Journal of Interdisciplinary Perspectives
ISSN Print: 2984-8288, ISSN Online: 2984-8385
Vol. 2, No. 4, pp. 120-129, April 2024

An Evaluation of the Efficiency of the Localize, Locate, and Pinpoint Strategy in Reducing Water Loss

Ken Lester O. Jariol
Davao City Water District, Davao City, Philippines

Author email: kenlesterjariol@gmail.com

Date received: February 1, 2024
Date revised: March 16, 2024
Date accepted: March 20, 2024

Originality: 90%
Grammarly Score: 99%
Similarity: 10%

Recommended citation:
Jariol, K.L. (2024). An evaluation on the efficiency of the localize, locate and pinpoint strategy in reducing water loss. *Journal of Interdisciplinary Perspectives*, Vol. 2, Number 4, pp. 120-129.
https://doi.org/10.69569/jip.2024.0058

Abstract. This study aimed to assess the efficiency of the Localize, Locate, and Pinpoint (LLP) strategy in curbing water loss within a water district. Employing a descriptive-comparative research design over seven days, the study utilized secondary data sourced from the water district office. This data, collected through noise loggers, electronic ground microphones, and other equipment associated with the LLP strategy, provided insights into the water loss reduction efforts. Before implementing the LLP strategy, the water district suffered from a high water loss exceeding 30%. Following the implementation, although the water loss remained high, it showed improvement, indicating that other factors might contribute to the loss. The results demonstrated a significant disparity in water loss before and after implementing the LLP strategy, suggesting that while complete elimination of losses may not be feasible, the strategy aids in substantial reduction. The study revealed that the noise levels, used as an indicator of potential leaks, exhibited a moderate confidence level before the implementation of the strategy. Conversely, after the LLP strategy adoption, the confidence level dropped to a low, indicating a decreased likelihood of leaks. Moreover, statistical analysis confirmed a noteworthy difference in noise levels before and after the implementation, lending support to the efficacy of the LLP strategy. Furthermore, this study underscores the positive impact of the Localize, Locate, and Pinpoint strategy on water loss reduction, despite not achieving complete elimination. The findings underscore the strategy's efficiency in identifying and minimizing potential leakages, thereby contributing to the reduction of non-revenue water within the water district.

Keywords: Water loss reduction; Localize, Locate, and Pinpoint strategy; District water management; Non-revenue water; Leakage detection.

1.0 Introduction

The problem of water loss stemming from leaks within distribution networks is a prominent concern in both the water utility sector and water resource management in various regions, presenting significant challenges to global water distribution systems. The structural integrity of these water distribution networks can deteriorate over time, leading to leakages and the depletion of precious water resources. When water pipes become damaged, it can degrade the quality of the conveyed water, resulting in issues such as changes in taste, odor, and aesthetics of the water supply, while also potentially impacting the health of consumers. Hence, addressing this critical issue of water loss due to pipeline leaks is in priority and it falls for the implementation of certain strategies and technologies, emphasizing the urgent need for effective management and mitigation measures.

This perennial problem of water leakage has been prevalent around the world. The study conducted by Slowey (2019) in the United States of America revealed that developed countries have more comprehensive leak detection systems compared to underdeveloped ones. This is important because even small water distribution line breaks can cost a lot, around $64,000 annually, as estimated by the Environmental Protection Agency (EPA). As claimed in the study of Mamede et al. (2023), despite the United States (US) adopting advanced technologies like the Internet of Things (IoT) and Artificial Intelligence for water leak detection and repair, there is still a need for other strategies to reduce water loss. In India, household water leakage contributes to 30-40% of water flow in the distribution network, posing risks to public health, finances, and natural resources. (Gopalakrishnan et al., 2017). Further, a study by Gupta & Kulat (2018) revealed that some areas in India, like Nagpur City, have adopted pressure management techniques, including variable speed pumps and pressure-reducing valves (PRVs), to reduce water leaks. As stated by the Office of the Auditor General Western Australia (2021), 52 billion liters of water were lost due to firefighting, theft, inaccurate meters, and pipe bursts, highlighting the importance of addressing leaks and overall water loss to improve efficiency. Nevertheless, the outcomes of the study conducted by Bazan et al. (2021) point out that the direct benefits of integrated IT systems such as SCADA may have limited direct benefits, a comprehensive strategy including leak detection technologies, infrastructure modernization, pressure management, and meter upgrades can lead to a highly efficient water management system.

