A Cost-Effective Approach for Leak Detection and Leak Localization in Multi-Family

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Background

The EPA states that 12% of water usage is due to leaks (Reference 1).

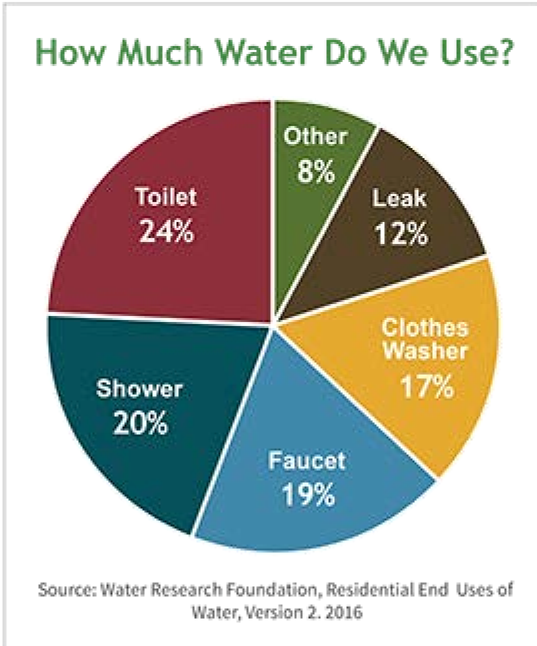


Figure 1 - A graph from the Water Research Foundation showing how residential buildings use water.

This means the average apartment wastes over 6,300 gallons of water each year costing property owners an average of $76/unit. From previous experience, NOWi has seen up to 28% of a portfolio of properties' water usage is due to leaks. These leaks come from several sources but a few of them dominate. An SFPUC report (Reference 2) found that 60% of the leaked water comes from toilets with irrigation as the second largest source. This SFPUC study focused mainly on residential buildings.

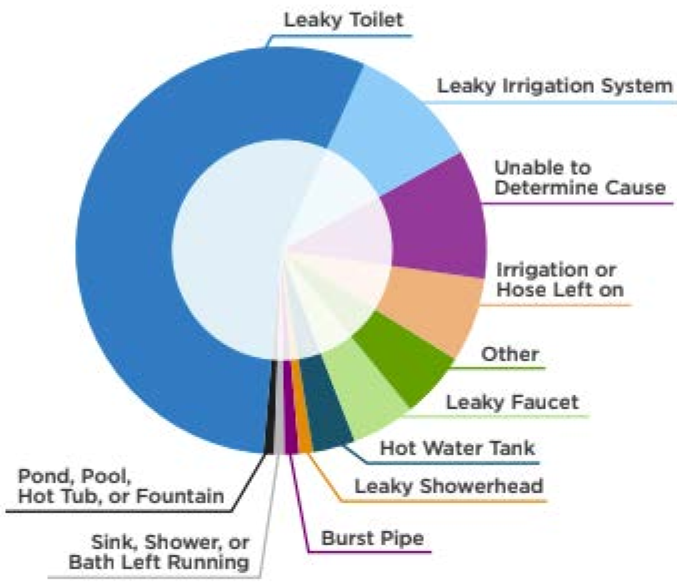


Figure 2 - A graph from the SFPUC study shows the source of leaks in their study.

From our experience, the amount of water usage due to leaks in multifamily buildings is much larger than these reports have found that include single-family residential buildings, and we've seen an even higher percentage of leaks due to toilets. Most tenants do not want their property managers to have to come into their living spaces. This means that most tenants will not report water leaks even when they are noticed so they do not have to have maintenance personnel come into their apartment. This increases the number of leaks due to toilets and the total amount of water wasted.

Another issue with multifamily properties is localizing where a leak is coming from. In a normal building, you may have a few toilets, a few sinks, a dishwasher, a shower, etc.. For each unit in a multifamily building, you have that many more of those appliances using water. For this reason, many utility water meters don't even have leak detection for multifamily buildings. Even if there is a leak detected, localizing where it is can be frustrating and even impossible without adding sensors in the building.

For all of these reasons, discussed above there is a large opportunity to save water at multifamily properties with a well-designed sensor solution.

Introduction

We are proposing a low-cost, easily installed leak detection and localization solution for multi-family apartment buildings that combines both mainline water monitors and individual toilet monitors. The mainline water monitor will detect any leaks within the building, and determine the size/cost of the leaks. The toilet monitors will localize any leaks that come from toilets, which in multi-family buildings is by far the most common type of leak. This approach will provide a substantially lower cost and more easily implemented solution to water leakage than any other solution available to multi-family property owners.

Sensors

The sensors that will be deployed are smart sensors that connect to the internet over LoRaWAN networks. Cloud-based algorithms monitor water usage from the sensors and alert property managers whenever a leak is detected. Property managers can go on our console or use our email reports to analyze in real time and track historical usage for a building.

Mainline water monitor:

https://nowisensors.com/pages/building-monitor

This sensor straps around a building's utility water meter and monitors a magnet that spins in the meter as water flows through. When configured accurately, these devices are >99% accurate with what the watermeter records.

Toilet water monitor:

https://nowisensors.com/pages/toilet-monitor

This sensor is easily and quickly installed on toilets and monitors whether water is flowing into the toilet.

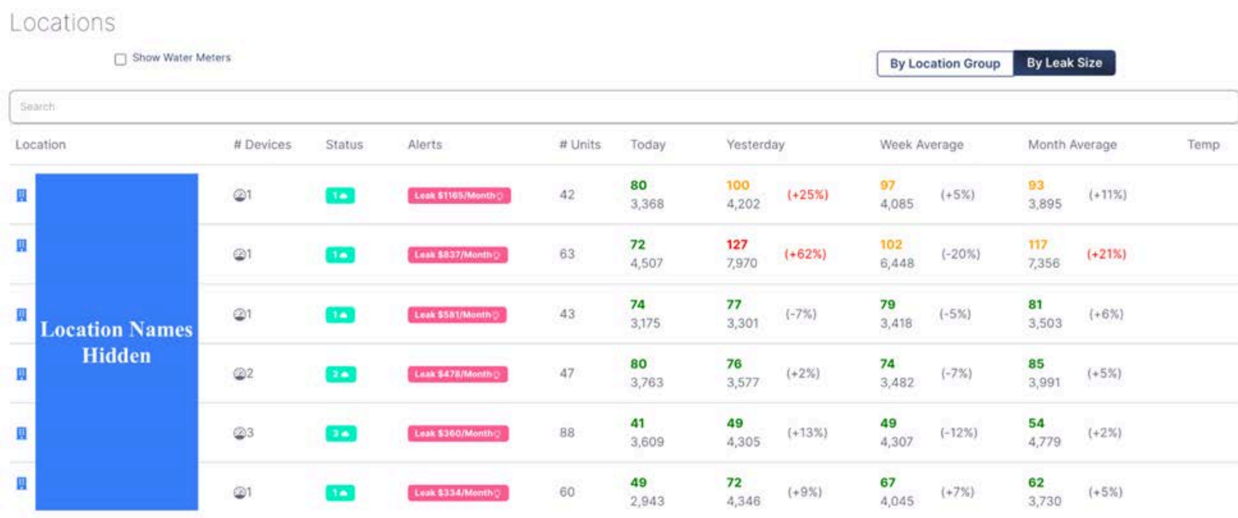
We deployed these sensors at a multi-family portfolio across Los Angeles consisting of 44 buildings and 857 units that are owned by Veritas Investments. We worked with a property management team to triage and fix the leaks. It's not enough for a system to just detect a leak. An important factor in determining the efficacy of these solutions is determining whether the data is actionable enough for property management teams actually to find and fix the leaks that are detected.

