Attachment list

Output	No.	Name	Contents
2	1	Work plan for enhancement of leakage control capacity	Work plan on the Pilot site
	2	Procedure manual	Procedure manual on NRW reduction
			Appendix 1: Case Study of Pilot Site Activity in Panadura RSC(W-S) Appendix 2: Guideline for Cost and Working Days Calculation Sheet for Leakage Detection Planning Appendix 3: Introduction of Remote Monitoring System Appendix 4: Mechanism of Ultrasonic Flow Meter Appendix 5: Data Collection and Management Appendix 6: Manuals of Instruments introduced by the Project Appendix 7: Backfilling Instatement Appendix 8: Theft Prevention Strategy
	3	Leakage repair record sheet	Detailed information about leakage repair
	4	Capacity assessment sheet	Questionnaire for Capacity assessment
3	5	Training guideline	Training guidelines for RP No.1 Leak Detection No.2. Distribution Pipe Installation No.3 Service Pipe Installation No.4 Leak Repair No.5 Measurement No.6 DMA No. 7. How to use the data obtained from pilot activity
	6	Capacity assessment sheet	Questionnaire for Capacity assessment

Attachment 1: Work plan for enhancement of leakage control capacity

National Water Supply & Drainage Board

Project for Enhancement of Operational Efficiency and Asset Management Capacity of Regional Support Center-Western South

Work Plan (ver.2)

for

Enhancement of Leakage Control Capacity

<Pilot Site> Panadura-Zone 1

October 2020

CTI Engineering International Co., Ltd.

Yokohama Water

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Chapter 1. Introduction

1.1 Objective of the Pilot Activities

National Water Supply and Drainage Board (NWSDB) was established in 1975 as a principal authority providing safe drinking water and facilitating the provision of sanitation in Sri Lanka, presently under the Ministry of Urban Development. NWSDB has been improving water supply facilities throughout the country for the realization of a stable water supply. Currently, although coverage of the water supply system of densely populated Colombo district has reached 94.5 %, that of the whole country is still 48.1 %. Therefore, NWSDB will continue to enhance water supply capacity and improve its service.

Enhancement of efficiency of its business operation and expanding water supply system is required to achieve its goal. NWSDB has been considering the introduction of Asset management to (1) improve its business operation by effective distribution of O&M and investment costs and (2) formulate a business plan based on prioritized of renewal demand of aging facilities.

Enhancement of its capacity for leakage control as that of their daily O&M work directly leads to reduction of non-revenue water (NRW) and an improvement of business operation and finance.

Improving the quality of pipe installation not only prevents leakages but also promotes prolonging the lifetime of water supply facilities.

The purpose of this pilot activity is to acquire the knowledge, technology, and skills necessary for leakage control through practical On-the-Job Training in the actual water distribution network.

These tasks must be undertaken under the initiative of NWSDB staff in Sri Lanka, utilizing the equipment, experience and knowledge provided by Japanese experts.

1.2 Pilot activity strategy

Pilot activities are an extremely important opportunity to acquire practical skills such as leak detection and repair.

The results of activities conducted by NWSDB staff can be confirmed from quantitative data through a series of tasks such as estimating the area of water leakage, taking countermeasures, and measuring the results

1.2.1 Construction of DMA

District Metered Area (DMA) means "Hydraulically isolated area where flow meter can control water inflow volume".

The DMA method is generally adopted to manage leakage reduction in the pilot area.。

By measuring the inflow of water from one or more inlet pipes with flow meters and deducting the total consumption of water recorded by customer meters, the amount of water loss in DMA during a certain period will be calculated.

There are three types of DMA as shown in the figure below.

Type 1: DMA with one inflow point

Type 2: DMA with two or more inflow points

Type 3: A DMA that has not only an inflow point but an outflow point to an adjacent DMA

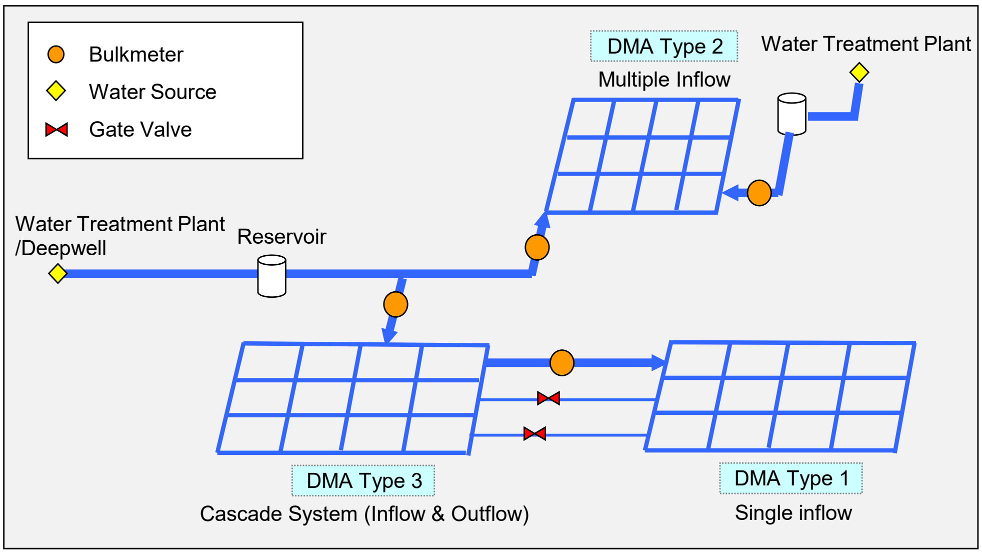


Figure 1.2.1 Type of DMA

1.2.2 Evaluation of Non-Revenue Water (NRW)

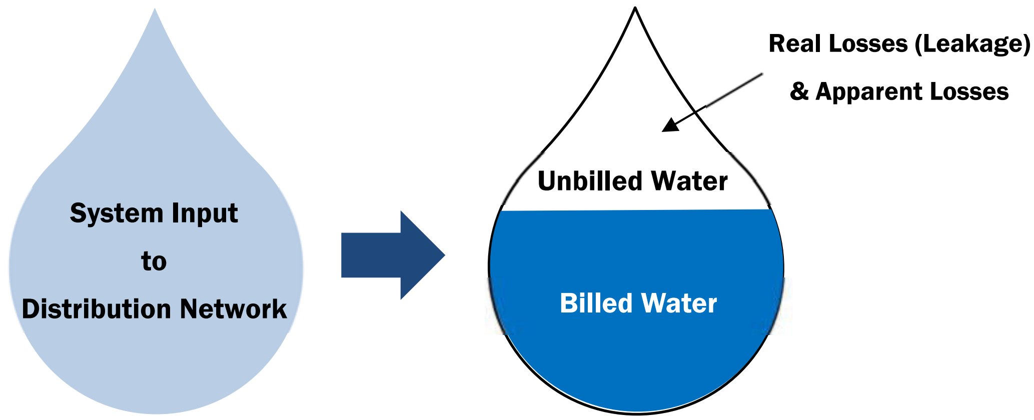
The amount of leakage reduced by a series of activities is a very important indicator for measuring performance.

Leakage reduction is not only essential for effective use of water resources, but also has a major impact on improving the management of water utilities.

"Non-Revenue Water" is also one of the factors in evaluating water supply management, and one of the major causes of NRW is leakage.

Therefore, in this pilot activity, the indicator of non-revenue water is also adopted as a performance indicator.

It is expected that this will not only deepen the understanding that the staff engaged in water leakage reduction activities are contributing to the administrative improvement of the water utilities, but also promote water leakage reduction activities for the entire organization.



$$\text{NRW (\%)} = \frac{\text{System Input Volume } (m^3) - \text{Billed Water } (m^3)}{\text{System Input Volume } (m^3)} \times 100$$

Figure 1.2.2 Definition of NRW

System Input Volume	"System Input" is the amount of water supplied to the user through pipelines and water tankers.
Billed Water	"Billed Water" is the amount of billable water authorized by the

water utilities. This includes not only the amount of water based on meter reading results, but also the estimated amount of use. The measurement period for "Billed Water" must match the measurement period for "System Input".

The first step in reducing NRW is to understand the whole picture of the water supply system, the person in charge of considering the measures is required to prepare a Water Balance table.

By creating this Water Balance, it will be possible to comprehensively understand the scale, causes, and required costs of NRW in an area.

The standard water balance table proposed by IWA is as follows.

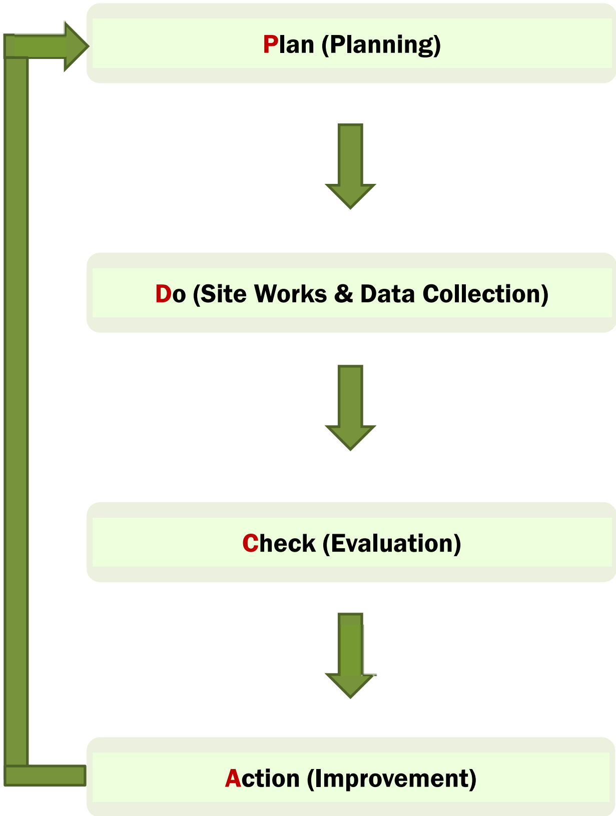
Table 1.2.1 Water Balance

System Input Volume	**Authorized consumption**	**Billed authorized consumption**	**Billed metered consumption**	**Revenue water**
			Billed unmetered consumption	
		Unbilled authorized consumption	**Unbilled metered consumption (Supply to Slum Area or Refugee)**	**Non-Revenue Water**
			Unbilled unmetered consumption (Washout, Pipe Cleaning or Maintenance use)	
	Water losses	**Apparent losses (Commercial losses)**	**Unauthorized consumption (Illegal use)**	
			Metering inaccuracies	
		Real losses (Physical losses)	**Leakage of transmission and distribution mains**	
			Overflow or leakage of storage tanks	
			Leakage between service connections and meter	

Source: Performance Indicators / First Edition 2000, IWA

1.3 PDCA Cycle

For future leakage reduction activities to be effective and sustainable, PDCA cycle-conscious efforts are necessary.



Plan (Planning):
- ･Setting the goal
- ･Action Plan for achievement of goal
- ･5W2H (Who, When, Where, What, Why, How, How much)

Do (Site Works & Data Collection):
- ･Implementation of the Action Plan
- ･Record of progress and results of activities
- ･Record of causes that hinder the achievement of goals

Check (Evaluation):
- ･Comparison of goal and achievement level
- ･Review of action plan
- ･Analysis of success factors and failure factors

Action (Improvement):
- ･Judgment of continuity
- ･Modification of activities
- ･Interruption of activities

Figure 1.3.1 PDCA Cycle

There are four points to effectively operate the PDCA cycle:

- ➢ To show targets numerically and to plan concretely activities
- ➢ To appoint a responsible person and to execute as planned
- ➢ To Make a comfortable schedule
- ➢ To check and evaluate progress periodically

1.4 Pilot activity flow

1.4.1 Activity implementation system

The pilot activities will proceed under the following system.

Since the selected pilot site belongs to OIC Panadura, the leakage reduction activities will be carried out by the engineers and staff of OIC.

The leader of the pilot project will be the P&C manager of RSC W-S, and will be responsible for securing the equipment and materials necessary for the activities, obtaining the license, and coordinating with other departments within NWSDB, while receiving reports from OIC Panadura.

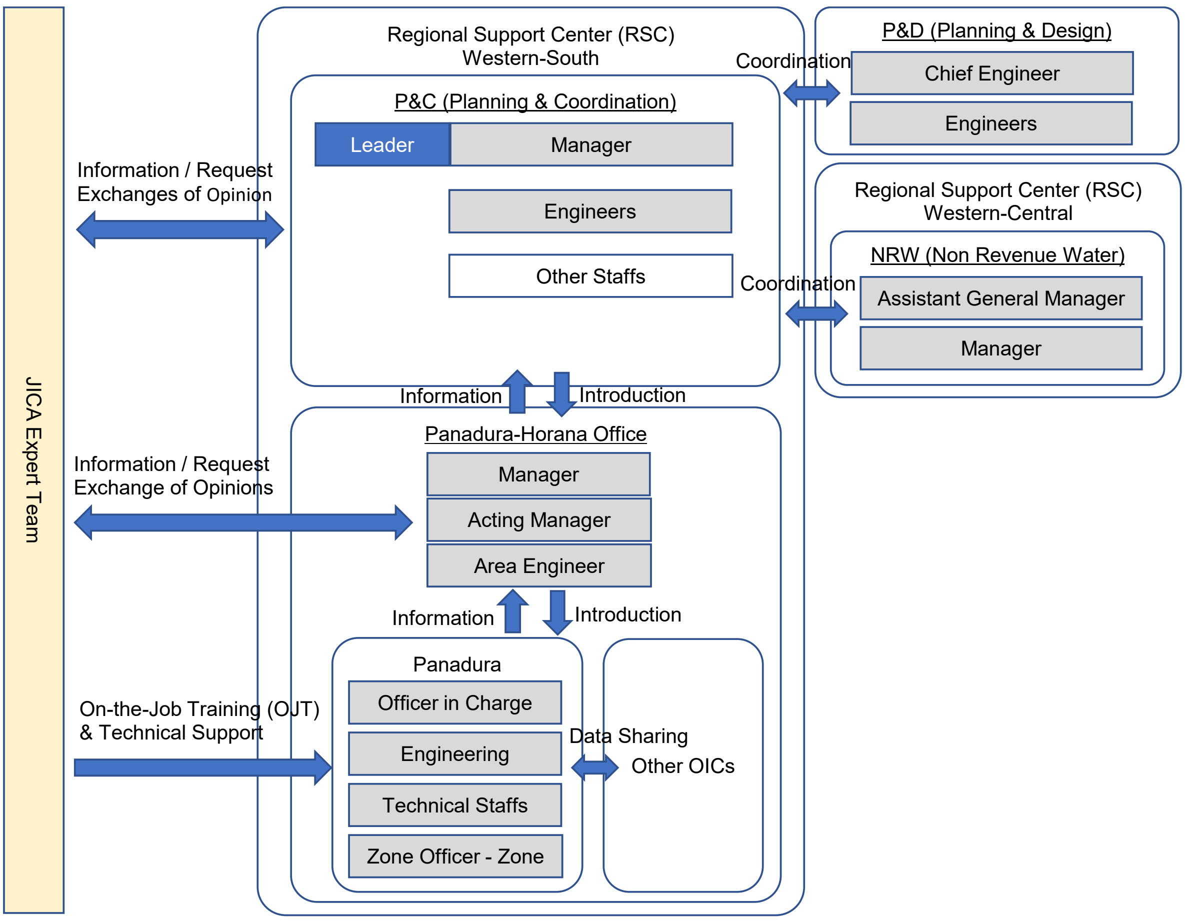


Figure 1.4.1 Activity implementation system

1.4.2 Implementation Steps of Pilot Activities

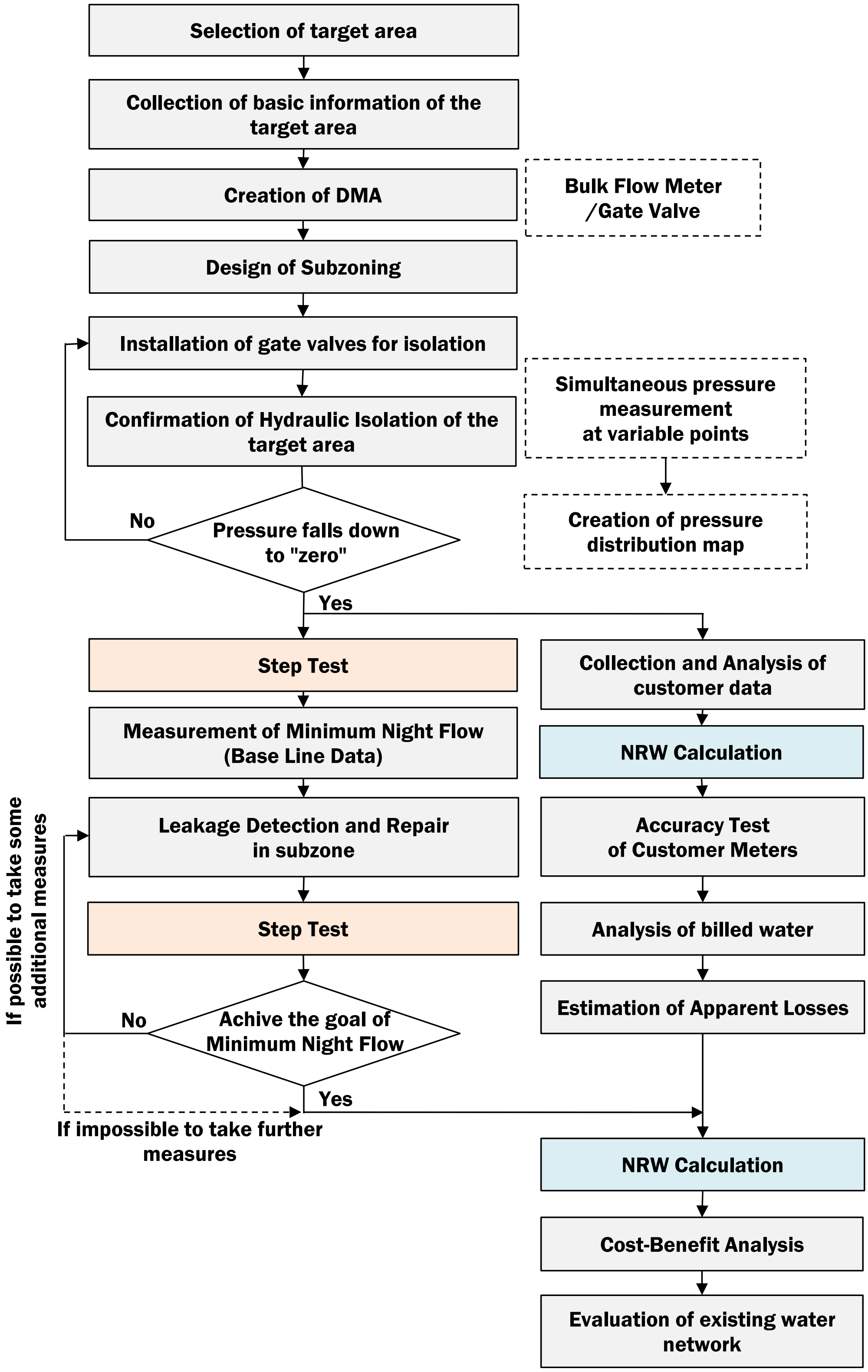


Figure 1.4.2 Implementation Steps of Pilot Activities

Chapter 2. Planning for water leakage reduction measures (Plan)

2.1 Setting goals and evaluation indicators

For all activities, it is necessary to determine the target area and achievement goals in advance. In general, the goals that can be set as pilot activities are as follows.

- To learn techniques to detect underground leakage

  Through practical training in field work, learn leak detection methods and equipment operation.

- To clarify the components of NRW.

  Quantitatively show the components of NRW in the pilot area and propose the most effective and efficient measures to reduce NRW.

- To improve NRW rate

  Implement the proposed measures and improve the NRW ratio.

This project assumes that most of NRW in the pilot area is dominated by underground leakages that are difficult to detect, and NWSDB staff aims to acquire the knowledge, technology, and skills necessary for underground leakage control.

The effectiveness of the measures will be evaluated by monitoring the following data.

- Minimum Night Flow (Q_{mnf})
- NRW ratio (%)

In case that, after activities, it is found that activities other than leak control are effective in reducing non-revenue water, we propose measures to be taken.

2.2 Evaluation of real losses (leakage)

The dynamic scheme of real losses (leakage) is shown below.。

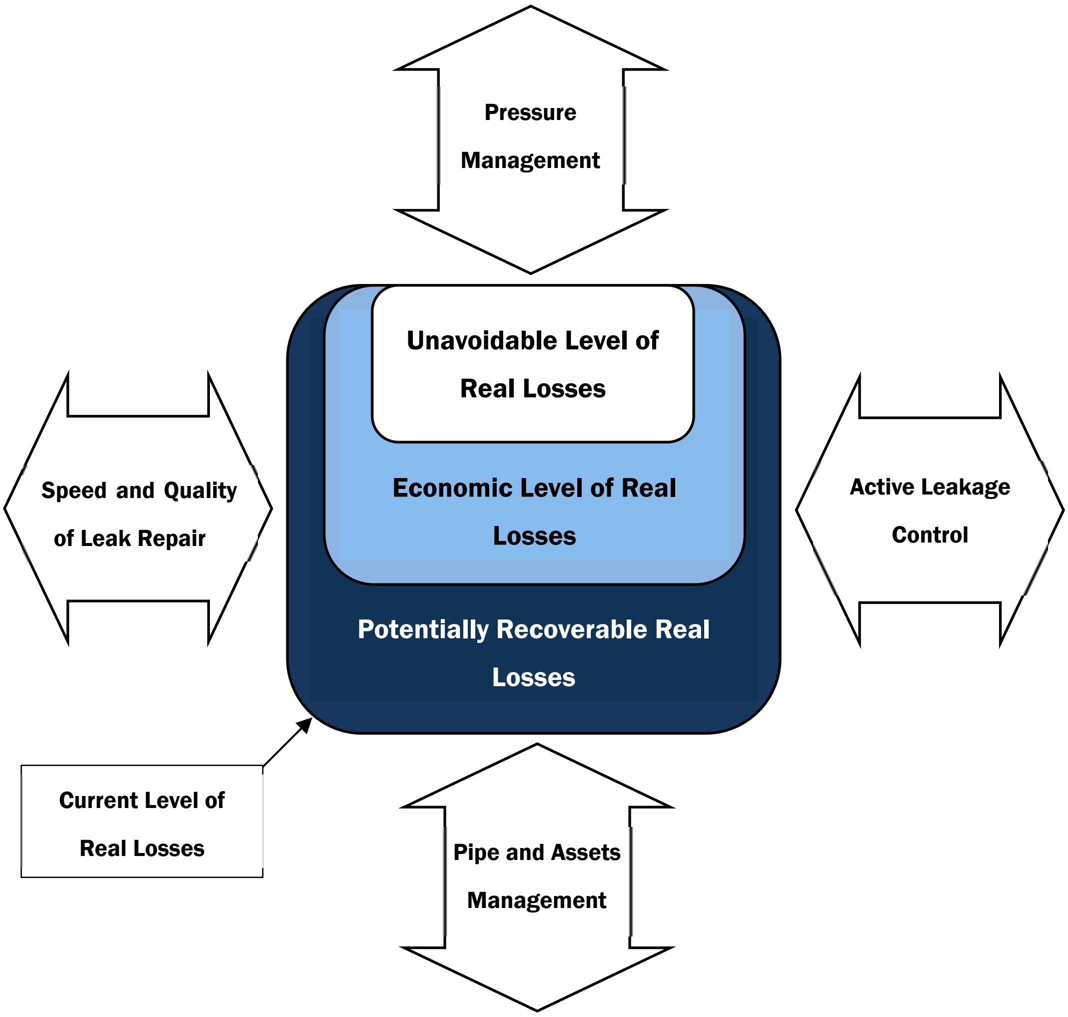


Figure 2.2.1 Dynamic scheme of real losses

To reduce water leakage, it is necessary to take measures from four directions, however, the priority of which depends on the characteristics of the district.

Therefore, in the pilot activities, the leakage repair will be carried out first and the effect will be confirmed. In addition, if a large amount of residual water leakage is observed, additional measures such as water pressure management and pipeline renewal will be taken, and measures will be continued until the amount of water leakage can be reduced from an economical point of view.

There is a level of leakage that is physically difficult to reduce. They call this level "Unavoidable Annual Real Losses (UARL)". The performance indicators of real losses are as follows.

