		**Emerg. Phone #:** 911	
Contact Person: David Sayers	**Title:** Engineer	**Phone:** (609)947-4161	
Test Supervisor: Asher Budka	**Title:** Project Manager	**Phone:** (219)405-2364	
Account Name: RL2 Van Dyke and Woodlawn 12"			
Building Name:		**Address:** Van Dyke St and Woodlawn St	
Meter Location: 4" Sensus TM @ Hydrant east of Crusade St and E State Fair St			
Confined Space: No	**O^2 Level:** N/A	**Gas Present:** N/A	**OK to Enter:** N/A
Fall Protection?: N/A	**Pumped Vault?:** N/A		**Ventilation Required?:** N/A
Test Date: 10/17/2018	**Time:** 10:49:43 AM	**Technicians:** Blake Winland	**Supervisor:** Asher Budka
Meter Brand:	**Type:**	**S/N:**	**Model:**
Size:	**Meter Coeff:**	**Venturi Coeff:**	**Meter Range:**
Sensor 1 Brand: N/A	**Sensor Scaling:**	**S/N:**	**Model:**
Sensor 2 Brand: N/A	**Sensor Scaling:**	**S/N:**	**Model:**
Location:			
Confined Space:	**O^2 Level:**	**Gas Present:**	**OK to Enter:**
Tap Location: 12" Gate Valve Vault in St NE corner		**Address:** Van Dyke St and Woodlawn St	
Confined Space: Yes	**O^2 Level:** 20.9%	**Gas Present:** No	**OK to Enter:** Yes
Fall Protection?: Yes	**Pumped Vault?:** Yes		**Ventilation Required?:** No
Corp Size: 1.00 in	**Pipe Material:** Cast Iron	**Nom. Diameter:** 12 in	**Measured Diameter:** 11 4/16 in
Corp Adaptors: 0	**Dir. of Flow:** East		**Area Tested:** .673 sq.ft
Rod Length: 3.0 ft	**Recorder #:** 20113511	**File Name:** RL2.IMM.12in.VanDyke.Woodlawn.Profile.101718	