Based on our extensive experience with multi-family operations and existing deployments of our water monitors, we believe we will find the combination of mainline water monitors and toilet sensors will be an effective and actionable solution to eliminate water leaks.

Console

The Toilet Monitor and Building Monitor send data up to the cloud where the data is analyzed and stored. NOWi's algorithms look for multiple signatures of leaks with the most common one being 24 hours of constant flow indicating a leak. Whenever a leak is detected real-time alerts are sent to maintenance personnel.

Property owners can also view the status of their properties on NOWi's console. There's an overview page where they can quickly scan their property usage and if there's a leak as well as the estimated size of the leak.



Locations

☐ Show Water Meters

By Location Group | By Leak Size

Search

Location	# Devices	Status	Alerts	# Units	Today	Yesterday		Week Average		Month Average		Temp
Location Names Hidden	1	1	Leak $1165/Month	42	80 3,368	100 4,202	(+25%)	97 4,085	(+5%)	93 3,895	(+11%)	
	1	1	Leak $837/Month	63	72 4,507	127 7,970	(+62%)	102 6,448	(-20%)	117 7,356	(+21%)	
	1	1	Leak $581/Month	43	74 3,175	77 3,301	(-7%)	79 3,418	(-5%)	81 3,503	(+6%)	
	2	2	Leak $478/Month	47	80 3,763	76 3,577	(+2%)	74 3,482	(-7%)	85 3,991	(+5%)	
	3	3	Leak $360/Month	88	41 3,609	49 4,305	(+13%)	49 4,307	(-12%)	54 4,779	(+2%)	
	1	1	Leak $334/Month	60	49 2,943	72 4,346	(+9%)	67 4,045	(+7%)	62 3,730	(+5%)	

Figure 3 - Overview tab of the console showing an overview of all of the properties, their water usage, if there's a leak and the size of the leak. The location names are hidden for privacy. The top number in the Day/Week/Month column is the average daily per unit usage over the last day/week/month. The middle number is the total usage for the building. Finally, the percentage is the usage change over the last period.

Building Monitor Graphs

Users can dig into property data by looking at real-time and historical graphs of each property's water usage. The Building Monitor sends up the total number of gallons it's seen and a timestamp. The console can derive gallons used over each period, and the flow rate from this data. The graph below shows the high-resolution data that comes from the devices along with the estimated leak size for the property.

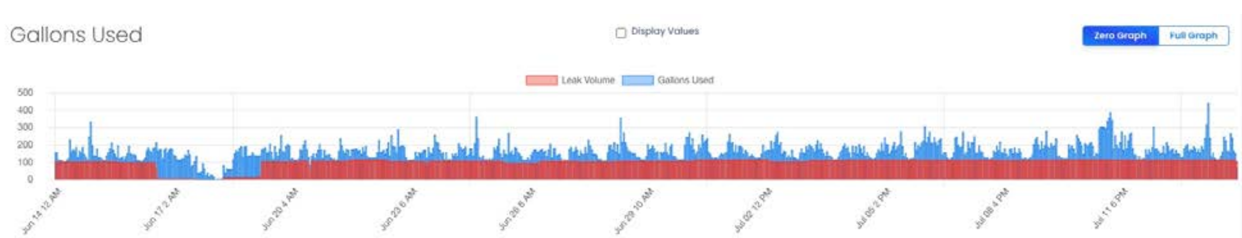


Figure 4 - This graph shows the water usage at a property with a leak. The bar graph in BLUE shows the total usage over each hour. The bar graph in RED shows the leak's estimated usage over each hour.

Toilet Monitor Graphs

Users can also dig into the Toilet Monitors graph with a separate graph. This graph shows the total number of flushes each day and the total duration the toilet was using water. Below is a graph showing a toilet with normal usage.

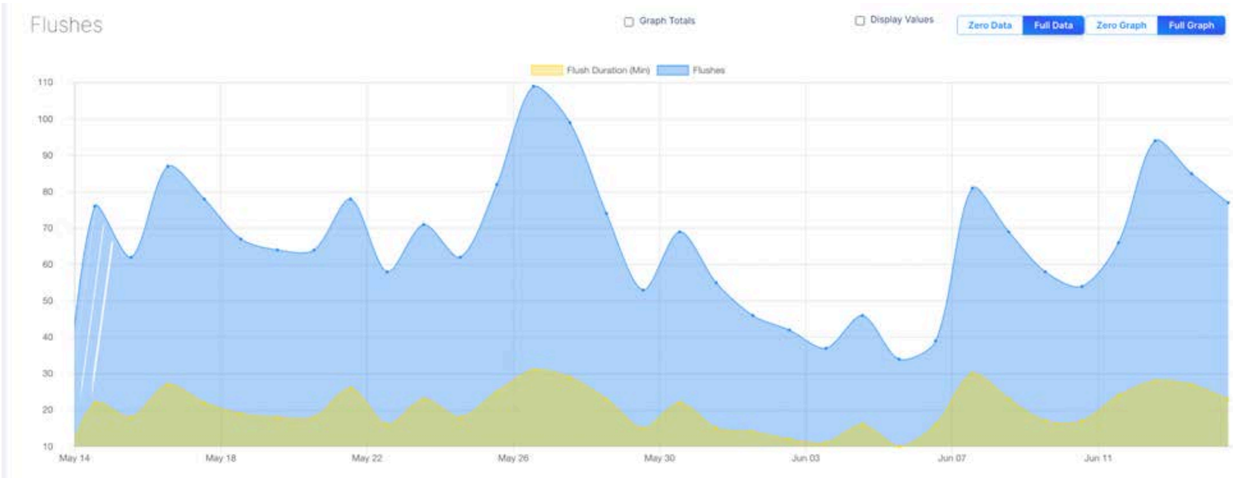


Figure 5 - This graph shows normal toilet usage data. The BLUE line is the number of times the toilet was flushed over each day. The YELLOW line is the number of minutes that the toilet was using water for each day.

Goals

1) What percentage of water usage in multi-family properties comes from water leaks? While there are numbers on residential water usage due to leaks (usually around 12%) these include single-family homes that have a different water usage profile than multi-family. We generally see higher rates of leaks for multi-family because in many cases tenants do not report/repair leaks as they would in a single-family home. We'll also be looking to determine what percentage of leaks in multi-family are from toilets.

2) Are mainline water monitors an effective way to monitor multi-family properties for leaks throughout the building? While mainline water monitors can detect water leaks, and how much water they are wasting, they cannot locate the leak within the building. This results in extra work for maintenance teams to localize the leak often resulting in smaller leaks going on indefinitely.

3) Does adding toilet sensors reduce labor costs and further reduce the number of water leaks?

4) How effective are a mainline water monitor and toilet sensors in finding and fixing leaks over an extended period?

Methodology

Much of the design of this experiment comes from our work with properties and property managers across the country where we have full-scale deployments. Their maintenance teams' time is valuable so deployment and triage are very time sensitive. For this reason, we only targeted buildings with large leaks detected by our main-line water monitors for toilet sensor deployment. We will, therefore, be deploying the toilet sensors while maintenance teams are already in the buildings doing the initial leak triages.

