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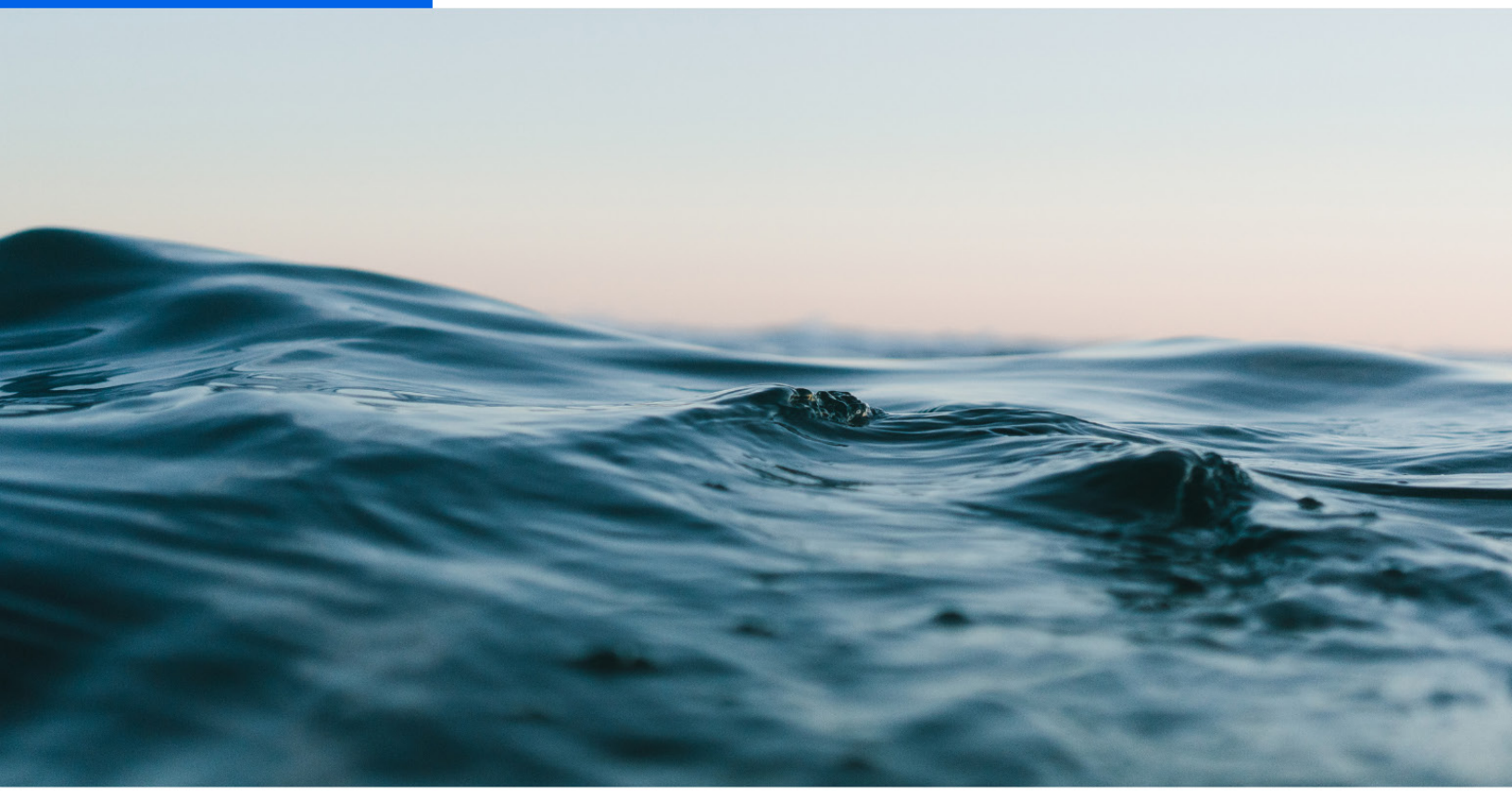

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The Technology used in Water Efficiency Projects: Case of Portmore Non-Revenue Water (NRW) Reduction Program

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ABSTRACT

Technology is a powerful tool that can be used to solve practical and complex issues and stimulate growth, innovation and sustainability. The present paper shows how the use of the best technologies available was crucial for a successful Water Efficiency Project, with emphasis on the Portmore Non-Revenue Water Reduction Program.

