

**SYSTEM DIAGNOSTICS:
A CASE STUDY FROM THE CITY OF VAUGHAN**

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ABSTRACT

In response to a relatively recent series of recurring complaints of low pressures within an established isolated pressure district of the City, a rather affordable and efficient diagnostic study was undertaken that resulted in rapidly deployed system adjustments in a logically progressive manner. Field testing of system pressures and the deployment of a transient monitoring device allowed for the rapid assessment of critical system components without the need for long-term monitoring or detailed modelling.

This case study illustrates how complex and dynamic water distribution system operations can be assessed and improved at reasonable costs and with significant positive impact. The key success factors of the study included the high degree of cooperation amongst the water utilities – the supply source in this case is owned and operated by an upper-tier municipality while the distribution was locally owned and operated – and the development community expanding such systems. Further, the importance of understanding that small changes in water systems can have wide reaching impacts on distant system elements and system-wide impacts is also illustrated. Finally, the role of an independent consultant to understand broad system performance issues in addition to individual elements and, perhaps of equal importance, effectively liaise and engage the various stakeholders with disparate interests is presented.

The results of this work have identified several important improvements to the administration and management of the City's water distribution system which, particularly in a growing municipality, undergoes constant changes and expansion that invariably affect overall system performance.

INTRODUCTION

The City of Vaughan's Pressure District 8 (PD8) zone is only one of two closed water distribution systems within the municipality with water and pressure supplied by a single pumped source which itself feeds a regional storage reservoir which, in turn, supports the single feed to PD8. This situation is largely the result of progressive expansion of the urban areas where there is insufficient infrastructure in place to support more robust system connectivity. With continued development within the municipality and the concurrent strengthening of water and other municipal infrastructure systems, it is expected that these conditions will improve.

The PD8 zone is supplied water by the Region of York's North Richmond Hill Pumping Station and has historically serviced a relatively mature and affluent area within the City (referred to herein as the "Original Service Area"). The northernmost area within PD8 is further isolated and serviced by a local booster pump to deal with the higher elevations in this area. (As will be noted later, this isolation negatively impacts the performance of the distribution system.) Recently, land development activities in the City have resulted in the expansion of the PD8 system (referred to herein as the "Expanded Service Area") including interconnectivity with the hydraulically lower PD7 system, although it is noted that the intent of this interconnectivity is for emergency supply purposes rather than routine operation. Figure 1 illustrates the lands in question.

Following the system expansion work in support of the land development, the City began receiving low pressure complaints from the residents in the original service area. Upon investigation of the complaints, the City's personnel found that the pressures were generally within acceptable ranges by their own standards as well as those of the Ontario Ministry of the Environment. The result is that, although there was a noticeable change in system performance, the new performance levels were not perceived to be a significant problem and did not give rise to a "crisis" situation which generally garners more attention. This situation continued for quite some time with the same cycle of complaints, investigations and determination of system adequacy. In 2009, the City decided to retain Fabian Papa & Partners Inc. to look into the problem.

SUMMARY OF INVESTIGATION

The engagement involved a desktop review of the system hydraulics, interviews with staff from both the City and Region responsible for water supply and distribution operations, selected field monitoring and testing. In addition, and what proved to be very useful in identifying the causes of the problem, the City had field pressure records for the system in question both before and after the onset of complaints. By looking at the system from a broader perspective, it became evident that there was a general and uniform drop in total head across the system largely as a whole which significantly narrowed the possible causes of the situation. Such a situation would either be caused by a significant lowering of the pressure at the system boundary where water was supplied such as at the pump station or a significant headloss in the distribution piping connected thereto. Figure 2 presents the data showing the drop in total head in relation to the initiation of complaints.



FIGURE 1. CITY OF VAUGHAN PD8 PRESSURE ZONE

The data presented in Figure 2 illustrates that the total head across the distribution system was at the theoretically modeled level prior to the initiation of complaints and, thereafter, was generally observed to be on the order of 10 m or 14 psi lower. A review of pressures at the pumping station indicated that it was indeed operating as originally intended and producing pressures consistent with the recordings before the problems manifested themselves. Therefore, the only alternative explanation for this situation was that there were significant head losses in the distribution piping.