In the ASEAN context, the problem of water leakage is also a major concern among the distributors of potable water. As Malaysia practices pressure-based leak detection techniques that are much more sensitive in detecting pipeline leaks (Abdulshaheed et al., 2017). However, the study by Ward (2019) in Malaysia's urban areas, claimed that approximately 40% of the country's water supply is lost due to leakages and faulty meters. In Indonesia, PDAM Tirta Kahuripan (Indonesian Regional Water Utility Company) suffered a water loss of more than 46% (Parwatiningtyas et al., 2017). Thus, as the result of the case study in Indonesia, implemented using ANFIS (Adaptive Neuro-Fuzzy Inference System) method a Matlab programming, forecasting water loss, and water loss rate has described and explained descriptively and backpropagation to check the error rate so that the data will be more accurate (Dhika et al., 2018). Meanwhile, Myanmar is facing a significant challenge of water loss with an estimated NRW (Non-Revenue Water) percentage of approximately 60% (Thein, 2018). Additionally, due to the high significant water loss rate issue in Myanmar, authorities are promoting systematic water meter installation, addressing water pipe leaks, managing irregular water consumption, controlling water loss in urban distribution, and cracking down on illegal connections to the water network (The Global New Light of Myanmar, 2020). Hence, in addressing high water losses in ASEAN countries, a combination of technological, infrastructural, managerial, and policy interventions can be employed (Ong et al., 2023).

Addressing water loss due to leakage is a pressing concern too in the Philippines, a country where access to clean and reliable water is essential for both urban and rural communities. The Manila Water Company already has a 12% non-revenue water (NRW) rate, the firm continues to strive to further reduce or maintain the NRW through aggressively repairing leaks and rehabilitating pipes (Raymundo, 2023). While in Cebu City, a 2021 Commission on Audit (COA) reported that the Metropolitan Cebu Water District (MCWD) experienced a significant NRW percentage of 29.04% in 2021. This translates to a loss of approximately P116.14 million in revenue for the district. The main cause of this loss was leakage in transmission lines that have been in service for several decades (Magsumbol, 2022). At present, Sitchon (2023) reported that MCWD currently employs three leak detection teams, each with six members and two detection devices. When a leak is reported, one team assesses it, and then a repair crew fixes the pipes. While in Cagayan de Oro City, a recent report by Gomez (2022) revealed that the bulk water supplier of the Cagayan de Oro Water District (COWD) is experiencing a significant loss of around 60 million liters of treated water within just 24 hours due to a major pipe leak. Thus, pressure management, meter upgrades, unauthorized connection detection, and data analytics monitoring were undertaken by water districts to address the problem (Cervancia et al., 2022).

The issue of leaks in Davao City is vital because it has repercussions on the dependability of water supply, economic stability, environmental well-being, and public health. As stated in the 2020 Performance Report of Davao City Water District, it has a goal to reduce water waste and losses by using different methods in Water Loss Reduction Management. This includes operating 34 District Metered Areas (DMA), getting eight (8) specialized leak detection tools, and setting up nine (9) pressure regulating valve (PRV) stations for easier monitoring of water pressure upstream and downstream (Davao City Water District, 2020). Subsequently, the first quarter performance report by Davao City Water District (2023) highlights a decrease in Non-Revenue Water (NRW) from 36.65% in August 2022 to 35.57% in March 2023. Despite this improvement, there is a recommendation to focus on intensified leak detection efforts due to concerns about the Davao City Bulk Water Supply Project (DCBWSP) in 2023 potentially causing more pipe bursts. Moreover, the Non-Revenue Water Management Division at Davao City Water District faced challenges in developing a water loss reduction strategy, leading to the creation of the "Localize, Locate, and Pinpoint Strategy" (LLP). This strategy utilizes advanced tools like noise loggers and electronic ground microphones to pinpoint and address water leaks in the distribution network with precision, minimizing the financial, environmental, and public health impacts of water loss.

Furthermore, it is possible to reduce NRW (Non-Revenue Water) by implementing improved maintenance practices, leveraging technology, and even implementing policy changes. Research is required to determine the highest level of leaks in water pipelines, and to manage and reduce water loss in these pipes. Studies have shown to reduce leaks from different water districts (Gomez, 2022; DCWD, 2023; Magsumbol, 2022) but less has been done to evaluate the efficiency of localizing, locating, and pinpointing strategies for reducing water loss effectively. Thus, The Localize, Locate, and Pinpoint (LLP) Strategy project of Davao City Water District served as the basis for the evaluation of the efficiency of the leak detection strategy in reducing water loss.

This study was anchored on the Resource Management Theory of Mitchel (1989). This theory suggests that improved resource management leads to better performance, productivity, and decision-making by aligning resource use with community goals. It focuses on the effective and sustainable utilization of resources, including water, to optimize allocation for specific objectives like reducing water loss. In this research, the researcher evaluated the efficiency of the "Localize, Locate, and Pinpoint" strategy in reducing water loss, which aligns with Resource Management Theory by emphasizing resource-efficient allocation through accurate leak detection. This approach promotes sustainability, data-driven decisions, and system efficiency, and addresses water scarcity risks, all contributing to effective resource management and waste reduction.