The use of acoustic technology to find non-visible leaks, electromagnetic meters to accurately and constantly measure flow; of data loggers to monitor and store flow and pressure data, pressure-reducing valves (PRV), and of controllers to balance the water demands and control the reservoirs and pumping stations, as well as the use of GIS mapping and data management software, drastically reduced the NRW by 8,000 m^3/day for Portmore [from 26,000 m^3/day – 18,000 m^3/day] between March 2021 to December 2022. These excellent results were achieved within only 22-months.

KEYWORDS

Non-Revenue Water, Leak Detection, Pressure Management, GIS, Acoustic Technology, Data Logger, Pressure Reducing Valves, Controllers, Operation and Maintenance.

Introduction

Non-Revenue Water (NRW) is the difference between the water supplied and water billed (water consumption or revenue water). A high level of NRW is mostly caused by leaks, water theft and meter inaccuracies and leads to social problems and challenges in achieving universal access to water. Furthermore, it can enhance the spreading of deadly diseases, the failure of economically viable enterprises and ultimately to huge negative impacts on the environment and on families. Portmore (Jamaica), a city with a population of about 230,000 inhabitants, is supplied by a mix of treated water coming from wells and from the Rio Cobre River. NRW in 2021 was 26,000 m^3/day (61% of the total water supplied) which resulted in negative impacts like intermittent supply, no water during the drought season, low pressure and an inefficient revenue system. To date, NRW has been reduced to 18,000 m^3/day, which resulted in the reduction of the required water supply in Portmore from 42,000 to 32,000 m^3/day.

Focused on being a major player in reducing the unsustainable amount of NRW, Miya Water Jamaica is a company that designs and implements solutions that significantly improve water systems

by reducing NRW and at the same time, via intense training, through the transfer of MIYA expertise to its client through an innovative Co-management program.

To be effective, the NRW Reduction program for Portmore combines both Physical and Commercial measures. On the Physical side, the activities of leak detection, prompt repairs, and effective pressure management are key. On the Commercial side, universal metering is mandatory and all unmetered and illegal customers must be connected.

The effectiveness of all these activities is ensured by using the best technologies available in the market in the form of:

- Equipment to find leaks using acoustic technology;
- Pressure-reducing valves and controllers to regulate water pressure;
- Ultrasonic meters, data loggers and sensors to measure, monitor and control the water network;
- Software including HWM (a web platform that shows real time flow and pressure data from data loggers), and a GIS Collector to gather and display information in graphs and maps.

Methods

Leak Detection Technologies

Leak detection is one of the main activities to reduce the NRW. Leaks can result from several causes, such as ageing pipes, high pressure, poor maintenance and improper installation of pipe and service connections. A significant number of leaks are non-visible and so cannot be found by simple visual inspection.

A water leak can be defined as water that accidentally escapes from a hole or a crack in a pipe or container. When a water leak occurs, it creates a disturbance of energy (vibration) which passes through the water and the pipe wall in the form of an acoustic wave that travels in all directions, becoming weaker with distance from the leak. **(Figure 1)**

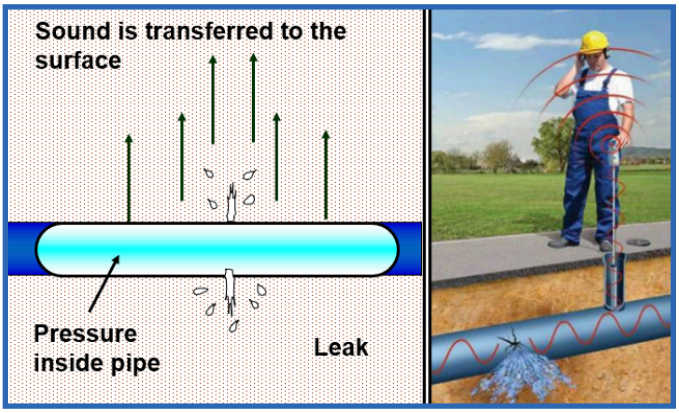


Figure 1 Sound produced by a water leak

This acoustic wave can be detected with acoustic equipment that will amplify, filter and measure the sound's characteristics, giving its user the ability to find underground non-visible leaks. The main characteristics of a leak's sound as seen in **Figure 2** are:

1. Frequency (Hz) – number of sound waves produced each second. Leaks in plastic materials produce lower frequencies when compared to metallic pipes;
2. Amplitude (dB) – maximum pressure difference in a sound wave measured from its equilibrium position i.e. peak to trough amplitude. The higher the amplitude (loudness) of a leak's sound the easier it is to hear it.