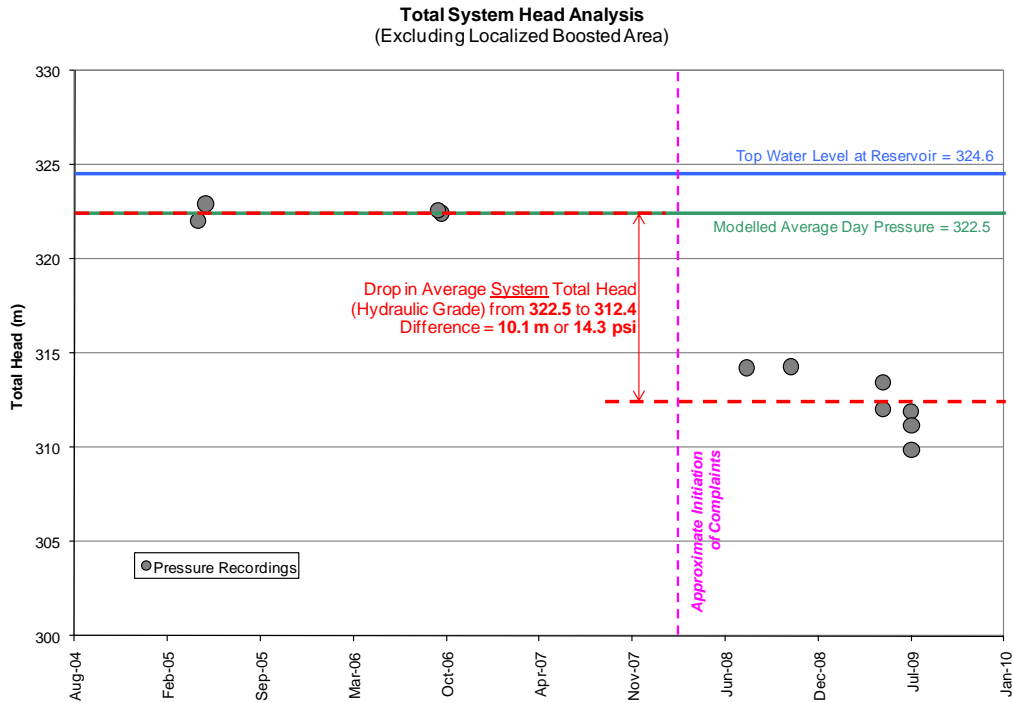


FIGURE 2. DROP IN DISTRIBUTION SYSTEM TOTAL HEAD

A review of the system hydraulics and the field investigation revealed that the creation of the localized boosted area at the northern limit of the pressure zone effectively created a single feed from the pumping station to the remainder of the service area. Moreover, this single feed (300 mm Ø) was over 1,200 metres in length. While this feed experienced modest and largely imperceptible head losses before the initiation of complaints, it was correctly speculated that this line was particularly vulnerable, in terms of head losses, to increases in flow. A simple application of the Hazen-Williams formula for estimating head losses was developed (see Figure 3) which indicated that, for a loss of approximately 10 m of head, the required flow rate would be on the order of 100 L/s.

Given that the City does not currently have flow meters in its system, alternative methods of verifying this situation were required. This prompted the review of billing records for the bulk supply of water from the Region which, fortunately, provided direct information for the supply line in question. Immediately the results of this analysis corroborated the speculation of head losses across this single feed. Furthermore, this rate of flow was 5 to 6 times larger than what would be conservatively expected under full build-out conditions for the expansion area which was not the case.