2.2.1 Current Annual Volume of Real Losses (CARL)

$$\text{CARL (L/day)} = \frac{\text{Annual Volume of Real Losses (m}^3\text{/year)} \times 1000}{\text{Number of Water Service Days}}$$

2.2.2 Real Losses per connection

$$Q_{pcd}\ \text{(L/connection/day)} = \frac{\text{Current Annual Volume of Real Losses}}{\text{Number of Service Connection}}$$

The IWA recommends an index (L/km/day) that uses the total length of water pipes instead of the number of water pipes for areas where the density of water pipes is less than 20 cases/km.

2.2.3 Infrastructure Leakage Index (ILI)

ILI is a value recommended by IWA as an indicator of the vulnerability of distribution pipes. To calculate this value, calculate UARL (Unavoidable Annual Real Losses) in advance with the following formula.

UARL (L/day) = (18×Lm + 0.8×Nc + 25×Lc) × P

Lm : Total length of distribution pipes (km)

Nc : House Connection Number

Lc : Total length of service connection pipes (km)

= Average length per connection (km/connection) × Ns. of connection

P : Average water supply pressure (m H_2O)

UARL is the amount of water that cannot be expected to be further reduced no matter what water leakage measures are taken. It is said that this value will be about 2 to 4% of the total amount of water distributed by any water utility, and it can be understood as the allowable amount of leakage.

ILI is the value obtained by dividing the amount of water leakage (CARL) shown above by this UARL and is used to judge how appropriately the distribution network is maintained.

$$\textbf{Infrastructure Leakage Index (ILI)} = \frac{\textbf{Current Annual Volume of Real Losses (CARL)}}{\textbf{Unavoidable Annual Real Losses (UARL)}}$$

The IWA Working Group reports that when comparing ILI values, they can be applied in relatively large systems at the national, city, and zone levels. The conditions are as follows.

Number of connection : more than 3,000 (no limit for density)

Average water supply pressure : more than 25m as water head

In the case of an ideal water distribution network with no problems, ILI=1.0, which is a purely technical ultimate indicator. However, it is a value that is practically impossible, ignoring cost-effectiveness, and it is not necessary to target this level.

If the current ILI and target value can be set in this way, the real losses to be targeted can be determined using the following matrix according to the ILI value and the average water supply pressure.

Table 2.2.1 Target value of real losses

Technical Performance Category		ILI	Physical Losses (L/connection/day) (when the system is pressured) at an average pressure of:				
			10m	20m	30m	40m	50m
Developed Countries	A	1 - 2		< 50	< 75	< 100	< 125
	B	2 - 4		50 – 100	75 – 150	100 – 200	125 – 250
	C	4 - 8		100 – 200	150 – 300	200 – 400	250 – 500
	D	> 8		> 200	> 300	> 400	> 500
Developing Countries	A	1 - 4	< 50	< 100	< 150	< 200	< 250
	B	4 - 8	50 – 100	100 – 200	150 – 300	200 – 400	250 – 500
	C	8 - 16	100 – 200	200 – 400	300 – 600	400 – 800	500 – 1000
	D	> 16	> 200	> 400	> 600	> 800	> 1000

Source: Roland Liemberger, IWA Leakage 2005 Conference

Category A Good。Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost-effective improvement

Category B	Potential for marked improvements; consider pressure management; better active leakage control practices, and better network maintenance
Category C	Poor leakage record; tolerable only if water is plentiful and cheap; even then, analyze level and nature of leakage and intensify leakage reduction efforts
Category D	Highly inefficient; leakage reduction programs imperative and high priority

2.3 Data Collection

In carrying out the pilot activities, the following information should be organized.

2.3.1 Basic data

Table 2.3.1 Data to be collected before commencement of activities

No	Items	No	Items
1	Number of connections	6	Distribution Network Drawing
2	Number of effective customer meter	7	Extension of pipes by type of material
3	Billing data during last 12 months	8	Extension of pipes by diameter
4	Meter reading data during last 12 months	9	
5	Number of users by category	10	

2.3.2 Updating commercial data

While conducting the activity, check the consistency between the data base of billing status and the current water users, so that NRW and real losses can be calculated accurately.

Table 2.3.2 Commercial data to be updated

No	Items	No	Items
1	ID Code of region	16	Sewerage service
2	Region	17	Status of meter box
3	Zone	18	Operating condition of meter
4	Registration number	19	Manufacturer of meter
5	Customer number for billing	20	Nominal diameter of meter
6	Direction	21	Serial number of meters
7	Type of connection	22	Type of service pipe
8	Water usage status	23	Diameter of service pipe
9	Contact number	24	
10	Customer name	25	
11	Type of building	26	
12	Economic status	27	
13	Type of commercial activities	28	
14	Water source	29	
15	Connection date	30	

2.4 Design of DMA

Determine the range where hydraulic independence is possible according to the distribution network map of the activity area.

2.4.1 Definition of DMA

In this activity, DMA is defined as follows.

Definition of DMA

DMA is the smallest leak management area constructed in the distribution network.
It is used to estimate the amount of water loss occurring in the sector by making it hydraulically independent at night when water demand is low and measuring the minimum inflow rate of nighttime (Q_{mnf}).

【Complementary conditions】

- Water communication between adjacent distribution networks is allowed, but valves must be installed in place to allow the distribution network to be independent (separate from surrounding distribution networks) when needed.
- Multi point Inflow is permitted.
- It is not an absolute requirement to install a flow meter at the inflow point, but it must be possible to install a portable flow measurement device and measure the inflow water amount at night.

Scale of DMA

DMA will be set in consideration of distribution network conditions, water demand, customer density, etc.
For efficient control of water leakage reduction activities, it is desirable that the number of water supply connections for one DMA is about 500 to 3,000.

The ideal DMA is a system that is always disconnected from the surrounding water distribution network 24 hours a day and allows you to compare the amount of water supplied to the sector with the amount of water consumed within a certain period.

In order to construct DMA with perfect condition, it is necessary to perform hydraulic calculation based on distribution pipe data, and to develop a pipe network that does not cause a significant shortage of water demand, which requires a great deal of cost and time.

2.4.2 Purpose of constructing a DMA

The purpose of constructing a DMA is as follows.

- After limiting the boundary of distribution network from the surroundings at night, measure the minimum inflow (Q_{mnf}) to roughly understand the level of water leakage occurring in the area.
- Divide Q_{mnf} by the number of customers existing in the area to calculate the minimum nighttime flow rate per connection (Q_{mnf}/connection).
- Divide Q_{mnf} by the pipeline extension in the area to calculate the nighttime minimum flow rate per km (Q_{mnf}/km).
- Compare the Q_{mnf} of different DMAs to identify areas with high levels of water leakage and NRW, and take efficient and effective water leakage reduction measures considering priority.
- It is recommended that the effect of the measures should be regularly confirmed in the DMA that has taken measures against water leakage, at least once a month.
- By installing a remote monitoring system in DMA, we can monitor daily inflow water volume and water pressure and respond to sudden leaks and water distribution network accidents.

2.4.3 Information needed for DMA design

The following information needs to be confirmed when designing a DMA.

- Location, diameter and actual status of existing valves and its diameter
- Location and diameter of Inlet pipe of a target area
- Information of distribution pipes near the expected boundary
- In case of sub-zoning, detail of pipeline of its boundary
- Water supply pressure

2.4.4 Preliminary design of DMA

Based on the information obtained in advance, the following preliminary design will be performed.

After that, the boundary may be modified while referring to the data of the water distribution network found by making the area hydraulically isolated and measuring the water pressure.

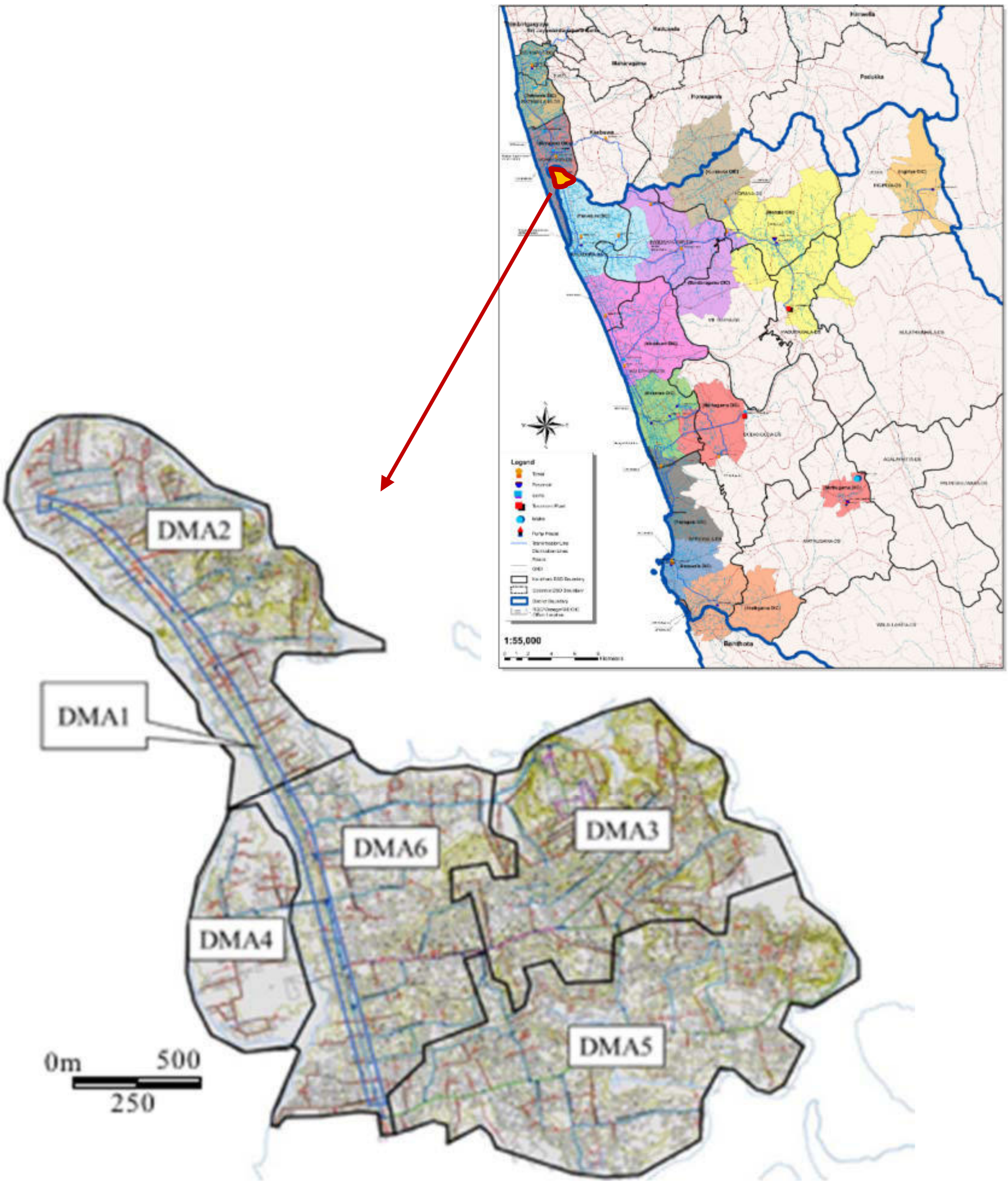


Figure 2.4.1 Preliminary design of DMA

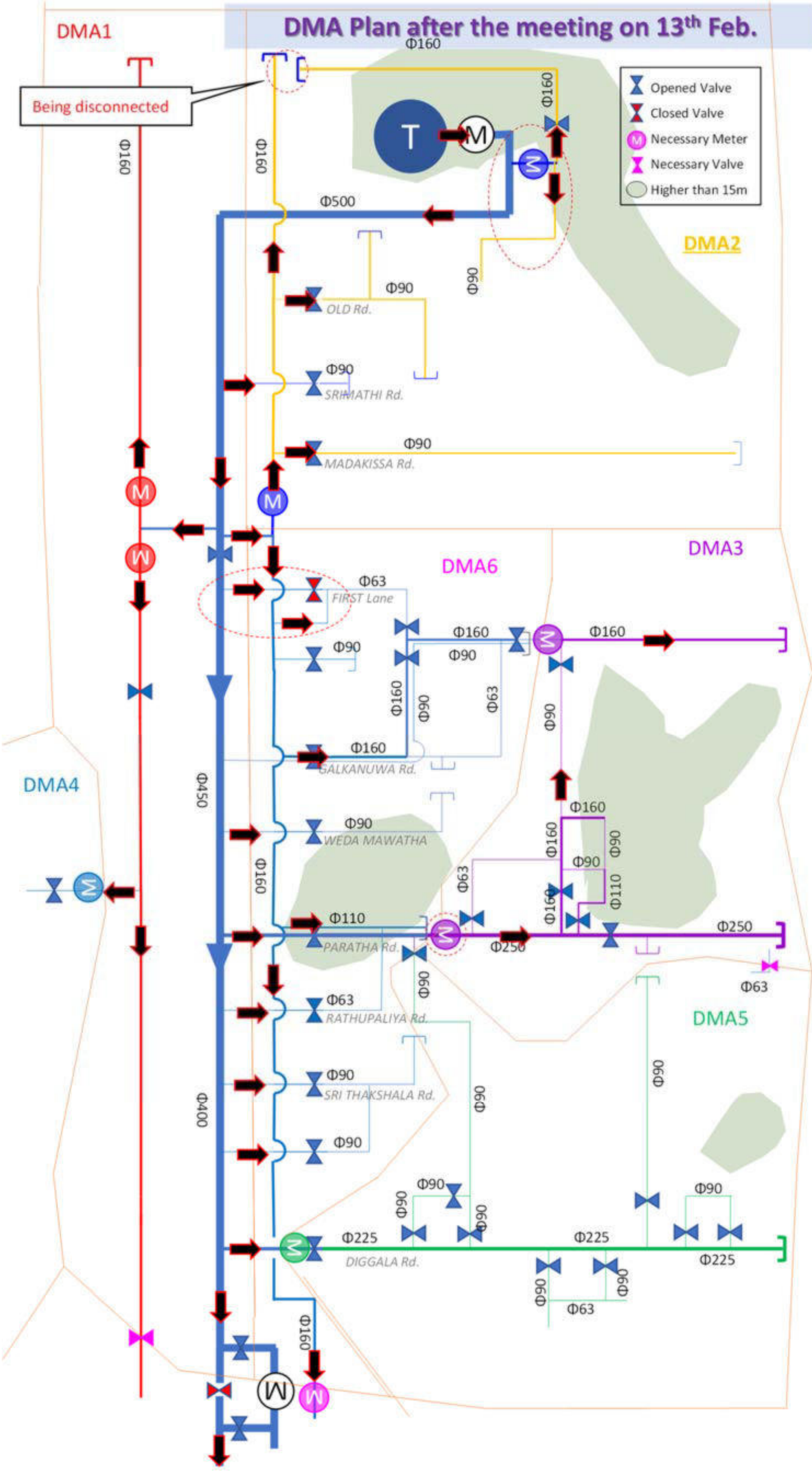
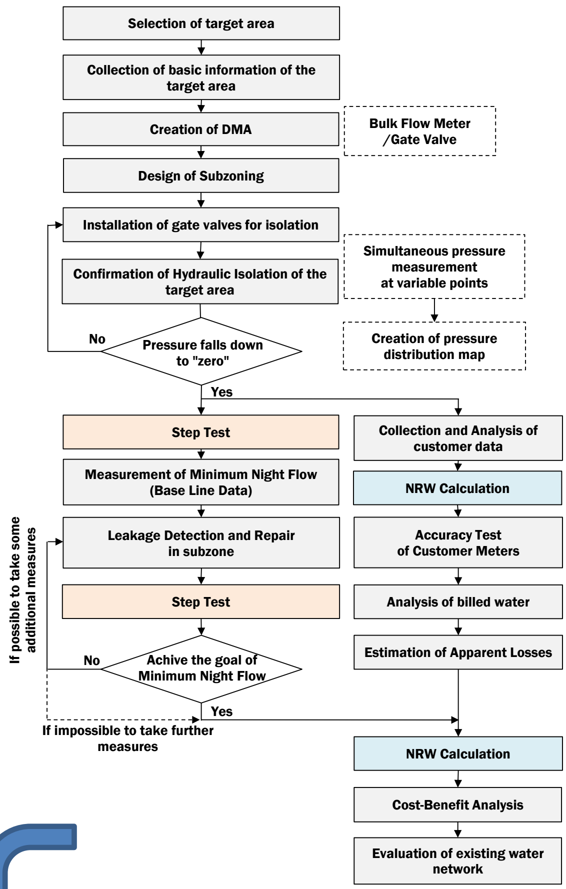


Figure 2.4.2 Schematic image of distribution pipes of DMA

2.5 Determination of activity schedule

The person responsible for implementing the activity sets the activity schedule based on the basic workflow described in Section 1.4.2.

- Implementation system and determination of activity members
- Secure activity budget
- Site survey and confirmation of construction conditions in the DMA target area
- Collection of customer information and billed water volume data in the area
- Procurement of materials and equipment necessary for hydraulic independence
- Construction of hydraulic isolation
- Measurement of inflow water and minimum flow rate at night
- Calculation of NRW rate
- Accuracy test of customer meters
- Detection and repair of leakage



Activities	January				February				March			
	1w	2w	3w	4w	1w	2w	3w	4w	1w	2w	3w	4w
1.												
2.												
3.												
4.												
5.												

Chapter 3. Practice of leakage control measures (Do)

The practice of water leakage control using DMA is carried out according to the following flow.

[Step 1] Confirm location and status of all the exiting valves and hydrants in DMA

↓

[Step 2] Install valves needed for the isolation of subzone

↓

[Step 3] Confirm hydraulic isolation of each subzone

↓

[Step 4] Identify subzones that require repair of leakage using minimum night flow measured by Step Test.

↓

[Step 5] Detect leakage points on the pipeline and repair leakages

↓

[Step 6] Execute 2nd Step Test to confirm the effect of leakage repair by variation of Minimum Night Flow

↓

[Step 7] Estimate the volume of remaining water leakage contained in Minimum Night Flow to find the most efficient measure for leakage reduction

Figure 3.1.1 Steps of leakage reduction activities

3.1 Hydraulic isolation of DMA

To proceed with the construction of the DMA, a field survey should be conducted based on the preliminary design created in advance. The distribution pipe, distribution status, the presence or absence of dead-end pipes, and the connection status with adjacent areas should be confirmed and should be reflected to updating work of pipeline network drawing.

After that, the changes from the preliminary design will be clarified and the boundaries for hydraulic independence will be set.

If the water pressure gauges are installed at multiple points in the area, the valves at the inflow points are closed, and the water supply pressure becomes zero after a certain period of time, it means that hydraulic independence has been achieved.

	
Measurement of pressure at the water tap	Equipment of pressure measurement at a certain point of distribution pipe.

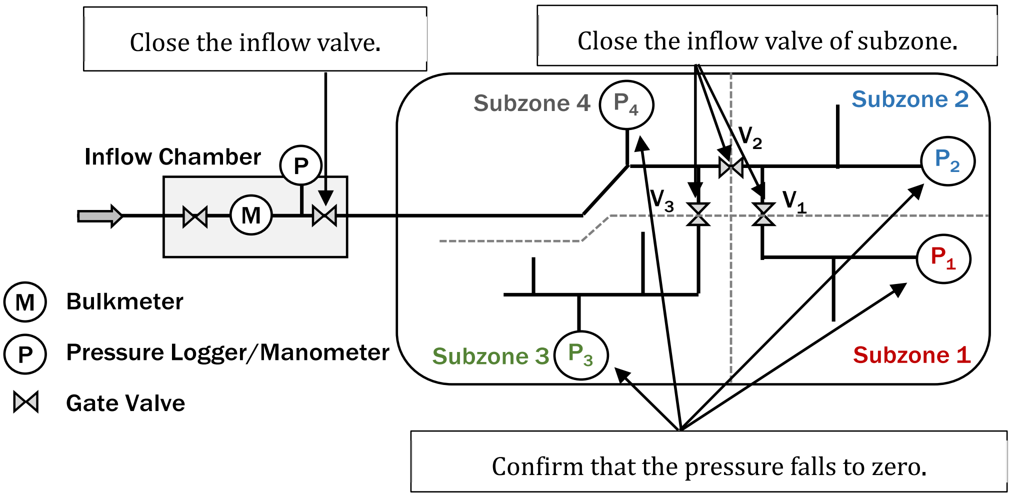


Figure 3.1.2 Image of pressure measurement in DMA

3.1.1 DMA4

Here, we will learn the basic techniques of DMA construction work, flow measurement, leak investigation, and leak repair.

The features of DMA4 are as follows.

- This is a small island-like terrain surrounded by the Bolgoda River, and is connected to other areas by a small bridge, so it is easy to set hydraulic independence.
- Since this is a quiet area with little difference in elevation, it has an ideal environment for learning the basic techniques for water leak detection.

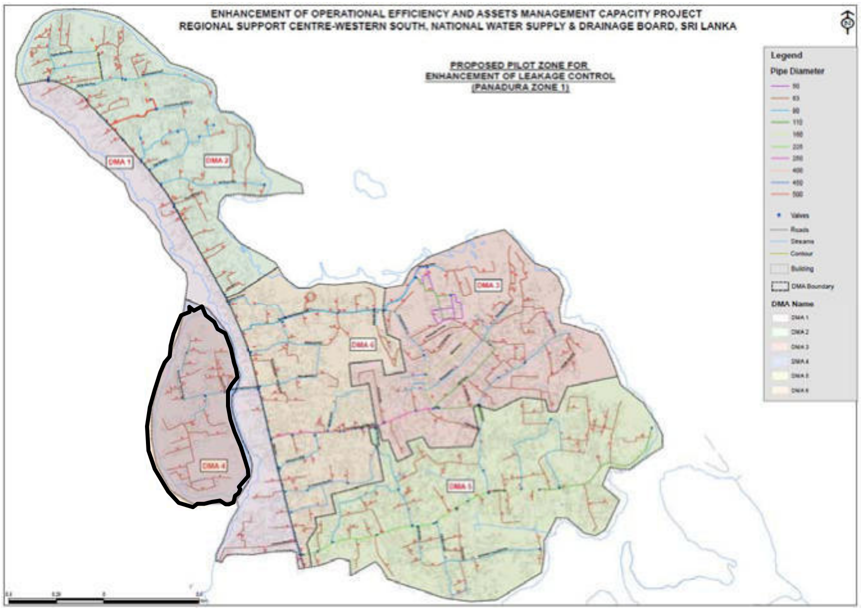


Figure 3.1.3 Location of DMA4

There is only one inflow pipe to the area. Establish a separation plan for subzones (hydraulically separated subdivisions) with gate valves so that inflow of each subzone can be measured by flow meters installed at the inlet point of DMA.

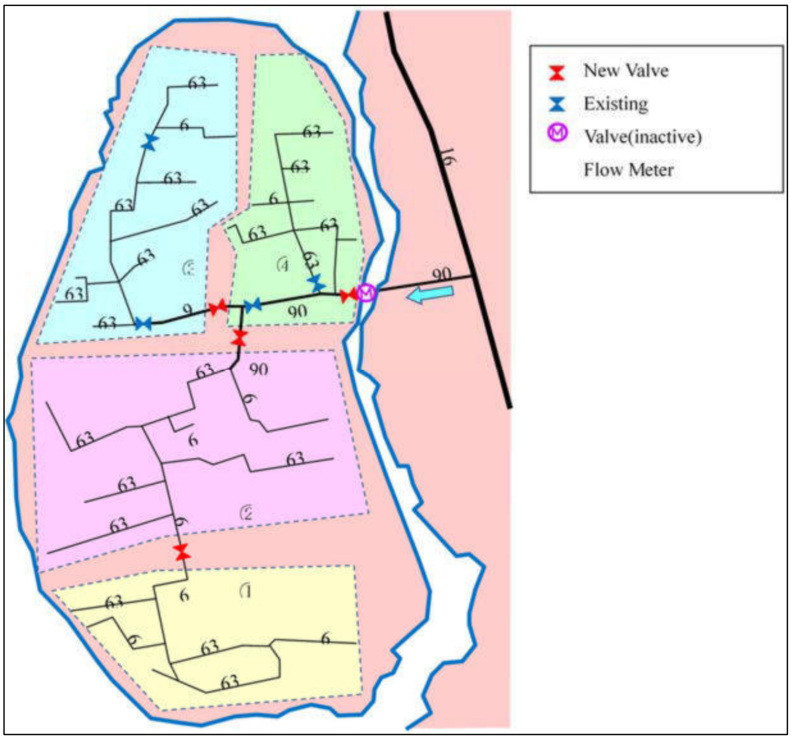


Figure 3.1.4 Sub-zoning of DMA4

The materials required for the construction of DMA and subzones are as follows.