The study will be conducted with the following stages:

Mainline Monitor Deployment (Stage 1)

This study will begin by deploying just mainline water monitors across the full portfolio. In combination with past and current water bills, we will calibrate the water monitors and determine each building's baseline water usage. The water monitors will also provide an indication of which buildings are leaking and the amounts of leakage.

Leak Triage and Fix Using Mainline Water Monitor Data + Toilet Sensor Deployment (Stage 2)

Once the mainline water monitors have determined which buildings are leaking and at what rate, the property management teams will go through the buildings to triage and fix leaks. Any buildings with leaks larger than 27,000 gallons/month (~$500/month worth of leaks this is a threshold our customers have used in the past to investigate leaks) will have the toilet sensors deployed. Based on prior experience with main-line monitors at multi-family portfolios, we estimate toilet sensors will be deployed at 20% of the buildings

The goal is to fix water leaks based on just the data from the mainline water monitors. From previous experience, there will be leaks that are not searched for and fixed in the initial triage, usually from toilets. Which is why the toilet sensors will be deployed. It also makes operational sense to deploy them as the maintenance teams will already be going through the buildings.

Leak Triage and Fix Using Toilet Data + Long-term monitoring (Stage 3)

Once the toilet sensors are in place, we'll use them to determine if we can find any leaks not fixed during the initial triage. The goal here is to determine how much value the toilet monitors add as compared to just mainline water monitoring.

Results

The Building Monitors were installed in March and April 2023. Between April and June, there were 8 tasks completed to fix significant leaks that were reported by NOWi's devices. There were another 6 leaks that were deemed not large enough (<$100 /month worth of water wasted) to send maintenance personnel to fix since the leaks were not localized within the buildings. This puts 33% of the buildings having leaks, with 19% of the buildings having significant leaks. The percentage of total usage due to leaks fluctuated throughout the study. At the beginning, of the study, 22% of the water usage was due to leaks as estimated by our leak detection algorithm. From NOWi's experience, this was a fairly low leak percentage at the start which is a credit to the property management team for maintaining the buildings well. 22% is significantly above the 12% of usage due to leaks that the EPA has stated. Over the first 3 months of the study, the Asset Management teams worked hard to fix the leaks that were detected. The water usage due to leaks dropped to 2.16% of usage. By the end of the study, due to the loss of resources to continue to tackle leaks the water usage due to leaks was 7.8%. Leaks are an ongoing battle, approximately 1 in every 60 toilets will begin to leak each month and irrigation leaks occur all the time. Without the resources to tackle the leaks, the accumulative amount of leaks will increase over time.

The Building Monitors were found to be an effective way to monitor the buildings, especially for smaller buildings with up to 30 units. While the devices were still effective in detecting and sizing leaks for larger buildings the amount of work required to localized leaks became an obstacle to tackling the leaks.

The Toilet Monitors were able to detect numerous types of toilet leaks including leaking flapper valves, broken fill valves, and stuck open flapper valves. During installation 2 leaks were detected right away. In total 104 toilet monitors were rolled out across the 42 buildings. The toilet monitors were able to localize each leak they detected to the exact unit that had the issue. This prevented maintenance personnel from having to knock on each unit in the building to track down a leak. Between 6% to 10% of toilets were leaking at any one time. In some buildings over 14% of toilets were leaking at the time of installation. Some toilets had issues with stuck open flapper valves where the toilet would leak a significant amount of water for some time and then fix itself on a flush only to re-leak later on. Since these toilets can leak the most amount of water, if one has signatures of this leak (flowing water > 100 minutes per day) within the last week we consider it a leaking toilet even if it was not leaking when the data was collected.

Building Monitor Installations

44 Building Monitors were installed on March 26th, 2024 and April 8th, 2024. Each device takes about 5-10 minutes to install once you're at the site. Installation only takes a few steps. First, the sensor is strapped around the water meter's register. Secondly, the node is attached so that the antenna is pointing towards the ski. Below are a few example installations.

Figure 6 - Is an example installation with the sensor strapped onto the register of a property's water meter.

At first, the devices were attached to the water meter pit lid with a zip tie. While this was a quick and effective way to install them, we later saw issues with the devices being damaged when the utility company opened the pits and read the meters. To fix this the devices were attached to a mount affixed to the side of the pit.

Figure 7 - A building monitor zip-tied to the lid of a water meter pid.

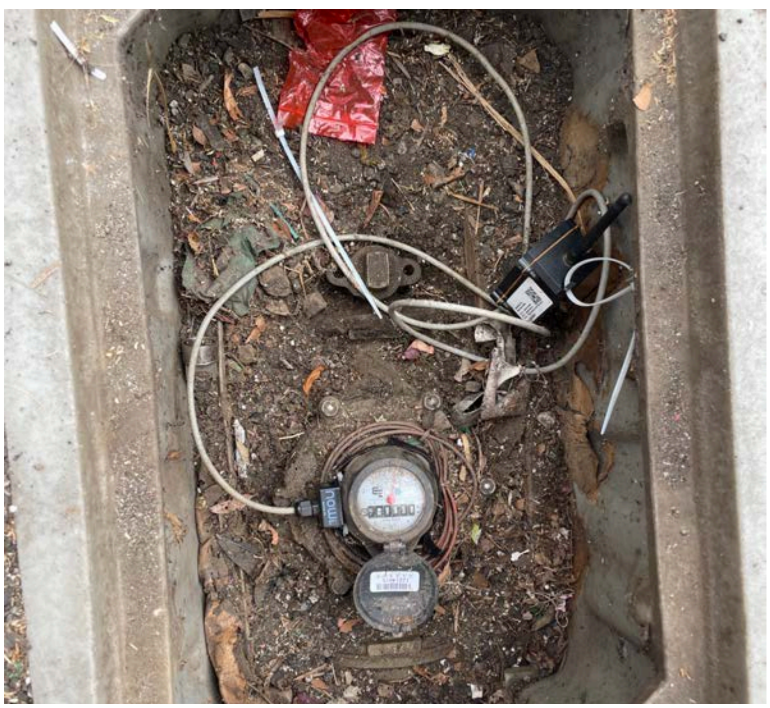


Figure 8 - A Building Monitor affixed to the side of the pit.

Another issue during installation was with the signal due to thick metal lids. Metal acts as a Faraday cage and blocks the signal from passing through causing signal issues. In some locations, we placed antennas outside of the lids. However, the most reliable way to get a signal to the devices was to put a gateway at the location. The ability to extend coverage with our own gateways was one of the advantages of the Helium network over say cellular networks.