Pipe Factor: **0.697**

Test Start Time: 10/17/18 10:49
Test End Time: 10/17/18 10:52



Metered Volume:	1,001	Gallons
Flow Rate:	309	GPM
	0.45	MGD

Pitot Volume:	1,549	Gallons
Flow Rate:	479	GPM
	0.69	MGD
	1.54	ft/s

METER READINGS

0	Gal
0	

9.2.6 NW DMA

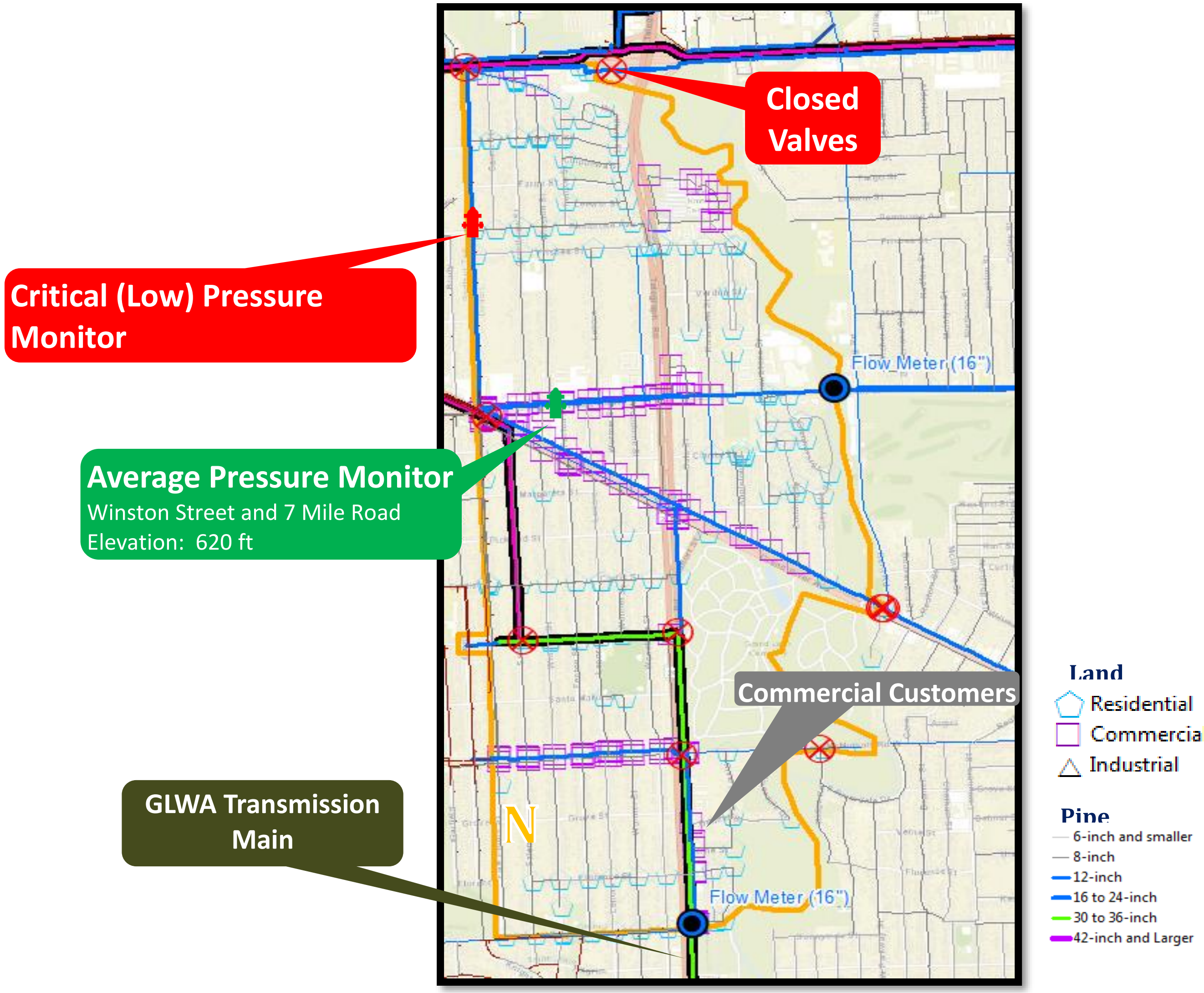


Figure 9-12 NW Overview

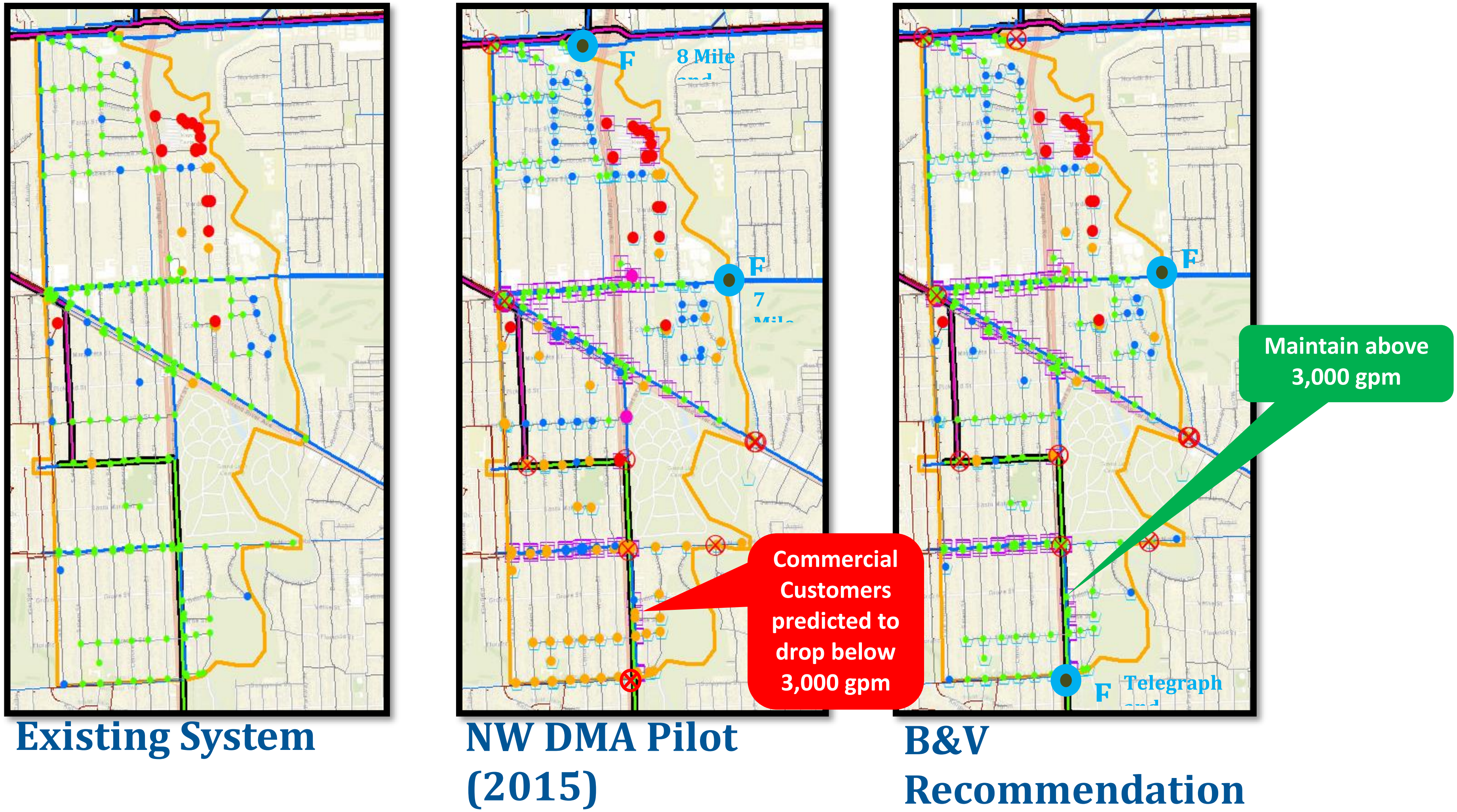


Figure 9-13 NW Flow Meter Location Analysis (Available FF Comparison)