Table 3.1.1 Material for hydraulic isolation of DMA4

Items	Qty
Bulk Flow Meter (DN80)	1
Gate Valve (DN80)	1
Gate Valve (DN63)	3
Flanges, Manhole cover, Valve key etc.	1 set

Table 3.1.2 Basic Information of subzone in DMA4

Subzone No.	Number of connections	Extension of distribution pipes (km)	General situation
1	47	1.3	It is a quiet residential area and the site area per house is relatively large. The difference of ground elevation is small.
2	107	1.3	
3	89	1.2	
4	85	0.8	
Total	328	4.6	-

3.1.2 DMA5

In the activity of DMA5, we will confirm the technology implemented in the activity of DMA4 and aim to improve it further.

The features of DMA5 are as follows.

- There is only one inflow pipe to the area.
- Since there are many existing valves in the area, it is easy to set the DMA boundary.
- There are multiple types of road pavement.
- There is a difference in elevation, and it is necessary to select an appropriate leak detection method according to the water pressure condition for each subzone.

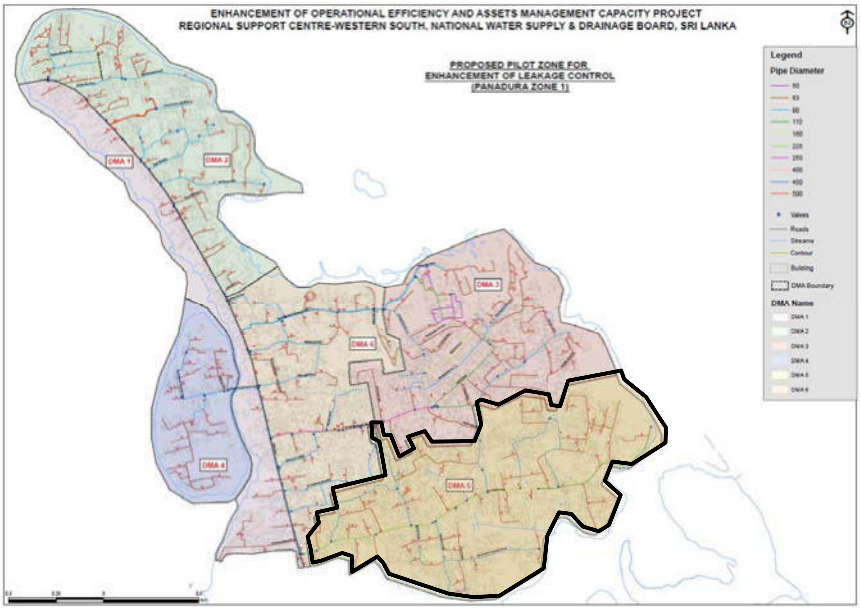


Figure 3.1.5 Location of DMA5

There is only one inflow pipe to the area. Establish a separation plan for subzones (hydraulicly separated subdivisions) with gate valves so that inflow of each subzone can be measured by flow meters installed at the inlet point of DMA.

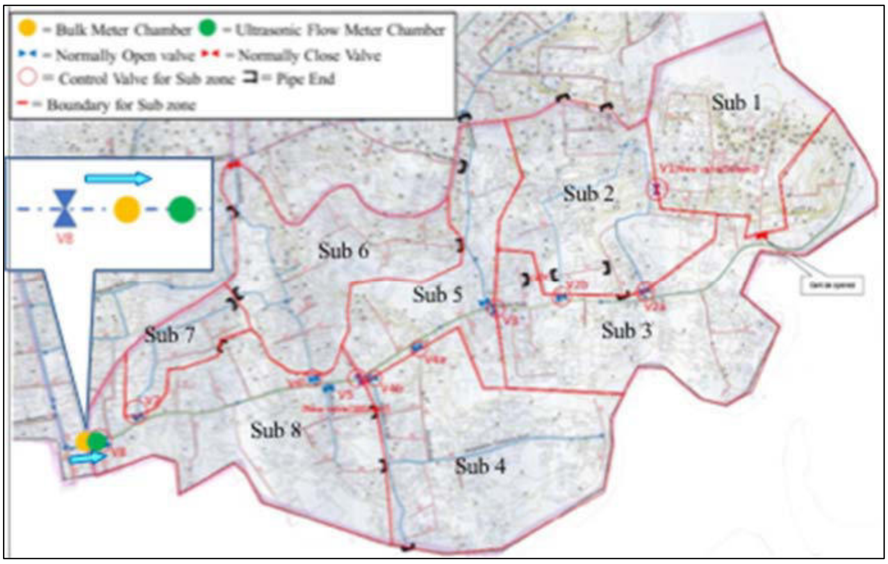


Figure 3.1.6 Sub-zoning of DMA5

The materials required for the construction of DMA5 and subzones are as follows.

Table 3.1.3 Material for hydraulic isolation of DMA5

Items	Qty
Bulk Flow Meter (DN200)	1
Gate Valve (DN200)	1
Gate Valve (DN50)	1
Flanges, Manhole cover, Valve key etc.	1 set

Table 3.1.4 Basic Information of subzone in DMA5

Subzone No.	Number of connections	Extension of distribution pipes (km)	General situation
1		1.9	Quiet residential area, good survey environment. The difference of ground elevation is large.
2		2.1	Quiet residential area, good survey environment. The difference of ground elevation is large.
3		2.5	Divided into noisy areas facing avenue and quiet residential areas Attention should be paid to noise on traffic road.
4		1.7	Quiet residential area, good survey environment. The difference of elevation in the area is small, but it becomes lower as it goes to the end of the pipeline.
5		1.3	Divided into noisy areas facing avenue and quiet residential areas Attention should be paid to noise on traffic road.
6		1.9	Quiet residential area, good survey environment. The difference of ground elevation is large.
7		1.0	Quiet residential area, good survey environment. There are some small factories, etc. The elevation at the valve V7 point is low and gradually increases toward the end of the pipe.
8		2.5	This area is facing the main road. There are many shops, and noise continues to occur during the day. The difference of elevation is small
Total		14.9	-

3.1.3 DMA 3

The features of DMA 3 are as follows.

- There are two inflow pipes to the area.
- The north area is supplied from the distribution pipe from DMA6 on the west side, and the distribution network is separated from the south area.
- For smooth and effective implementation of leakage control activities, it is recommended that the southern area indicated below should be included in DMA 3 and the north area be included in DMA 6.

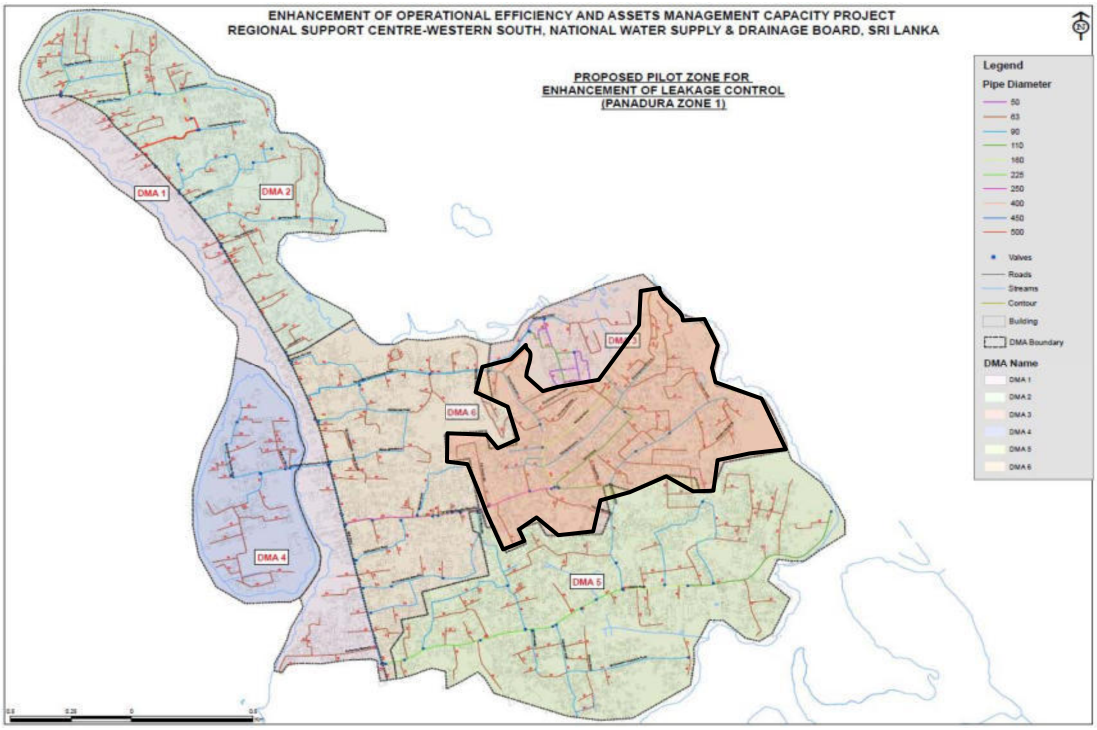


Figure 3.1.7 Location of DMA 3

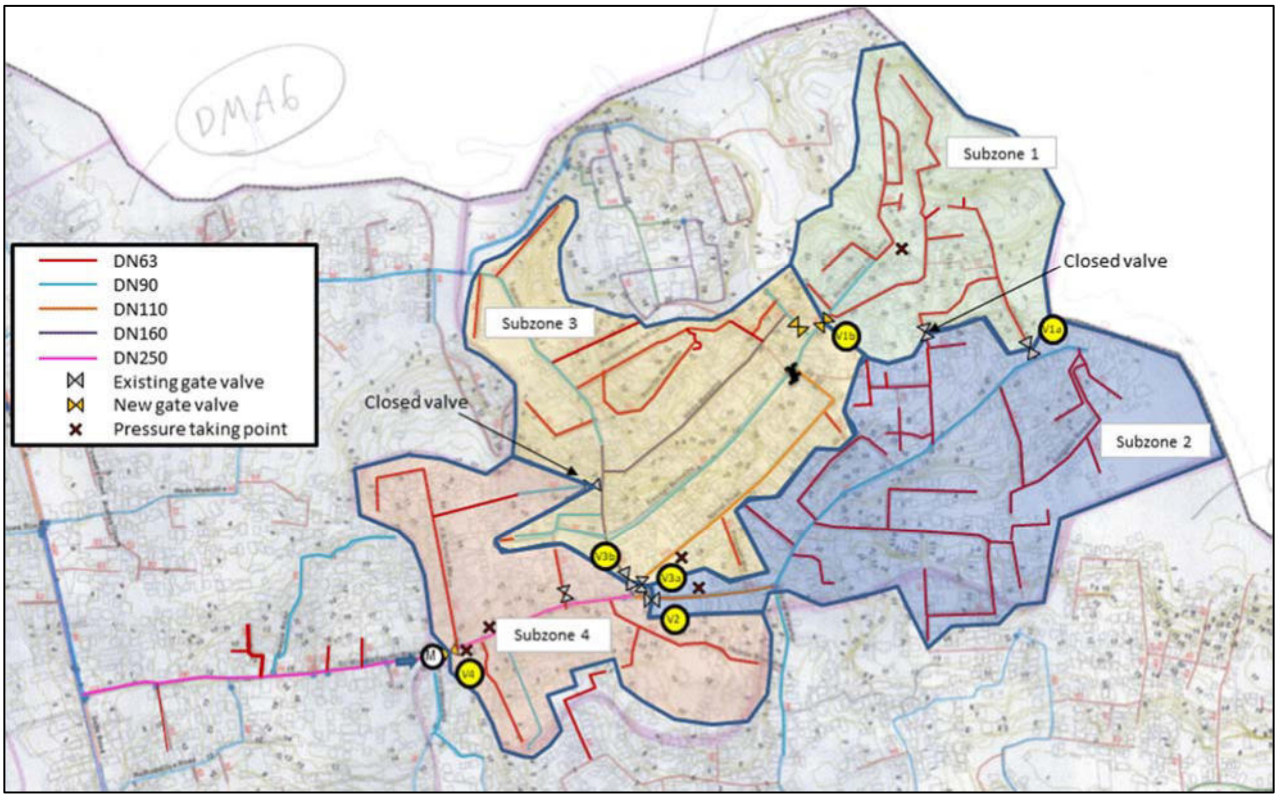


Figure 3.1.8 Sub-zoning of DMA 3

The materials required for the construction of DMA3 and subzones are as follows.

Table 3.1.5 Material for hydraulic isolation of DMA 3

Items	Qty
Bulk Flow Meter (DN250)	1
Bulk Flow Meter (DN150)	1
Gate Valve (DN250)	1
Gate Valve (DN80)	1
Gate Valve (DN50)	3
Flanges, Manhole cover, Valve key etc.	1 set

Table 3.1.6 Basic Information of subzone in DMA 3

Subzone No.	Number of connections	Extension of distribution pipes (km)	General situation
1		2.2	
2		3.7	
3		3.5	
4		2.1	
Total	1,123	11.5	-

3.1.4 DMA 2

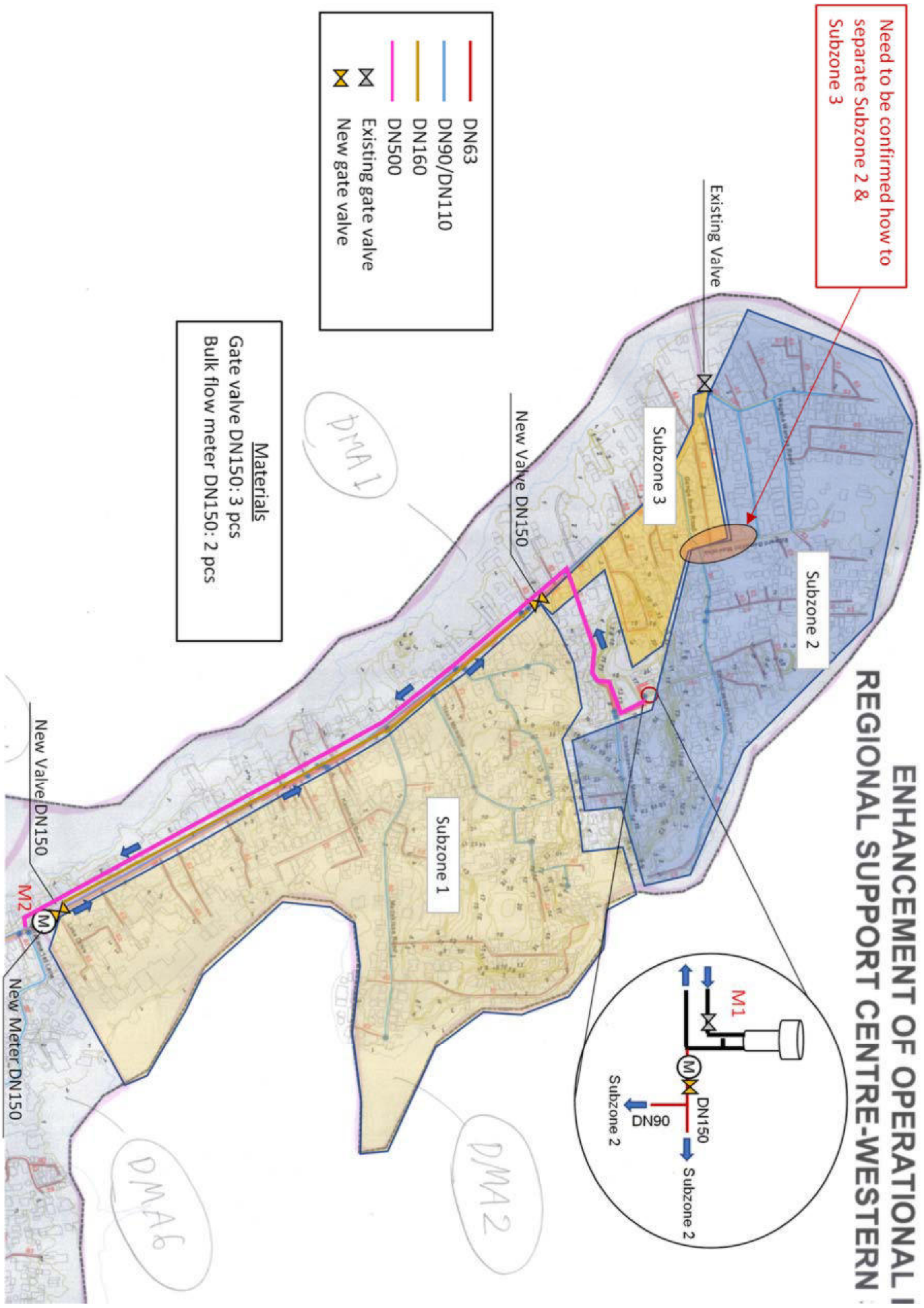


Figure 3.1.9 Sub-zoning of DMA 2 (Preliminary Design)

Table 3.1.7 Material for hydraulic isolation of DMA 2

Items	Qty
Bulk Flow Meter (DN150)	2 (Plan)
Gate Valve (DN150)	3 (Plan)
Flanges, Manhole cover, Valve key etc.	1 set

Table 3.1.8 Basic Information of subzone in DMA 2

Subzone No.	Number of connections	Extension of distribution pipes (km)	General situation
1		**	
2		**	
3		**	
4		**	
Total		16.5	-

3.1.5 DMA 1

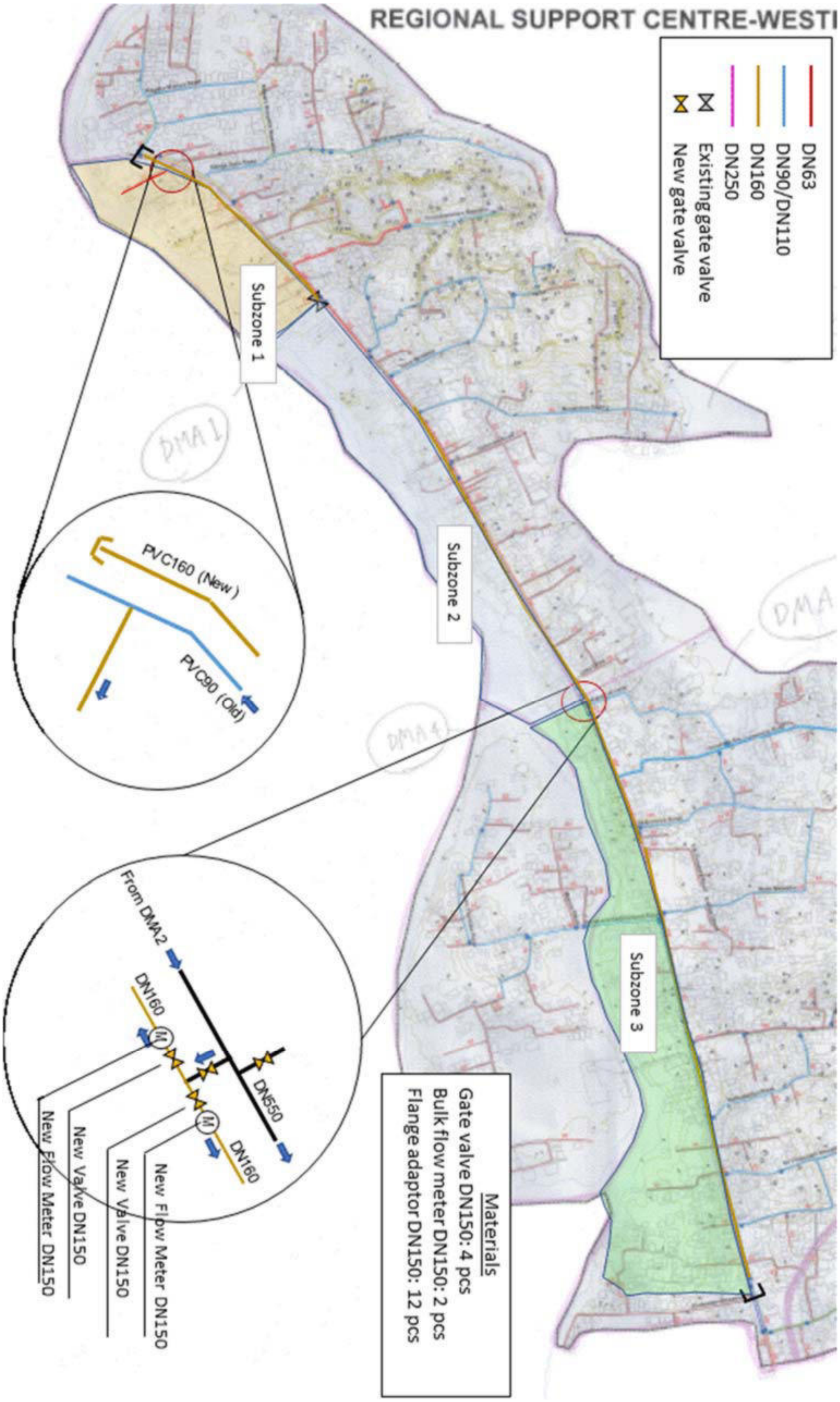


Figure 3.1.10 Sub-zoning of DMA 1 (Preliminary Design)

Table 3.1.9 Material for hydraulic isolation of DMA 1

Items	Qty
Bulk Flow Meter (DN150)	2 (Plan)
Gate Valve (DN150)	4 (Plan)
Flanges, Manhole cover, Valve key etc.	1 set

Table 3.1.10 Basic Information of subzone in DMA 1

Subzone No.	Number of connections	Extension of distribution pipes (km)	General situation
1		2.2	
2		1.9	
3		4.9	
Total		9.0	-

3.2 Collection of customer information

Once the DMA has been hydraulically separated and sub-sectors have been constructed, the customer information in each sub-zone should be clearly indicated in the drawing.

The information arranged here is not only indispensable for the calculation of non-revenue water, but also important for estimating the apparent loss that is a loss other than water leakage.

- Customer number
- Customer category
- Date of meter installation
- Serial Number of meters
- Nominal diameter of meter
- Manufacturer of meter
- Diameter and material of service connection pipe
- Meter reading record during last 12 months (Monthly water use, Accumulated reading value)
- Billing record during last 12 mouths

Regarding the amount of billed water, the department in charge shall adjust this so that the data can be shared monthly with the leakage reduction activity team.

3.3 Measurement of water distribution and water pressure

3.3.1 Measurement of Minimum Night Flow (MNF)

An ultrasonic flow meter and a water pressure data logger shall be installed at the target DMA inflow point, and the flow rate and water pressure will be measured for at least 24 hours. The MNF Measurement Method is a method of grasping the consumption water volume in the network at night when the water use on the user is small. This measured volume will be an approximate value of the leakage that has occurred in the network.