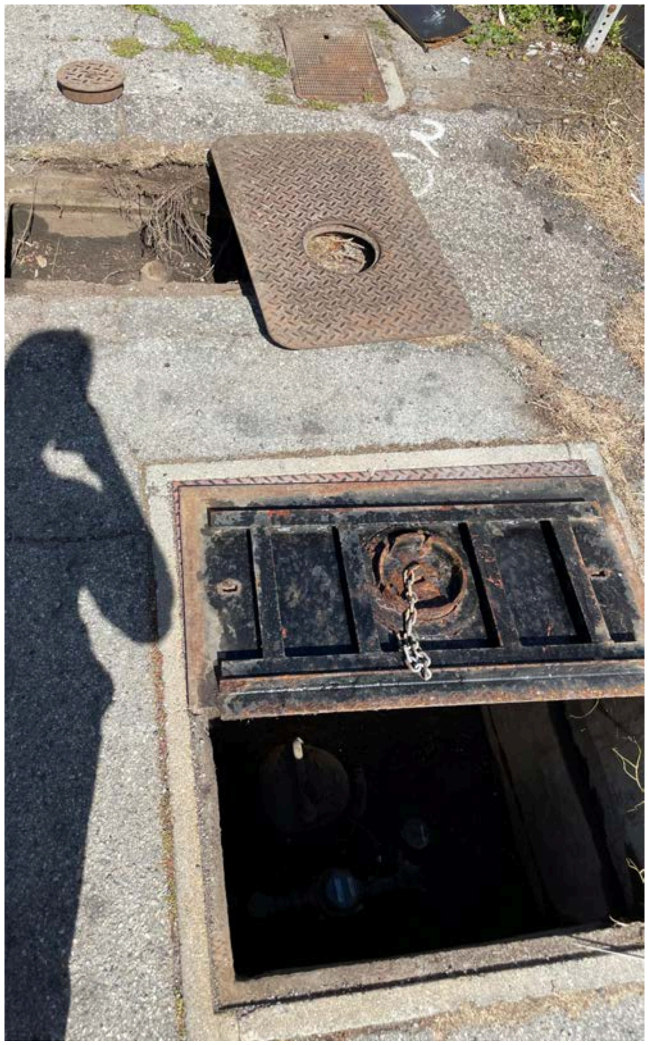


Figure 9 - Example of metal lids that acted as Faraday cages and blocked the signal.

Signal Checks

As the Building Monitors were installed a special device was used to ensure that there was a network signal at each location. Figure 10 shows an example of a recording at one of the sites. This was later abandoned since each location had a good signal.

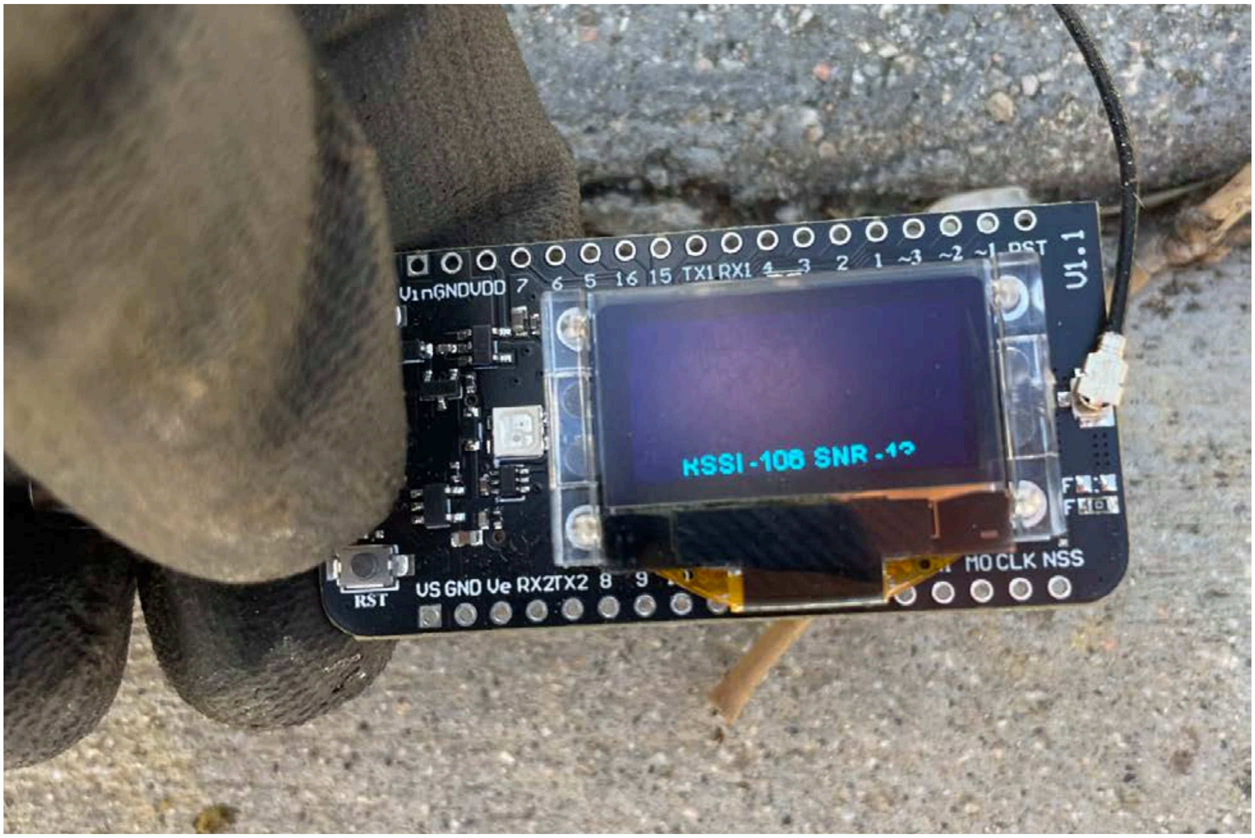


Figure 10 - Shows a prototype of a device we used to check the network signal at each location.

Meter Configurations

The Building Monitors need a configuration for each model and size of a water meter for example a model T-10 size ¾” or 1-½” meter. To build these configurations, two pictures were taken of the water meter register spaced out by at least one day to ensure usage in between. From here a configuration can be built for the number of cycles of the water meter per gallon of usage. We’d cross-verify these configurations with multiple buildings to validate their accuracy.

Comparing Building Monitor Data Vs Utility Data

The accuracy of the Building Monitors was determined by comparing the usage seen by the devices with the water bills. We weren’t able to get all of the utility bills due to time and resource constraints of ours and the property owners we worked with. Below is a table of the data we do have. In general, we see a high degree of accuracy. There’s some amount of difference expected due to recording differences between the devices and the water company. For example, the data from our devices is from midnight of the start date to midnight of the end date, however, the utility company may have recorded it at other times such as 9 am and 4 pm.

Location	Billing Period Start Date	Billing Period End Date	Water Bill Usage (HCF)	NOWi Usage (HCF)	Accuracy
Location A	1/18/2024	3/20/2024	49	45.184	92.21%
Location B	1/18/2024	3/18/2024	55	54.726	99.50%
Location B	11/14/2023	1/18/2024	59	58.000	98.31%
Location B	9/14/2023	11/14/2023	57	55.504	97.38%
Location C	2/1/2024	3/1/2024	38	37.259	98.05%
Location D	1/11/2024	3/13/2024	85	83.452	98.18%
Location E	1/30/2024	3/30/2024	188	186.300	99.10%

Figure 11 - Shows multiple locations' (with their names hidden) utility water usage compared to NOWi's devices' reported usage. Location B has multiple rows to show the accuracy persisted over multiple periods.

Toilet Monitor Installations

The toilet monitors have two components, a sensor and a communication node that are connected by a wire. The sensor goes into the tank and senses whenever the toilet is flowing. The communication node is placed hidden behind the toilet. The monitor was designed to be very simple to install, requiring just a few minutes without any plumbing needed.