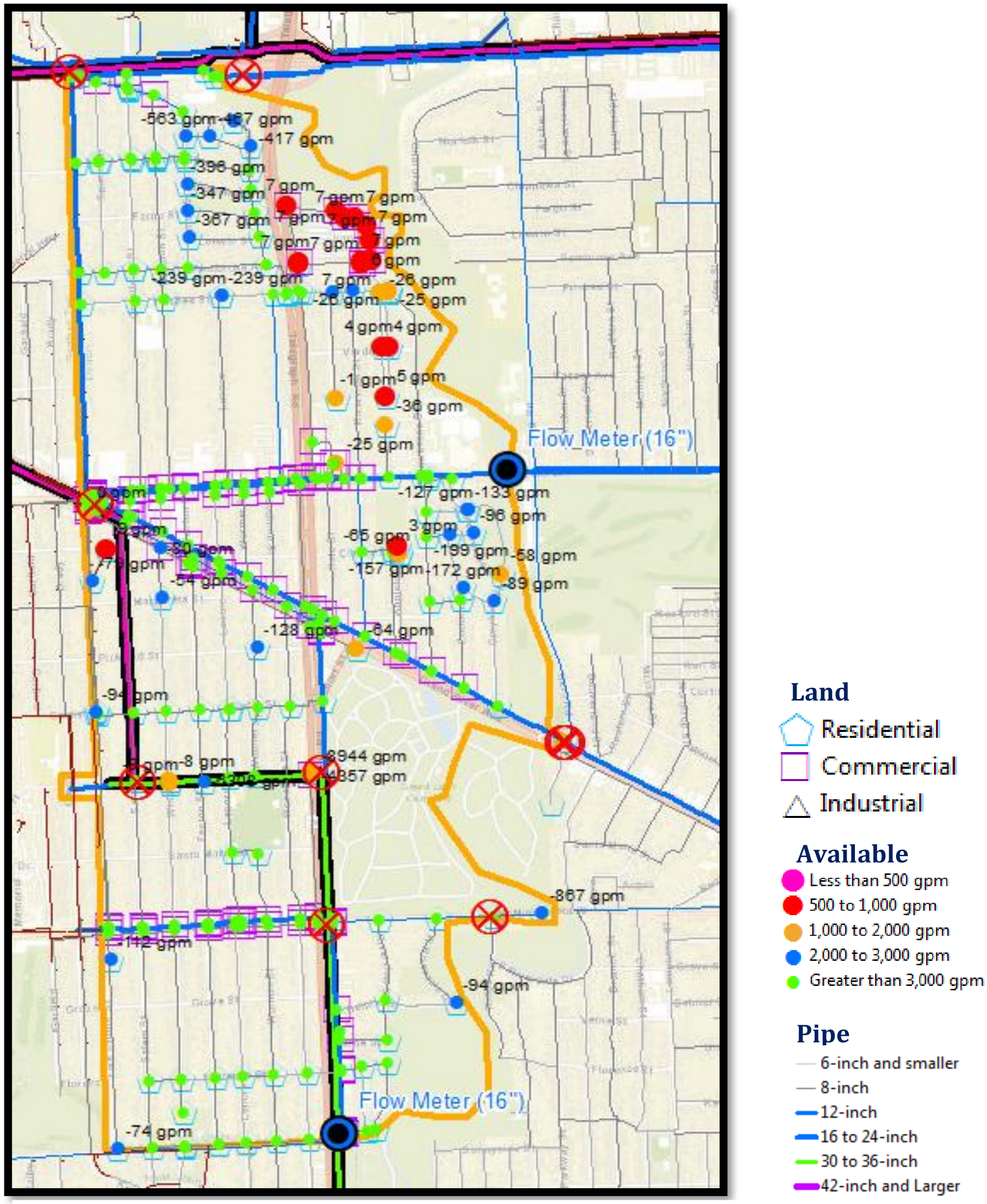


Figure 9-14 NW Fire Flow Impact

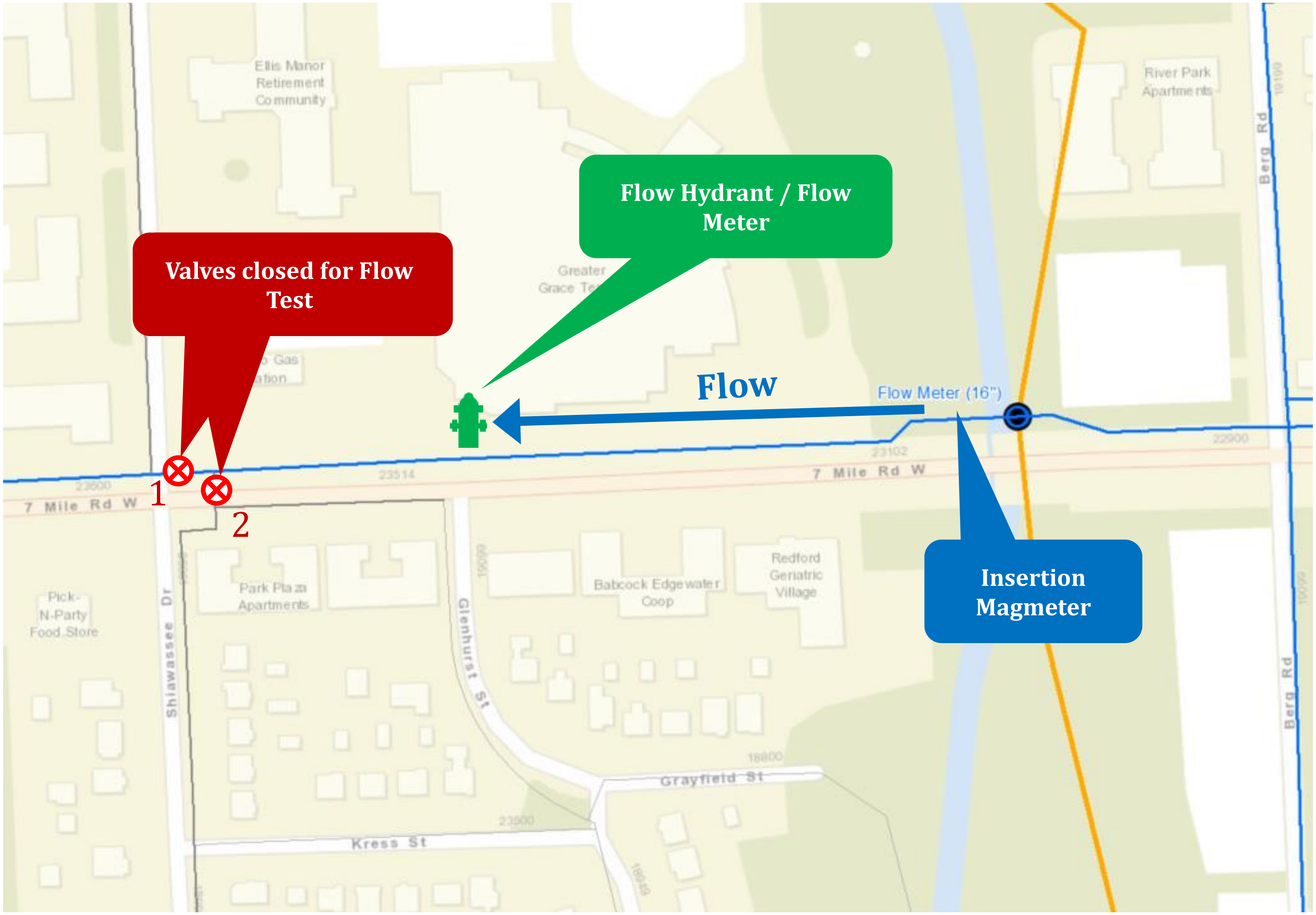