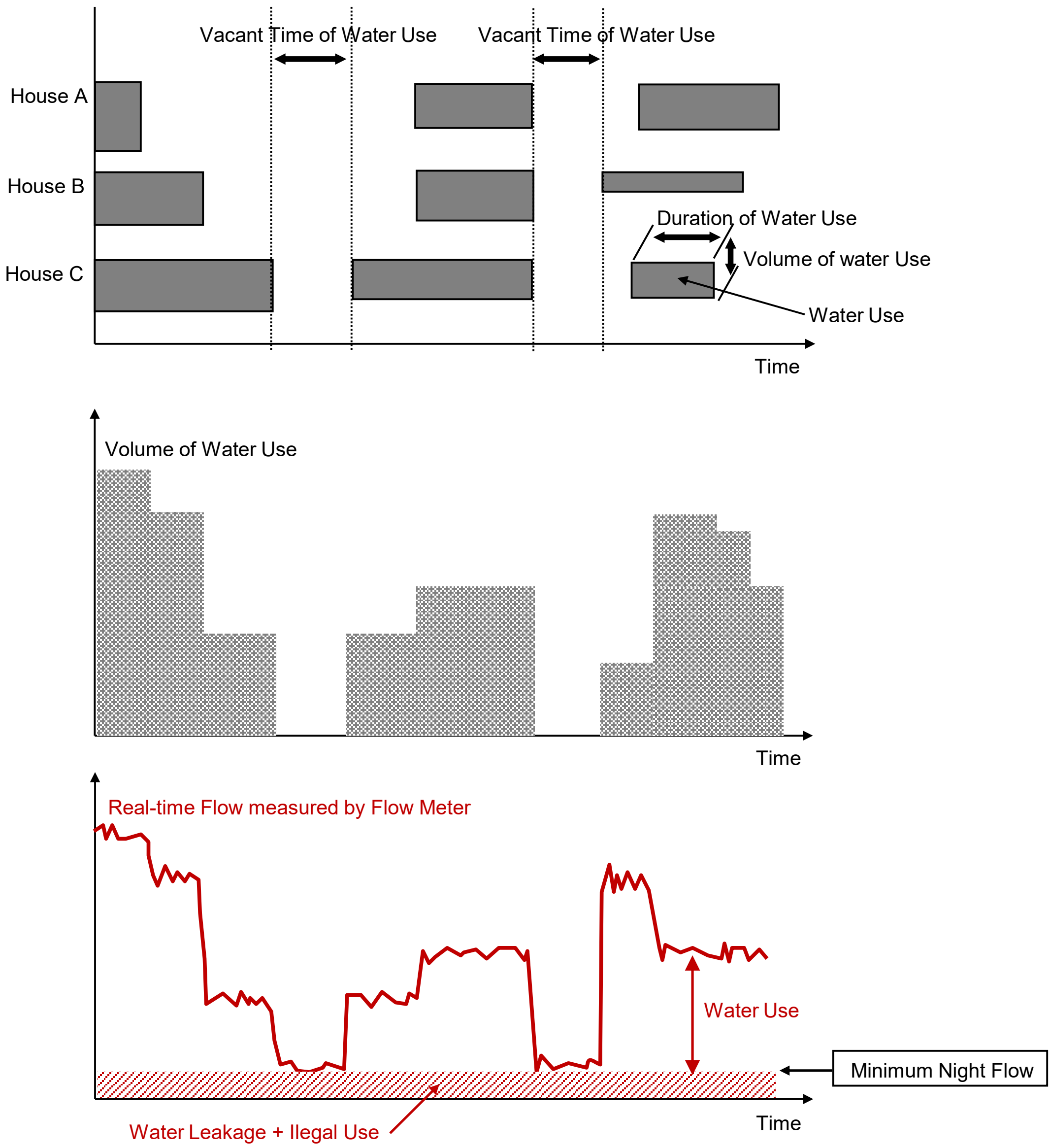


Figure 3.3.1 Minimum night flow and vacant time of water use

3.3.2 Step Test

The work of grasping how the amount of water distribution in the DMA is distributed and estimating the degree of deterioration of the pipeline that produces many leaks is called "Step Test".

The step test has the effect of running out of water in the entire DMA, so it must be performed during the time when water use is the least.

Generally, the core time of measurement is from 1:00 to 4:00 midnight, and the time before and after is also used for measurement depending on the actual conditions of water use in the area.

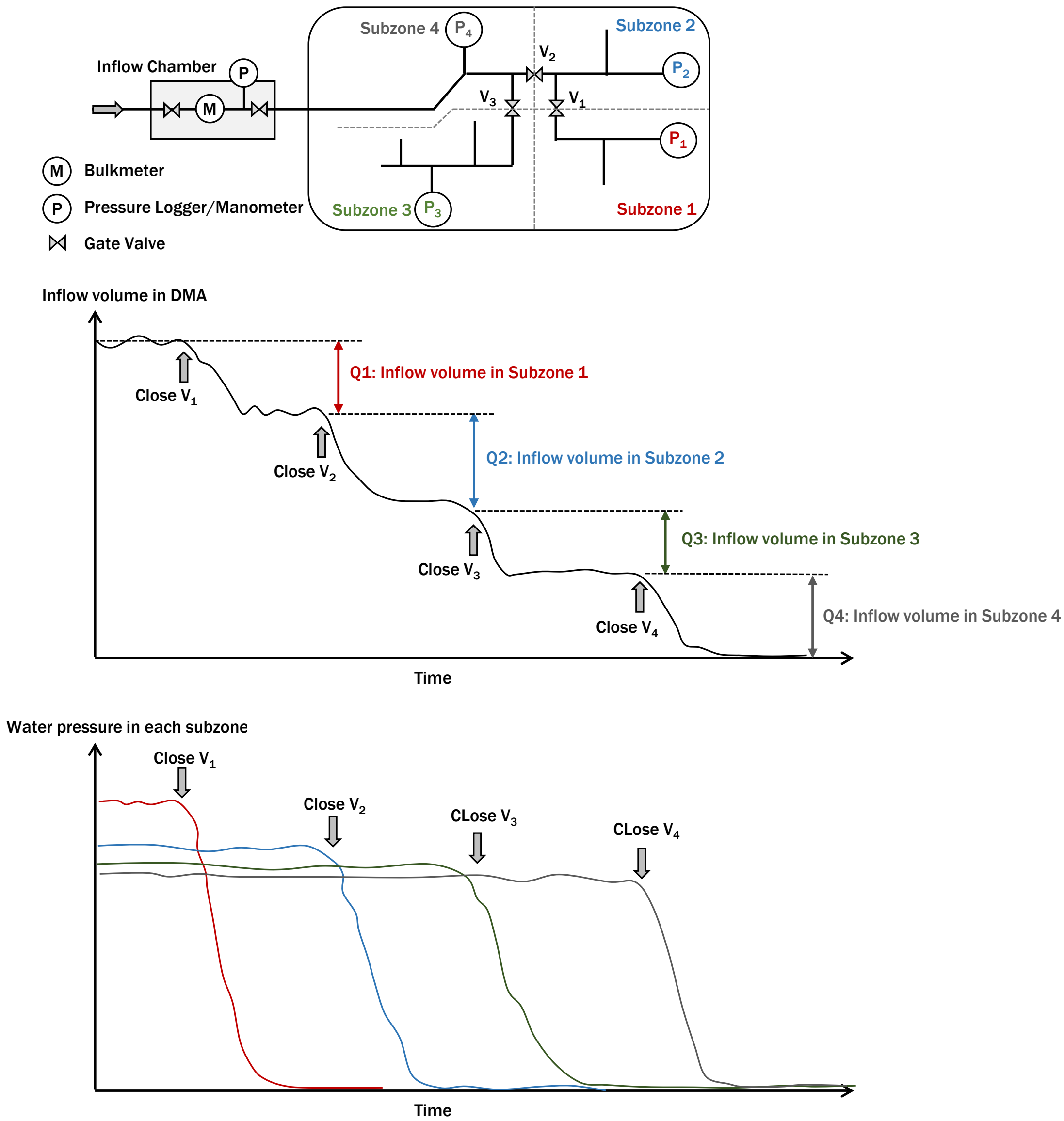


Figure 3.3.2 Imagen of Step Test procedure

In MNF measurement and Step Test, flow rate fluctuations must be recorded at minimum 10-second intervals, so a flow meter with the following functions is required, such as "Ultrasonic Flowmeter" or "Electromagnetic Flowmeter (with pulse generator)".

- Flow rate can be measured at intervals of at least 10 seconds.
- Being capable of logging instantaneous flow rate and cumulative flow rate.
- Being capable of measuring in the low flow rate band.

In the case of an ultrasonic flow meter, the accuracy may be greatly reduced at a minute flow rate of 0.3 m/sec or less.

A general bulk flow meter with impeller cannot measure an instantaneous flow rate, and has a slow response speed to a flow rate fluctuation, so that it is impossible to determine a vacant time of water use. Therefore, this type of flow meter is used for long-term monitoring of water distribution and for analysis of daily or monthly fluctuation of inflow rate.

In the step test, an ultrasonic flow meter is installed in the inflow chamber, and the valve operation of each sub-sector is performed while monitoring the MNF rate (Q_{mnf}). It is necessary to record the valve operating time and the measuring time required for the judgment.

In addition, the unit of flow rate should be unified so that the analysis will not be confused even if the measurer is different.

Secure a connection for water pressure measurement on the inflow pipe, and record the water pressure at the time of testing with a data logger.

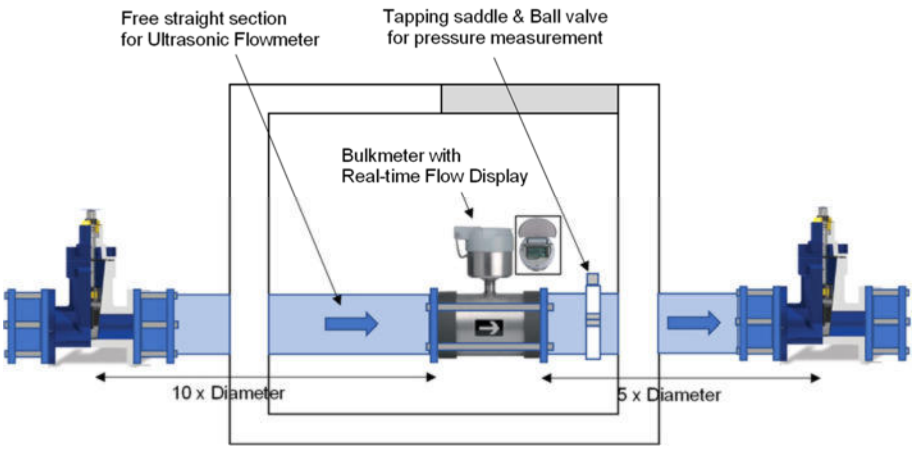


Figure 3.3.3 General equipment at Inlet of DMA

The timing of closing the subzones must be carefully considered in advance, but the measurement time of one subzone should be maintained for 10 minutes or more.

One or more water pressure data loggers should be installed in each subzone to record water pressure fluctuations during the step test.

The sub-sector where the water pressure does not reach zero after the valve is closed indicates that hydraulic independence is incomplete.

3.3.3 Measurement of water supply pressure

When performing water pressure measurement at multiple points in the area, record the continuous water pressure fluctuation for about one week including the step test period.

By grasping water pressure fluctuations during normal times over a long period of time, it is possible to judge whether there occurs an abnormality of water pressure during a step test.

In the water pressure survey, data loggers are used to simultaneously measure water pressure changes at multiple points. By showing the result as a water pressure distribution map, it is possible to grasp the area where the water pressure is insufficient in the area and to estimate whether there is a problem in the capacity of the pipeline.

In addition, the amount of water leakage estimated from the minimum flow rate at night is the value in the late-night hours, so it is necessary to consider the daily water pressure fluctuations and correct it in order to calculate the amount of water leakage of the average daily value

Water pressure surveys are important because they enable such a wide variety of analyses.

(1) Pressure measurement with data logger

A port for pressure measurement should be provided in the DMA inflow pipe using a tapping saddle and a ball valve (incorporation valve).

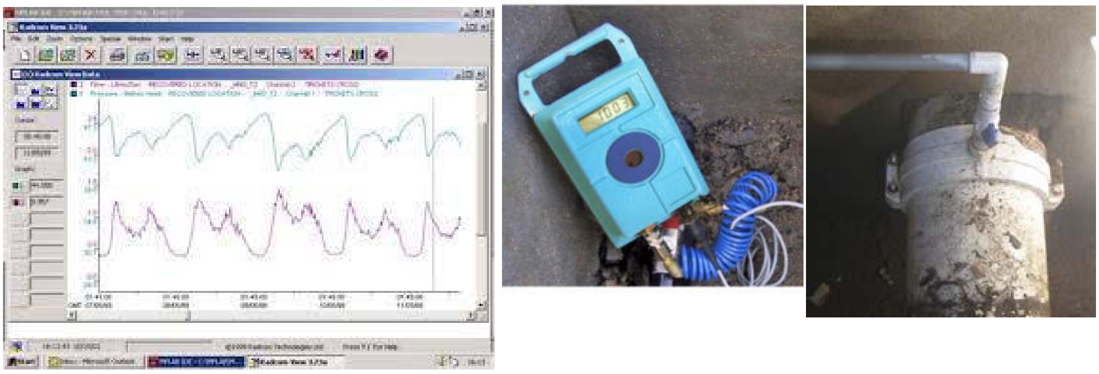


Figure 3.3.4 Installation of pressure data logger

(2) Logging interval

Since the water pressure fluctuates according to changes in the amount of water in the distribution network, it is necessary to set an appropriate interval according to the purpose of measurement.

Table 3.3.1 Recommended interval for each purpose

Logging Interval	Purpose
1sec	Suitable for observing instantaneous water pressure fluctuations. Especially analysis of water pressure fluctuations and water hammer pressure in pump water pipes, etc. There is also a high-precision Logger that can record in 1/100 second.
10sec	Suitable for detailed analysis of water supply pressure in DMA. It is also possible to estimate the household use hours and usage patterns from water pressure fluctuations, and it will be the basic data for considering the renewal of the pipe network.
1min	Suitable for monitoring water pressure fluctuations in the distribution network. If there is a large fluctuation in units of 1 min, shorten the interval and measure again.

(3) Drawing of water pressure measurement results

The measured value is visually displayed as follows.

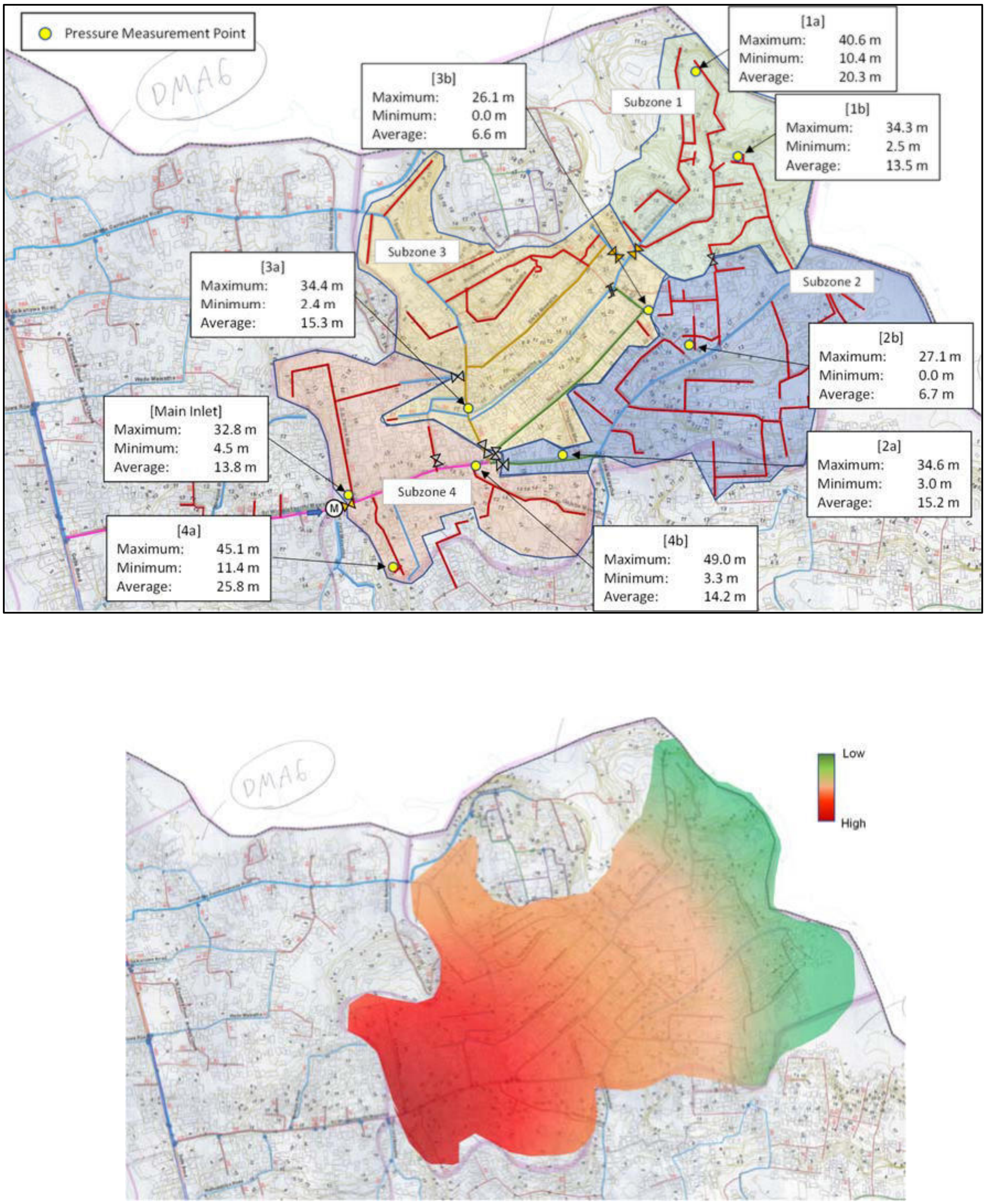


Figure 3.3.5 Pressure distribution map (Example)

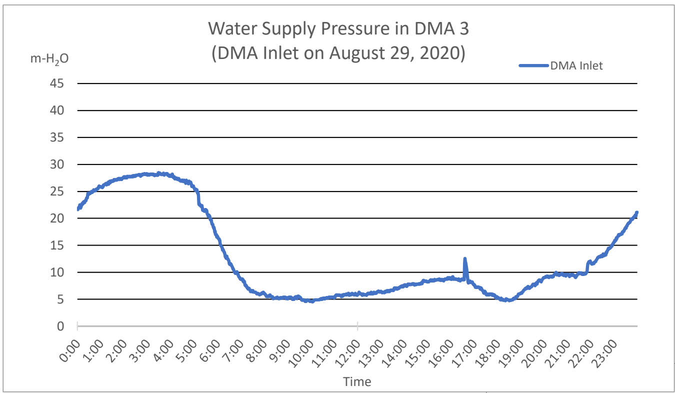
The pressure distribution map allows us to understand the following situation:

- Where is the water pressure during the daytime less than 10 bar?
- Which route has a high maximum water pressure and a high risk of water leakage?
- Where is the area where the water pressure is low even though the pipe diameter is sufficient?
- Where is the area where the water pressure fluctuation during daytime and nighttime is large and the water supply demand is large?

3.3.4 Trend analysis of water pressure fluctuation

Using the measured water pressure data, the water pressure fluctuation for each time zone is summarized as follows.

This is the key data used to estimate the actual amount of leak reduction



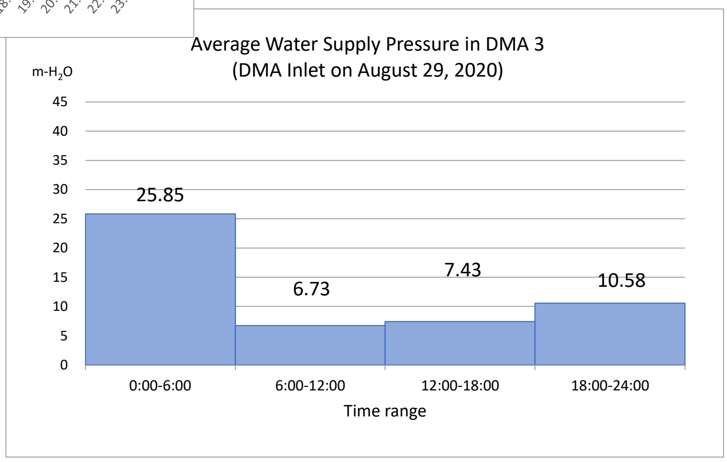


Figure 3.3.6 Water pressure fluctuation pattern (DMA 3)

3.4 Setting the base line data

Based on the results of the Step Test and the MNF measurement, set the baseline data before starting water leakage reduction measures.

The results of the step test and baseline data for DMA5, which has already been conducted, are as follows. New DMA activities will be performed in the same procedure.

Table 3.4.1 Result of Step Test in DMA5

Subzone	Time	Flow		Average value of drop-down (L/min)	Length of pipe (km)	Average volume of drop-down / km (L/min･km)
		L/min	m^3/h			
MNF (Base Line)	**:** am	380.64	22.84			
Step 1	**:** am	304.60	18.28	76.04	1.9	40.0
Step 2	**:** am	235.70	14.14	68.90	2.1	32.8
Step 3	**:** am	218.13	13.09	17.57	2.5	7.0
Step 4	**:** am	174.93	10.50	43.20	1.7	25.4
Step 5	**:** am	157.51	9.45	17.42	1.3	13.4
Step 6	**:** am	98.70	5.92	58.81	1.9	31.0
Step 7	**:** am	53.95	3.24	44.75	1.0	44.8
Step 8	**:** am	0.00	0.00	53.95	2.5	21.6
					14.9	

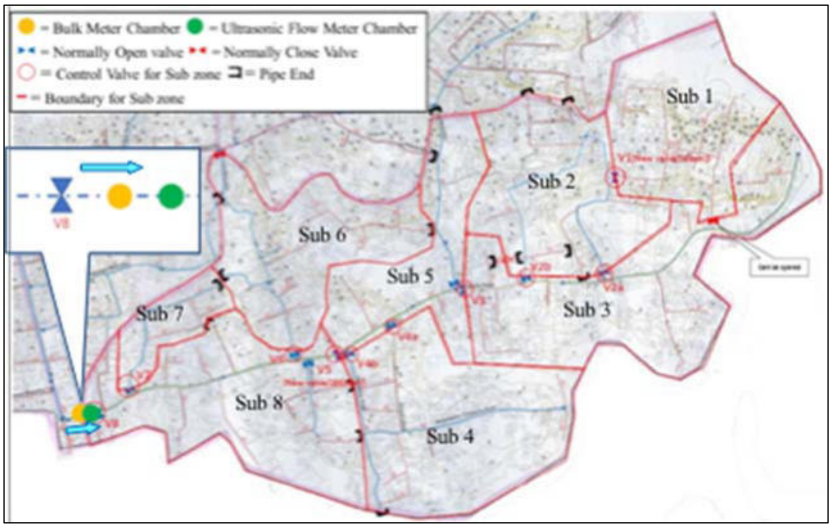


Figure 3.4.1 Sub zoning of DMA5

Here, if the current potential leakage is close to Q_{mnf}, consider what level should be targeted for reduction.

【Unavoidable Annual Real Losses in DMA 5】

UARL (L/day)

= (18×Lm + 0.8×Nc + 25×Lc) × P = (268.2 + 1792.8 + 168.075) x 25

= 55726 (L/day) = 38.7 (L/min)

Lm : Total extension of distribution pipe (km) = 14.9 km

Nc : Number of service connection = 2,241

Lc : Total extension of service connection pipe (km)

= 0.003 km/connection × 2241 = 6.723

P : Average pressure (m H_2O) = 25 m as water head

In the above calculation, the allowable water leakage of DMA5 is 38.7L/min, and the recorded Q_{mnf} is equivalent to 10 times the allowable water leakage.

Distributing this allowable amount of water leakage at the rate of extension of pipelines in each subzone is as follows.

Table 3.4.2 Leakage amount and priority of subzone

Subzone	Inflow volume (L/min)	Length of pipe		UARL (L/min)	"Inflow volume" / "UARL"	Criteria 10≦e: High 5<e<10: Middle e≦5: Low
		(km)	(%)			
	a	b	c	d=a*c	e=a/d	
Sub 1	76.04	1.9	12.8	4.9	15.5	High
Sub 2	68.90	2.1	14.1	5.5	12.5	High
Sub 3	17.57	2.5	16.8	6.5	2.7	Low
Sub 4	43.20	1.7	11.4	4.4	9.8	Middle
Sub 5	17.42	1.3	8.7	3.4	5.1	Low
Sub 6	58.81	1.9	12.7	4.9	12.0	High
Sub 7	44.75	1.0	6.7	2.6	17.2	High
Sub 8	53.95	2.5	16.8	6.5	8.3	Middle
MNF (Q_{mnf})	380.64	14.9	100.0	38.7	9.8	

When setting the priority of each subzone, pay attention to the ratio of the current inflow to UARL, and evaluate it as high if 10 times or more and low if 5 times or less.

However, since the measured Q_{mnf} includes the amount of water used at night to some extent, it is difficult to uniformly set the above evaluation criteria.

Therefore, it is necessary to individually consider the evaluation criteria and activity target values based on the results of the step test of each DMA.

3.5 Estimation of apparent losses

The apparent loss mainly consists of the following three, but this project deals only with the error of the meter body.

- Illegal water use
- Error of meter reading and data input
- Error caused by inaccuracy of meter

3.5.1 Instrumental error of water meter

The instrumental error of a water meter is the value obtained by subtracting the true value that should be indicated from the value indicated by the measuring instrument, and is expressed as a percentage by the following calculation formula.

$$E\,(\%) = \frac{V_{MBP} - V_{PC}}{V_{PC}} \times 100$$

V_{MBP} : Water volume recorded by water meter

V_{PC} : Water volume measured by a standard tank

As an example, the instrumental error of a water meter DN15mm is explained below using ISO-4064 Class B and Class C as an example.