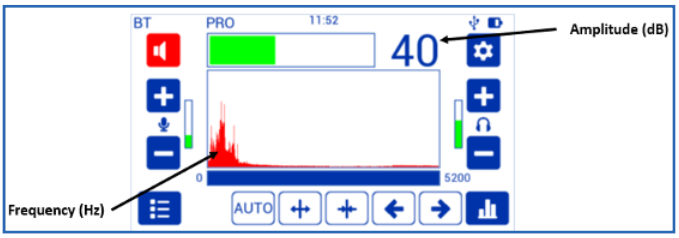


Figure 2 Amplitude and Frequency of a leak's sound displayed on the DXMic

The acoustic equipment used in Portmore is the Ground Microphone and the Listening Stick, both connected to a powerful electronic device **(DXMic – see Figure 3)** that displays the sound characteristics, automatically filters out background noises and creates audio recordings; this means that several sound noises can be recorded on the DXMic and these sounds are sent to a platform where they can be stored and played back using an app or web platform (HWM). These features are very important to reduce human error in the leak detection process.[1]

Legend

1. Acoustic shielded ground microphone used on hard ground surfaces
2. Tripod foot used on uneven surfaces
3. High quality headphones
4. DXMic device used to display all the characteristics of a sound and to apply filters, increase the sound volume and microphone sensitivity

Figure 3 Leak detection acoustic equipment

The leak detection technicians **(Figure 4)** are trained to use the equipment to detect and recognize leak sounds. During the period of March 2021 to December 2022, an intensive program of leak detection was conducted in the 33 km^2 of the Portmore communities. More than 11,000 km of pipes were inspected, which is equivalent to 24 full sweeps of the 470 km pipe network of the Portmore system.

All the suspected non-visible leaks found were reported and mapped on a GIS (via an app called Collector) and the impact of those leaks was analyzed by using a software that gathers all the information recorded on the data loggers installed on the network (HWM).

Figure 4 Leak Detection technician using acoustic technology to find leaks

Pressure Management

Pressure management is one of the most effective ways to control & operate the water systems and reduce the NRW. Although high pressure can be used to increase consumption and revenue, it also results in a higher probability of leaks and bursts and increasing the amount of water lost from existing leaks. Additionally, pressure spikes cause stress and turbulent flows in the network, creating leaks.

Pressure Reducing Valves (PRV) and controllers to reduce and control pressure and data loggers to monitor pressure in the system were installed at strategic points within the Portmore network.

PRV's are self-operating valves that can efficiently reduce NRW by controlling and reducing any excess pressure and flow in a system, thus decreasing the likelihood of leaks or pipeline bursts. There are 2 types of PRV: [2]

- Direct-acting PRV - designed for point-of-use installation. Direct-acting pressure-reducing valves are ideal for small loads such as a single residential house or stand-alone equipment that requires a fixed water pressure level.
- Pilot-operated PRV - generally used for larger loads requiring close pressure control. They provide a faster response to load variations and are suitable for a broader range of pressures and flow rates. **(Figure 5)**

Figure 5 Typical Pilot-operated PRV installed in a concrete chamber

Pilot-operated PRVs **(Figure 6)** control pressure through a fully automatic self-contained operation, without an external power source or, alternatively, with an external programmable Controller operated by batteries and using a modem to send data to the web platform. This PRV Controller can be programmed using a communication cable connected to the laptop or remotely via the Web Platform.[4]

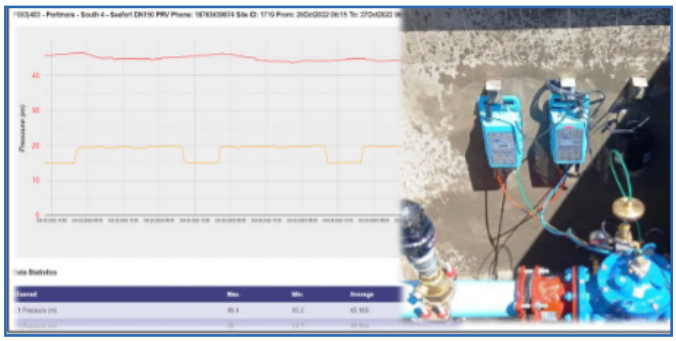


Figure 6 Pilot Operated Pressure Reducing Valve with PRV Controller (right) and its online pressure profile