2.0 Methodology

2.1 Research Design

This study employed a quantitative method and utilized a descriptive-comparative research design. Descriptive research design refers to a specific approach used to gather information systematically to describe a particular phenomenon or situation (Creswell & Creswell, 2018). In this study, descriptive research design was used to examine the NRW (Non-Revenue Water) rate before and after the implementation of the Localize, Locate, and Pinpoint Strategy using simulated/computed data. This was also used to measure the extent of noise before and after the implementation of the LLP Strategy. Meanwhile, comparative research design involves the act of comparing two or more things to uncover insights or knowledge about one or all the items being compared (Creswell & Creswell, 2018). Thus, in this study, the comparative research design was used to evaluate the efficiency of Localize, Locate, and Pinpoint Strategy in Reducing Water Loss.

2.2 Research Locale

This study was conducted in the Geographical Information System (GIS)” of Davao City Water District to determine the geographical references of the district meter area, the installed valves, and the number of customers in the specific location.

2.3 Research Measures

The data that were gathered from the Noise Logger Correlator are secondary data which is a state-of-the-art "lift and shift" acoustic device designed to be used as a temporary or semi-permanent water network survey tool. This verifies the presence of a leak in an area by correlating the distance a leak sound traveled between two points. Secondly, the Electronic Ground Microphone device was utilized to detect and amplify the sound produced by leaks occurring in main pipes and service line pipes. These devices were crucial components of leak detection teams, as they operated equipment to identify the closest leak sites and accurately pinpoint suspected leak locations. Moreover, a sub-component like Logger Antenna was used also. This component of the noise logger correlator will transmit the recorded noise in a software serve that is used to analyze the data. Another component is the Programmer Console, a device that was used to set a programming logging time or recording schedule. On the other hand, headphones were used as a component that was connected to the electronic ground microphone. It was used to listen to the noise that was captured by the electronic ground microphone with noise filtration. The last component of the electronic ground microphone is the Console Panel. It displays on its LCD the intensity of the noise that was captured per location where the electronic ground microphone is placed.

On the other hand, the researcher used "The Geographical Information System (GIS)" of Davao City Water District to determine the geographical references of the district meter area, the installed valves, and the number of customers in the specific location. The latest GIS map with the pipe network layer under the DMA Project of Dumoy 31 was requested from the Davao City Water District. This layer was with data fields containing pipe materials, the number of valves installed at Dumoy 31, and active services or customers' connections. Moreover, the data obtained from the noise logger can be seen on its application, where the confidence level of the correlated data between the two loggers and the recorded noise intensity can be viewed. Also, the data obtained from the ground microphone is displayed on its console panel, allowing the closest noise to be seen. Table 1 for the range of leakage noise, from the Operational Manual of LWUA, shows the inherent characteristics of a steel pipe, a frequency level of noise is used to determine potential leaks.

Table 1. Range of leakage noise

Pipe Material	Leak Frequency Range	Descriptive Level	Interpretation
Steel	400Hz-1500Hz	Potential Leakage	This means that there is a potential leakage recorded.
	<399Hz	No Leakage	This means that there is no leakage recorded.

Finally, the data obtained from the water loss was recorded from the flowmeter within the DMA and to active service connections. Presented in Table 2 is the prescribed standard for water loss established by the Local Water Utilities Administration (LWUA) Board, under LWUA Memorandum Circular No.11-18. This circular emphasizes the need to efficiently address water loss, facilitating the reduction of Non-Revenue Water (NRW) to meet the permissible rate of 30% or less.

Table 2. Water loss percentage

Water Loss Percentage (NRW)	Descriptive Level	Interpretation
More than 30%	Not Acceptable	This means that the water loss recorded is high.
Less than 30%	Acceptable	This means that the water loss recorded is low.

2.4 Data Gathering Procedure

The following are the procedures followed in conducting this study: First, the letter was sent to the General Manager of Davao City Water District requesting permission to use the secondary data in evaluating the efficiency of LLP implemented in the said institution. After which, the secondary data were gathered, which is a sample data of water loss. These data are sets of hourly recordings starting from July 16, 2023, to July 22, 2023 (before LLP) and sets of hourly recordings (after LLP) from July 24, 2023, to July 30, 2023. These data were obtained from the District Meter Area of Dumoy 31 that were generated from the electromagnetic flow meter from the water district. Then, after finalizing the data, a statistician was consulted for mathematical computation as part of the analysis and interpretation. Finally, interpretation was done based on the statistical results of the study.