Table 3.5.1 Class of meter and standard flow rate for accuracy test

Symbol	Description	Classification by ISO 4064 for DN15mm	
		Class B	Class C
Q_1	Minimum flow	30 L/h	15 L/h
Q_2	Transitional flow	120 L /h	22,5 L/h
Q_3	Permanent flow	1.5 m^3/h	1.5 m^3/h
Q_4	Overload flow	3.0 m^3/h	3.0 m^3/h

The numerical values and units in the above table are the values set for each reference flow rate, and the accuracy is confirmed by conducting a test in this flow rate band at the time of manufacturer shipment.

3.5.2 Allowable meter error

Performance requirements are set for water meters.

The maximum flow rate that is guaranteed to be accurately measured is Q_3, the minimum flow rate is Q_1, and the measurement range is expressed as $R=Q_3/Q_1$.

A meter with R=100 indicates that there is a 100-fold difference from a small flow rate to a large flow rate, and if the meter has the same diameter, the larger the R value, the more accurately the small flow range can be measured.

If the meter complies with the ISO4064 standard, it guarantees an instrumental error of +/-5% when $Q_1 \leqq Q < Q_2$ and +/-2% when $Q_2 \leqq Q \leqq Q_4$ as the inherent error of the meter.

In other words, in the case of a Class B meter, if the error is within ±5.0% when the flow rate range is between Q_1 and less than Q_2 and within ±2.0% when the flow range is between Q_2 and Q_4, the meter is approved as a shipped product.

On the other hand, for a meter that is in use by customer, twice the above error is allowed.

Therefore, if $Q_1 \leqq Q < Q_2$ is within +/−10% and $Q_2 \leqq Q \leqq Q_4$ is within +/−4%, it is determined that the meter in use does not have any problem.

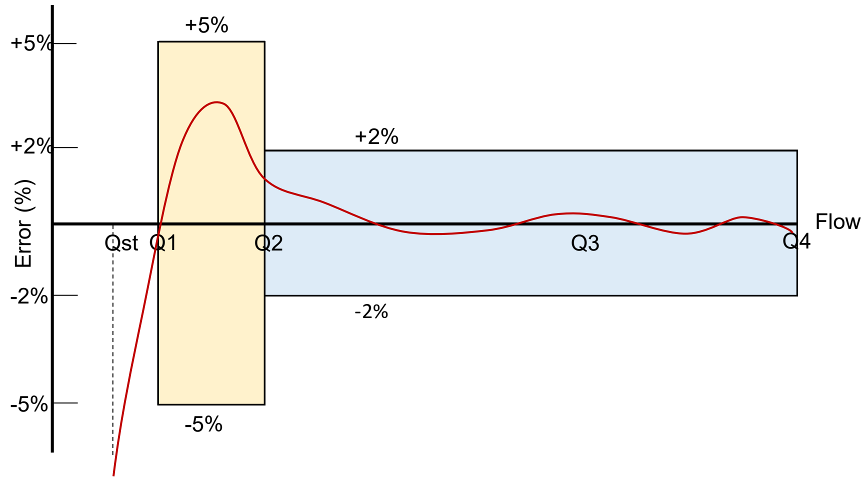


Figure 3.5.1 Instrumental Error Curve

3.5.3 Accuracy inspection of customer meter using electrical test meter

(1) Survey plan and equipment preparation

First, the target area and the number of cases, the number of investigators, and the approximate survey period should be decided. For equipment, a portable electronic test meter and standard tank (20 liters) will be prepared.

Figure 3.5.2 Example of a test meter and a standard tank

(2) Type of inspection method

There are two methods for on-site meter inspection, but this Work Plan describes a simple method.

It should be noted that all water meters have a permissible error, so a predetermined error will occur even when inspected with an electronic test meter.

In order to perform meter inspection with higher accuracy, it is recommended to prepare a standard tank whose volume is accurately measured with officially appropriate method in advance, instead of using a potable reservoir, and compare the amount of water accumulated in the reference tank with the meter reading. ..

【Simple method】

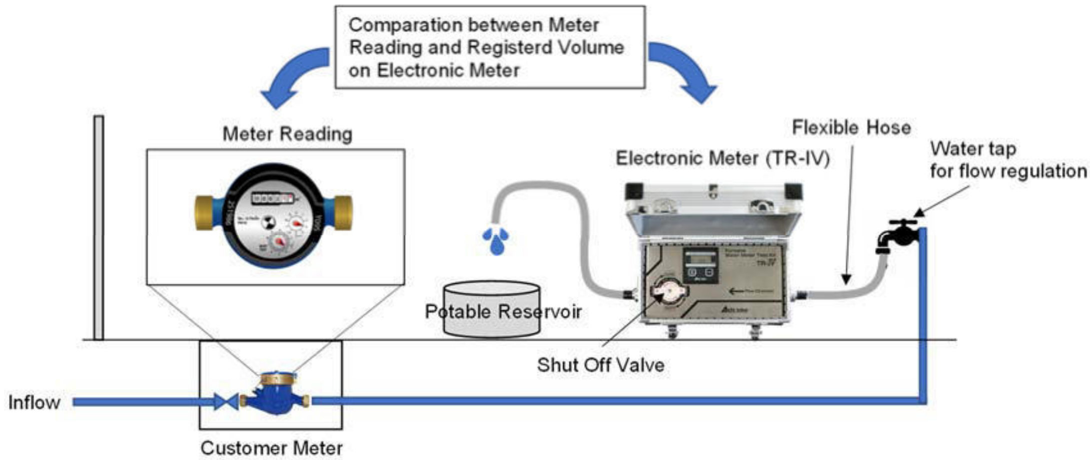


Figure 3.5.3 Method of Inspection with Test Meter

The allowable error of the water meter is determined by the flow rate band.. Therefore, it is necessary to adjust the amount of water for each flow rate zone for inspection, and an electronic test meter is used to set this flow rate zone.

The meter body inside the test meter has the following specifications.

Aichitokei-Denki Electronic Meter: Model EDS-20 (DN20)

Q_1: 0.040 m^3/h (0.67 L/min)

Q_2: 0.064 m^3/h (1.07 L/min)

Q_3: 4m^3/h (66.67 L/min)

Q_4: 5m^3/h (83.33 L/min)

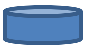
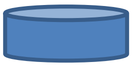
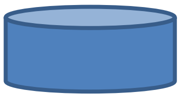
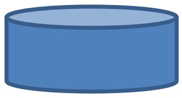
The error table of the instrument difference of the test meter shows the error at three points: large flow rate (1,000 L/h), medium flow rate (200 L/h), and small flow rate (100 L/h), in the factry pre-shipment inspection. Refer to the test result certificate in the meter box.

Table 3.5.2 Instrumental Error of Test Meter

Model: TR-IV Serial No.	Instrumental error by flow rate		
	1000L/h (16.67L/min)	200L/h (3.33L/min)	100L/h (1.67L/min)
***	**%	**%	**%

When confirming the accuracy of the meter in use, it is desirable to perform a test in the following multiple flow rate bands, make corrections using errors close to the flow rate bands, and perform a comprehensive evaluation.

Table 3.5.3 Example of meter test pattern

	Step 1 Starting Flow Q_{st}	Step 2 Between Q_1 & $1.1*Q_1$	Step 3 Between Q_2 & $1.1*Q_2$	Step 4 Approx. Q_3	Step 5 Between $0.9*Q_3$ & Q_3
Image					
Flow rate	3L/h～10L/h	27～33 L/h	108～132 L/h	Approx.600L/h	1350～1500 L/h
	0.05～ 1.66L/min	0.45～0.55L /min	1.8～2.2 L /min	Approx.10 L /min	22.5～25 L /min
Total Test Volume		5L 	10L 	20L 	20L 

(3) Test Procedure

1) Preparation of the Test Meter

1a. Remove the air from the meter so that the meter is filled with water.

1b. Secure a higher place than the main body in the middle of the outlet hose so that air does not enter the hose when water is stopped.

1c. Close the test meter valve and check that there is no water leakage from the piping or hose joint.

1d. Switch the LCD counter display to "Instantaneous Flow Rate Mode".

In instantaneous flow mode, a U is displayed to the left of the number. 4-digit display, unit is L/min

1e. Fully open the Shut Off Valve of the test meter body and adjust it so that it is within the flow rate range of the inspection target while changing the opening of the Water Tap.

1f. After adjusting the flow rate to the specified range, fully close the Shut Off Valve on the test meter body.

1g. Use of water from other taps in the residential area is prohibited during the inspection.

2) Test procedure

Since the counter display was set to ”Instantaneous Flow Rate Mode” during flow rate adjustment in the preparation stage, change the display mode to “Trip Mode” or “Cumulation Mode” before starting the test.

- The display of the counter changes when the L/min button is pressed for about 3 seconds.
- Press the Total/Trip button to display zero reset in Trip Mode.

2a. Record the reading on the water meter before starting the test.

2b. Determine the amount of test water for each flow rate band. (Small flow: 10 Lts, Medium flow: 10 Lts, Large flow: 20 Lts).

2c. Set the counter of the test meter to “Cumulation Mode” and reset to zero

2d. Simultaneously with the start of the test, open the valve of the test meter body and start passing water.

2e. While checking the display on the test meter, close the valve on the test meter main body at the moment when the predetermined amount of test water is reached to stop water flow.

2f. Record the amount of water passing through with a test meter.

2g. Check the instrumental error (%) in the flow rate range indicated in the test meter instrumental error report.。

2h. Check the reading on the water meter and record the amount of water measured within the above time.

2i. Calculate the instrumental error of the water meter by the following formula.

$$\text{Error (\%)} = \frac{\text{Water Volume measured by Customer Meter} - \text{Water Volume registered by Test Meter}}{\text{Water Volume registered by Test Meter}} \times 100$$

+ Instrumental Error of Test Meter

3.5.4 Aggregate meter accuracy inspection results

The test results are recorded in the table below.

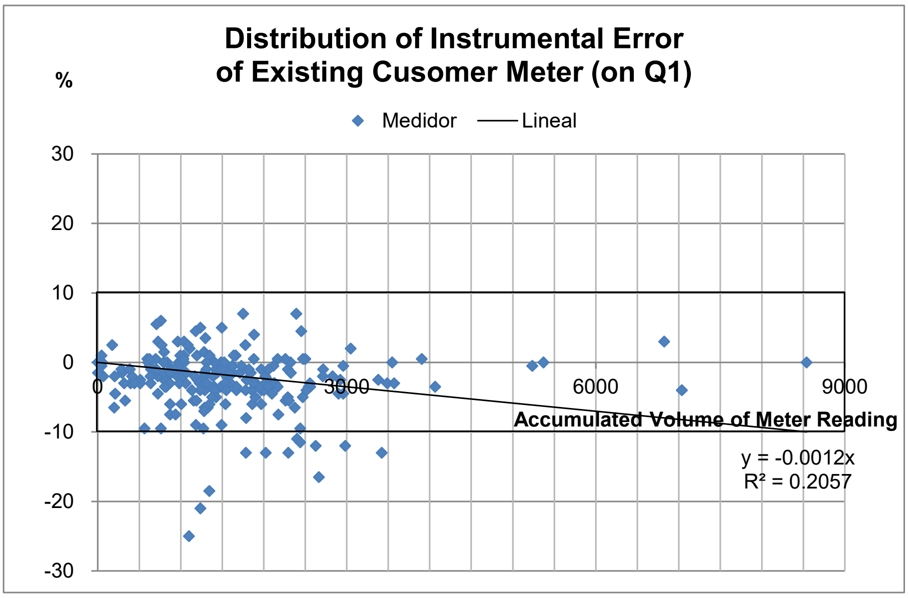
Table 3.5.4 Format of test record

Meter ID					
Step	1	2	3	4	5
Target test flow rate	Starting Flow	30 L/h (0.5 L/min)	120 L/h (2.0 L/min)	600 L/h (10 L/min)	100%
Total test volume	Variable	5 L	10 L	20 L	20 L
Initial reading of customer meter					
Final reading of customer meter					
Registered volume of customer meter "A" (L)					
Registered volume of Electrical Test Meter "B" (L)					
Test time (min)					
Test flow rate of TR-IV (L/min)					
Difference of volume between A & B ("A"-"B")					
Error ((A-B)-B)*100 (%)					

3.5.5 Meter reliability evaluation

Generally, the larger the cumulative cumulative value of the meter, the longer the years of use, so that it tends to be aged and malfunction. By plotting the cumulative water volume of the meter on the horizontal axis and the meter instrument error on the vertical axis, you can read the accumulated meter value of the meter and the tendency of the generator difference.

If there is a high correlation between the accumulated flow rate value and the occurrence of instrumental error, it is possible to determine when it is desirable to update the existing meter.



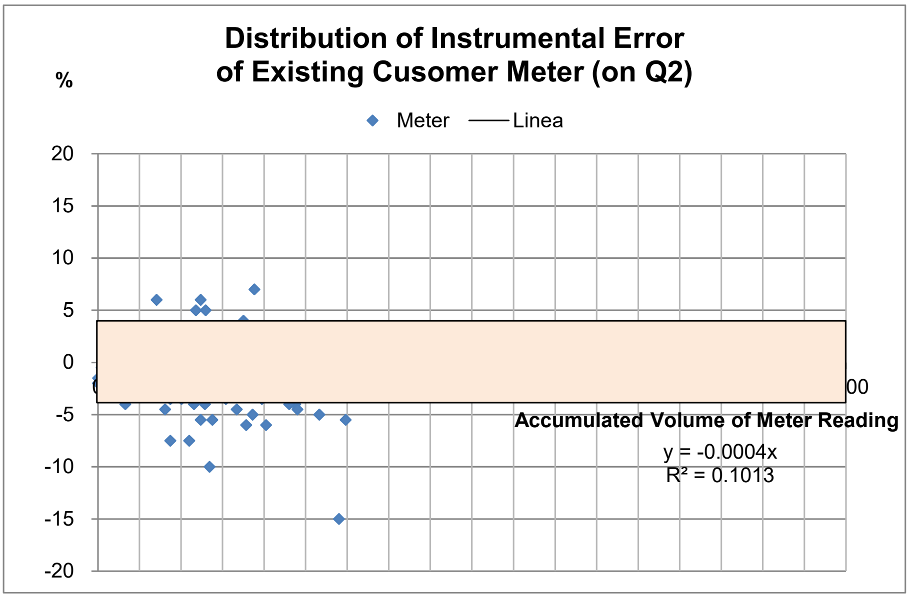


Figure 3.5.4 Relation between cumulative water volume and instrumental error

3.5.6 Estimation of apparent losses

If all test results are plotted on a graph, it can be shown as follows.

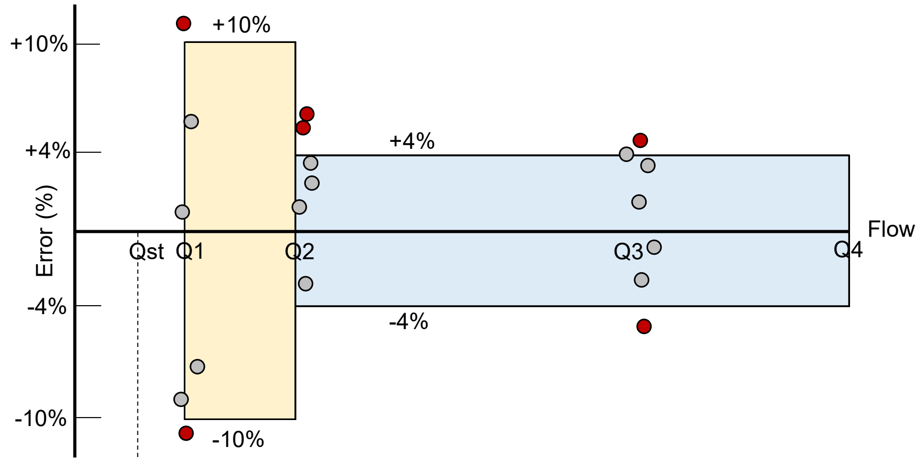


Figure 3.5.5 Distribution of instrumental error of customer meter

The error of the existing meter differs depending on each flow rate band.

For households that use water in a large flow rate, the error near Q_3 has a large effect on the amount of billed water. On the other hand, for low-income households who often use water in a small flow rate, the error near Q_1 to Q_2 greatly affects the billed water.

As mentioned above, since the measurement error occurs depending on the band and frequency of the actual water consumption of the household, it is necessary to investigate the water consumption band of the household in order to estimate the influence of the meter error on the billed water amount.

Therefore, when calculating the apparent loss of water due to meter error using a simple method, use an error in the vicinity of Q2 (100 to 120 L/h), which is the band, for the typical amount of water usage flow band.

Once the monthly NRW is calculated, the ratio of apparent loss and actual loss can be estimated by the following formula.

By comparing the calculated actual water loss and the MNF rate, it becomes possible to grasp the amount of water leakage remaining more accurately in the DMA.

$$\text{Apparent Losses (L/min)} = \frac{\text{Billed Water (m}^3\text{/month)} \times \text{Error (\%)} / 100}{\text{Billing Interval (days)} \times 24 \times 60 \times 1000}$$

$$\text{Real Losses (L/min)} = \text{Non-Revenue Water (L/min)} - \text{Apparent Losses (L/min)}$$

3.5.7 Determination of sample size

When considering the sample size under the following conditions, the statistical size is as shown in the table below.

- Allowable error: 5%
- Confidence level: 95%

Table 3.5.5 Table of sample size

Total number of customer meter in DMA	Sample size (Number of meter)	Percentage against total number of meters
250	152	60.8%
300	169	56.3%
400	196	49.0%
500	220	44.0%
800	260	32.5%
1,000	280	28.0%
2,000	325	16.3%
3,000	345	11.5%
5,000	360	7.2%
10,000	370	3.7%
25,000	380	1.5%
50,000	385	0.8%
> 100,000	385	< 0.4%

3.6 Leakage detection and repair

From the results of MNF measurement and Step Test, we can identify subzones that should be prioritized in countermeasures, and proceed to leak detection and repair.

The general procedure for water leak detection is as follows.

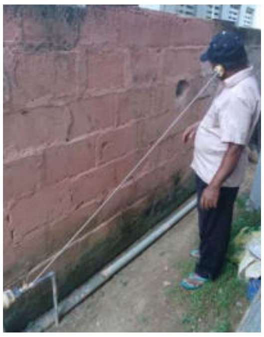
[Step 1] House-to-house survey

↓

[Step 2] Road surface survey

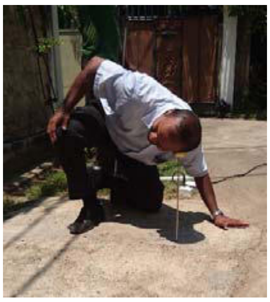
↓

[Step 3] Pinpoint survey



House to house survey

Road surface survey

Pinpoint identification of leakage

Figure 3.6.1 Basic procedure of leakage detection

3.6.1 House-to-house survey

a. Investigate the sound of water leaks on all customer meters using a listening stick. With this method, it is possible to easily find the leak that occurs between the water distribution pipe and the water supply pipe. the skilled worker can also supplement the sound of water leak from the water pipe.

b. It is also possible to use the electronic listening stick in place of the normal listening stick. Even if the level of skill of the worker is low, the sound amplified electrically can be easily heard by the electronic sound stick, and the sound pressure level can be confirmed on the monitor.

c. This House-to-house survey can detect leaks as well as abnormal sounds from meters, leaks in residential areas, and illegal connections.

d. It is necessary to prepare a list of customers to be surveyed and mark the location of customer meters in the drawing area.

e. Record any suspicious events other than water leakage

f. Through this survey, we will narrow down the routes and areas where there is a suspicion of leakage, and carry out the following Ppipeline Route Survey.

g. If there observed a section of pipeline that can be closed by valves at the both ends of section, a correlative leak detector is also effective. The correlative leak detecter can roughly determine the location of water leaks on a section from 10m to 300m lengh, If sufficient water pressure is secured.

Figure 3.6.2 Survey with an acoustic listening stick

Water pipes are usually operated under internal pressure, so if water leaks, an irregular vibration noise will continuously be generated from that location.

In the correlation survey, detectors (slave units) were installed at two points in the pipeline that sandwiched the leak point, the difference in the detected leak waveform was computerized on the main unit, and the distance to the leak point was displayed on the screen.

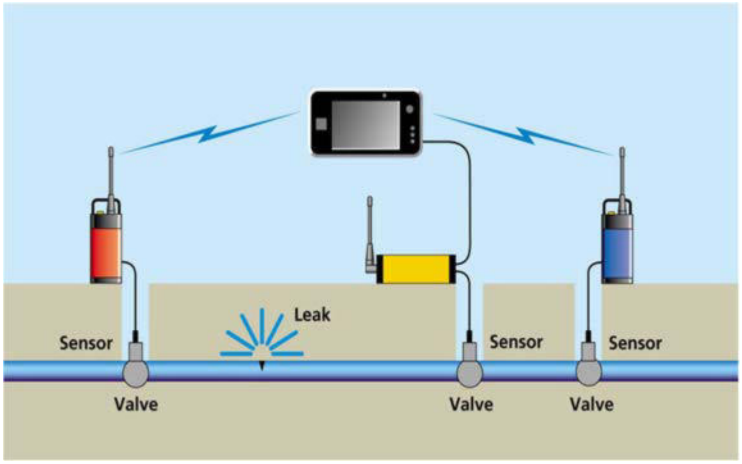


Figure 3.6.3 Survey with a 2 points correlative method

3.6.2 Road surface survey

a. The road surface survey will be conducted using an electronic leak detector on all or part of the road where the pipeline is buried.

b. In this study, the sound of water leakage is detected by the sensor and headphones, so it is greatly affected by road noise. Therefore, as a general rule, it should be carried out at midnight when road traffic is low.

c. Since this survey is carried out after the detection using the correlation machine or after the House-to-house survey, it is possible to narrow down the location of leakage.

Figure 3.6.4 Survey with electronic leakage detector

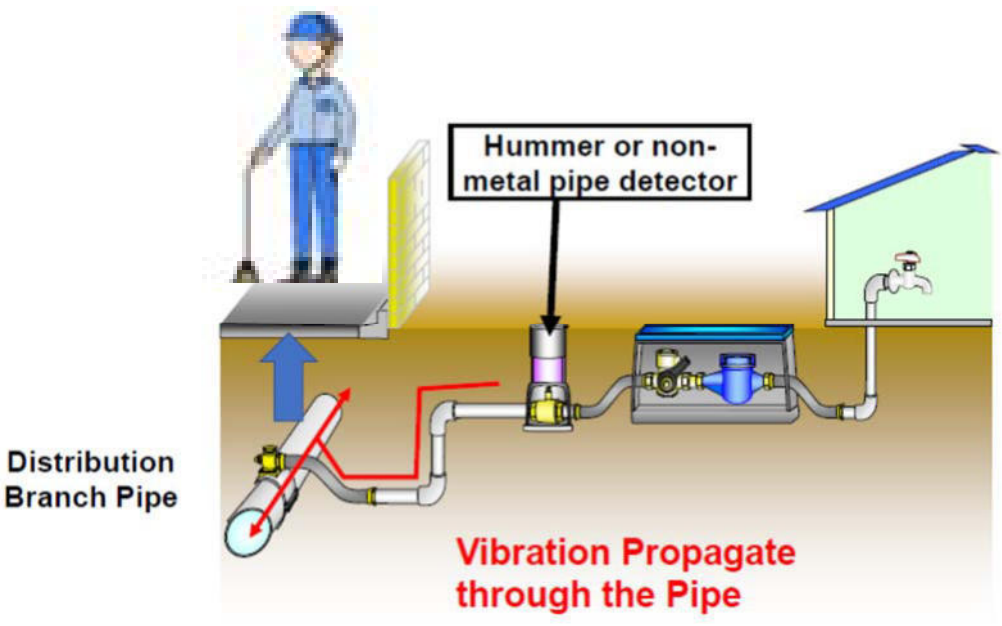


Figure 3.6.5 Trace of pipeline 1

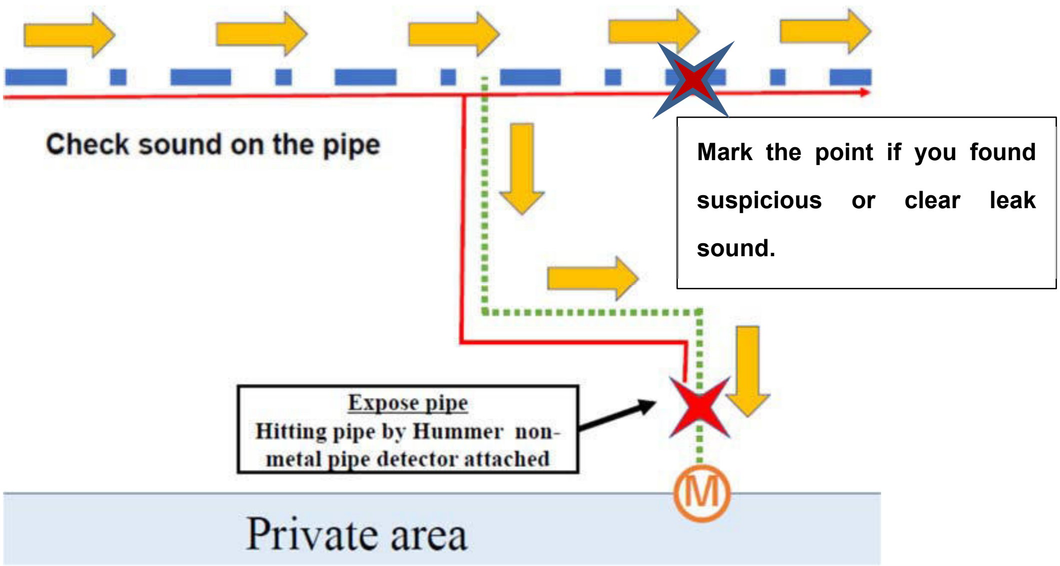


Figure 3.6.6 Trace of pipeline 2

3.6.3 Pinpoint identification survey

a. Subsequent to the road surface survey, a leak detector is used to carefully investigate the location of the leak sound and pinpoint the leak location.

b. If it is not possible to clearly identify the leak location, drill a hole in the pavement with a boring bar or hammer drill and check the internal condition with a listening stick. If the surrounding ground water level is low and the sound stick is wet, it is suspected that water leakage occurs in the vicinity.