As of December 2022, nine Pilot Operated PRVs were installed, and a total of 5 Pressure Zones (PZs) were established in Portmore **(Figure 7).**

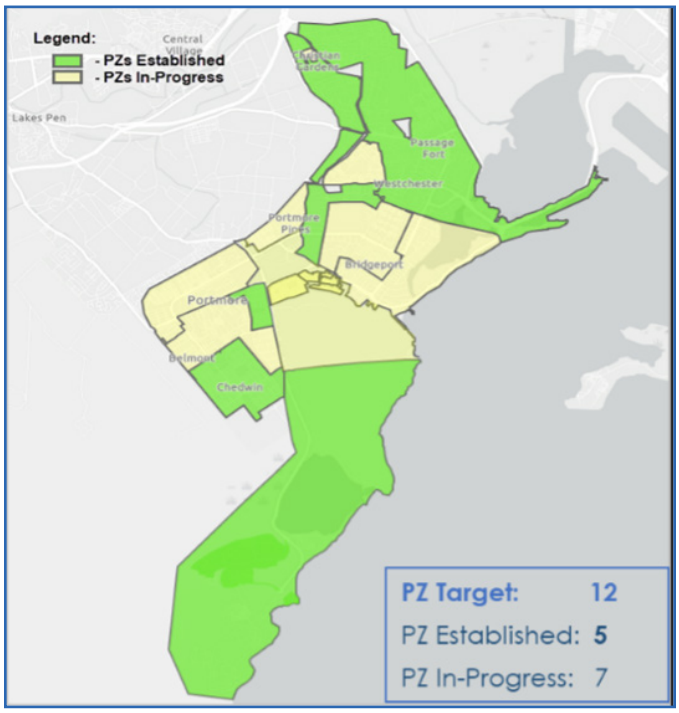


Figure 7 Pressure Zones established to date in Portmore

Figure 8 indicates the satetlite map and plan for the Pressure Reducing Valve location in Gregory Park, Portmore.