2.5 Data Analysis

The data that were obtained from this study were based on the actual device readings which served as outputs of the Localize, Locate, and Pinpoint (LLP) strategy in water leakage detection. The secondary data were obtained through computer simulation and computed data. These data were analyzed and interpreted using the statistical tools as follows.

NRW Formula. This was used to examine the water loss before and after the implementation of the Localized, Locate, and Pinpoint Strategy in reducing water loss in Davao City, Philippines.

$$NRW = \frac{A_p - A_c}{A_p}\%$$

Where:

A_p = volume of the water produced per time unit
A_c = volume of consumption of water per time unit

Mean. This was used to measure the average of the water loss and extent of noise before and after the implementation of localize, locate, and pinpoint strategy in reducing water loss.

Wilcoxon signed-rank test. This statistical tool is a non-parametric test that was used in determining if there is a significant difference in the extent of noise before and after the implementation of the Localize, Locate, and Pinpoint Strategy in reducing water loss in Davao City, Philippines. Furthermore, the Wilcoxon signed-rank test was used to compare two related samples, matched samples, or to conduct a paired difference test of repeated measurements on a single sample to assess whether their population mean ranks differ.

Paired Sample T-test. This was used in determining if there was a significant difference in the mean volume of water loss before and after the implementation of the Localize, Locate, and Pinpoint Strategy in reducing water loss in Davao City, Philippines. Furthermore, the t-statistic value, p-value, and confidence interval value will be obtained to explain variability, probability of observing the obtained difference, and range of plausible values for the true population mean difference, respectively.

2.6 Ethical Considerations
This study did not involve any human or animal participation; however, the study was dedicated to evaluating the efficiency of the Localize, Locate, and Pinpoint strategy in reducing water loss with a strong ethical foundation such as data privacy and security. Data privacy and security were given utmost importance in the study. Since the study involved sensitive data related to water infrastructure and distribution, measures were taken to ensure that the data collected were treated with the highest level of confidentiality and were protected from unauthorized access. While the study did not directly involve human or animal participants, it was crucial to consider the broader environmental impact of implementing the strategy. Ensuring that the proposed approach did not cause unintended negative consequences on the environment was essential for responsible water management. The study prioritized the benefits of the water management system and the communities it served. Moreover, adhering to rigorous scientific methods and standards was crucial to ensure the study's validity and reliability. This includes using appropriate data analysis techniques and considering potential confounding factors that could influence the results.

3.0 Results and Discussion
The presented results, detailed in Tables 3 to 8, offer insights into the efficiency of the Localize, Locate, and Pinpoint (LLP) strategy in mitigating water loss through leak detection and management.

Table 3. The extent of noise before the implementation

Logger 1	Logger 2	Interpretation
446Hz	442Hz	Potential Leakage
441Hz	441Hz	Potential Leakage
448Hz	446Hz	Potential Leakage
450Hz	449Hz	Potential Leakage
378Hz	376Hz	No Leakage
374Hz	372Hz	No Leakage
370Hz	370Hz	No Leakage
Mean 415Hz	**414Hz**	**Potential Leakage**

Table 3 shows the extent of noise intensities from noise loggers 1 and 2 before the implementation of the localize, locate, and pinpoint strategy. These intensities were measured in hertz (Hz). As it can be gleaned, the start of the observation recorded data in logger 1 of 446Hz and logger 2 of 442 Hz at a range of potential leakage, while the last day of observation shows logger 1 and 2 of 370Hz or interpreted as no leakage. Furthermore, the average noise intensities, 415 Hz and 414 Hz, recorded from noise loggers 1 and 2, respectively, fall in the range of 400 – 1500 Hz. These results indicate a potential leakage of water. These findings further indicate that within a 7-day observation, it recorded a potential leakage before the implementation of the localize, locate, and pinpoint strategy.

This finding conforms to the study of Davao City Water District (DCWD, 2022) that without implementation of such a strategy, it can lead to its peak or intense leakage without noticing it. Moreover, Chen et al. (2020) provide insights into the extent of water leakage before implementing the LLP strategy. Thus, the non-revenue water component due to leaks highlighted the significant financial implications of unaddressed water leakage on utility revenues and water resource management (Magsumbol, 2022).