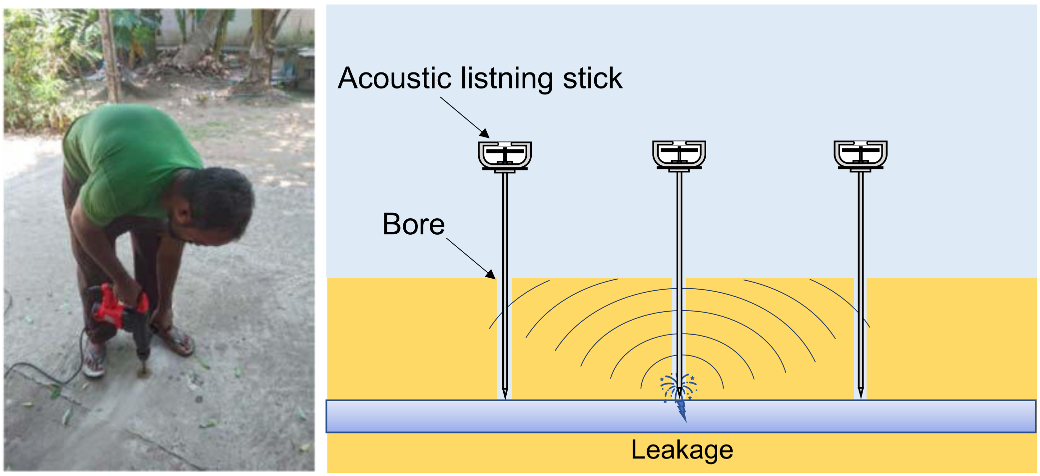


Figure 3.6.7 Survey with a boring bar or hammer drill

3.6.4 Record of the leakage points

The surveyed locations should be shown in the drawings as follows.

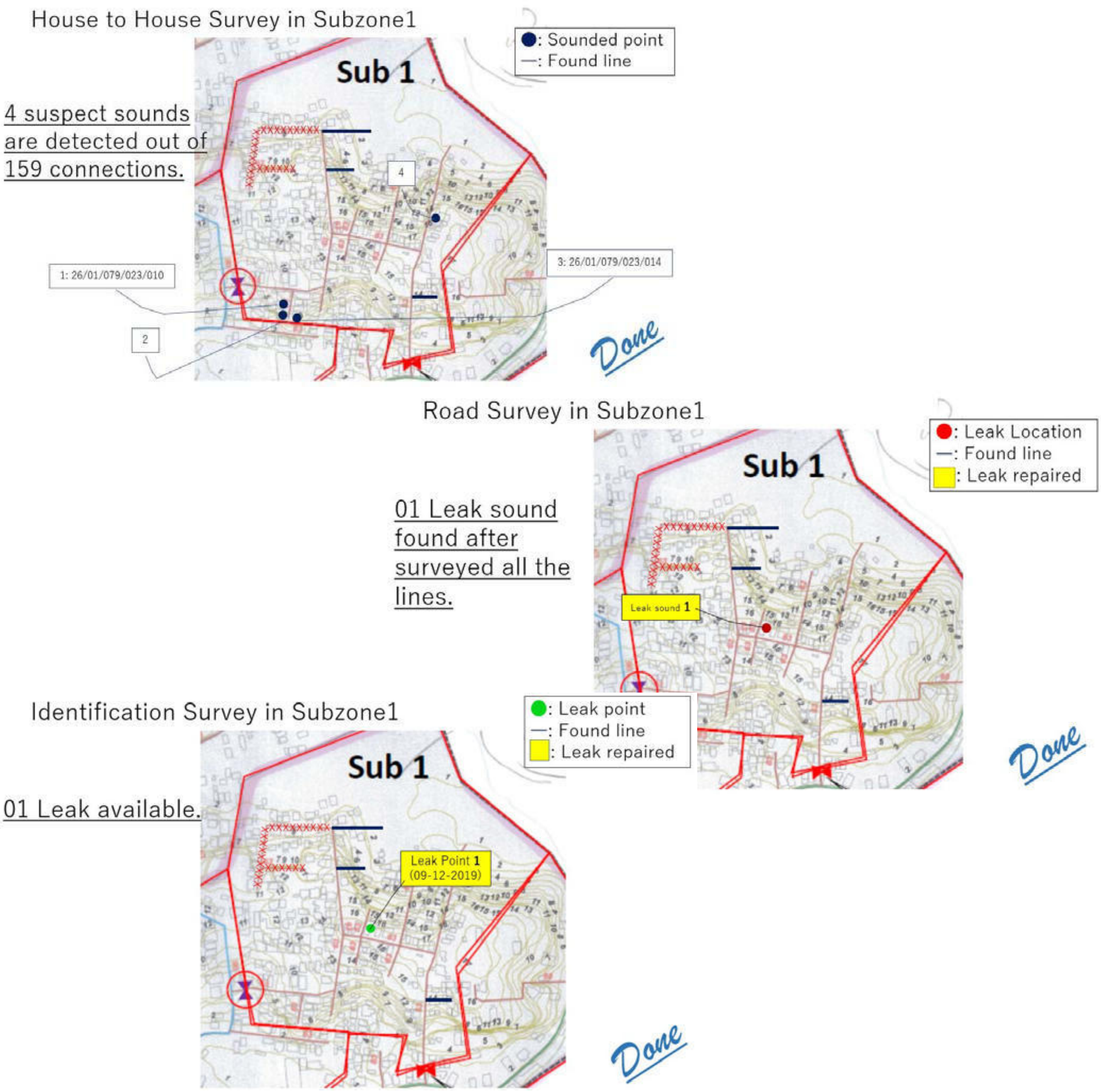


Figure 3.6.8 Example of record of leakage detection

3.6.5 Leakage repair work

(1) Preparation

- Confirm the pipeline information of the leakage point found in the survey.
- Investigate valves that can stop water flow on the target route.
- Notify customers along the target route before repair.
- Procure materials and equipment needed for repairs

(2) Repair work

- When a leak is repaired, the supervisor should check it and record the repair result.
- Prepare a measurement bucket so that workers can directly measure the amount of water leakage
- If leaked water can be collected from the leak hole, measure the leak rate per minute.
- Record items are as follows.

Location, Type of pavement, Diameter and material of pipe, Installation depth of pipe, Detail of leakage, Estimated cause, Amount of leaked water, Material used to repair, Person responsible for repair, etc.

3.7 Measuring the effects of water leak repair

3.7.1 Minimum Night Flow (Q_{mnf})

An effective method for estimating the amount of water leakage existing in a certain area and its severity is to measure the amount of water flowing into a hydraulically independent zone and analyze the minimum night flow (Q_{mnf}).

Although there is a certain amount of water used at night, it is considered that most of Q_{mnf} is due to the amount of water leakage occurring in the sector, since the water demand of users is the smallest.

The measurement time period is from midnight to 6:00 in the early morning, and the core time of Q_{mnf} analysis is generally between 1:00 and 4:00.

The MNF rate (Q_{mnf}) is often measured for the number of connections of about 500 to 1,000 according to the size of DMA. As an example, if the DMA can be divided into 5 sub-zones as follows, a sub-zone with a large potential leakage can be identified by performing a step test.

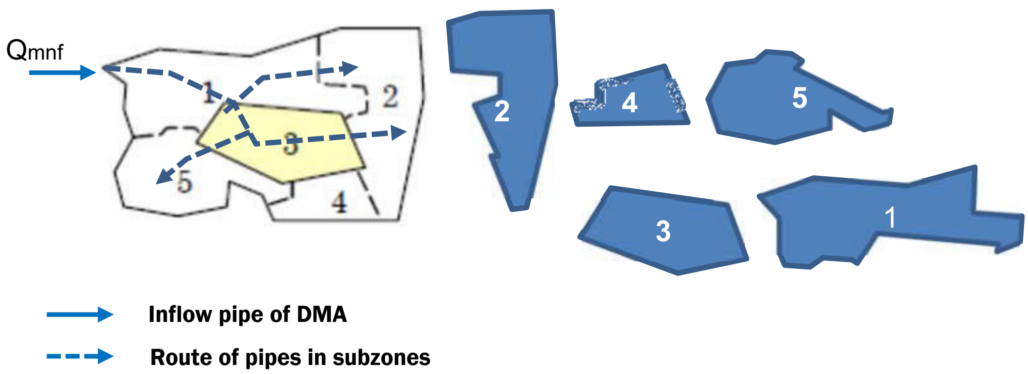


Figure 3.7.1 Imagen of DMA and sub zoning

3.7.2 Calculation of amount of leaked water

The MNF rate (Q_{mnf}) measured in DMA includes the amount of water used at night and the amount of illegal water used in addition to water leakage.

Especially when each household has a water storage tank and water is continuously stored at night, Q_{mnf} contains a considerable amount of water used, it is necessary to notify residents in advance or secure closure of meter valves.

The breakdown of the amount of water contained in the MNF is shown below.

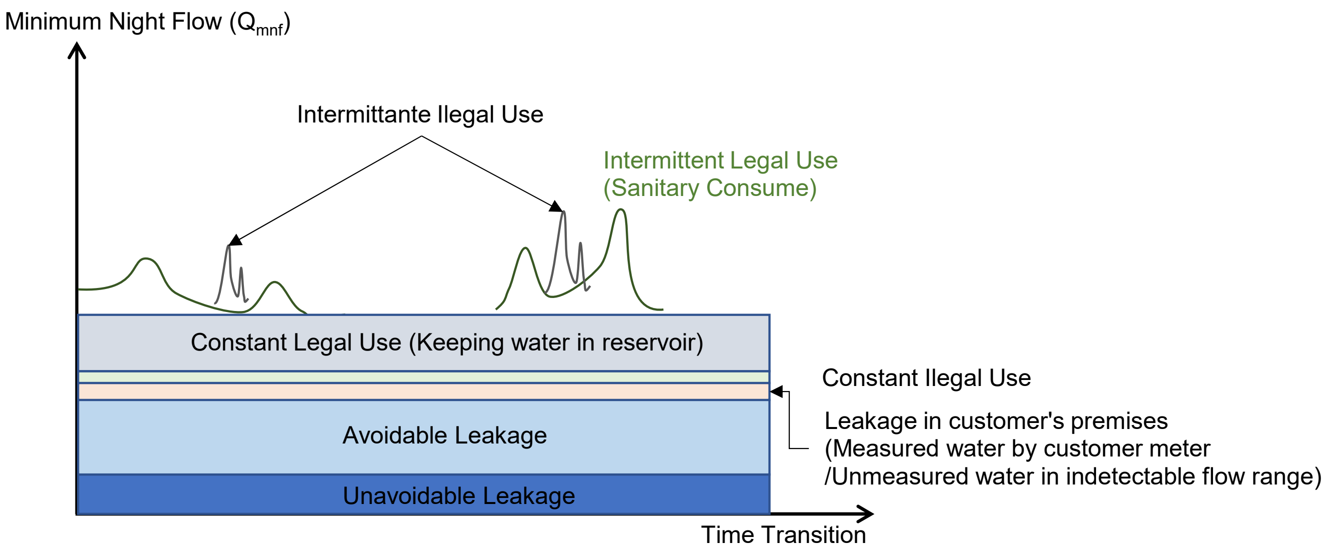


Figure 3.7.2 Breakdown of MNF (Q_{mnf})

The value of Q_{mnf} will be gradually lowered by the leak detection and repair.

The reduced amount of water leakage can be calculated by performing Q_{mnf} measurement and step test again when all the measures for water leakage have been completed.

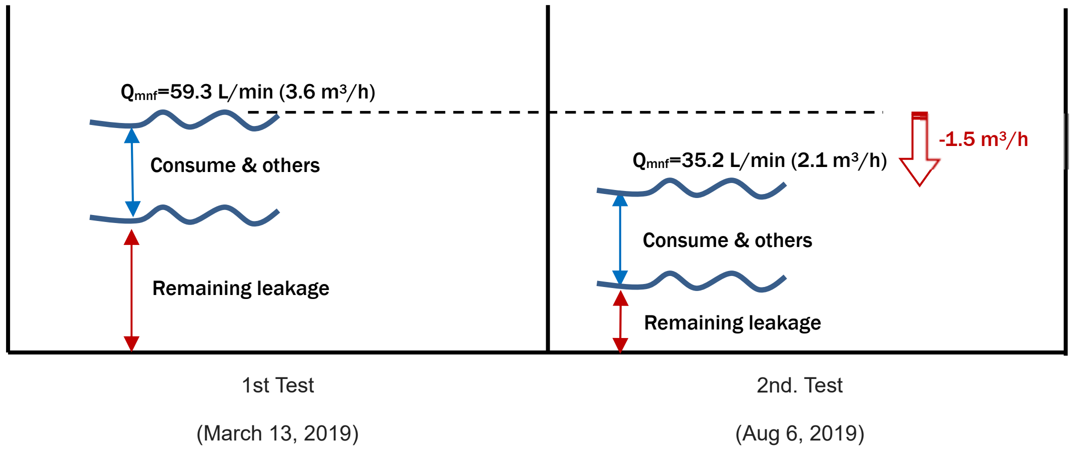


Figure 3.7.3 Monitoring of Minimum Night Flow

In the example of DMA4, Q_{mnf} has decreased by 1.5 m^3/h due to the leak detection/repair work, and if the amount of water used does not fluctuate, it can be considered as the reduced amount of leak.

However, this amount of water is the value at midnight when the water pressure is the highest, so in order to convert it into the average amount of water per day, it is necessary to take into account the fluctuations in water pressure during the day and correct it.

The amount of water leaking from a single hole is highest at midnight when the water pressure is high, and is low during the day when the water pressure is low. This relationship is shown as follows. The coefficient N depends on the size and shape of the leak hole and the material of the pipe.

Leak from small orifice: N=0.5

Leak from crack of pipe or flange joint: N=1.15

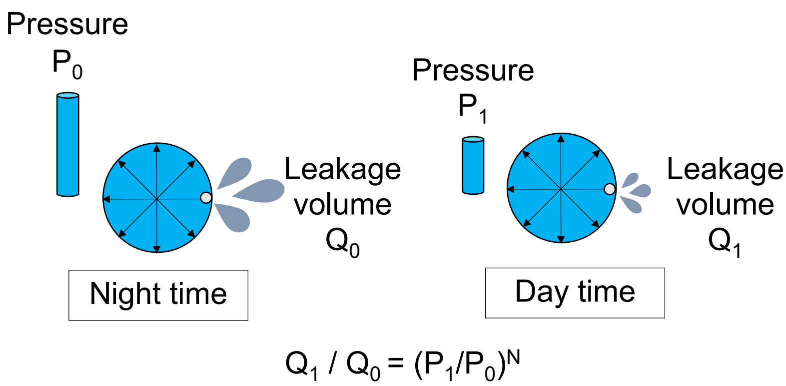


Figure 3.7.4 Relation between leak volume and pressure

Here, assuming that the average water pressure of DMA is changing as follows, the daily average value of the leakage reduction amount is calculated as follows.

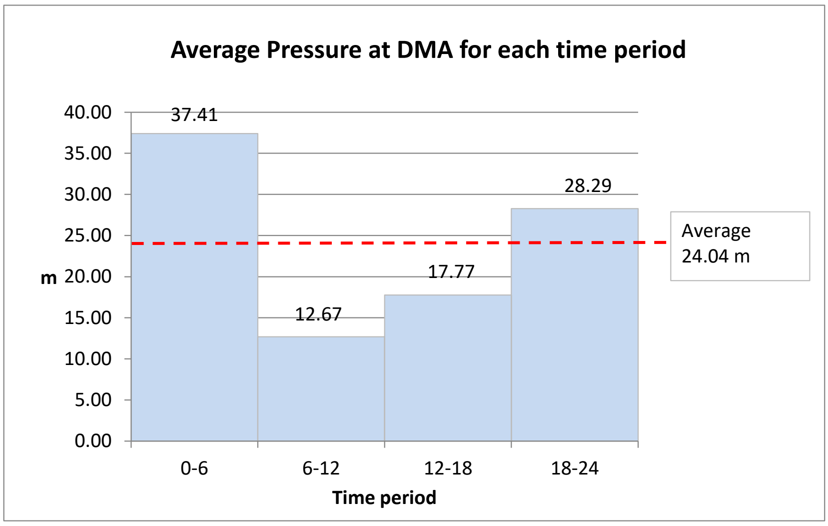


Figure 3.7.5 Average water pressure by time period

Table 3.7.1 Calculation of prevented water leak

Items	Time period				Average
	0:00-6:00	6:00-12:00	12:00-18:00	18:00-24:00	
Pressure (m H_2O)	37.41	12.67	17.77	28.29	24.04
Ratio (P_x/P_o)	1.00	0.339	0.475	0.756	
$(P_x/P_0)^{0.5}$	1.00	0.582	0.689	0.869	
Flow (m^3/h)	1.50	0.87	1.03	1.30	1.18

Reduction of Q_{mnf} (0:00-6:00 flow, 1.50)

Average volume of avoided leakage (Average flow, 1.18)

$Q_x = (P_x/P_0)^{0.5} \times Q_0$

Q_0: Water flow at a reference time band

P_0: Pressure at a reference time band

P_x: Pressure at a target time band

Calculating in the above example,

Prevented leakage at midnight: 1.50 m^3/h (at pressure of 37.41m H_2O)

Average volume of prevented leakage: 1.18 m^3/h (at pressure 24.04m H_2O)

3.8 Calculation of NRW

Finally, the results of the activities so far are organized as indicators.

The results of the DMA4 activities are as follows.

Table 3.8.1 Activity Result of DMA4

Item	Result of activities	
	March 13, 2019	August 6, 2019
Step 1	8.5 L/min	0.0 L/min
Step 2	12.1 L/min	28.9 L/min
Step 3	12.3 L/min	4.6 L/min
Step 4	25.2 L/min	3.4 L/min
Q_{mnf} (Total Area of DMA4)	59.3 L/min	35.2 L/min
System Input Volume	257.4 m^3/day	223.2 m^3/day
Revenue Water Volume	197.3 m^3/day	202.2 m^3/day
NRW	23.4 %	9.4 %
Number of repaired leakages	-	9

Chapter 4. Evaluation of Pilot Activities (Check)

4.1 Calculation of Cost-Benefit

Calculate the cost-effectiveness when the activity in one DMA is completed.

4.1.1 Total Cost

Total cost consists of the following items.

(1) Personnel costs and machine costs related to DMA construction

For simple calculation, personnel costs and machine costs are calculated based on the number of flow meters and valves installed in the DMA, using the unit cost for water leak repair.

(2) Material cost for DMA construction

Cost of materials used for construction of DMA and construction of subzones are included in the purchase cost.

Table 4.1.1 Material cost for DMA construction

Items	Specs	Nos.	Price	Depreciation Period	Cyclic Year (Duration of effect)	Cost
		a	b	c	d	e=(a*b/c)*d
Valve	DN50	1	9,850	38	3	778
	DN80	3	49,500	38	3	11,724
Bulk meter	DN80	1	44,500	38	3	3,514
Surface box	BS5834 /D400	5	21,500	38	3	8,487
PVC pipe	DN110	5	11,225	38	3	4,431
Manhole cover	D600	1	29,500	38	3	2,329
Chamber	Concrete	1	142,000	38	3	11,211
Necessary fittings	Flange adaptor, Bolts & Nuts	1	85,340	38	3	6,738
					Total	49,212

(3) Personnel cost related to water leakage measures

Unit cost of personnel by labor category × Working hour by work item

Table 4.1.2 Calculation Format of personnel cost

Work Item	Personnel Category	Working Hours	
		Day time	Nighttime
Map upgrading & Site inspection	1	32.0	0.0
	2	0.0	0.0
Step test & MNF measurement	1	0.0	35.0
	2	0.0	60.0
House to house survey	1	25.0	0.0
	2	65.5	0.0
Road surface survey	1	10.0	8.0
	2	9.0	8.0
Pinpoint identification survey	1	7.5	0.0
	2	10.0	0.0
Meter accuracy test	1	9.5	0.0
	2	9.5	0.0
Data summarizing & evaluation	1	42.0	0.0
	2	0	0.0
Total working hours	1	126.0	43.0
	2	94.0	68.0

Table 4.1.3 Personnel cost for the leakage reduction activities

Personnel Category	Day time			Nighttime			Cost (Rs)
	Working hours	Unit Rate	Cost	Working hours	Unit Rate	Cost	
1	126.0	1,000	126,000	43.0	1,500	64,500	190,500
2	94.0	750	70,500	68.0	1,125	76,500	147,000
						Total	337,500

(4) Equipment cost for leakage detection

Unit rate of equipment × Using time by activity item

Table 4.1.4 Unit rate of equipment

Equipment	Base Price	Coefficient	Unit Rate (Rs)
	a	b	c=a*b
Ultrasonic flow meter	5,300,000	0.0038	20,140
Pressure logger	1,700,000	0.0021	3,570
Acoustic listening stick	59,148	0.0028	166
Water leak detector	463,266		741
Boring bar	45,275	0.0016	543
Hammer drill	23,261	0.0120	44
Electronic test meter	645,000	0.0019	2.451
Generator	-	-	958

Table 4.1.5 Equipment cost for the leakage reduction activities

Equipment	Unit	Unit rate per day	Number of units	Cost (Rs)
		a	b	c=a*b
Ultrasonic flow meter	day	20,140	3	60,420
Pressure logger	day	3,570	12	42,840
Acoustic listening stick	day	166	10	1,660
Water leak detector	day	741	7	5,187
Boring bar	day	543	2	1,086
Hammer drill	day	44	2	88
Electronic test meter	day	2.451	2	4,902
Generator	day	958	5	4,790
			Total	120,973

(5) Cost for leakage repair

It is the procurement cost of the materials used for leakage prevention.

Procurement Cost of Valves and meters for DMA Creation

&

Material Cost for leakage repairing

If it is difficult to add up all material costs, calculate the material costs using the unit cost for leak repair per location.

【Reference data from Kalutara region】

Number of repair from 2018 to 2019：	446 points
Cost of repair from 2018 to 2019：	Rs.11,951,022.75
Unit cost of repair work:	Rs.26,797 / point

【In case of 9 points of leakage work】

Estimated cost of repair：	Rs.26,797 × 9 points = Rs.241,173

4.1.2 Effect

The effect is calculated from the value of the amount of water leakage prevented in the future.

Unit Sales Cost × Prevented Amount of Leakage × Total Number of Cyclic Year (Duration of effect)

Calculate the prevented water leakage from the following formula.