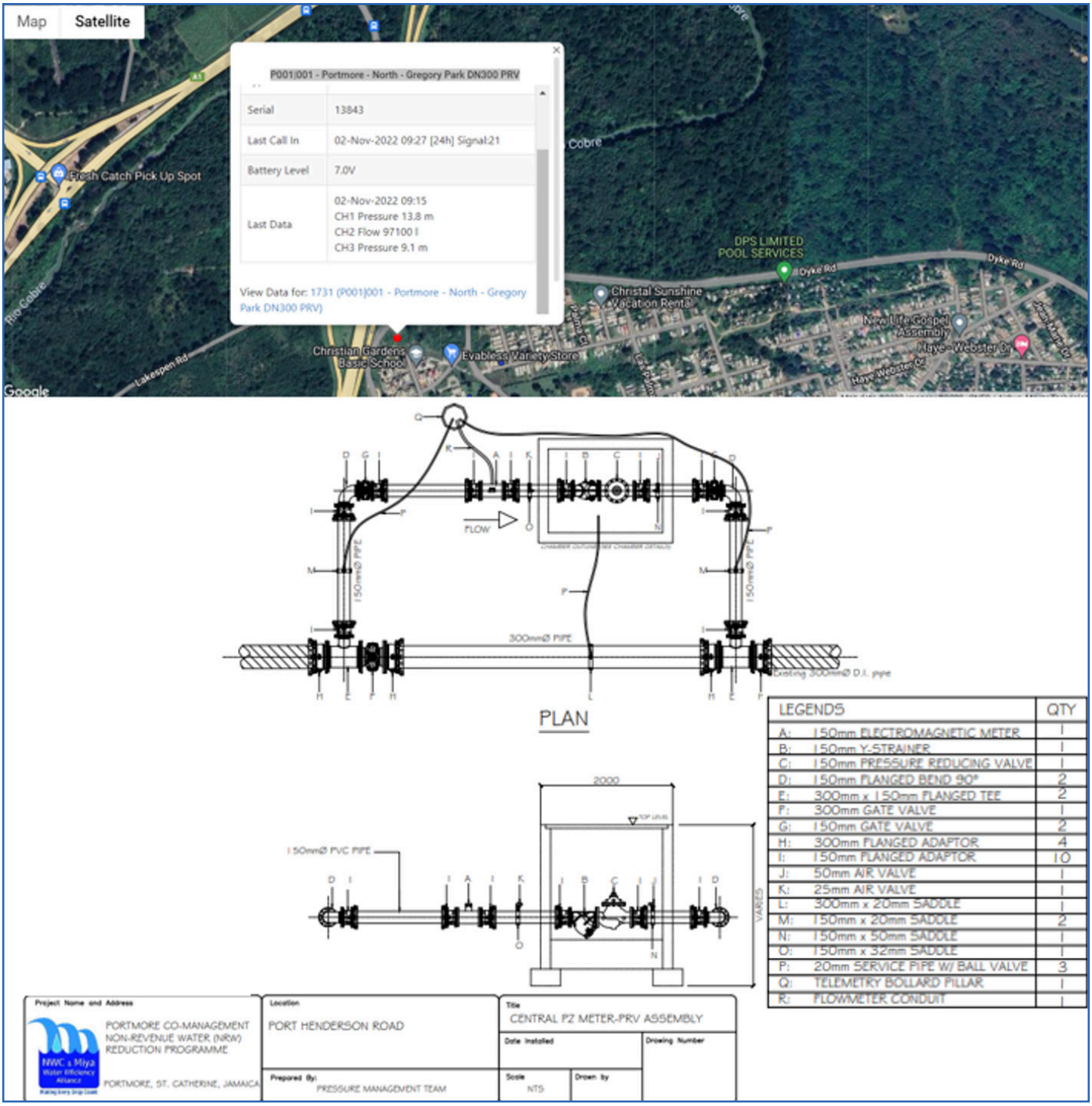


Figure 8 Pressure Reducing Valce (PRV) Location in Gregory Park

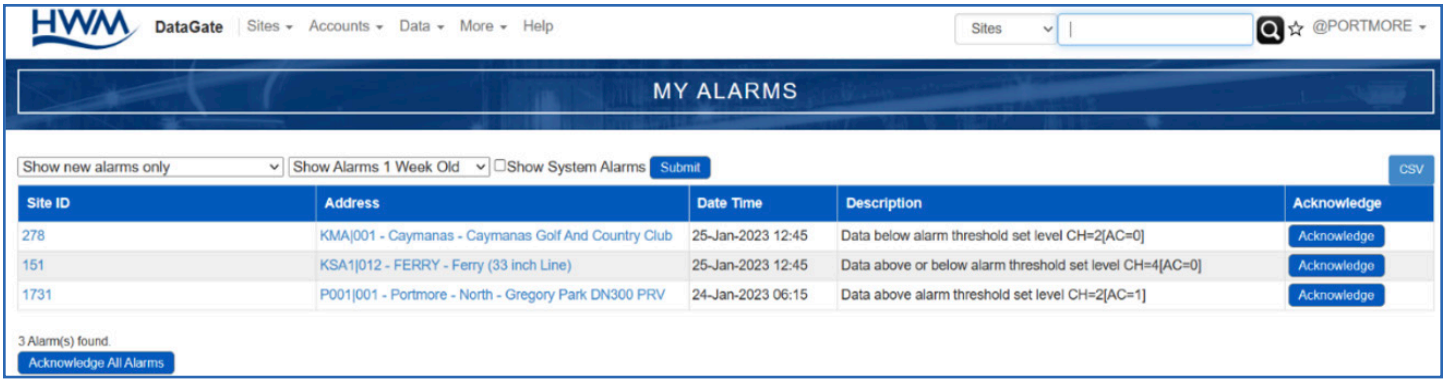


Figure 9 Telemetry Supervisory Control and Data Acquisition (SCADA) System Alarms

Operation and Maintenance

It is imperative that all the maintenance activities are performed in order to optimize the water system and its assets so as to ensure that they are operating effectively.

In Portmore, some reservoirs were overflowing, the pumps didn't have any type of control, the number of bulk flowmeters was insufficient and there was no SCADA (Supervisory Control and Data Acquisition) system used for controlling, monitoring and analyzing devices and processes **(Figure 9)**. The HMW web platform sends a System Alarm to the responsible person if the parameter is above or below limit value.