Table 4. The extent of noise after the implementation

Logger 1	Logger 2	Interpretation
363Hz	363Hz	No Leakage
363Hz	363Hz	No Leakage
362Hz	362Hz	No Leakage
362Hz	362Hz	No Leakage
360Hz	360Hz	No Leakage
360Hz	360Hz	No Leakage
360Hz	360Hz	No Leakage
Mean 361Hz	**361Hz**	**No Leakage**

Table 4 shows the extent of noise intensities after the implementation of the localize, locate, and pinpoint strategy. The data show on day 1 with 363Hz in loggers 1 and 2 with the interpretation of no leakage. This means that there is no leakage recorded. On the other hand, on the last day of observation, it yielded 360Hz in loggers 1 and 2. The average noise intensities, 361 Hz and 361 Hz, recorded from noise loggers 1 and 2, respectively, fall below 399 Hz. These results indicate the absence of water leakage. These findings further indicate that the seven-day implementation of the localize, locate, and pinpoint strategy, helps to reduce the possibility of potential leakage that is below 399Hz.

This indicated that the LLP Strategy contributed to reducing the likelihood of potential leakage with a frequency lower than 399 Hz, as supported by Davao City Water District (DCWD, 2022; Raymundo, 2023) that a reduction of leakage is evident when the strategy has been implemented. Moreover, Wang et al. (2018) found that the Localize, Locate, and Pinpoint Strategy was effective in localizing and locating leaks, with an accuracy of over 90%. Also found that the Localize, Locate, and Pinpoint Strategy was able to reduce leak noise levels by up to 50%.

Table 5. Test of difference in the extent of noise before and after the implementation

	W-value	p-value	Remarks
Logger 1 (Before) and 1 (After)	0	0.018	Reject the null hypothesis
Logger 2 (Before) and 2 (After)	0	0.018	

0.05 level of Significance

Table 5 shows the significant difference in the extent of noise intensities before and after the implementation of the localize, locate, and pinpoint strategy of loggers 1 and 2. Using the Wilcoxon signed-rank test at 0.05 significance level and a two-tailed test, the computed W-value is 0 and the p-value is 0.018 (<0.05 level of significance) for logger 1 and 2. Since the computed W-value is less than the critical W-value =2 at n=7 and the computed p-value is less than the significance level, there is sufficient evidence to reject the null hypothesis. This indicates that given the first set of recordings of noise intensities from the logger correlator, there is a significant reduction in the noise intensity after the implementation of the LLP strategy.

This result supports the assertion that the strategy effectively curbed potential water leakage. On the other hand, this result conforms to the study of Gomez (2022), which stated that it is possible to manage leakage by implementing improved maintenance practices, leveraging technology, and even implementing policy changes. Moreover, Raymundo (2023) revealed that the firm continues to strive to further reduce or maintain the NRW through aggressively repairing leaks and rehabilitating pipes. Meanwhile, Magsumbol (2022) revealed that if preventive maintenance is not implemented, it could lead still to a possibility of water loss. On the other hand, by implementing advanced leak detection technologies and embracing a data-driven approach, water districts can improve operational efficiency and reduce water loss (Herrera et al., 2017).

Table 6. The mean volume of the water loss before the implementation

Date	Production Volume (cu.m.)	Consumption Volume (cu.m.)	Water Loss (cu.m.)	NRW Percentage	Interpretation
July 16, 2023	30.08	18.18	11.90	31.74%	Not Acceptable
July 17, 2023	30.50	18.45	12.05	32.00%	Not Acceptable
July 18, 2023	30.10	17.98	12.12	32.02%	Not Acceptable
July 19, 2023	30.18	17.98	12.20	32.21%	Not Acceptable
July 20, 2023	30.17	18.06	12.11	32.00%	Not Acceptable
July 21, 2023	30.08	18.01	12.08	32.21%	Not Acceptable
July 22, 2023	31.15	19.14	12.01	30.79%	Not Acceptable
Over-all Mean	**30.32**	**18.26**	**12.07**	**31.85%**	**Not Acceptable**

Table 6 shows the daily averages of production volume, consumption volume, water loss, and the NRW percentage before the implementation of the Localize, Locate, and Pinpoint Strategy. It can be gleaned that at the start of the observation, the recorded water loss was 11.90 cubic meters (31.74%). This can be interpreted as not acceptable or simply indicated that the recorded water loss is high. On the other hand, on the last day of observation, it yielded a result of 12.01 cubic meters (30.79%), which can be interpreted as not acceptable. This further indicates that it recorded a high water loss still. Furthermore, on average it can be shown a water loss of 12.07 cubic meters (31.85%) can be interpreted as not acceptable since it is more than the 30% range of acceptable water losses. The average NRW percentage, greater than 30%, is an unacceptable water loss level.

This indicates that the recorded water loss is high. The results align with the investigation conducted in the study by Chen et al. (2020) that the staggering statistic that 40% of the water supply is lost due to leakages and faulty meters underscores the urgency of addressing this issue. This level of water loss does not only affect the economic sustainability of water utilities but it also has environmental implications and threatens the availability of safe drinking water for communities (Herrera et al., 2017). Leakages in the distribution network and inaccurate or faulty meters contribute significantly to water loss. Aging infrastructure, inadequate maintenance, and poor installation practices are commonly cited reasons for distribution network leakages (Ganeshan et al., 2018).