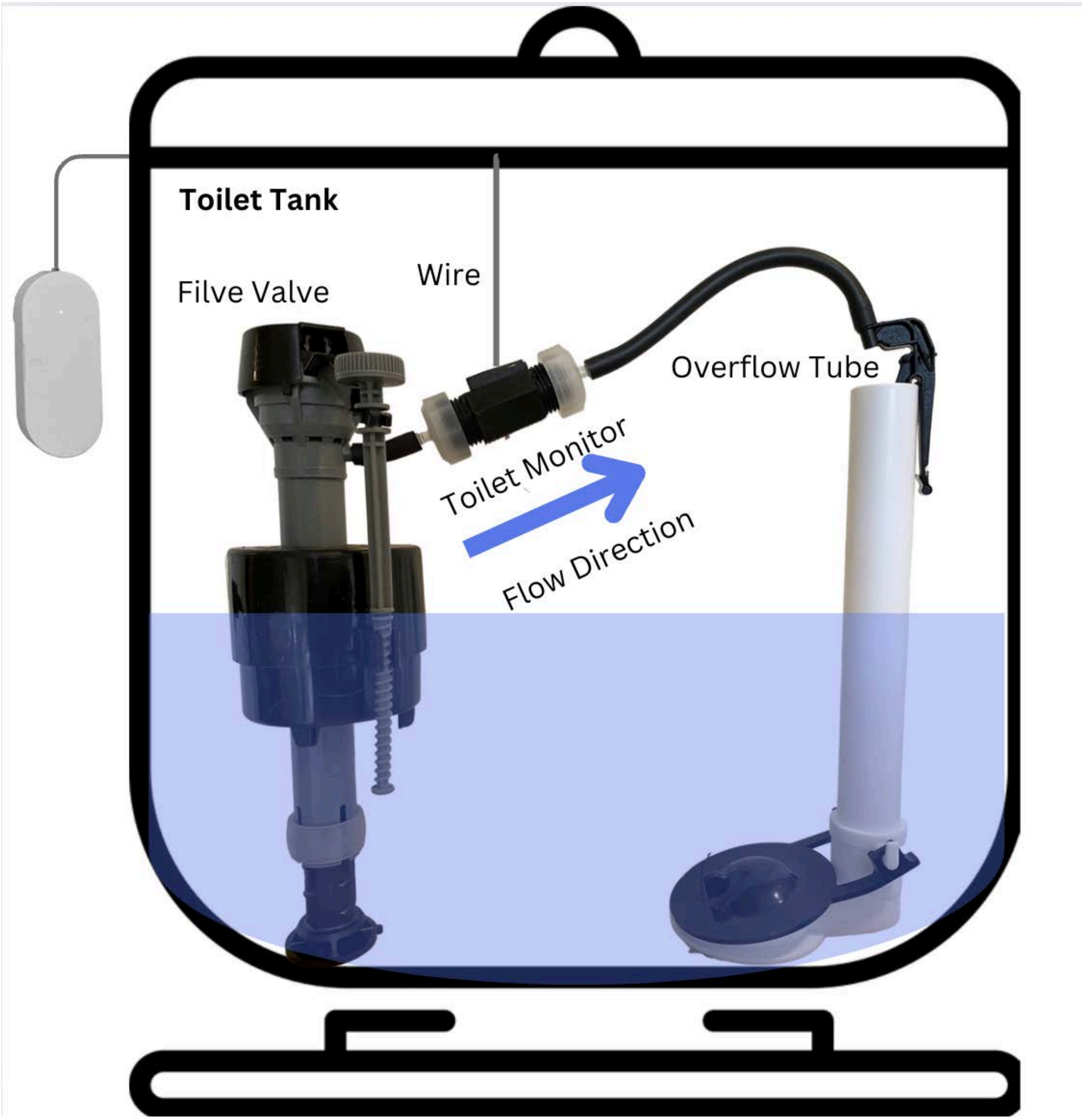


Figure 12 - Shows how the Toilet Monitor is installed within a toilet.

Figure 13- Shows the Toilet Monitor's communication node hidden behind the toilet between the wall.

Figure 14 - Shows two examples of how the Toilet Monitor sensor is installed within the toilet.

Figure 15 - Shows how the toilet monitor is completely hidden from the tenants after installation.

Examples Of Leaks Detected

Below are several examples of different types of leaks from broken pipes, irrigation leaks, and different types of toilet leaks. All of these leaks discussed below were leaks that were detected at properties in this study.

Broken Pipe

A Building Monitor detected a leak of 191 Gallons/Hour. The on-site maintenance team was able to narrow it down to a pipe that was leaking into the ground. This leak would likely have been noticed during the next water bill and wasted 137,000 gallons per month.

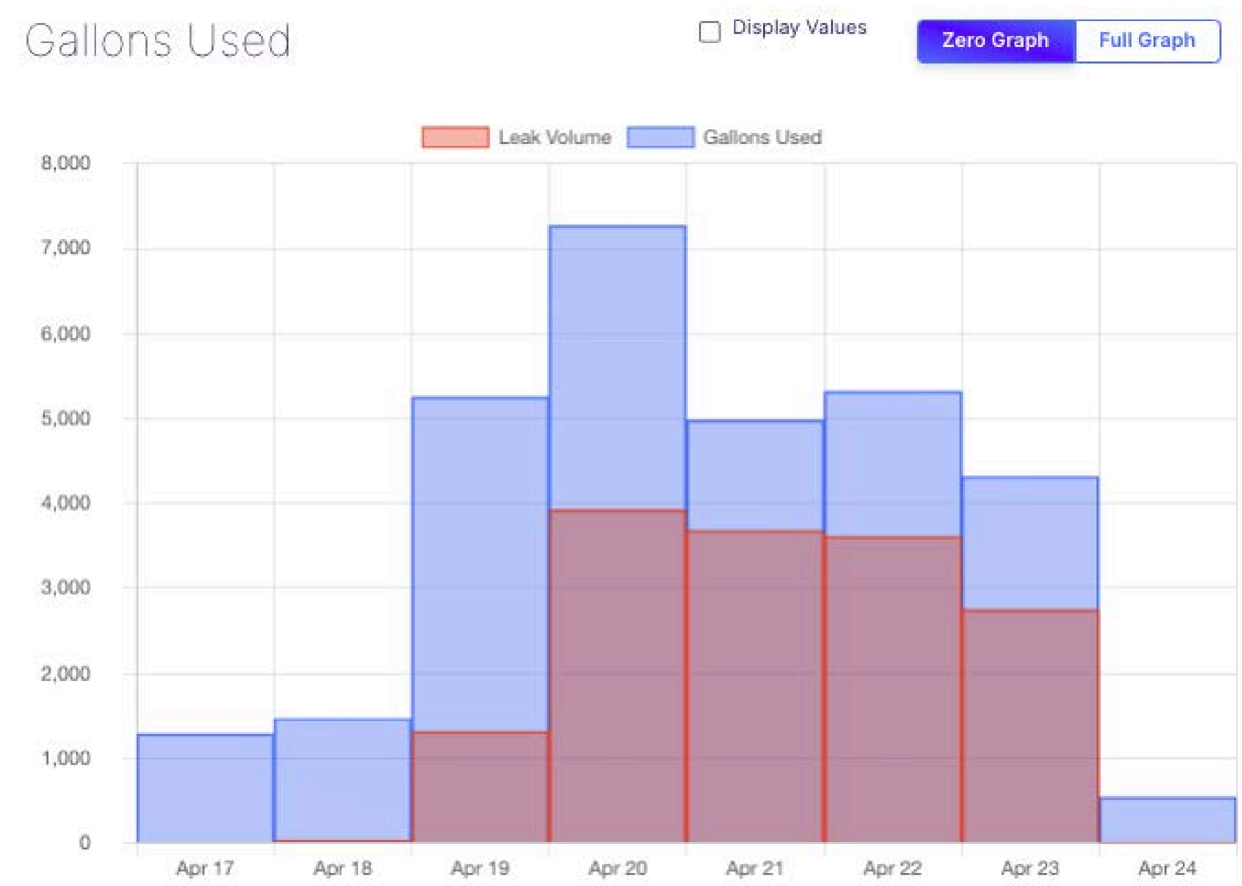


Figure 16 - Blue is the total gallons used daily, and red is NOWi's leak detection algorithm's estimated leak size daily.