To solve these issues, an Operation and Maintenance (O&M) program was designed to include a quick assessment of the network assets (reservoirs, pumps, PRV, flowmeters, etc.) and an investment in technology to improve their efficiency and lifespan as seen in **Figure 10**. The following were procured and installed:

- 8 Altitude Valves (Level Controllers) to avoid overflowing, thus saving water and energy. These valves are designed to automatically switch off the pump when the reservoir is full and feed the consumer by gravity; [3]
- Pressure switches with programmable timers for pump control, increasing the lifespan of the pumping stations and reducing the energy consumption;
- 120 data loggers to measure and store relevant data;
- 30 electromagnetic flowmeters to measure the volume of water in the system.

Legend

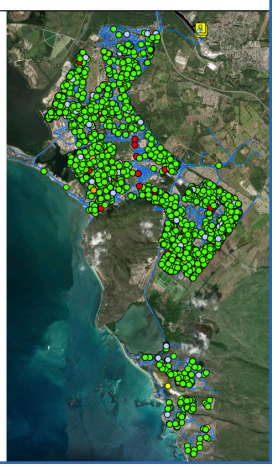
1. Programmable pump switch
2. Altitude valve
3. Electromagnetic Flowmeter
4. Data logger

Figure 10 Operation and Maintenance (O&M) Technology installed in Portmore

Results

A total of **2,089** suspected non-visible leaks were found (green dots on map in **Table 1**) using the acoustic technology (Ground microphones and listening stick) with the following breakdown:

Table 1 Breakdown by Type of Non-Visible Leaks

Type of leak	Total	GIS
Main	208	
Service Connection	1717	
Meter	52	
Valve	43	
Hydrant	7	
Customer Side Leak (leak downstream the client meter)	62	

From the total of suspected non-visible leaks found using acoustic technology, 90% were confirmed as actual leaks by the leak repair team after excavation, showing the effectiveness of this technology. **(Figure 11)**

Figure 11 Suspected non-visible leak reported (before and after excavation)

The prompt detection and repair of these leaks reduced the water losses by approximately 4,000m^3/day. The establishment of 5 PZs with efficient pressure control (PRV Controllers) has resulted in a more stabilized pressure throughout the system and approximately 2,000 m^3/day of water savings. These savings will increase with the implementation of the remaining 7 PZs and further optimization of the existing ones. The flowmeters and the data loggers installed measured, stored and transmitted all the data necessary to understand and optimize the water system (see **Figure 12**).

The altitude valves installed on the reservoirs prevented them from overflowing and resulted in approximately 1,500 m^3/day of water savings. Additionally, the combination of the use of altitude valves in reservoirs and pressure switches in pumping stations optimized energy consumption and reduced usage from 146,325 KWh to 96,772 KWh. **(Figure 13)**

Overall Results

With use of the technologies mentioned in this paper, the Non-Revenue Water, when system pressurized (WSP), of the Portmore distribution network was reduced from about 26,000 m^3/day to 18,000 m^3/day [July – December 2022] as represented by the orange line in **Figure 14**. A one year (12M) rolling average (gray line in **Figure 14**) shows the consistent downward trend of NRW. In December 2022, the 12 Months Rolling Average NRW is at 18,891 m^3/day which is below the contract target, represented by the blue shaded area in the graph.

The approximately **50% reduction**, or 8,000 m^3/day (1.76 M gallons/day) of water saved was achieved mainly due to leak detection and repair activities, pressure management, operations & maintenance and automation of the facilities.