Figure 9-15 In-Situ Flow Test on 7 Mile Rd. (NW DMA)

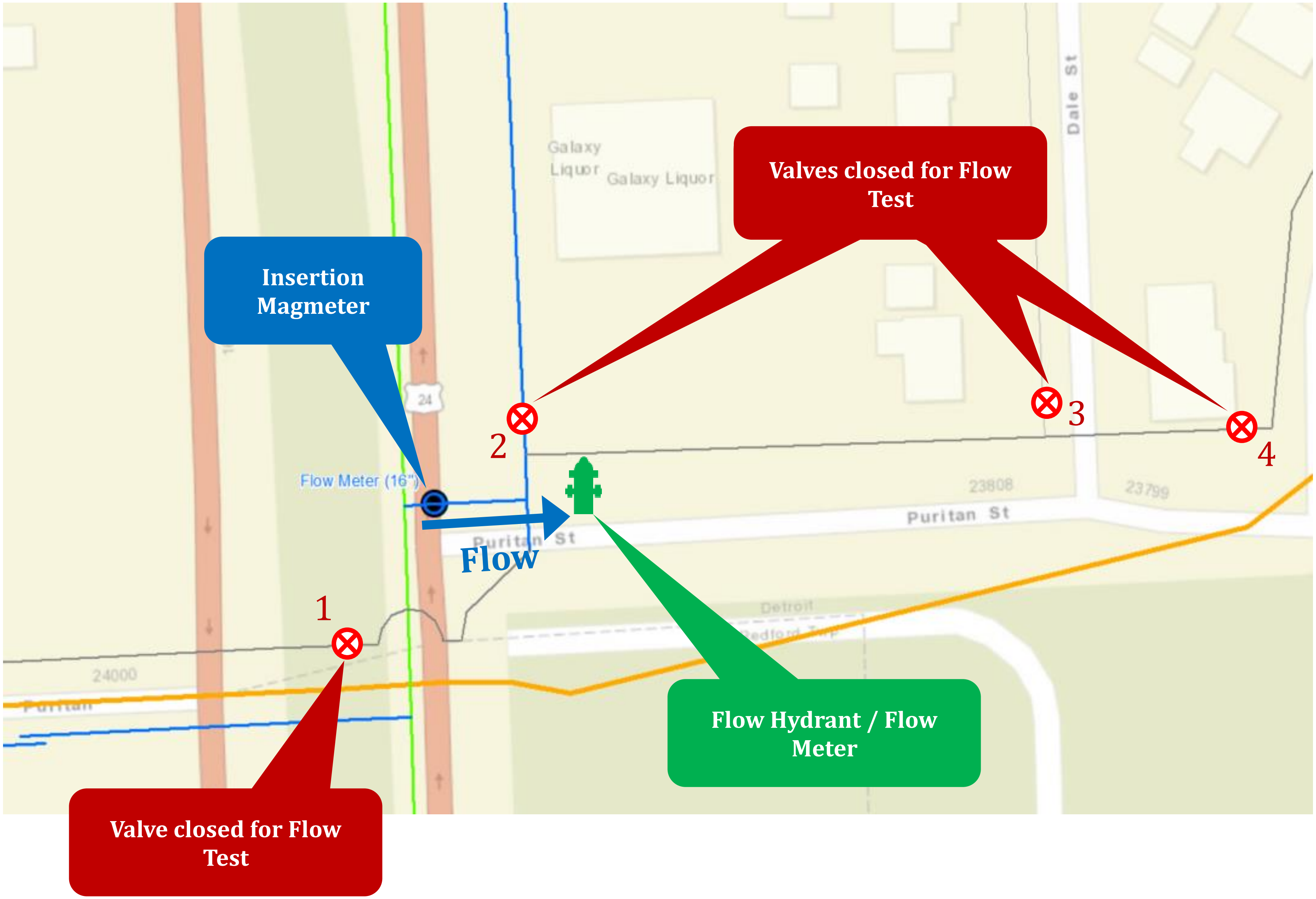


Figure 9-16 In-Situ Flow Test on Puritan St. (NW DMA)