Prevented Amount of Leakage

= (NRW ratio (%) before starting activities − NRW ratio (%) after termination of activities) × Average Inflow into DMA

Table 4.1.6 Effect of leakage repair

Status	Average Input Volume in DMA4		Average Revenue Water in DMA4		NRW
	m^3	m^3/day	m^3	m^3/day	
Before starting activities (March 2019)	6,962.0	257.5	6,116.0	197.3	23.4%
After termination of activities (August 2019)	6,472.4	223.2	6,067.0	202.2	9.4%

【Prevented Amount of Leakage】

(23.4% - 9.4%) × (257.5 m^3/day + 223.2 m^3/day) / 2 = 33.6 m^3/day → 12,264 m^3/year

【Value of Prevented Water Loss】

Rs.55 × 12,264 m^3/year × 3 years = Rs.2,023,560

(6) Cost/Benefit

Table 4.1.7 Result of calculation of Cost/Benefit

Description		Value
Cost		**990,031**
DMA Creation	Personnel, Machinery	241,173
	Materials	49,212
Leakage Detection	Personnel	337,500
	Machinery	120,973
	Materials	0
Leakage Repairing (Personnel, Machinery, Materials)		241,173
Benefit		**2,023,560**
Benefit / Cost		**2.0**

4.2 Setting the target level of leakage management

Water pipes deteriorate over time due to various factors such as deterioration, corrosion, and traffic load, and this deterioration causes water leakage.

Also, unless the deteriorated pipeline is completely renewed, a new leak will occur soon after the repair.

This phenomenon is called "Leakage Recurrence"

There are only two methods to reduce the amount of residual water leakage.

- Continue water leakage prevention work at a pace that exceeds the amount of water leakage recurrence.

  ・Increase the amount of water leakage prevention work. (Investment of human resources)

  ・Improve water leak detection technology. (Training and accumulation of experience)

  ・Adopt efficient leak detection and repair technology. (New technology)

- Erasure of restoration itself by renewing dilapidated pipelines

  ・Use a pipe that does not easily leak water. (Change of material)

  ・Shorten the length of the pipe to make an efficient piping route. (Improved efficiency)

  ・Adopt appropriate piping technology. (New technology)

It is estimated that the recurrence of water leakage appears in the pattern shown in the schematic image below.

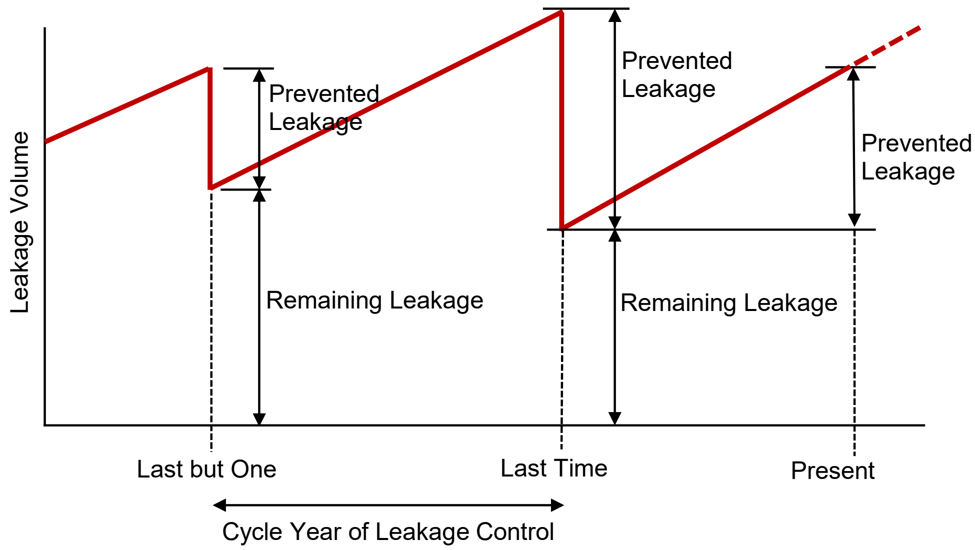


Figure 4.2.1 Image of Leakage Recurrence

Practically, the costs and human resources available to prevent water leakage are limited. For this reason, it is necessary to set the criteria for determining the allowable amount of water leakage and pipeline renewal while considering the amount of water that has been prevented, the amount of residual water, and the cost spent for prevention activities.

To this end, it is necessary to investigate how quickly the reduced water leakage will be restored, and it is recommended to monitor the water inflow to the DMA and Q_{mnf} monthly.

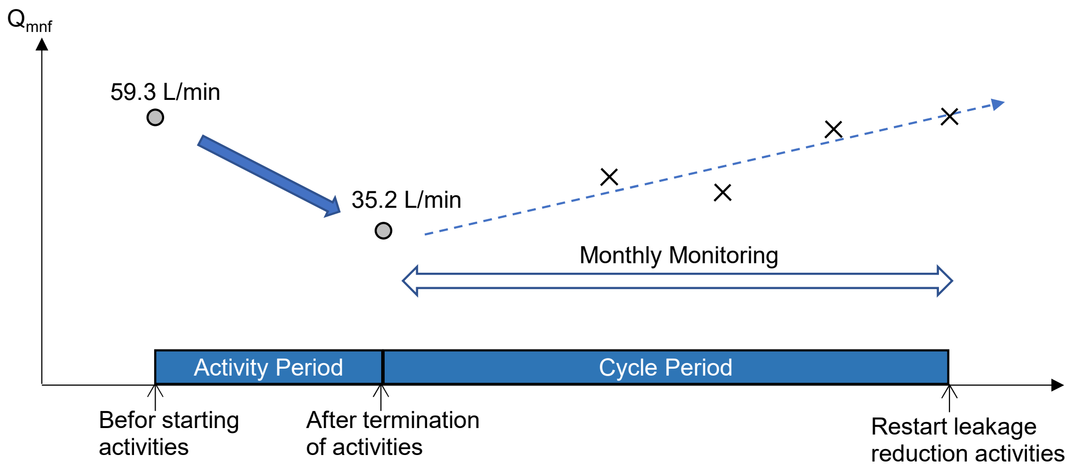


Figure 4.2.2 Monitoring for Leakage Control

One way to efficiently carry out this monitoring is to build a remote communication system.

The following is the content to be proposed assuming the situation where Japanese experts cannot resume their local travels early.

【Work in Japan】

- Procure data loggers with built-in communication modems, electronic water meters, etc., and prepare training materials for remote monitoring systems.
- Utilizing the Japanese mobile phone communication network, transmit the pulse signal of the test meter to the data server and perform the operation test of the monitoring system using the Web browser.
- If the operation test is successful, purchase the electromagnetic flowmeter to be installed in DMA3 and DMA5.
- One candidate of Data Server will be the Online Service named "HWM DataGate" with 1 year-license contracted between HWM and Japanese Experts Team.
- Collect the theory of pulse measurement of flow rate, detailed work required for system construction, equipment selection, monitoring method and its utilization as a manual, and share it with the C/P of the Output 2 team.
- The members of Output 2 team access the monitoring system constructed in Japan and understand the monitoring method through the manual and the remote instruction.

【Work in Sri Lanka】

- Replace the Bulk Flow meter in DMA3 and DMA5 with Electromagnetic Flowmeters (with pulse output).
- In case of monitoring DMA3, the target area to be monitored will be the southern area whose water is provided by DN250mm pipe.
- In case of replacing Bulk Flow meter at DMA3, the diameter of flow meter shall be DN200mm as a maximum diameter of manufacturer's lineup for submersible electromagnetic flowmeter. Therefore, 2 flange adaptors (DN200) and 2 reducer (DN250-DN200) will be required for installation work.
- Transport and install the monitoring system equipment from Japan.
- Use the SIM card of the local communication company to set the communication

modem.

- The monitoring system is operated by the C/P, and daily fluctuations in water distribution are monitored under the guidance of Japanese experts to understand the tendency of water leakage recurrence.

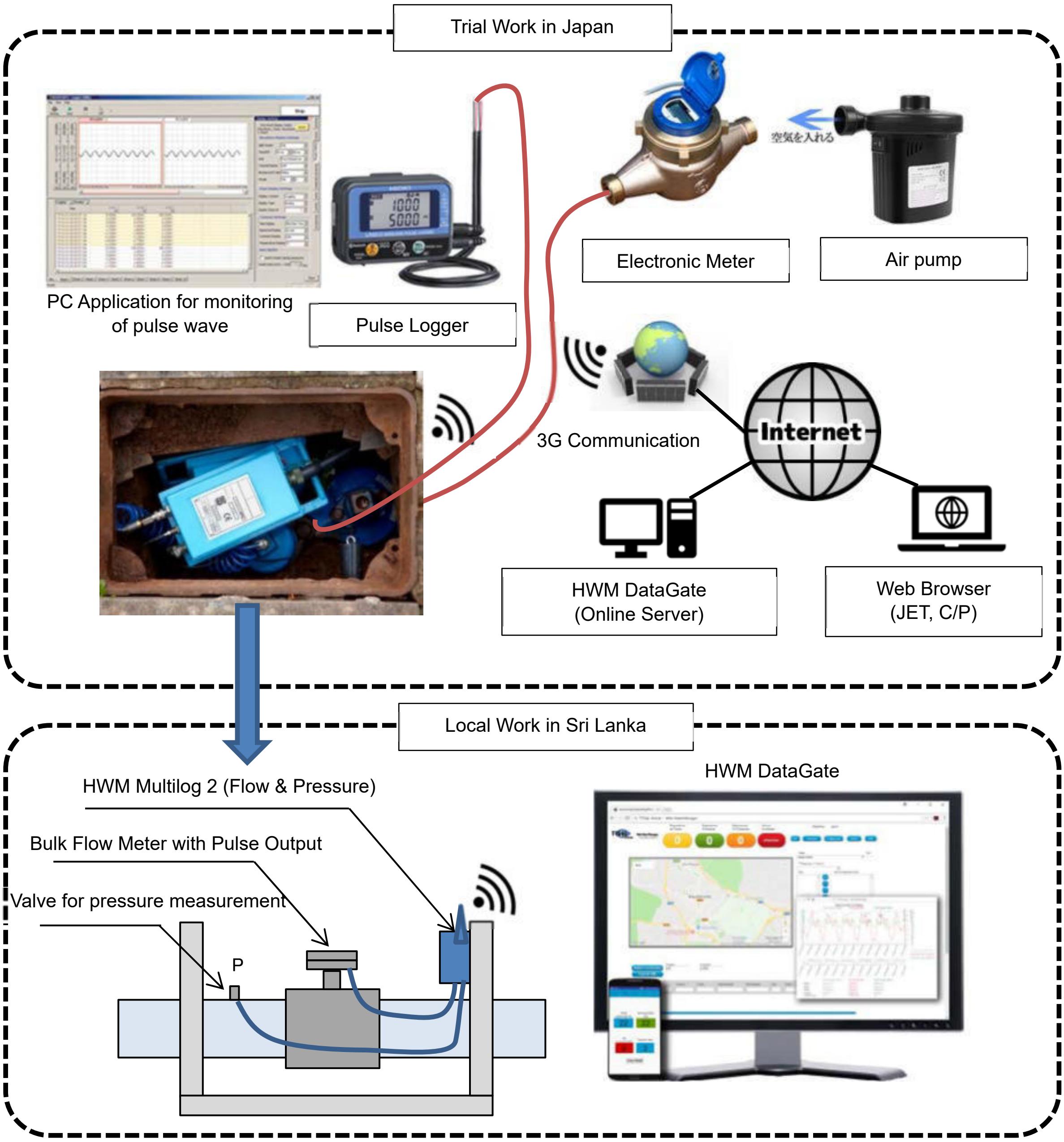


Figure 4.2.3 Remote Monitoring System for Leakage Control

CLEAN WATER

HWM

Multilog 2

Multi-channel Data Logger

Multilog 2 is the highly advanced and versatile multi-channel data logger designed to monitor any combination of digital and analogue signals.

Multilog 2 is ideal for a wide variety of specialised applications, including monitoring PRV flow and/or pressure in a district or zone to assess demand, leakage and conformance.

Accurate, powerful and robust, Multilog 2 is an effective data logging solution.

Key Features and Benefits

- **Telemetry:** integral SMS/GPRS/3G/NBIoT/LTE-M (Cat-M1) cellular options
- **Serial input option:** for connection to digital meters, SonicSens level sensor, Modbus, SDI12, RS232, Badger/Sensus/Neptune serial meter interfaces
- **4 channel logging:** 8 or 16 channels available on request
- **Fast logging:** primary logging to 1 second as standard - 25hz for transient events
- **Alarm:** full alarm functionality
- **Robust:** rugged die cast aluminium case
- **True readings:** true max and min flow and investigation of pressure spikes
- **Pulse interval timing:** smooths reading of infrequent pulses
- **External antennas:** support improved signal strength - contact HWM for more information
- **Local data download:** 10 pin military plug connected to laptop or desktop PC
- **Fully waterproof:** the IP68 rating has been tested at 10m depth over a 24 hour period
- **Optional outputs:** replicate inputs or trigger on alarm, allows operation of third party sensors, e.g. water samplers
- **Long-term monitoring:** 5 year battery life

Applications

After installation, all firmware upgrades and programming changes are made remotely. As well as ensuring that changes are made efficiently, this is also cost-effective, as it removes the need for site visits.

An innovative feature of Multilog 2 is a secondary channel, enabling additional fast logging down to 25Hz.

Secondary logging can be triggered on time schedule and/or in response to an alarm condition being triggered. This is invaluable when more detailed investigation is required, such as pressure spikes and 'true' minimum night flow.

AUTOMATED
METER READING

HWM

DataGate

Remote data management

DataGate is HWM's web hosted data server that provides a fast, convenient and secure remote data management solution via the internet. Information can be received from all mobile networks via several different methods including FTP, VMN and modem.

DataGate currently processes over 1.7 million messages received from HWM telemetry devices every day. This rapid transmission is possible because data is sent in a file format which is converted to a secure data stream. This eliminates the problem of sending data as an email which can be blocked by IT firewalls and spam filters. No host modem is required, which is another weak point of a traditional remote handling system as all data transfer now takes online.

Key Features and Benefits

- **Manage large data volumes quickly:** Designed to handle large volumes of SMS/GPRS data traffic
- **Compatible:** Works on all mobile networks
- **Fast data transmission:** Enables rapid data transmission
- **Eliminates data blockages:** Caused by IT firewalls and SPAM filters.
- **No host modem:** No modem required to receive data.
- **Secure Servers:** Data can be archived indefinitely on secure servers
- **Detailed message transmission:** To enable diagnostic investigation if required
- **Logger alarms:** Automatically sent to multiple users to enable prompt action
- **Data accepted from multiple sources:** FTP, VMN and modem
- **Data can be viewed online:** HWM Online or other corporate system
- **DataGate LS:** Option for customers outside the UK to transmit data to a data server in their own country
- **Real time data:** 99.99% uptime and real time data back

Applications

Data can be viewed in graphical or table format from any internet enabled device using our web viewer HWM Online or seamlessly integrated into a third party corporate system.

On receipt of an alarm DataGate can send automatic alerts to multiple users to enable action to be taken promptly. The system will even store data from loggers it does not recognise, and then add this information to the logger's history when it is registered on the system. Multiple accounts can be set up and configured to ensure that users only see data from the specific loggers they require.

HWM

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Chapter 5. Improvement of pilot activities (Action)

To promote water leakage reduction activities more effectively and efficiently, the activities of the next DMA will be started, reflecting the points to be improved from the evaluation results of the pilot activities.

5.1 Target of leakage prevention at RSC Western-South

This pilot activity has been conducted for NWSDB Staff to understand the actual state of water leakage in some DMAs and to acquire the technology to reduce it effectively and efficiently.

After that, the activity to be carried out by NWSDB is the formulation of a water leakage prevention plan in the RSC Western-South

Usually, when formulating a water leakage prevention plan, a basic investigation is first conducted, an analysis of the current situation is conducted, and the water leakage prevention target is set after a thorough understanding of the actual state of water leakage.

And, it is necessary for the entire organization to work to achieve those goals efficiently and effectively.

As a result of the pilot activities, it was revealed that most of the non-revenue water was due to leakage, so the leakage prevention target in the case of NWSDV may be replaced with the non-revenue water reduction target value.

Table 5.1.1 Result of calculation of Cost/Benefit

RSC	Target value of NRW (%)					Future Target	
	2016	2017	2018	2019	2020	2025	2030
Western-Central	34.8	34.1	33.5	32.8	32.1		
(Colombo)	45.0	44.0	43.0	42.0	41.0		
(Other)	18.0	17.5	17.0	16.5	16.0		
Western-South	27.3	26.4	25.5	24.6	23.5	???	???
Western-North	23.5	23.0	22.5	22.0	21.5		
South	26.5	26.0	25.5	25.0	24.5		
Uva	21.2	20.3	19.4	18.5	17.6		
Central	23.0	22.0	21.0	20.0	19.0		
Sabaragamuwa	24.6	23.8	23.0	22.2	21.4		
Western-North	10.0	10.0	10.0	10.0	10.0		
Eastern	15.4	13.3	11.0	10.0	10.0		

RSC	Target value of NRW (%)					Future Target	
	2016	2017	2018	2019	2020	2025	2030
North-Central	16.1	15.2	14.3	13.4	13.0		
North	23.0	21.0	19.0	18.0	17.0		
National	27.8	27.3	26.7	26.0	25.3		

Source: NWSDB Corporate Plan 2016-2020

5.2 Formulation of water leakage prevention plan

This work is a matter that NWSDB should carry out after the project.

The formulation of the plan is based on the results of the pilot activities, NWSDB's strategic plan, the target values of other regions, etc. are set, and the target values are set. From the long-term (10 years) and the medium-term (3 to 5 years) Plan.

5.2.1 Setting of target area

- Basically, all target areas should be selected from the areas served by the distribution network. Since the target area should be selected based on the trend analysis of water leakage, the following information is indispensable as the basic data necessary for selecting this area.
- Historical record of leakage and repair
- Installation year of pipeline
- Material of pipeline

If such information is not sufficiently prepared, it is possible to identify the area where leakage control should be prioritized using the following data collected in each zone or water supply area within RSC.

Table 5.2.1 Example of indicator for selection of target area

Indicator	Description
1. NRW (%)	This is the NRW rate for each DMA. When comparing non-revenue water rates (NRW) of different DMAs, due to differences in the length of the network, the density of the number of water taps, and the amount of water used per connection, the evaluation results of the network are different even among sectors with the same NRW rate.
2. NRW (L/connection/day)	This is the total amount of non-revenue water converted into the amount of water per user and per day. Strictly speaking, since it is calculated by the number of branches from the water distribution pipe, it is not necessary to consider the total number of users in the case of apartment houses and condominiums. This is highly linked to physical loss. If there is little leakage in the distribution pipe, this indicator can be used to evaluate the amount of water loss.
3. NWR (L/km/min)	This is the total amount of non-revenue water is converted into the amount of water per 1 km of distribution pipe, and it is highly linked to physical loss as in (2). If there are more leaks in the distribution pipe than in the service connection pipe, this indicator can be used to evaluate the amount of water loss.
4. UARL	Unavoidable Annual Real Losses (UARL) is the amount of water that cannot be reduced any further, and is a theoretical value calculated using a formula. However, if cost-effectiveness is ignored, it can be reduced to zero, but it is difficult in reality. The unit is L/connection/day.
5. NRW/UARL	The indictor based on (4) is the ILI (Infrastructural Leakage Index), which is known as an index recommended by IWA. ILI is a value calculated as Current Annual Real Losses (CARL) / UARL, and if this value is large, it indicates that the problem of water leakage in the distribution network is prominent and that the degree of deterioration is progressing. CARL: Current physical real losses UARL: Unavoidable Annual Real Losses that cannot be reduced any further. Since an accurate survey is required to accurately grasp the amount of water leakage (CARL), here we propose an index in which CARL is replaced

Indicator	Description
	with non-revenue water only for the purpose of comparing the degree of deterioration of distribution networks.
6. MNF/URL	If data on minimum nighttime flow (MNF) is available, "MNF/UARL" using MNF instead of NRW is effective in determining the degree of pipe network deterioration.

5.2.2 Determination of DMA construction

This pilot project adopted the method of building DMA to detail the regional distribution of actual leak occurrences and to find the most efficient and effective measures.

However, in the water distribution network, there are areas where it is difficult to construct a DMA and areas where leakage can be prevented without constructing a DMA.

Normally large initial investment is required to build DMA, and a huge budget and period are required to manage all areas with DMA. Therefore, the necessity of DMA must be judged according to the regional characteristics.

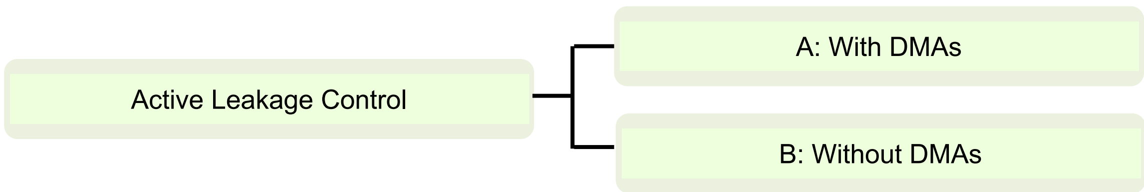

Table 5.2.1 Method of Active Leakage Control

Table 5.2.2 Pros and Cons of each method

Method	Pros	Cons
ALC with DMAs	➢ By measuring the minimum nighttime flow rate, the current state of water distribution can be grasped in detail. ➢ By using the step test together, it is possible to identify the area in the area where leakage is significant. ➢ The effect of the activity can be evaluated quantitatively.	➢ It takes time and money to procure the materials needed to build DMA. ➢ Before realizing hydraulic independence, it is necessary to simulate water distribution effects by hydraulic calculation. ➢ With hydraulic independence, negative impacts such as water quality deterioration, low water pressure, and restrictions on inflow routes may occur. ➢ Even if hydraulic independence is achieved only at night, the water supply situation in the adjacent area will be negatively affected during the survey period.
ALC without DMAs	➢ It is possible to prevent negative repercussions (environmental impact, various adjustments, water interruption, etc.) when constructing DMA. ➢ It can reduce the cost and period for DMA construction.	➢ It is difficult to quantitatively evaluate the results of activities because the amount of water leakage cannot be measured. ➢ NRW is the only indicator that can quantitatively evaluate the results of activities.

5.2.3 Annual plan

Generally, the entire water supply area is vast and it is impossible to take measures against water leakage within one year.

Therefore, it is necessary to plan the leakage control of the water supply area so that one cycle can be completed within several years, and the size of the target area to be covered in one year should be considered according to the capacity of the water board.

When one cycle is completed, start the second cycle activity from the first target area.

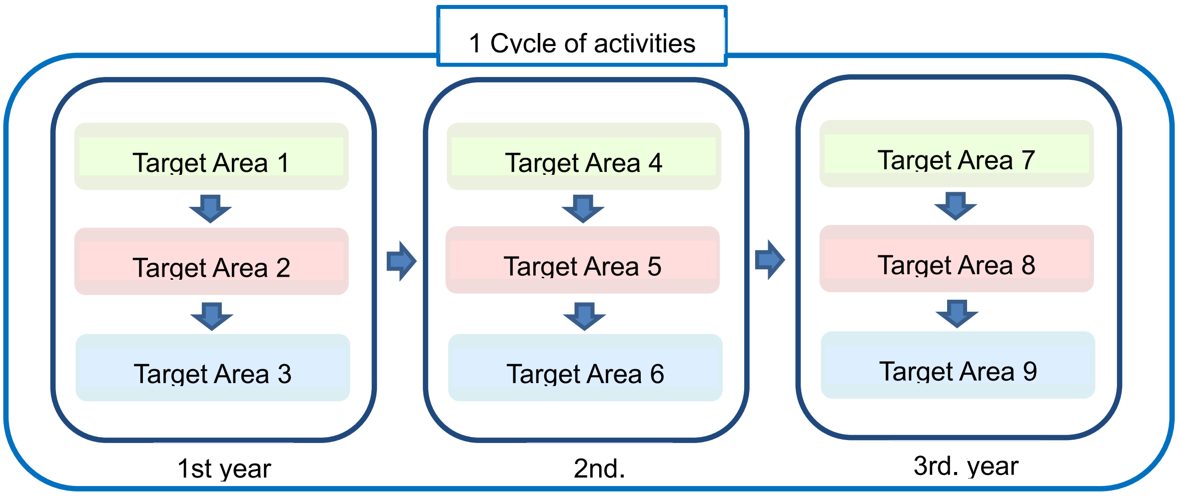

Table 5.2.2 Relation between 1 cycle of activities and target areas

The extension of water pipes in the target area is one of the effective indicators for determining the scale to be covered in one year.