Table 7. The mean volume of the water loss after the implementation

Date	Production Volume (cu.m.)	Consumption Volume (cu.m.)	Water Loss (cu.m.)	NRW Percentage	Interpretation
July 24, 2023	30.05	19.17	10.88	28.18%	Acceptable
July 25, 2023	30.22	19.36	10.86	28.02%	Acceptable
July 26, 2023	30.06	19.23	10.83	27.83%	Acceptable
July 27, 2023	30.11	19.12	10.98	28.33%	Acceptable
July 28, 2023	30.22	19.24	10.98	28.28%	Acceptable
July 29, 2023	29.07	18.35	10.72	28.52%	Acceptable
July 30, 2023	29.67	18.37	11.30	29.72%	Acceptable
Over-all Mean	**29.91**	**18.98**	**10.94**	**28.41%**	**Acceptable**

Table 7 shows the daily averages of production volume, consumption volume, water loss, and the NRW percentage after the implementation of the Localize, Locate, and Pinpoint Strategy. The result yielded 10.88 cubic meters (28.18%) or interpreted as acceptable. This means that it recorded a low water loss, despite it being almost 30%. While on the last observation, 11.30 cubic meters (29.72%) were recorded or can be interpreted as acceptable. This means that there are still water losses but recorded on the acceptable range value. Moreover, the average water loss is 10.94 cubic meters (28.41%) and is interpreted as acceptable. Subsequently, this result shows that there was a relative reduction of the mean volume of water loss after the LLP implementation by 1.13 cubic meters. The average NRW percentage is less than 30%, interpreted as an acceptable water loss level. This indicates that the recorded water loss is low. This further indicates that there are still water losses but a minimal closer to the 30% range of acceptable water losses. These findings would mean that there may be another source of water losses after implementing the Localize, Locate, and Pinpoint Strategy.

As supported in the research by Sharma et al. (2020), demonstrated a case study where the implementation of leak detection technologies resulted in a substantial decrease in water loss. The study showed that after the strategy was deployed, the utility experienced a measurable reduction in non-revenue water, which is directly attributed to water loss through leaks. Implementation of the strategy not only leads to water conservation but also enhances the operational efficiency of water utilities. By accurately localizing leaks, utilities can minimize excavation and repair efforts, leading to cost savings in terms of labor, material, and equipment usage (Ganeshan et al., 2018).

Table 8. Test of difference in the mean volume of water loss before and after the implementation

	Mean	t-value	p-value	Remarks
Mean Volume of Water Loss (Before)	12.07	9.77	0.000	Reject the null hypothesis
Mean Volume of Water Loss (After)	10.94			

0.05 level of Significance

Table 8 shows the significant difference in the mean volume of water loss before and after the implementation of the localize, locate, and pinpoint strategy. The data show that the mean volume of water loss before the implementation (12.07) and after the implementation of Localize, Locate, and Pinpoint Strategy (10.94) with a t-value of (9.77) and a p-value of (0.000) which is (<0.05) level of significance. Since the computed p-value is less than the significance level, there is sufficient evidence to reject the null hypothesis. This indicates that there is a significant difference in the mean volumes of water loss before and after the implementation of the LLP strategy. Furthermore, since the t-value is positive, the mean water loss before the implementation of the LLP strategy is significantly higher than the mean volume of water loss after the implementation of the LLP strategy. Therefore, the implementation of the LLP strategy has significantly reduced the volume of water loss. Subsequently, the finding shows that the implementation of LLP (Localize, Locate and Pinpoint Strategy) can help reduce water losses although it cannot be eliminated it will help to reduce water loss or the non-revenue water of the water district.

This result aligns with the understanding that complete eradication of water loss may be unfeasible due to various factors, such as aging infrastructure (Xu et al., 2019). The LLP strategy leverages technological advancements, including acoustic sensors, pressure monitoring systems, and GIS mapping. The integration of these technologies facilitates efficient leak detection, which is crucial for achieving the desired water loss reduction outcomes (Khan et al., 2021). The findings from various studies collectively emphasize the potential benefits for water districts in adopting the LLP strategy. Moreover, with the foregoing result, the LLP strategy, with its incorporation of advanced technologies, presents a promising avenue for water districts to address water loss challenges, as underscored by the research conducted by Herrera et al. (2017).