9.3 WTP PRODUCTION FLOW DATA ANALYSIS

A summary of the data analysis for flow testing conducted at each WTP is provided below:

Northeast WTP: Flow was recorded using six Venturi flowmeters (VM) that are installed on the combined headers of the pump station discharge piping. Data was gathered hourly from SCADA during normal operation. VM No. 1 provided only negative values, ranging from 0 to -0.4 MGD. All data reported from VM No. 2 listed “Bad Input”. The remaining four meters recorded usable data. Individual meters were not available for each pump, so individual pump hydraulic performance could not be evaluated. No information was provided regarding which pumps were in operation and which header they were connected to when the data was recorded. Valve position and VFD data was not recorded. If valves related to VM Nos. 1 and 2 were closed during testing, the total plant output during this time could be calculated by adding the outputs of the four operating meters, as identified in Table 9-1. However, if valves to either VM Nos. 1 or 2 were open during testing, the total plant output is unknown and cannot be calculated with the available data.

Water Works Park WTP: Data was recorded manually using portable external ultrasonic flow metering (Flexim) technology at each discharge of Pump Nos. 3, 5, 7, 8, 10, 11, and 12. No data was recorded for Pump Nos. 1, 2, 4, 6, and 9. To maintain plant flow and discharge pressures, Pump No. 5 was kept online during most of the tests and was throttled when other pumps were being tested. Raw flow data was only provided for Pump Nos. 10 and 11 operating at maximum capacity. The flow data provided for Pump Nos. 3, 5, 7, 8, and 12 was in a summary of the test results. The flow data for Pump Nos. 5, 7, 8, 10, 11 and 12 were measured based on inlet/outlet valve open positions of 25%, 50%, 75%, and 100%. The flow data for Pump No. 3 was only recorded at valve open positions of 25% and 50%. Pump Nos. 10 and 11 produced usable flow data. The pressure for each pump was manually recorded at the pump suction, casing, and discharge and were included in the test summary. Based on the available data for each tested pump, the average maximum capacity (at 100% open valve positions) is indicated in Table 9-1.

Southwest WTP: Flow data was recorded manually using portable external ultrasonic flow metering (Flexim) technology at each discharge of Pump Nos. 1, 4, 5, 6, and 7. Generally, the pumps were tested in the same manner as the pumps at Water Works Park. No data was recorded for Pump Nos. 2 and 3. To maintain plant flow, Pump No. 4 was kept online during all the tests to maintain system pressure and throttled when other pumps were being tested. Raw flow data from the flowmeters was provided for all pumps tested. Of the pumps tested, only testing of Pump No. 4 produced useable data. The data acquired for all other pumps ranged widely, with some numbers indicating negative flows. Thus, this data is deemed inadequate for analysis. The pressure for each pump was recorded manually at the pump discharge pipe and at the wall and were included in the test summary. Given the inaccuracy of the available data, the average maximum flow for only Pump No. 4 could be established as shown in Table 9-1.

Springwells WTP: Flow data was recorded manually using portable external ultrasonic flow metering (Flexim) technology on combined discharge headers at two locations – High Pressure

Upper and Intermediate Pressure Lower headers. The pumps were generally tested in the same manner as the pumps at Water Works Park. Pump Nos. 11, 13, 19, and 23 were on the high-pressure portion of the upper header and Pump No. 20 was on the intermediate pressure side of the lower header. Data was recorded manually for Pump Nos. 11, 13, 19, 20, and 23. No data was recorded for Pump Nos. 12, 14, 15, 16, 17, 18, 21, 22, 24, 25, and 26. Raw flow data was provided for all pumps tested. However, Pump No. 25 was operated against a discharge valve throttled to approximately 25 percent open throughout testing, according to notes on the provided schematics. The proximity of the flowmeter to Pump Nos. 11, 13 and 20 may have resulted in increased flow disturbance and reduction of accuracy of flow measurement. Thus, of the pumps tested, only testing of Pump Nos. 19 and 23 produced usable flow data from the flow meters. The pressure for each pump was not recorded. The pressure in the upper and lower discharge headers were recorded from SCADA. The flowmeter for Pump Nos .11, 13, 19, and 23 was located on the upper header while Pump No. 25 was online and producing an unknown flow throughout the test. The average maximum flow for Pump Nos. 19 and 23 (with Pump 25 running against a 25 percent open valve) is indicated in Table 9-1.

Lake Huron WTP: Flow data was recorded manually using portable external ultrasonic flow metering (Flexim) technology at each pump discharge. Generally, the pumps were tested in the same manner as the pumps at Water Works Park. Flow was measured separately for Pump Nos. 2, 3, 4, 5, 6, 7, 8, and 9. Raw flow data was provided for all pumps tested. The data for Pump Nos. 3, 4, 5, 6, 7, 8, and 9 were only recorded at a valve open position of 100%, while Pump No. 2 was tested at several speeds. All the flowmeters produced usable flow data. The pressure for each pump was recorded manually at the pump discharge and was included in the test summary. No valve positions or discharge header pressures were recorded.