Irrigation Leak

Below is an example irrigation leak that was detected by a Building Monitor. The leak was leaking around 173 Gallons Per Hour and had gone unnoticed by the on-site staff until our monitor detected the leak.

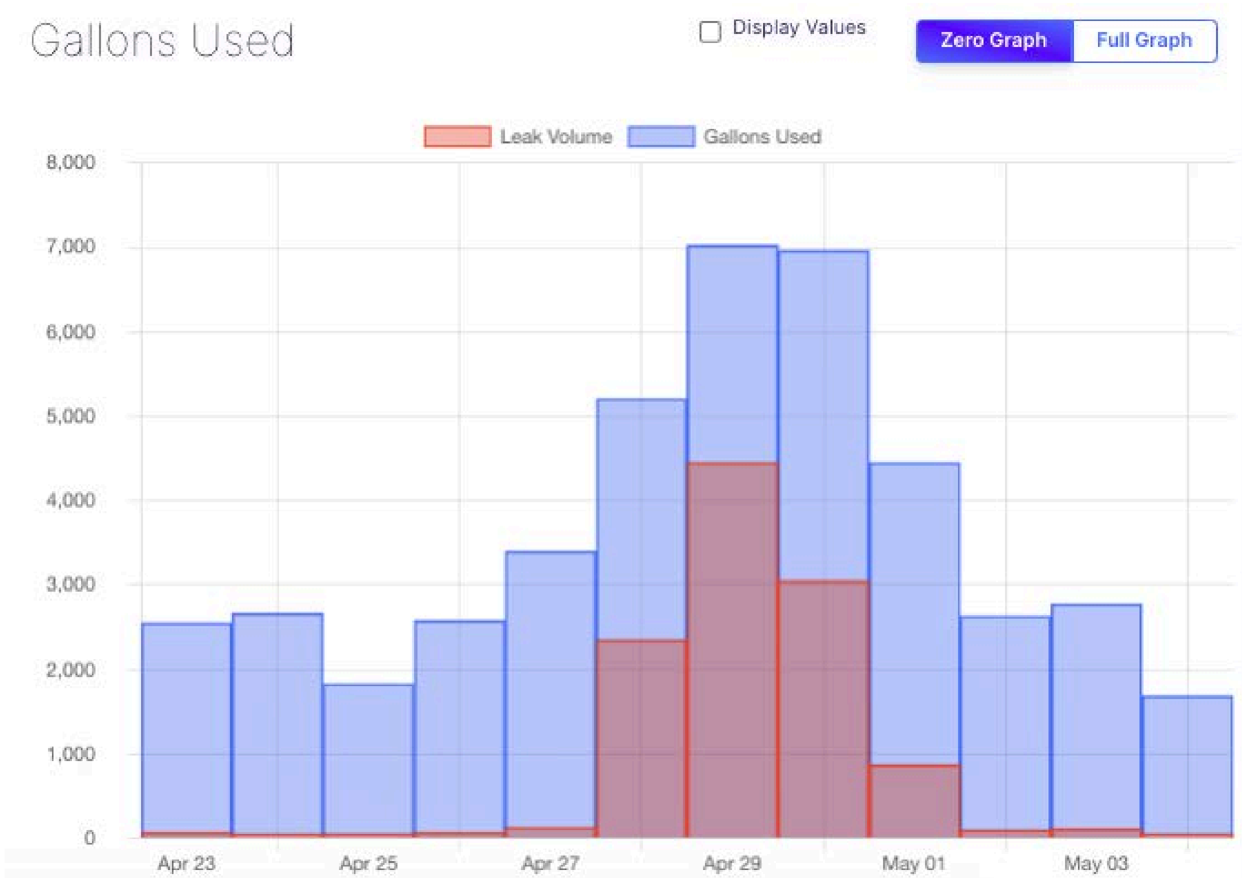


Figure 17 - BLUE is the total gallons used daily, and RED is NOWi's leak detection algorithm's estimated leak size daily. The Y-axis is the number of gallons used and the X-axis is the date.

Increasing Leak

The example below is a building that grows over time. This is very common and can be very hard to detect with water bills. For example, if one water bill is 5% higher, and the next is just another 5-10% higher, the ops team may not notice it like they would a quick spike in usage. One common cause of this type of leak is old flapper valves that continue to degrade. As more and more **sentiment** hardens the flapper valves more and more water leaks down the drain. Other examples are irrigation or broken pipes where the leak hole increases in size. At the time of this report, this leak is under investigation.

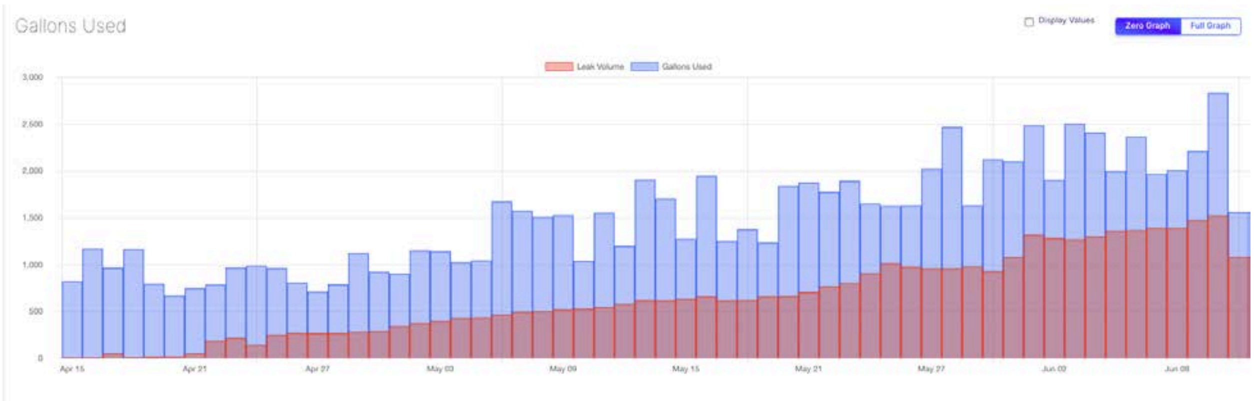


Figure 18 - BLUE is the total gallons used daily, and RED is NOWi's leak detection algorithm's estimated leak size daily. The Y-axis is the number of gallons used and the X-axis is the date.

Toilet Monitor Installation Finding Undected Leaks

Below is an example of a property that struggled to fix its leaks until toilet monitors were installed. Initially, an irrigation leak was detected and fixed. However, there were ongoing leaks at the location. In January the toilet monitors were installed and by March the leaks had been fixed.