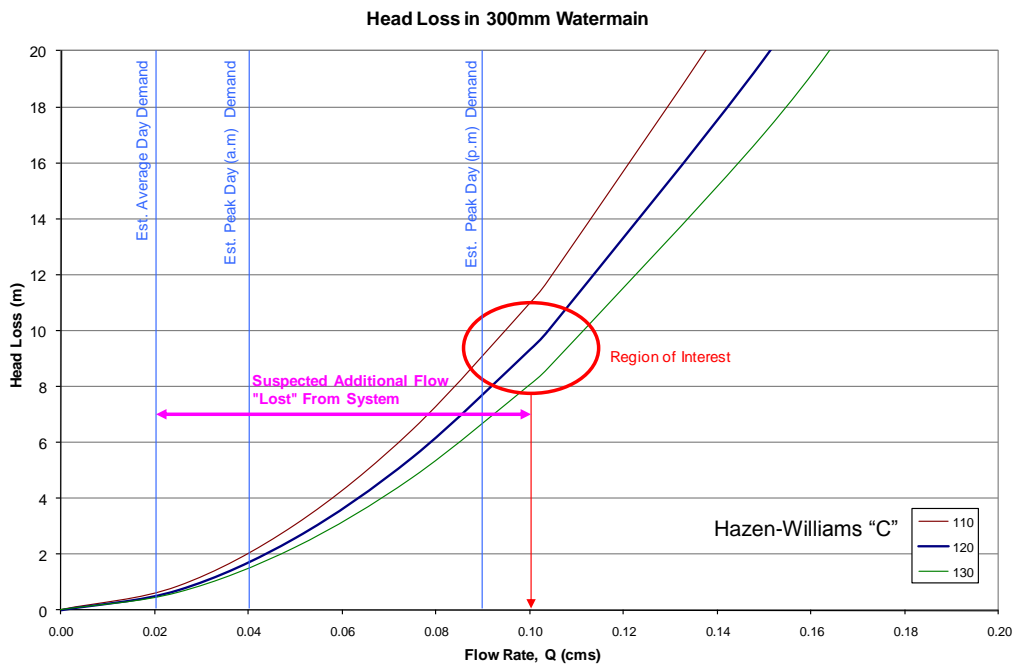


FIGURE 3. ESTIMATED HEAD LOSSES IN SINGLE FEED

At this point, it became apparent that there was a “loss” of water from the PD8 system which could have been a combination of several factors including regular and persistent high demand from non-residential uses, physical leakage or the flow of water from PD8 to the lower PD7 system. Although a systematic flushing program had been initiated for the new development area, it was determined that this would not likely have contributed to the volumes and pattern of usage witnessed. As well, physical leakage to this extent was considered to be highly improbable as it would have very likely been noticed over the course of the almost 2 years that this situation was occurring.

A review of the interconnections of the PD8 and PD7 systems revealed the installation of pressure reducing valves (PRVs) which are intended to only permit the flow of water from PD8 to PD7 in the case of extremely low pressures in PD7. Accordingly, a set of field tests was conducted and which indicated that one of the PRVs was very likely allowing the flow of water between these pressure zones under regular conditions. The developer was notified and immediately mobilized its forces to work with the City and Region to investigate the PRV which was confirmed to be fully open on account of its pressure regulator not having been set.

Figure 4 below illustrates the metered flows into the system, the theoretical headloss across the 1,200 m single feed, and the timing of events. The adjustment of the PRV on 23 July 2009 had an immediate and significant effect, improving pressures throughout the PD8 system.