Table 9-1 Water Treatment Plant Flow Testing

WATER TREATEMENT PLANT	PUMP NUMBER	VENTURI METER NUMBER	APPROXIMATE MAXIMUM FLOW (MGD) AS TESTED	RATED CAPACITY (MGD)
Northeast WTP		VM-3	16.4*	12-80 MGD
		VM-4	31.3*	12-80 MGD
		VM-5	35.4*	12-80 MGD
		VM-6	17.9*	12-80 MGD
Water Works Park WTP	Pump 5		57.7	60
	Pump 7		58.0	60
	Pump 8		59.5	60
	Pump 10		39.7	40
	Pump 11		39.8	40
	Pump 12		37.0	40
Southwest WTP	Pump 4		37.3	40

WATER TREATEMENT PLANT	PUMP NUMBER	VENTURI METER NUMBER	APPROXIMATE MAXIMUM FLOW (MGD) AS TESTED	RATED CAPACITY (MGD)
Springwells WTP	Pump 19		37.5	60
	Pump 23		43.3	60
Lake Huron WTP	Pump 2		65.2	60
	Pump 3		59.1	60
	Pump 4		62.5	60
	Pump 5		56.6	60
	Pump 6		58.8	60
	Pump 7		58.8	60
	Pump 8		56.6	60
	Pump 9		56.7	60

* Venturi meter flow, not pump.

9.4 POLCON® PITOT TESTING METHODOLOGY

Pitot Testing information provided by M.E. Simpson Co., Inc.

Pitot Testing is a method in which the meter is operated under normal conditions, while monitoring the flow-rate with an inserted Pitot rod and flow-recorder acting as a test-meter (*see Figure 1)*. The performance of both the test-meter and meter are compared at various flow-rates, spanning the range of the meter. From this comparison, the meters' accuracy is calculated at each flow-rate, and its' performance is documented. Meters which "fail", or fall outside of the accuracy range (as per the AWWA M6), should be repaired or replaced by the utility.

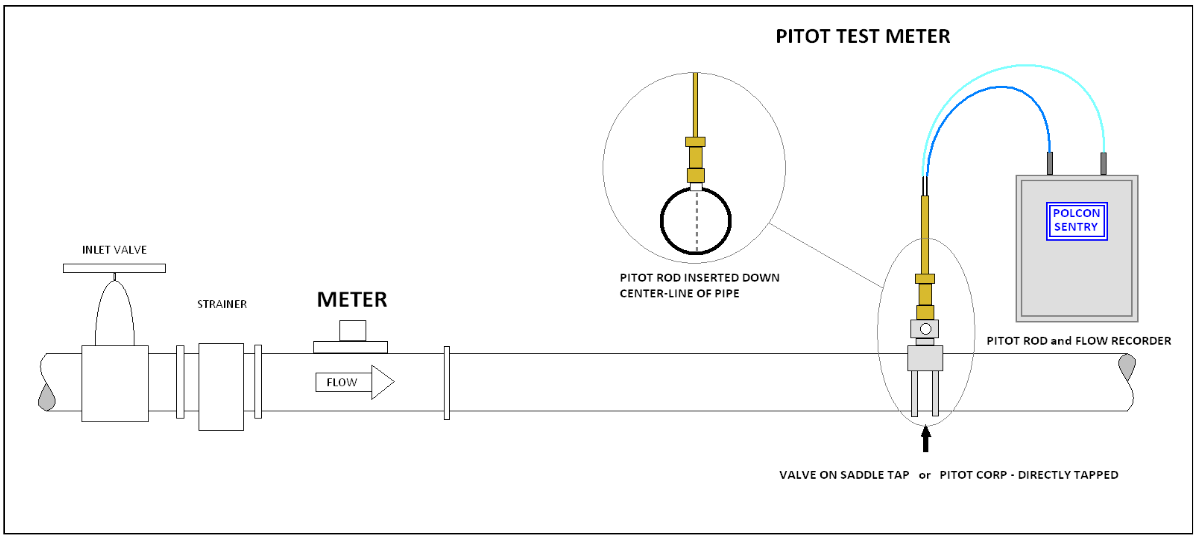


Figure 1. Polcon® Pitot Test Schematic

In order to conduct a Pitot test, there are certain hydraulic requirements. Ideally the selected test site would have twenty pipe-diameters upstream and ten pipe-diameters downstream of any obstruction, which includes elbows, butterfly valves, strainers, meters, pumps, and flow-straighteners (*see Figure 2*). Realistically, ten diameters upstream and five downstream is acceptable.

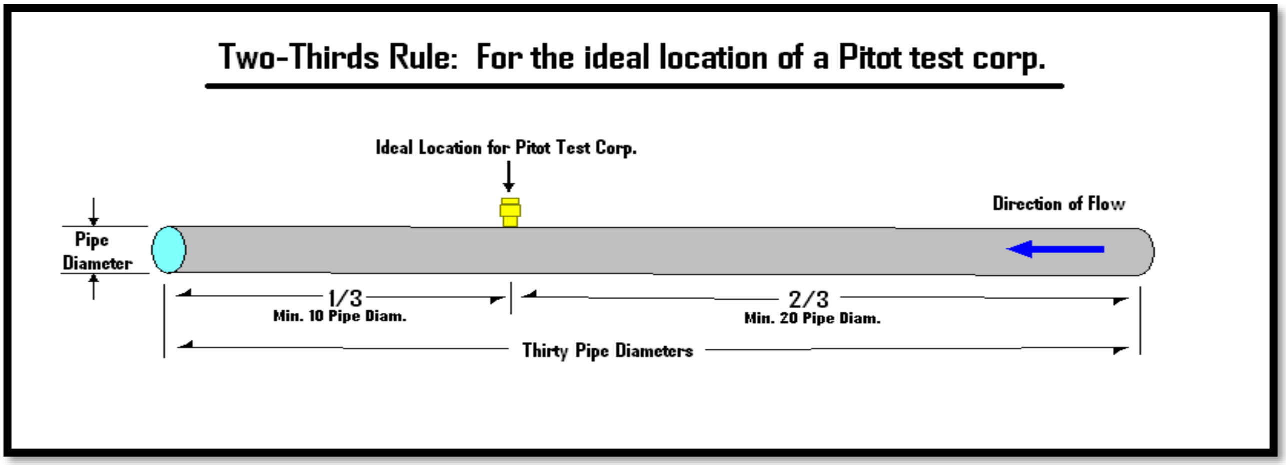


Figure 2. Ideal location of a Pitot Corp

The test corps can be installed directly, or on "Saddle-taps".