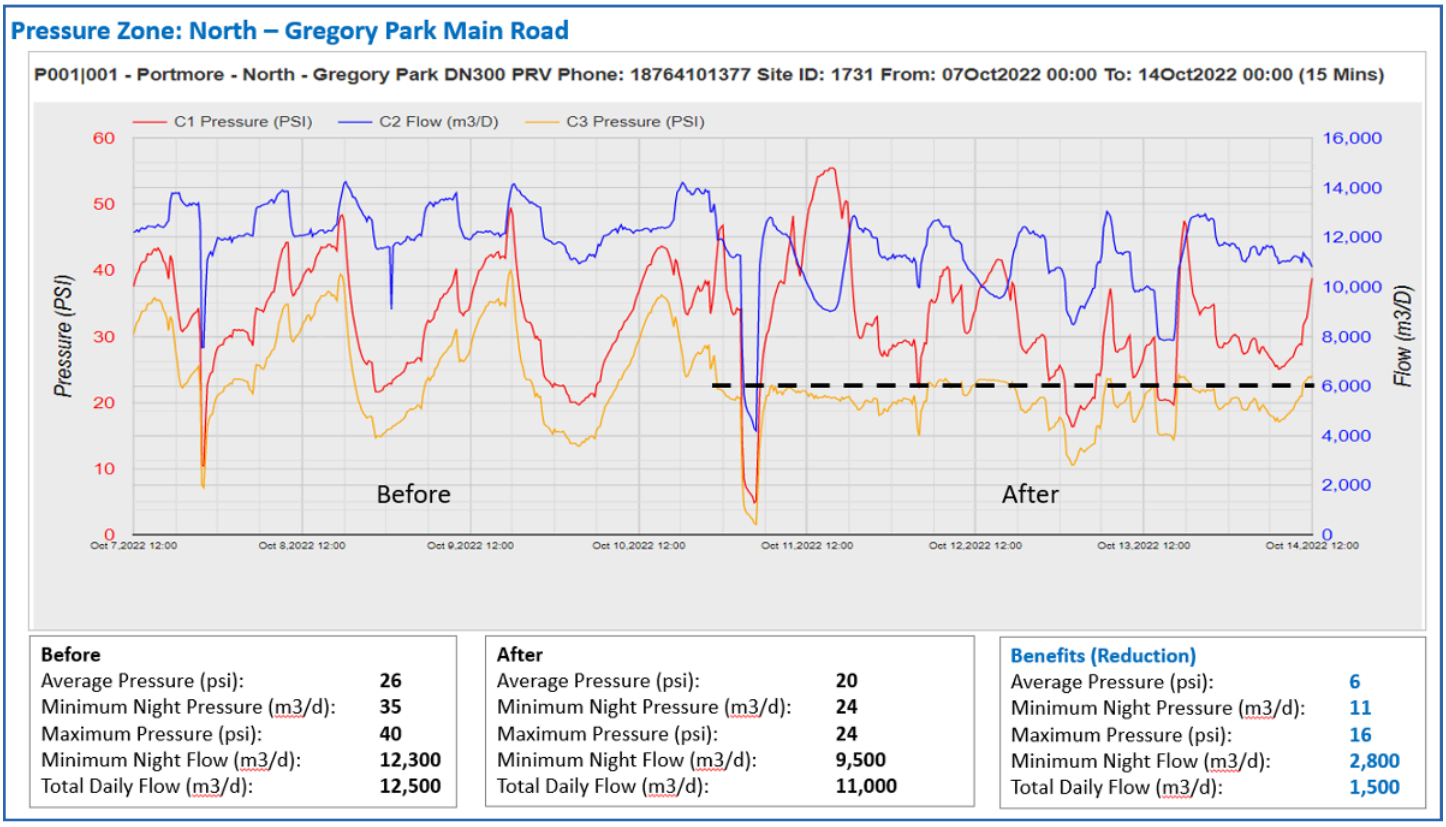


Figure 12 Pressure management results of Gregory Park PRV. Data gathered from data logger and flowmeter and displayed on the HWM software