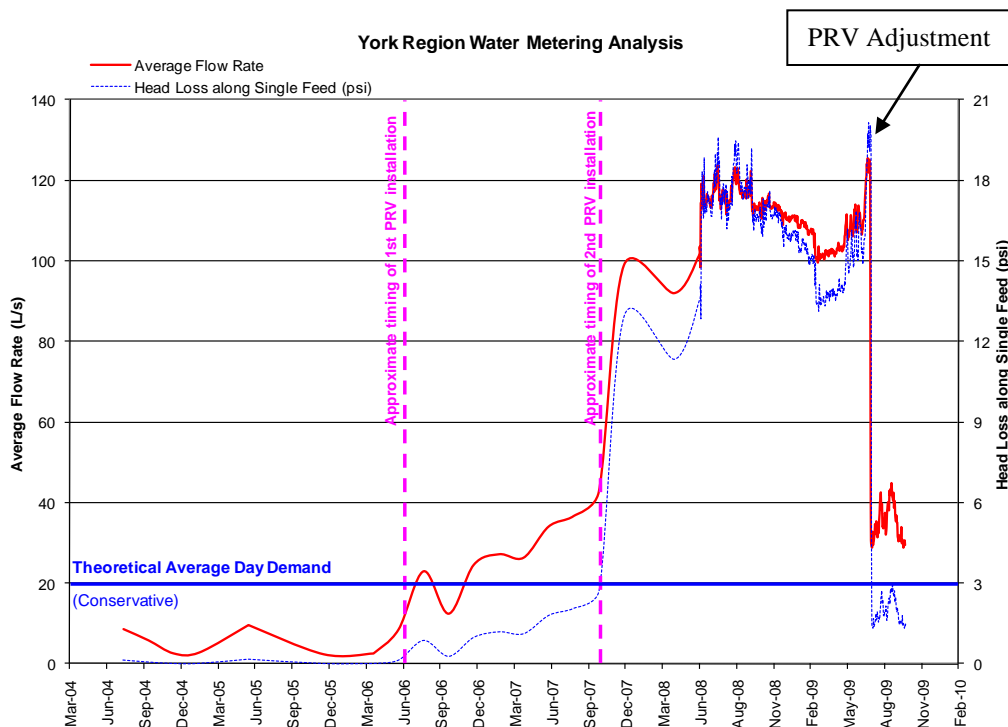


FIGURE 4. FLOW RATES AND HEADLOSSES IN SYSTEM

Despite the improvements to the system shown in Figure 4, it also appears that the entire problem has not been fully resolved since flow rates remain higher than the conservatively estimated demand for the service area and that a further 15 to 20 L/s may continue to flow from PD8 to PD7. As at the time of writing, the City is working with the developer to identify and resolve this situation which requires additional effort.

THE COMPLEXITY OF WATER SYSTEMS

Solving problems in water supply and distribution systems is inherently complex given the intricate connectivity of these systems within pressure zones, across pressure zones and, as will be illustrated in this section, across different system elements and jurisdictions.

The pumping station which supplied water and pressure to the PD8 pressure zone is owned and operated by the Region of York which, of course, is hydraulically connected to the City's distribution system. The Region had established its pumping protocols based on the flows generated by the station and were able to maintain rather smooth operations while these excessive flows were being conveyed from PD8 to PD7. What is interesting is how the pumping station behaved following the rectification to the PRV noted above.

Prior to any work on the system and while information was being collected and reviewed by the consulting team, a TP-1 transient pressure monitor was installed by HydraTek & Associates Inc. in the discharge header of the pumping station to observe its behaviour. As noted above, prior to the adjustment to the PRV, the station performed admirably with relatively few pump switches and good transient (also referred to as “waterhammer” or “surge”) controls. Following the adjustment, however, with the significantly lower flow requirements, there was a significant increase in the frequency of pump switches and mild transient events with a wider fluctuation of discharge pressures. Figure 5 shows the transient pressure monitoring data for the period of installation.