NOTE: For a saddle-tap, the tap hole must be at least 1.5" in diameter, MEASURED, with a 1.5" standard pipe-thread ball valve.

RECOMMENDED PITOT CORPS FOR DIRECT TAPS

Mueller: Mueller *Pitot* Tap H-9991N

Ford: Part Number: F800-4NL

A Y McDonald: Part Number: 73120 1"

EQUIPMENT USED

Pitot testing is conducted using Polcon® Pressure and Flow Monitoring equipment which is designed and manufactured by M.E. Simpson Company, Inc.

The **Polcon® Pitot Rod** is a constructed with high-grade brass to insure a device that is durable as well as accurate. Its' primary function is to convert the velocity of the fluid flowing past it into a differential pressure, which is measured by a differential pressure sensor. The "O" ring packing and a locking device assures that all Polcon® Pitot Rods will provide a safe and leak proof installation. The solid orifice plate assures the upstream and downstream orifices remain in the same plane and directly opposite one another assuring an accurate measurement of the velocity in the pipe. A **Polcon® Pipe Caliper** is used to accurately measure the inside pipe diameter.

The **Polcon® Sentry Recorder** is a solid-state microprocessor type pressure-sensor and recorder that senses, gathers, stores, and processes differential pressure from the Pitot rod. The Sentry generates a 4-20mA signal using a Rosemount differential pressure transducer and stores this value using a Telog® ILR-31 data-logger.

Each data-logger can be set to collect data at an interval as short as one second, or as long as eight hours, and can continuously record data from *seven hours* up to *twenty-three years* depending on the recording frequency (although the internal battery is only rated for three to five years).

The Sentry is self-contained, has its own power pack, weighs less than 30 lbs., and fits into the standard 20.25" manhole entrance. Data is downloaded, using a laptop computer, for further analysis. All data is permanently stored on a computer hard drive, and backed up off-site. The data is exported to a Microsoft Excel® so that it can be analyzed and used to generate a test report.

POLCON® PITOT TESTING PROCEDURE

M.E. Simpson Co., Inc. employs the use of a Polcon® Pitot rod to accurately measure the velocity of flow in the pipe for determining the accuracy a flow meter. This consists of an insertion Pitot tube that is placed through the cross section of the pipe (*as shown in Fig. 1*), in the exact center, to measure the average mean flow velocity**,** $\mathbf{V_{avg}}$. A Polcon® Pipe Caliper is used to accurately measure the inside pipe diameter, and from this, the pipe area, $\mathbf{A_{pipe}}$**,** is calculated. Both of these values are multiplied together to determine $\mathbf{Q_{Pitot}}$, the flow rate, using the following basic relationship.

$$Q_{Pitot} = A_{pipe} * V_{avg} \quad \left\{\frac{ft^3}{s}\right\}$$

The results are compared to the readings of the flow meter being tested for the same time period and the accuracy is calculated for the flow meter. According to the AWWA M33 manual, "*Flow Meters in Water Supply*" Pitot testing can produce results of $\pm$ 1/2 % to 5% of full scale with a "Repeatability" of 0.5 %.

A Polcon® Sentry recorder is used to record differential pressure over the test period. Because the recorder registers differential pressure to within one one-hundredth of an inch of water column, the overall test accuracy is improved to $\pm$ 2.0% with a repeatability of 0.5%

The Utility assists with general safety, site monitoring, and information acquisition. Additionally, the Utility provides flow-data from their SCADA system, and access to the facilities where the test-sites are located.

VENTURI CALIBRATION

The following relationship is used to calculate the flow rate of cold water moving through a Venturi tube. This formula is based on Bernoulli's Head Equation.

$$\boldsymbol{Q\{gpm\} = A_t * V_t = P_t * C_d * A_t * \sqrt{\frac{\frac{2}{\rho} * H_{inwc} * 5.1948051}{1-\beta^4}} * 7.48}$$

$$P_t = time\ period\ \{s\}$$

$$\beta = \frac{d_{throat}}{d_{upstream}} = \frac{d}{D}$$

The conditions of operation and the local hydraulic configuration have a tremendous impact on the accuracy of a Venturi meter. The specifications provided by any given manufacturer are only as good as the meters' setting and other factors like age, mineral build up within the device, and differential-pressure sensor conditions. For these meters to function properly, they must be calibrated *in-situ,* using a secondary method of establishing the flow-rate. One of the most accurate methods for establishing the flow rate of a meter is Pitot-testing, as described previously.

The flow rate through and the differential pressure across the Venturi are measured simultaneously, to establish the relationship between the true (Pitot) flow rate and Venturi differential. This takes into consideration the local hydraulic configuration and operational characteristics which affect the meters' operational parameters.

Venturi meters utilize differential pressure sensors which convert the non-linear differential pressure into a linear 4-20 mA output, which is directly proportional to the flow rate. If the sensors range is changed, then, for the same Venturi-differential, the sensor should produce a different flow-rate.