4.0 Conclusion

Based on the findings of the study, the following conclusions are drawn:

1. The extent of noise intensities before the implementation of the Localize, Locate, and Pinpoint strategy shows a potential leakage of water.
2. The extent of noise after the implementation of the Localize, Locate, and Pinpoint strategy shows the absence of water leakage. This means that both loggers recorded an acceptable level of leakage. This finding further indicates that the implementation of the Localize, Locate, and Pinpoint strategy, helps to reduce the water loss.
3. The significant difference in the extent of noise before and after the implementation of the Localize, Locate, and Pinpoint strategy using logger 1 and 2 shows a p-value less than 0.05 level of significance. Moreover, since the computed p-value is less than the significance level, there is sufficient evidence to reject the null hypothesis. This indicates that, given the first set of recordings of noise intensities from the logger correlator, there is a significant reduction in the noise intensity after the implementation of the LLP strategy.
4. The water loss before the implementation of localize, locate, and pinpoint strategy is in the range of not acceptable water loss or greater than 30% NRW. This indicates a high water loss.
5. The water loss after the implementation of the localize, locate, and pinpoint strategy is in the range of acceptable water loss or low water loss although it can be noted that it is nearly in an acceptable range of 30%, but this would mean that there are still other factors of water losses. Subsequently, the result shows that there was a relative reduction of the mean volume of water loss after the LLP implementation by 1.13 cubic meters.

6. The finding shows a significant difference in the water loss before and after the implementation of LLP (Localize, Locate, and Pinpoint Strategy). Therefore, the implementation of the LLP strategy has significantly reduced the volume of water loss.

5.0 Contributions of Authors

This is single-author research.

6.0 Funding

This work received no specific grant from any funding agency.

7.0 Conflict of Interests

The author declares no conflicts of interest

8.0 Acknowledgment

The researcher would like to take this opportunity to express his heartfelt gratitude and appreciation to all those who have supported him throughout his journey of conducting this research and writing this capstone project. First and foremost, the researcher is deeply indebted to his thesis adviser, *Harry Dave B. Villasor, MAEd*, and panel members: *Alex D. Niez, PhD, EdD, Kirt Anthony R. Diaz, PhD, and Lemuel M. Sayao, PhD*. Their exceptional expertise, valuable insights, and continuous support have been invaluable in every phase of this capstone project. The researcher is immensely grateful for their unwavering commitment, patience, and guidance, which have undoubtedly enriched his understanding of the subject matter. Moreover, the researcher would like to express his sincere appreciation to *Benedicto Norberto V. Aves, PhD*, for his exceptional proficiency in statistical data analysis. The researcher is deeply grateful to *Lemuel M. Sayao, Ph*D, who served as the research instructor and provided invaluable assistance throughout the development of this capstone project paper. Subsequently, the researcher is grateful to the *management of Davao City Water District*, for allowing him to conduct and gather the data. Without them, this capstone project would not have been possible. Lastly, the researcher would like to express his deepest appreciation to his family and friends for their unwavering support, encouragement, and love throughout this journey. Above all, to the Almighty Father, for providing the researcher the courage, insight, and faith necessary to complete this capstone project.

9.0 References

Abdulshaheed, A., Mustapha, F., & Ghavamian, A. (2017). A pressure-based method for monitoring leaks in a pipe distribution system: A Review. Renewable and Sustainable Energy Reviews, 69, 902-911.

Cervancia, K., Gomez, C.J., Niega, C.E., & Tividad, K.M. (2022). Assessment, monitoring, and reduction strategy development for non-revenue water (NRW) of Calamba Water District (CWD), Calamba City, Laguna, Philippines. IOP Conference Series: Earth and Environmental Science, Volume 1022. https://doi.org/10.1088/1755-1315/1022/1/012058

Chen, J., Chen, S., Chen, L., & Liu, L. (2020). Leak detection in water distribution networks based on data analytics: A Review. Water, 12(9), 2552.

Creswell, J.W. & Creswell, J.D. (2018) Research design: Qualitative, quantitative, and mixed methods approaches. Sage, Los Angeles

Davao City Water District (2020). Davao City Water District 2020 performance report. https://rb.gy/cayigz

Davao City Water District (2023). Performance report of the first quarter. https://rb.gy/wsk8ug

Dhika, H., Daengs, A., & Ambarsari, E. W. (2018). Forecasting water loss due to pipeline leakage by using ANFIS And Backpropagation Approach. Study Case at PDAM, Tirta Kahuripan On District of Bogor. https://eudl.eu/pdf/10.4108/eai.23-4-2018.2277589

Ganeshan, D., Farisha, B., Sachin, B., Saheen, K. & Binoy, N. (2018). Leak detection in water-distribution pipe system. 1-4. 10.1109/ICCONS.2018.8663193.