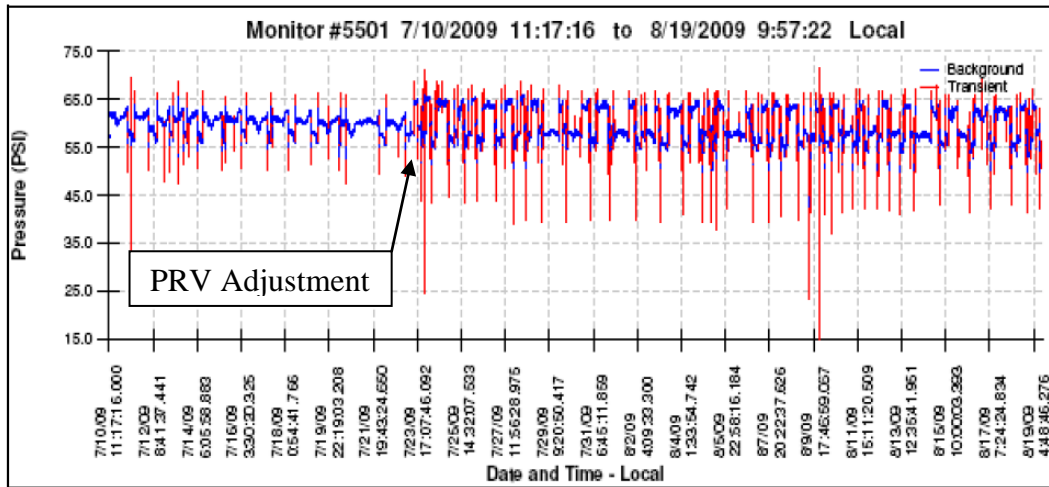


FIGURE 5. TRANSIENT PRESSURE MONITORING DATA

This is an excellent example of how changes to system components can have far reaching and significant impacts on other elements of the physical system, irrespective of administrative boundaries.

DISCUSSION AND CONCLUSIONS

The management of water supply and distribution systems is inherently complex stretching beyond purely the realm of the technical. There are a number of interested parties whose activities require integration and a system-wide approach to the ongoing modifications to any system. In the case presented herein, the interested parties included the City of Vaughan responsible for the quality and reliability of supply to its customers, the Region of York responsible for the bulk supply to the City and the private sector land development group responsible for the expansion of the system. Moreover, there are various departments and layers of organization within each of these main parties, all of whose voices need to be heard and resources channelled in the right direction to deal with any problems.

In recognition of the need to manage precious resources as judiciously as possible, the City of Vaughan has embarked on several initiatives which aim to

developing sophisticated municipal infrastructure systems. These include the development of City-wide master plans for sustainable water, wastewater and storm drainage and will include provisions for appropriate accounting of its assets and the flow of water. Moreover, although the City's water infrastructure is relatively new, the City plans to implement the necessary systems to audit water inflows and outflows so as to control water loss from its systems now and, more importantly, into the future as its stock of infrastructure ages.

The foresight of the City is what enabled the engagement of the consulting team to swiftly resolve a problem through a system-wide approach to the technical and non-technical aspects of its water supply system. As a result of this work, the City is now in a position to develop and enforce standards that will prevent similar problems from occurring going forward.

As well, a simple yet very important lesson learned from this exercise is that the collection of data is never useless. In this case, pressure recordings of the PD8 system were taken and archived at a time when the system was operating without incident or complaint. The ready availability of this information for use in comparing with newly obtained field measurements dramatically narrowed the focus of the investigation thereby saving significant time and effort in providing resolution to the problem. Often times, too much data can be just that, but it is our opinion that it is always better than no data at all. One cannot manage what one does not measure.

The problem dealt with in this case study did not require laborious hydraulic modelling, but rather the understanding of system behaviour and the use of a single well-known equation. Dealing with the remaining excess flow in the system will very likely require the assistance of a detailed model which can be compared to field measurements to hone in on the potential source of this demand and will be an invaluable tool in doing so. The point is that the tool selected for any given application has to be appropriate for the application, and it is the experienced engineer with a system-wide view that can help guide which activities will yield the greatest benefit when dealing with problems.

Finally, a word about professional freedom. The success of this experience can largely be attributed to the City for allowing the consultant to execute its work with sufficient freedom so as to arrive at a solution in an extremely time and cost-effective manner – the resolution to this 1.75+ year problem was on the order of a few weeks. Municipalities in general can be overly cautious when retaining professionals for its work and for good reason. This approach may be very well suited for new design work or other projects for which the scope and processes can be tightly defined. In dealing with problems on existing systems, scopes cannot be defined as such and it takes courage for City staff to entrust the professional community to assist them and such an approach should be seriously considered where conditions warrant.