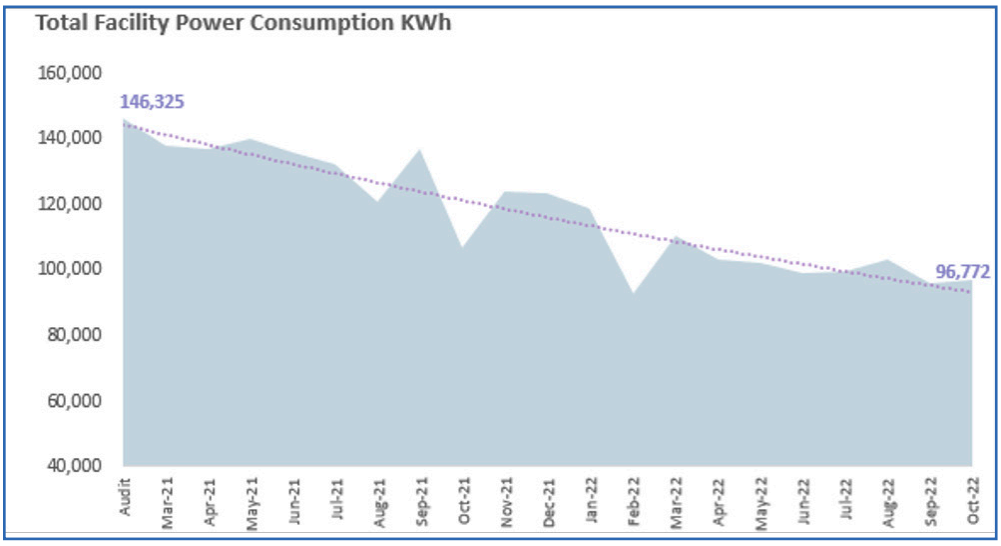


Figure 13 Total facilities power consumption

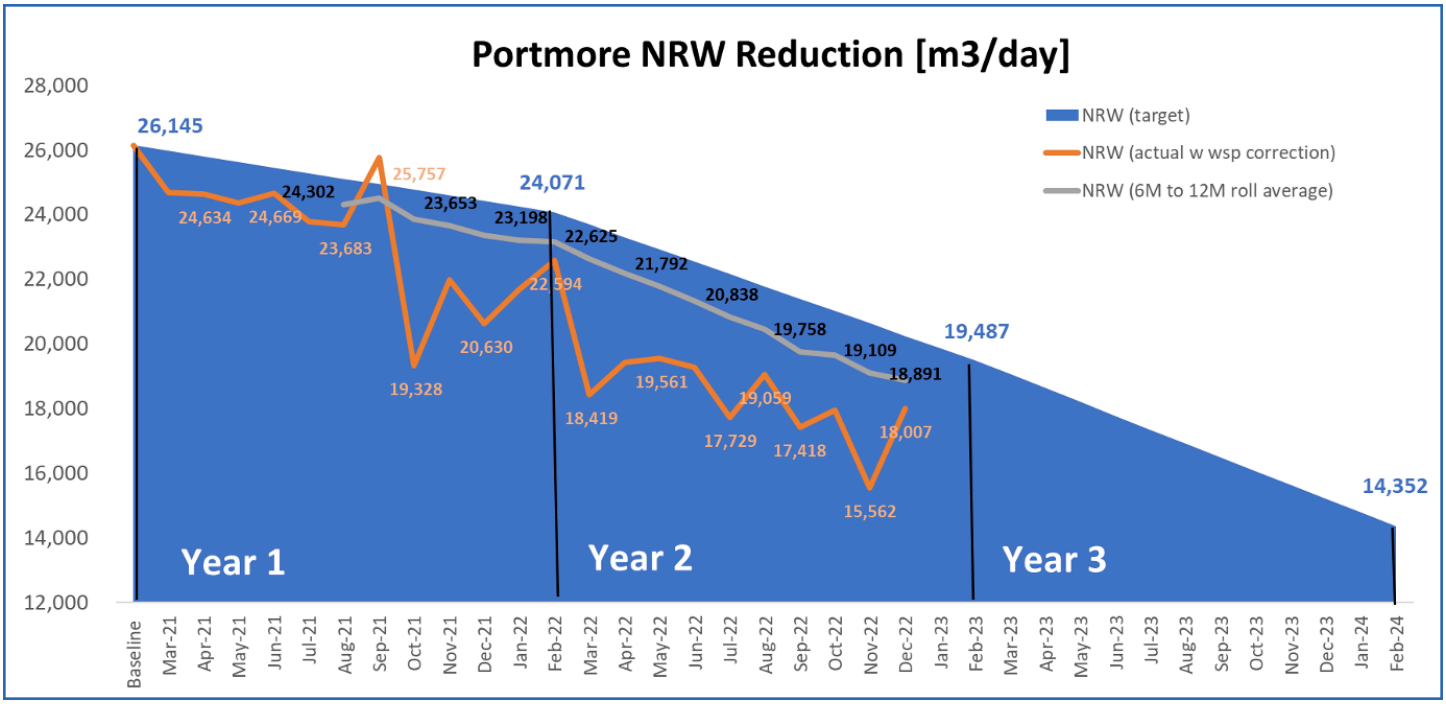


Figure 14 Portmore NRW results

Conclusion

Implementing a holistic approach to reduce NRW combined with the use of effective technologies are key to an efficient water distribution network. The use of acoustic leak detection, pressure management, automation and maintenance of the facilities, can reduce NRW, and will result in savings in electricity / operating costs and the amount of potable water produced and transported to customers' premises. These four pillars must be implemented simultaneously, and each pillar must be executed according to Standard Operation Procedures (SOPs) for a successful leak management strategy.

Otherwise, the network will continue to deteriorate. The final goal of this Portmore project is to continue implementing the described holistic approach combined with addressing unauthorized consumption and meter inaccuracies to reduce the NRW by the targeted 10,000 m3/day before the end of the project (February 2026).

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