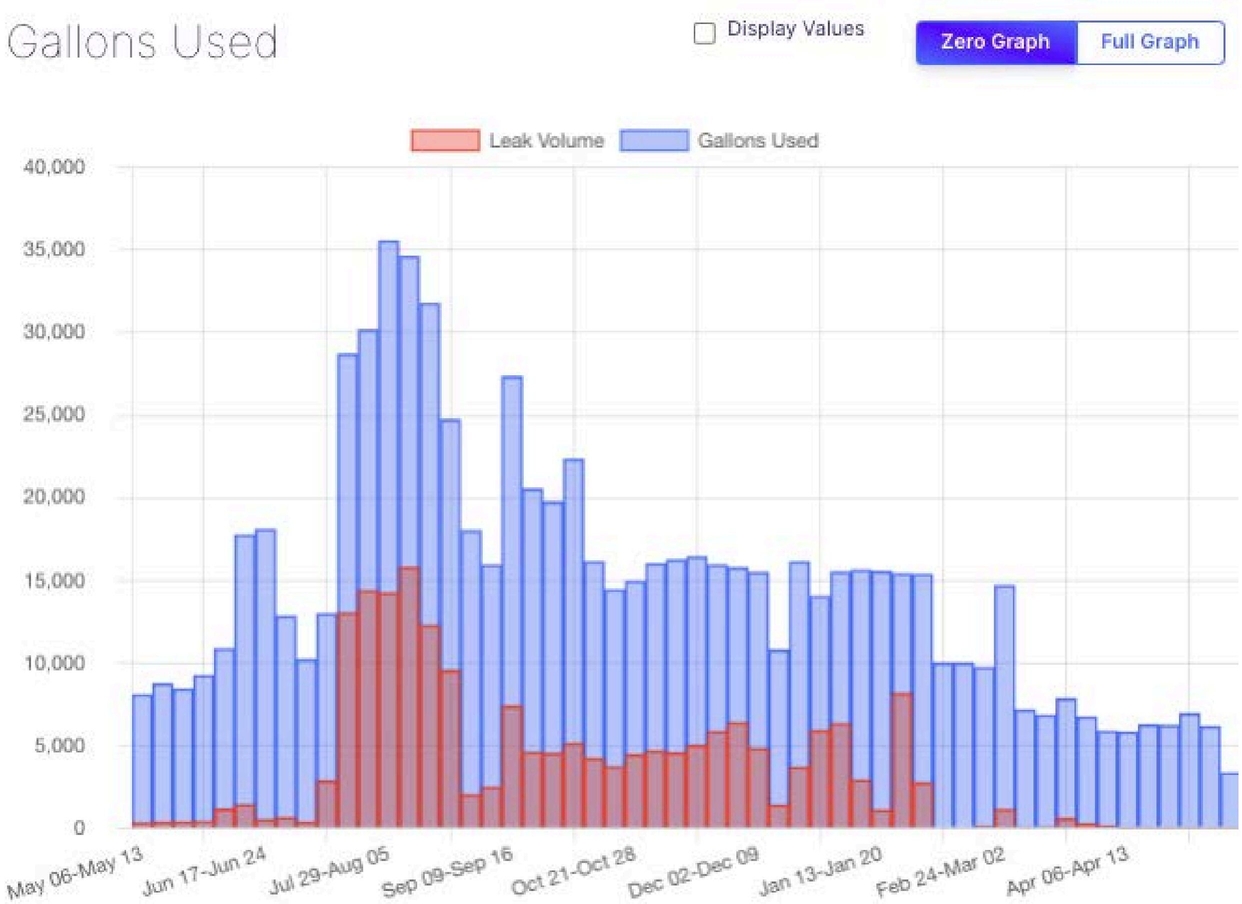


Figure 19 - BLUE is the total gallons used daily, and RED is NOWi's leak detection algorithm's estimated leak size daily. The Y-axis is the number of gallons used and the X-axis is the date.

Toilet Leaking Flapper Valve

Here is an example of a leaking flapper valve. When a flapper valve leaks the toilet fills up (turns on), then leaks the tank over time into the bowl (turns off), then starts filling up again. A toilet can do this once every 10 minutes down to once a minute or even constantly filling. Any toilet that flushes (turns on and off) more than 100 times in a day is typically a leak. The toilet below is flushing up to 1150 times in one day. If this toilet is even a 1.68 Gallon low flush toilet that means it wastes up to 1,900 gallons per day.

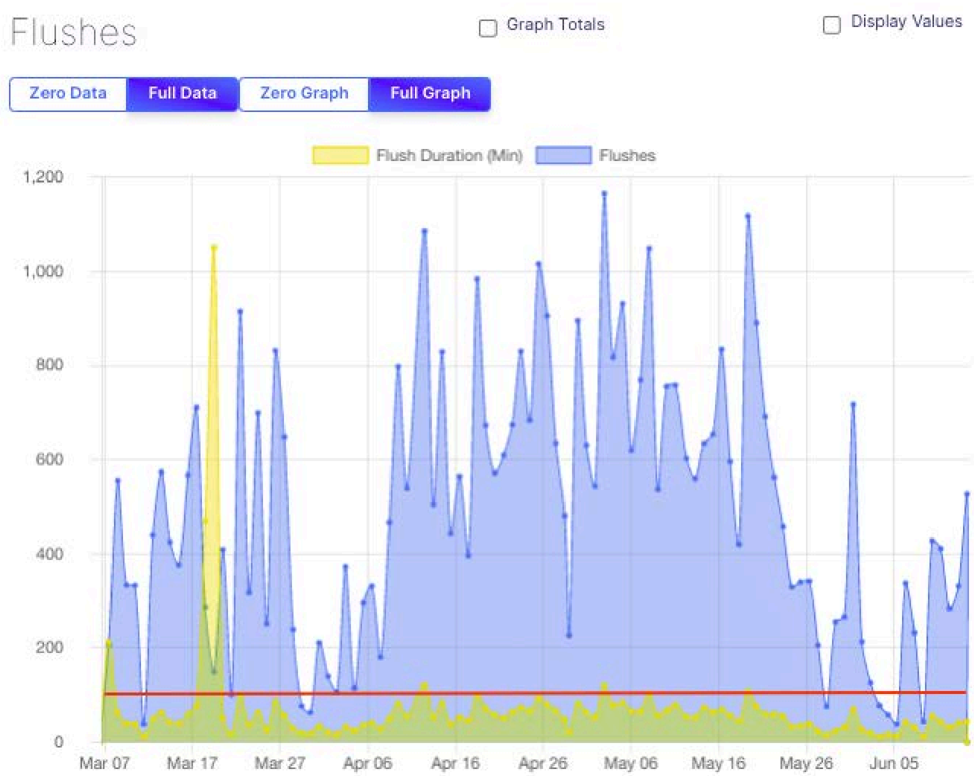


Figure 20 - The BLUE line is the number of flushes seen over each day. The YELLOW line is the duration of flow in minutes over each day. The RED line is the threshold for either metric, above which the toilet is considered leaking.

Toilet Open Flapper Valve Leak

Below is an example of an open flapper valve leak at one of the properties. When a flapper valve is stuck open the tank is constantly flowing to fill the tank. This means that NOWi's toilet monitors see a long period of flow but low to no flushes. Open flapper valve leaks are common when the flapper valve gets old or is not installed correctly. For example, if the chain is too long or too short it can get stuck and hold the flapper valve up. These leaks can be hard to detect because they can be fixed with a flush if it's a stuck chain issue. This means that it can leak for 8 hours straight, then a tenant flushes the toilet, it fixes itself, but then restarts on the next flush. When maintenance personnel go around a building looking for toilet leaks, they can easily miss this leak if it's temporarily fixed while they're in the bathroom of the issue toilet. This can be seen in the graph below where the toilet flows for up to 1450 minutes one day, gets fixed for a few days then re-starts. Since the toilet is fully flowing when the leak is occurring it can waste excessive amounts of water. For example, many toilets refill at around 4 gallons per minute, which means the toilet leaking in the graph below was leaking up to 5,800 gallons in a single day.