Ganeshan, M., Frisk, E., Gustafsson, A. M., & Hellström, D. (2018). Leak detection and localization in water distribution networks: A review. Water Resources Management, 32(4), 1297-1315.

Gomez, H. (2022). Major pipe leak disrupts water supply in many Cagayan de Oro villages. Rappler. https://rb.gy/dccpc1

Gopalakrishnan, P., Abhishek, S., Ranjith, R., Venkatesh, R., & Jai Suriya, V. (2017). Smart Pipeline Water Leakage Detection System, 12(16), 5559-5564.

Gupta, A. D., & Kulat, K. (2018). Leakage reduction in water distribution system using efficient pressure management techniques. Case study: Nagpur, India, Water Supply (2018) 18 (6): 2015–2027. https://doi.org/10.2166/ws.2018.023

Herrera, M., Perez, R., & Iglesias, R. (2017). Smart metering and smart sensors for water leakage control. Procedia Engineering, 186, 306-313.

Khan, U.N.A., Abbas, S.M., & Shamsuddin, S.M. (2021). A review on leak detection and localization techniques in water distribution networks. IOP Conference Series: Earth and Environmental Science, 1036(1), 012016.

Magsumbol, C. (2022). Due to leakage in pipes: MCWD loses P116.14 million in income. Philstar. https://www.philstar.com/the-freeman/cebu-news/2022/08/25/2205014/due-leakage-pipes-mcwd-loses-p11614-million-income-

Mamede, H., Neves, J.C., Martins, J., Gonçalves, R., & Branco, F. (2023). A Prototype for an Intelligent Water Management System for Household Use. Licensee MDPI, Basel, Switzerland, 23(9), 4493; https://doi.org/10.3390/s23094493

Office of the Auditor General Western Australia. (2021). Water Corporation: Management of water pipes – Follow-Up (2021-22). https://audit.wa.gov.au/wp-content/uploads/2021/11/Report- 7_Water-Corporation-Management-of-Water-Pipes

Ong, C., Tortajada, C., & Arora, O. (2023). Key challenges to urban water management in ASEAN. in: Urban water demand management. SpringerBriefs on Case Studies of Sustainable Development. Springer, Singapore. https://doi.org/10.1007/978-981-19-8677-2_2

Parwatiningtyas, D., Ambarsari, E.W., & Mariko, S. (2017). The calculation of the highest leak level of the water pipeline region at PDAM Tirta Kahuripan using fuzzy C-means and ArcGIS method analysis. AIP Conference Proceedings, 1862(1), 030196. https://doi.org/10.1063/1.4991300

Raymundo Jr., P. (2023). Manila Water prepares for the summer months. The Philippine News Agency. https://www.pna.gov.ph/articles/1197421

Sharma, R., Choudhury, P., & Sharma, D. (2020). Case study of water leakage reduction in a water distribution system using flow meters and GIS. Environmental Science and Pollution Research, 27(22), 27553-27563.

Sitchon, J. (2023). Cebu's water district recorded almost 9,000 system leakages in 2022. Rappler. https://rb.gy/qjf4ng

Slowey, K. (2019). Leak detection tech can save contractors the cost of water waste and damage. Construction dive. https://www.constructiondive.com/news/leak-detection-tech-can-save-contractors-the-cost-of-water-waste-and-damage/558967/

The Global New Light of Myanmar. (2020). Yangon water pipeline replacement project completed completed 80%. https://cdn.myanmarseo.com/file/client-cdn/gnlm/wp-content/uploads/2020/07/28_July_20_gnlm.pdf

Thein, M. (2018). Urban water supply and sanitation in Yangon. Urban Delta Seminar: Enhancing water security in the urbanizing Ayeyarwady Delta region, Yangon, Myanmar. https://www.myanmarwaterportal.com/repository/411-urban-water-supply-and-sanitation-in-yangon.html

Wang, X., Li, X., Wang, X., Zhang, X., & Wang, Y. (2018). Leak localization in water distribution networks using a localize-locate-pinpoint strategy. Water Resources Management, 32(1), 90-100.

Ward, O. (2019). Why technology alone won't solve ASEAN's water crisis. https://www.aseantoday.com/2019/08/why-technology-alone-wont-solve-aseans-water-crisis/

Xu, J., Chai, K.T., Wu, B., Han, E.L., Wai, C., Li, W., Yeo, J., Nijhof, E. & Gu, Y. (2019). Low-cost tiny-sized MEMS hydrophone sensor for water pipeline leak detection. IEEE Trans. Ind. Electron, vol. 66 no.8, pp. 6374-6382

Xu, Z., Chu, J., Ye, W., & Fan, Y. (2019). A review of water losses in the urban water supply system. Water, 11(2), 269.