Adjusting the Sensor Output

Once the relationship between the true flow (Pitot) and the Venturi are established for a meter, the sensors range can be modified to correct any inaccuracy which might have been discovered.

Calibrating Mechanical and Static Meters

Depending on the type and brand, mechanical meters can usually be repaired or adjusted. Some mechanical meters have programmable register heads which allow for calibration. It may not be possible to repair or adjust the meter, in which case the meter must be replaced.

Static meters, such as Magnetic and Ultrasonic, are usually programmable allowing the utility to make calibration adjustments based on the results of the Pitot test.

M.E. SIMPSON Co., Inc.

3406 Enterprise Ave., Valparaiso, IN 46383 | Ph: (800) 255-1521 | Fax: (888) 531-2444 | www.mesimpson.com | salesinfo@mesimpson.com

9.5 GLWA WHOLESALE WATER AUDIT DATA COLLECTION PROTOCOL

Potential protocol for collection of data necessary to perform a simplified water audit for GLWA's wholesale customers.

Dear Wholesale Customer,

In an effort to improve the accuracy of Non-Revenue Water (NRW) and to support equitable cost allocation to member communities for the Units of Service analysis, GLWA is requesting that wholesale water customers provide the following data:

1. Monthly retail water sales consumption for calendar years 20XX through 20YY (if monthly data is not available annual numbers would be acceptable).
2. The most recent number of connections or accounts (preferably 20YY data, but if not then please reference the year).
3. The number of miles of main (preferably 20YY data)
4. Billing frequency (monthly, quarterly, etc.)

This is part of a collaborative effort to improve the measurement and knowledge of NRW for each customer and the GLWA system, an exercise that will benefit both GLWA and the wholesale customer community. Also, moving forward, GLWA is requesting that wholesale water customers provide their annual retail water sales (item 1 above) to GLWA annually.

NRW is an issue for GLWA and our wholesale customers. GLWA will work with the wholesale customers through the One Water Partnership Analytical Workgroup (AWG) to review the results. This should help identify issues with GLWA metering, community water loss, or other issues with the goal of providing the most accurate water accounting possible and to support a collaborative exchange of information and approaches to mitigate NRW. Our goal is to have all of this data collected by [Date].

GLWA requests your cooperation with this effort as it should be beneficial to all. If you have any concerns, please contact me via email at [email] or call me at [phone].

9.6 IDENTIFICATION OF WATER LOSS VIA SYSTEM METERING

System Analytics and Meter Operations

The System Analytics and Meter Operations Group monitors consumption for all 88 wholesale water customers. In last 12 months we have identified four significant water loss incidents for wholesale customers and assisted the customer with resolving the issue. An early detection and notification of the abnormal consumption increase helped customers in avoiding high bills and billing disputes.

Village of New Haven — Water Loss 0.42 to 0.74 MGD

On November 9th, 2015 the wholesale water consumption increased for Village of New Haven by 166% from 0.26 MGD to 0.68 MGD. The customer is fed by one meter location (NH01), an 8" magnetic meter. After an investigation by System Analytics & Meter Operations, the conclusion was the consumption was accurate and there was no metering issue. New Haven's water system includes storage; the customer controls the flow and in the normal operation customer does not take flow every hour of the day. When the daily consumption increased on November 9th, the hourly consumption did not increase, but there were more hours of consumption per day. At the time of the initial consumption increase it was thought that it could be a temporary operational change. The customer was notified, and the flow continued to increase until it exceeded 1.0 MGD. The customer found a gate valve leaking (bolts rotted out) downstream of the meter pit and had it repaired. The consumption went back down to normal levels.

City of Auburn Hills — Water Loss 0.65 MGD

Consumption through the meter location AH02 increased by approximately 0.65 MGD in December. Meter operations were checked to verify that it was not an internal issue, and the customer was notified of the potential problem. The customer performed some preliminary checks and did not identify any issues. The metering was double checked and presented to the customer to clearly point to a possible main break downstream from the meter site. The customer had a water leak detection contractor check the system and found a main break under the Clinton River. After the repairs were made, the consumption returned to the normal levels.

City of Gibraltar — Water Loss 0.3 MGD

On January 11th, 2016 the wholesale water consumption increased for City of Gibraltar by 85% (0.29 MGD) from 0.33 MGD to 0.61 MGD. The increase was observed from the GR02 location. After an investigation by the GLWA's System Analytics & Meter Operations Group, the conclusion was the consumption was accurate and there was no metering issue. At the time of the initial consumption increase it was thought that it could be a temporary operational or demand change but the consumption continued at that level. System Analytics notified the customer and a severe main break was found in the woods behind a High School. After the repairs were made the consumption returned to the normal levels.

City of Romulus — Water Loss 1.0 MGD

On September 17th, 2016 the wholesale water consumption increased for City of Romulus by 17%. The increase was from meter location RS04 (Ecorse & Inkster), an 8" compound mechanical meter that typically has very low flows. Consumption is usually below 0.01 MGD but the location increased to 1.0 MGD. After an investigation by the GLWA's System Analytics & Meter Operations Group the conclusion was the consumption was accurate and there was no metering issue. The customer was notified, and they performed an investigation into their system. Romulus found an industrial meter registering the same flow increase that serves Sunoco. City of Romulus contacted Sunoco expecting an operational change, but it was determined there was a main break in Sunoco's private water system at a tank farm that did not surface. There are deep crevices on the property that the flow was going to. After the repairs were made the consumption returned to the normal levels.