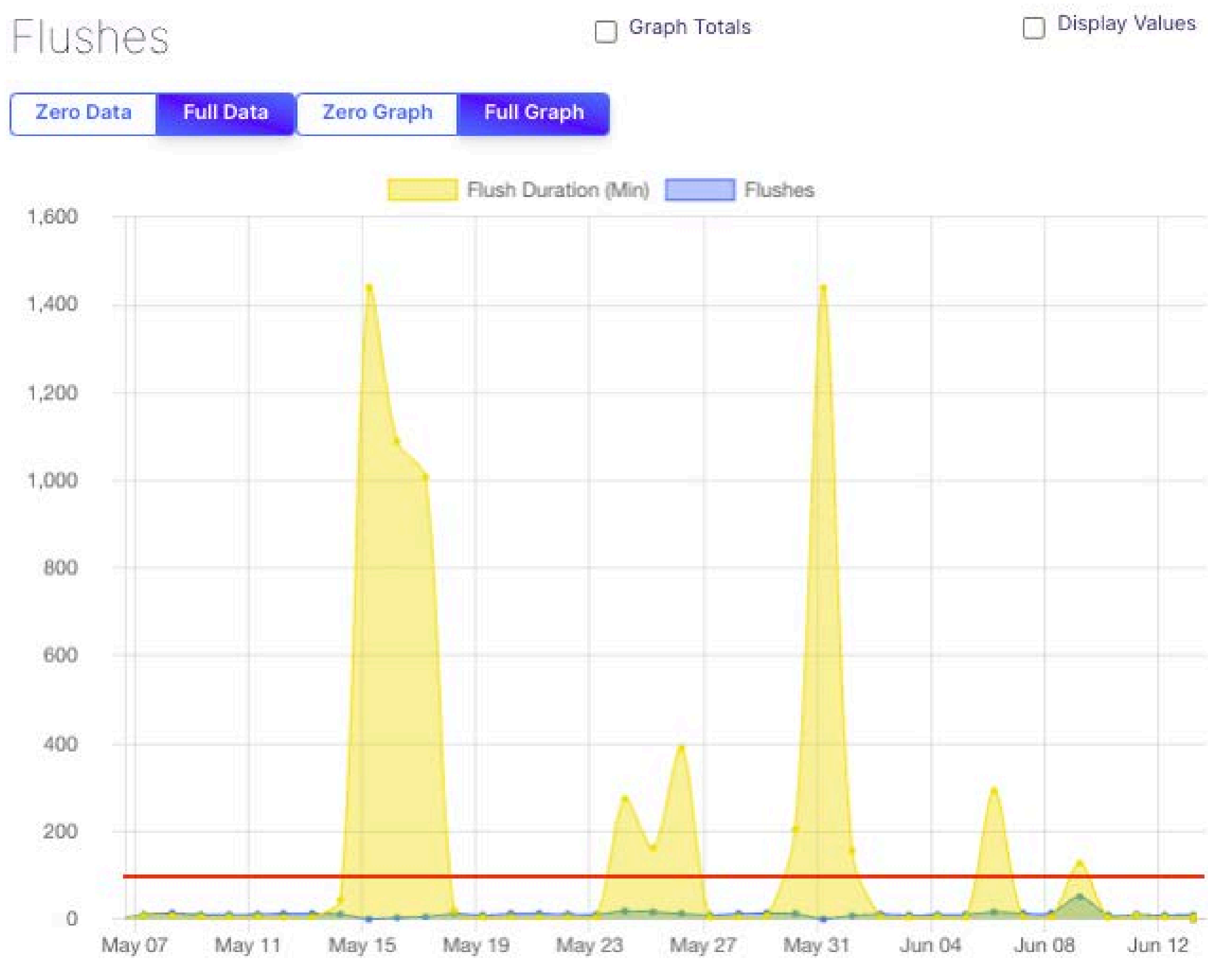


Figure 21 - The BLUE line is the number of flushes seen over each day. The YELLOW line is the duration of flow in minutes over each day. The RED line is the threshold for either metric, above which the toilet is considered leaking.

Challenges

Property Owner Management Change

When we began the study the asset management team for the LA portfolios we were working with had three members of the team. Due to a change of positions and the loss of a member, the management team ended with just one member. The management team stayed dedicated to the study and did their best to fix leaks when they were detected. However, with a loss of resources, it became difficult to prioritize and push tasks to the finish line.

Devices Issues

NOWi continually iterates on and updates its devices. This large-scale study provided the opportunity to identify and address issues that might not surface in smaller deployments. Throughout the study, the devices were regularly updated to incorporate the latest algorithms. An exceptionally high precipitation year in Los Angeles caused many water meter pits to flood. Despite the devices being IP67-rated, extended submersion posed challenges. NOWi engineered a solution and enhanced the device enclosures to overcome these issues.

Conclusions

This study has demonstrated the effectiveness of a combined approach using mainline water monitors and individual toilet monitors for leak detection and localization in multi-family apartment buildings. The deployment across 44 buildings and 857 units has yielded significant findings:

1. **Leak Detection Efficacy:**
    - Mainline water monitors effectively detected significant leaks, especially in smaller buildings with up to 30 units.
    - Toilet monitors localized leaks to specific units, significantly reducing the labor required for maintenance personnel to identify and fix leaks.
2. **Water Savings:**
    - The initial water usage due to leaks was 22%, significantly higher than the EPA's average of 12% for residential buildings.

    - Following the deployment and leak repairs, the water usage due to leaks dropped to 2.16%. However, this increased to 7.8% towards the end of the study due to resource constraints.
3. **Cost-Effectiveness:**
    - The cost-effective nature of the sensors and their ease of installation (5-10 minutes per device) make this solution viable for large-scale deployment.
    - The ability to detect and localize leaks promptly ensures that water wastage is minimized, leading to significant cost savings for property owners.
4. **Operational Challenges:**
    - Changes in property management teams and device issues posed challenges. Despite this, the study highlighted the resilience of the monitoring system and its adaptability through continuous improvements.
5. **Actionable Data:**
    - The data provided by the sensors was actionable, allowing maintenance teams to promptly address leaks. The combination of mainline and toilet sensors proved to be an effective strategy for comprehensive leak management.

In conclusion, this study validates the approach of using a dual-sensor system for leak detection and localization in multi-family properties. The significant reduction in water usage and the high accuracy of leak detection demonstrate the potential of this system to save water and reduce costs for property owners. The ongoing battle against leaks highlights the importance of continuous monitoring and prompt maintenance interventions.

Acknowledgments

We'd like to thank the Metropolitan Water District for this grant. It was an incredible opportunity to test and analyze the benefits of our water monitoring solution in a large deployment.
We'd also like to thank Veritas Investments and their Los Angeles office for allowing us to deploy our devices on their buildings and working with us throughout the study.
Finally, we'd like to thank the Helium Network for providing us with technical support whenever we ran into one with this deployment.

References

1) https://www.epa.gov/watersense/how-we-use-water
2) https://sfpuc.org/sites/default/files/documents/Water%20Resources%20Annual%20Report%20FY%2019-20.pdf