In case of major water utilities in Japan that has over 5,000km length of pipeline, 3 years is commonly applied for 1 cycle period.

【In case of DMAs method】

One or more DMAs will be selected as the target area for one year, taking into consideration the extension of the distribution pipe of each DMA.

【In case of Non-DMAs method】

The target area is extracted from the whole area in consideration of topographical features (river, road, pipeline length).

5.2.4 Example of annual planning

The pipeline length to be investigated in one year can be determined according to the target leakage rate (or non-revenue water rate).

However, if the number of personnel engaged in the survey cannot be secured, it can be decided according to the capacity of the water business utilities.

(1) Calculation of annual survey extension from the number of staff that can be invested

- Unit of leak detection work

  3 persons per 1 unit (1 chief and 2 workers)

  Equipment: Acoustic listening stick, Water leak detector, Pipe locator, Metal detector, Boring bar, Hammer Drill, Vehicle

- Conditions of the work considered herein

  Considered area: RSC Western-South

  Number of work unit： 1 unit (1 chief and 2 workers)

  Number of working date: 244 days per year

  (365days - Saturday and Sunday×52 weeks - Other holidays 17 日)

  Working hours: half a day in each day

  Average survey extension of pipeline： 0.24km/day

  (In accordance with the experience of pilot activities in JICA project)

  Annual survey extension of pipeline: 0.24km/day×244day=58.6km/year

  Cyclic period: 3 years

  Extension of existing pipeline: 2,852km (data provided by RCS-WS)

  Necessary input of manpower: 2,852 / 3 / 58.6 = 16.2 units

  According to above mentioned calculation, if you secure 16 units of manpower, you will be able to conduct surveys of all regions at the pace of one cycle for three years.

(2) Calculation of annual survey extension from target leakage rate

- Conditions of the work considered herein

  Considered area: RSC Western-South

Extension of existing pipeline:	2,852km (data provided by RCS-WS)
Annual production volume:	71,344,743 m^3/year
Leakage recurrence ratio:	15% of leakage volume
Target leakage ratio:	The leakage rate in the first year (19.4%) will be reduced evenly every year, and will decrease to 15% after 5 years. In this case, annual reduction rate = (19.4-15.0)/5 = 0.88%

- Necessary input of manpower

  When completing the 2,852km survey in 5 years, it is necessary to input about 10 units because the survey distance is 58.6km per unit per year.

(3) Supplementary notes

The above estimation case is based on the assumption that the water leakage is widely dispersed in the area and the density of the water leakage is evenly distributed.

However, many leaks concentrate in areas where pipes have deteriorated and where water pressure is excessive.

For example, areas and routes that have only been in the pipeline for a few years can be excluded from the first cycle. In addition, the priority of measures will be lowered in areas where the water supply pressure is relatively low.

Therefore, it is essential to analyze existing data and narrow down the target area for efficient and effective water leakage reduction.

Table 5.2.3 Annual survey extension of pipeline calculated with the target leakage ratio

Id	Items	Unit	Formula	Annual plan				
				1st year	2nd year	3rd year	4th year	5th year
a	Initial leakage ratio by year	%		19.40	18.52	17.64	16.76	15.88
b	Target reduction value by year (equally set)		(19.4-15.0)/5	0.88	0.88	0.88	0.88	0.88
c	Target leakage ratio after activities	%	a-b	18.52	17.64	16.76	15.88	15.00
d	Approximate survey length of pipe	km	m/o	570	577	585	593	603
e	Extension of distribution pipe	km		2,852	2,852	2,852	2,852	2,852
f	Water production volume	m^3/year		71,344,743	71,344,743	71,344,743	71,344,743	71,344,743
g	Initial leakage volume	m^3/year	(a/100)*f	13,840,880	13,213,046	12,585,213	11,957,379	11,329,545
h	Initial leakaga dentity	m^3/hour/km	f/d/365/24	0.55	0.53	0.50	0.48	0.45
i	Recurrence ratio of leakage	%		15.00	15.00	15.00	15.00	15.00
j	Increasable leakage volume by year	m^3/year	f*i/100	2,076,132	1,981,957	1,887,782	1,793,607	1,699,432
k	Target leakage volume	m^3/year	(c/100)*f	13,213,046	12,585,213	11,957,379	11,329,545	10,701,711
l	Target reduction volume of leakage	m^3/year	g+j-k	2,703,966	2,609,791	2,515,616	2,421,441	2,327,266
m		m^3/hour	l/365/24	308.7	297.9	287.2	276.4	265.7
n	Target leakage density	m^3/hour/km	k/e/365/24	0.53	0.50	0.48	0.45	0.43
o	Average leakage density between Initial & Target values	m^3/hour/km	(h+n)/2	0.54	0.52	0.49	0.47	0.44

Annex 1: Format of activities schedule of DMA

DMA Activities Schedule

DMA Number:

Number of Connection:

Projected number of subzone:

		Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21
DMA 3									
1	Determination of design of sub-zoning								
2	Procurement of materials								
3	Arrangement of workers								
4	Installation of Bulk Flow Meter								
5	Installation of gate valves for sub-zoning								
6	Multipoint pressure measurement for 1 week								
7	Hydraulic isolation check with manometer								
8	Boundary check with valve operation								
9	MNF Measurement and 1st Step Test								
10	Leakage Repair (1st term)								
11	2nd Step Test								
12	Updating Customer Data								
13	Collection of Historical Billing Data for last 12 months								
14	Calculation of NRW								
15	Meter Accuracy Test at site								
16	Analysis of Apparent Losses								
17	Effect Evaluation of Leakage Repair								
18	Leakage Repair (2nd term) (if necessary)								
19	3rd Step Test (if necessary)								
20	Cost-Benefit Analysis								

Work to be executed by DWSDB by themselves

Work to be executed by NWSDB under remote assistance by Japanese Experts

Collaboration Work with Japanese Experts in Sri Lanka

Annex 2: Format of Step Test Record

Local Recording Format of Step Test

Location	
DMA No.	
Date	

Time	Local reading data at Inflow Point: Valve Operation		Pressure	Cumulative Amount	Increased Amount	Flow Rate	Average Flow Rate	Minimum Flow Rate		Estimated Minimum Inflow in each subzone			Pressure ($m H_2O$)
	Opened	Closed	($m H_2O$)	(m^3)	(m^3)	(L/min)	(L/min)	(L/min)			(L/min)	(%)	
0:45:00	V**	V**		0.000	-		-		-	-	-	-	
0:50:00													
0:55:00									$Q_{mnf-all}$	-	-	-	
1:00:00													
1:05:00									-	-	-	-	
1:10:00													
1:15:00									$Q_{mnf-sub1}$	Inflow Subzone 1			
1:20:00													
1:25:00									-	-	-	-	
1:30:00													
1:35:00									$Q_{mnf-sub2}$	Inflow Subzone 2			
1:40:00													
1:45:00									-	-	-	-	
1:50:00													
1:55:00									$Q_{mnf-sub3}$	Inflow Subzone 3			
2:00:00													
2:05:00									-	-	-	-	
2:10:00													
2:15:00									$Q_{mnf-sub4}$	Inflow Subzone 4			
2:20:00													
2:25:00									-	-	-	-	
2:30:00													
2:35:00									$Q_{mnf-sub5}$	Inflow Subzone 5			
2:40:00													
2:45:00									-	-	-	-	
2:50:00													
2:55:00									$Q_{mnf-sub6}$	Inflow Subzone 6			
3:00:00													
							-		-	-	-	-	

Basic Information

Subzone	No of Connections	Estimated population = 4.8 * connection (persons)	Extension of distribution pipes (km)	Estimated Legitimate Water Use at Night = 0.0006 * connection (m^3/h)
Subzone 1				
Subzone 2				
Subzone 3				
Subzone 4				
Subzone 5				
Subzone 6				

Annex 3: Personnel Work Record for DMA activities

Working Record in DMA4 Work Item: DMA Creation, MNF Measurement, Step Test, Leakage Survey, Meter test, Data Summarizing

Date	Item	Name	Job Status	Morning			Afternoon			Night			Equipment
				Start	End	Hours	Start	End	Hours	Start	End	Hours	
	Map updating & site inspection		Catefory1	8:30	12:30	4:00	13:30	17:30	4:00				
	Map updating & site inspection		Catefory1	8:30	12:30	4:00	13:30	17:30	4:00				
	Map updating & site inspection		Catefory1	8:30	12:30	4:00	13:30	17:30	4:00				
	Map updating & site inspection		Catefory1	8:30	12:30	4:00	13:30	17:30	4:00				
15.02.2019	Valve Installation		Catefory1	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
16.02.2019	Valve Installation		Catefory1	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
25.02.2019	Meter Installation		Catefory1	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Meter Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Meter Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Meter Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Meter Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Meter Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
26.02.2019	Chamber Installation		Catefory1	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Chamber Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Chamber Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Chamber Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Chamber Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Chamber Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
13.03.2019	MNF, Step Test	1	Catefory1			0:00			0:00	23:00	4:00	5:00	Ultra-sonic flow meter
	MNF, Step Test	2	Catefory1			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	3	Catefory2			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	4	Catefory2			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	5	Catefory2			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	6	Catefory2			0:00			0:00	23:00	4:00	5:00	
	MNF, Step Test	9				0:00			0:00	23:00	4:00	5:00	
	MNF, Step Test	11				0:00			0:00	23:00	4:00	5:00	
14.03.2019	Data summaraizing	9	Catefory1	8:30	12:30	4:00	13:30	16:30	3:00			0:00	
	Data summaraizing	11	Catefory1	8:30	12:30	4:00	13:30	16:30	3:00			0:00	
14.03.2019	House to House Survey	1	Catefory1	10:00	12:30	2:30	14:00	16:30	2:30			0:00	Acoustic bar
	House to House Survey	2	Catefory1	10:00	12:30	2:30	14:00	16:30	2:30			0:00	Acoustic bar
	House to House Survey	3	Catefory2	10:00	12:30	2:30	14:00	16:30	2:30			0:00	
	House to House Survey	4	Catefory2	10:00	12:30	2:30	14:00	16:30	2:30			0:00	
	House to House Survey	7	Catefory2	10:00	12:30	2:30	14:00	16:30	2:30			0:00	
	House to House Survey	8	Catefory2	10:00	12:30	2:30	14:00	16:30	2:30			0:00	
	House to House Survey	9		10:00	12:30	2:30	14:00	16:30	2:30			0:00	
	House to House Survey	11		10:00	12:30	2:30	14:00	16:30	2:30			0:00	
15.03.2019	House to House Survey	1	Catefory1	9:30	13:00	3:30			0:00			0:00	Acoustic bar
	House to House Survey	2	Catefory1	9:30	13:00	3:30			0:00			0:00	Acoustic bar
	House to House Survey	3	Catefory2	9:30	13:00	3:30			0:00			0:00	
	House to House Survey	4	Catefory2	9:30	13:00	3:30			0:00			0:00	
	House to House Survey	7	Catefory2	9:30	13:00	3:30			0:00			0:00	
	House to House Survey	8	Catefory2	9:30	13:00	3:30			0:00			0:00	
	House to House Survey	9		9:30	13:00	3:30			0:00			0:00	
	House to House Survey	11		9:30	13:00	3:30			0:00			0:00	
18.03.2019	Meter Accuracy Check	1	Catefory1			0:00	14:00	17:00	3:00			0:00	Meter test kit
	Meter Accuracy Check	2	Catefory1	10:00	12:30	2:30			0:00			0:00	
	Meter Accuracy Check	3	Catefory2	10:00	12:30	2:30	14:00	17:00	3:00			0:00	
	Meter Accuracy Check	11		10:00	12:30	2:30	14:00	17:00	3:00			0:00	
19.03.2019	Meter Accuracy Check	2	Catefory1	10:00	12:30	2:30	15:00	16:30	1:30			0:00	Meter test kit
	Meter Accuracy Check	3	Catefory2	10:00	12:30	2:30	15:00	16:30	1:30			0:00	
	Meter Accuracy Check	11		10:00	12:30	2:30	15:00	16:30	1:30			0:00	
26.03.2019	House to House Survey	2	Catefory1	10:00	12:30	2:30			0:00			0:00	Acoustic bar
	House to House Survey	3	Catefory2	10:00	12:30	2:30			0:00			0:00	Acoustic bar
	House to House Survey	4	Catefory2	10:00	12:30	2:30			0:00			0:00	

Date	Item	Name	Job Status	Morning			Afternoon			Night			Equipment
				Start	End	Hours	Start	End	Hours	Start	End	Hours	
	House to House Survey	5	Catefory2	10:00	12:30	2:30			0:00			0:00	
	House to House Survey	6	Catefory2	10:00	12:30	2:30			0:00			0:00	
	House to House Survey	7	Catefory2	10:00	12:30	2:30			0:00			0:00	
	House to House Survey	8	Catefory2	10:00	12:30	2:30			0:00			0:00	
	House to House Survey	10		10:00	12:30	2:30			0:00			0:00	
	House to House Survey	11		10:00	12:30	2:30			0:00			0:00	
	House to House Survey	other				0:00			0:00			0:00	
	House to House Survey	other				0:00			0:00			0:00	
28.03.2019	House to House Survey	1	Catefory1	9:45	12:30	2:45			0:00			0:00	Acoustic bar
	House to House Survey	2	Catefory1	9:45	12:30	2:45			0:00			0:00	Acoustic bar
	House to House Survey	3	Catefory2	9:45	12:30	2:45			0:00			0:00	
	House to House Survey	4	Catefory2	9:45	12:30	2:45			0:00			0:00	
	House to House Survey	5	Catefory2	9:45	12:30	2:45			0:00			0:00	
	House to House Survey	6	Catefory2	9:45	12:30	2:45			0:00			0:00	
	House to House Survey	7	Catefory2	9:45	12:30	2:45			0:00			0:00	
	House to House Survey	8	Catefory2	9:45	12:30	2:45			0:00			0:00	
	House to House Survey	10		9:45	12:30	2:45			0:00			0:00	
	House to House Survey	11		9:45	12:30	2:45			0:00			0:00	
01.04.2019	Road survey	1	Catefory1	10:00	14:00	4:00			0:00			0:00	Water leak detector
	Road survey	2	Catefory1	10:00	13:00	3:00			0:00			0:00	
	Road survey	3	Catefory2	10:00	14:00	4:00			0:00			0:00	
	Road survey	10		10:00	14:00	4:00			0:00			0:00	
	Road survey	11		10:00	14:00	4:00			0:00			0:00	
04.04.2019	Road survey	2	Catefory1	10:00	12:00	2:00			0:00			0:00	Water leak detector
	Road survey	3	Catefory2	10:00	12:00	2:00			0:00			0:00	
	Road survey	4	Catefory2	10:00	12:00	2:00			0:00			0:00	
	Road survey	10		10:00	12:00	2:00			0:00			0:00	
	Road survey	11		10:00	12:00	2:00			0:00			0:00	
05.04.2019	Road survey	1	Catefory1	10:00	11:00	1:00			0:00			0:00	Water leak detector
	Road survey	3	Catefory2	10:00	11:00	1:00			0:00			0:00	
	Road survey	10		10:00	11:00	1:00			0:00			0:00	
	Road survey	11		10:00	11:00	1:00			0:00			0:00	
10.04.2019	Identification survey	1	Catefory1	10:00	12:30	2:30			0:00			0:00	Hammer drill
	Identification survey	3	Catefory2	10:00	12:30	2:30			0:00			0:00	Boring bar
	Identification survey	4	Catefory2	10:00	12:30	2:30			0:00			0:00	Generator
	Identification survey	10		10:00	12:30	2:30			0:00			0:00	Acoustic bar
	Identification survey	11		10:00	12:30	2:30			0:00			0:00	Water leak detector
12.04.2019	Identification survey	1	Catefory1	10:30	13:00	2:30			0:00			0:00	Hammer drill
	Identification survey	2	Catefory1	10:30	13:00	2:30			0:00			0:00	Boring bar
	Identification survey	3	Catefory2	10:30	13:00	2:30			0:00			0:00	Generator
	Identification survey	4	Catefory2	10:30	13:00	2:30			0:00			0:00	Acoustic bar
	Identification survey	10		10:30	13:00	2:30			0:00			0:00	Water leak detector
	Identification survey	11		10:30	13:00	2:30			0:00			0:00	
01.05.2019	Road survey	1	Catefory1			0:00				22:00	0:00	2:00	Water leak detector
	Road survey	2	Catefory1			0:00				22:00	0:00	2:00	
	Road survey	3	Catefory2			0:00			0:00	22:00	0:00	2:00	
	Road survey	4	Catefory2			0:00			0:00	22:00	0:00	2:00	
10.05.2019	Road survey	1	Catefory1			0:00				22:00	0:00	2:00	Water leak detector
	Road survey	2	Catefory1			0:00				22:00	0:00	2:00	
	Road survey	3	Catefory2			0:00			0:00	22:00	0:00	2:00	
	Road survey	4	Catefory2			0:00			0:00	22:00	0:00	2:00	
10.07.2019	MNF, Step Test	1	Catefory1			0:00			0:00	23:00	4:00	5:00	Ultra-sonic flow meter
	MNF, Step Test	2	Catefory1			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	3	Catefory2			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	4	Catefory2			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	5	Catefory2			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	6	Catefory2			0:00			0:00	23:00	4:00	5:00	
	MNF, Step Test	11				0:00			0:00	23:00	4:00	5:00	
11.07.2019	Data summaraizing	9	Catefory1	8:30	12:30	4:00	13:30	16:30	3:00			0:00	
	Data summaraizing	11	Catefory1	8:30	12:30	4:00	13:30	16:30	3:00			0:00	
05.08.2019	MNF, Step Test	1	Catefory1			0:00			0:00	23:00	4:00	5:00	Ultra-sonic flow meter
	MNF, Step Test	2	Catefory1			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	Mr. Ajith	Catefory1			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	3	Catefory2			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	4	Catefory2			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	5	Catefory2			0:00			0:00	23:00	4:00	5:00	
	MNF, Step Test	6	Catefory2			0:00			0:00	23:00	4:00	5:00	
	MNF, Step Test	9				0:00			0:00			0:00	
	MNF, Step Test	11				0:00			0:00			0:00	
07.08.2019	Data summaraizing	9	Catefory1	8:30	12:30	4:00	13:30	16:30	3:00			0:00	

Date	Item	Name	Job Status	Morning			Afternoon			Night			Equipment
				Start	End	Hours	Start	End	Hours	Start	End	Hours	
	Data summaraizing	11	Catefory1	8:30	12:30	4:00	13:30	16:30	3:00			0:00	
						0:00			0:00			0:00	
						0:00			0:00			0:00	
						0:00			0:00			0:00	
						0:00			0:00			0:00	
						0:00			0:00			0:00	
						0:00			0:00			0:00	
						0:00			0:00			0:00	
						0:00			0:00			0:00	
						285:30			127:30			126:00	

Working Hours

Category	Daytime	Nighttime
1	126	43
2	94	68
JET		

Excluding Chamber, Meter, Valve Installation

Annex 4: Format of Leak Repair Record

<table>
<tr><td colspan="8">E.O.E.A.M.C. of RSC-WS</td></tr>
<tr><td colspan="3" rowspan="3">**DRAFT Leak Repair Detail Sheet**</td><td colspan="5">National Water Supply & Drainage Board</td></tr>
<tr><td>Office</td><td></td><td>Complaint Ref.No.</td><td></td></tr>
<tr><td>Officer Name</td><td colspan="3"></td></tr>
<tr><td>Awareness date and time</td><td colspan="2"></td><td>Reported date and time</td><td colspan="4"></td></tr>
<tr><td>Reported by</td><td colspan="4">☐Complain(Consumer / Public) ☐Meter Reader ☐Leak Detection ☐Others</td><td>Recorded by</td><td colspan="2"></td></tr>
<tr><td>Complainer's Name & Address</td><td colspan="7"></td></tr>
<tr><td>Attended Date and Time</td><td colspan="2"></td><td>Completed Date and Time</td><td colspan="4"></td></tr>
<tr><td colspan="8">Leakage Information</td></tr>
<tr><td rowspan="6">Location</td><td>Address</td><td colspan="6"></td></tr>
<tr><td>Meter No.</td><td colspan="6"></td></tr>
<tr><td>Consumer Account</td><td colspan="6"></td></tr>
<tr><td>Coordinate(GPS Point)</td><td colspan="6"></td></tr>
<tr><td>☐Service pipe</td><td colspan="3">☐Distribution pipe</td><td colspan="3">☐Transmission pipe</td></tr>
<tr><td>☐Joint
☐Pipe Body
☐Stop Valve
☐Ferrule
☐Meter</td><td colspan="3">☐Joint (Fl, Coupl)
☐Pipe Body
☐Valve (W/O, A, S, B)</td><td colspan="3">☐Joint (Fl, Coupl)
☐Pipe Body
☐Valve (W/O, A, S, B)</td></tr>
<tr><td>Considerable Cause</td><td colspan="7">☐Deterioration ☐Ageing ☐Traffic Load ☐Poor Construction ☐Less Clear Cover
☐Poor Material ☐Exposed Sunlight ☐Others( )</td></tr>
<tr><td>Pipe Material</td><td colspan="7">☐DI ☐PVC ☐PE ☐Others( )</td></tr>
<tr><td>Pipe Dia.</td><td>mm</td><td>Pipe Depth</td><td>m</td><td>Pipe Laid Year</td><td colspan="3">year</td></tr>
<tr><td>Road Surface</td><td colspan="7">☐Asphalt ☐Tarred ☐Concrete ☐I.L.B ☐Shoulder ☐Others ( )</td></tr>
<tr><td>Traffic Density</td><td colspan="7">☐Heavy ☐Medium ☐Light</td></tr>
<tr><td>Leake Repair</td><td>☐Yes ☐No</td><td colspan="2">Estimated Leak Volume</td><td colspan="3"></td><td>m3/h</td></tr>
<tr><td colspan="8">Repair information</td></tr>
<tr><td>Material used</td><td colspan="7"></td></tr>
<tr><td>Machinery Used</td><td>Day</td><td>Night</td><td colspan="5">Location(Sketch)</td></tr>
<tr><td>1) Worker (Nos.)</td><td></td><td></td><td colspan="5" rowspan="7"></td></tr>
<tr><td>2) Excavator (Hrs.)</td><td></td><td></td></tr>
<tr><td>3) Water Pump (Hrs.)</td><td></td><td></td></tr>
<tr><td>4) Compactor (Hrs.)</td><td></td><td></td></tr>
<tr><td>5) Power Light (Hrs.)</td><td></td><td></td></tr>
<tr><td>6)</td><td></td><td></td></tr>
<tr><td>7)</td><td></td><td></td></tr>
<tr><td colspan="8">Measurment</td></tr>
<tr><td>BOQ Item No.</td><td colspan="2">Description</td><td>Unit</td><td>L(m)</td><td>B(m)</td><td>D(m)</td><td>Qty</td></tr>
<tr><td></td><td colspan="2"></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2"></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2"></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2"></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="8">Comment</td></tr>
</table>

Contractor Officer NWSDB Officer

Attachment 2: Procedure manual

Active Leakage Control

PROCEDURE MANUAL

Technical cooperation project for Enhancement of Operational Efficiency and Asset Management Capacity of Regional Support Center- Western South of NWSDB in Sri Lanka
by Japan International Cooperation Agency

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Appendix 2 Guideline for Cost and Working Days Calculation Sheet for Leakage Detection Planning

Appendix 3 Introduction of Remote Monitoring System

Appendix 4 Mechanism of Ultrasonic Flowmeter

Appendix 5 Data Collection and Management

Appendix 6 User's Manuals

Appendix 7 Backfilling Instatement

Appendix 8 Theft Prevention Strategy

Foreword

This manual was developed under the technical cooperation project named “The Project for Enhancement of Operational Efficiency and Asset Management Capacity of Regional Support Center-Western South of NWSDB in Sri Lanka “with the assistance of the Japan International Cooperation Agency (JICA).

RSC-WS and MDTD worked as the main counterparts for the Project. Therefore, this manual refers to the experiences and lessons at the Project site in RSC-WS. However, these valuable lessons are applicable everywhere, and this manual aims to generalize the experience and serve for the use of all NWSDB staff members in the whole country.

For the convenience of all readers, the manual consists of a main body and appendices.

Main body; Description of background, basis, and theory

Appendices

(1) A case study in the pilot site. It will be helpful to know the real procedures and countermeasures which have been taken at the project site in detail.

(2) Guideline for Cost and Working days Calculation Sheet. One of the project outcomes is a Cost and Working days Calculation Sheet for Leakage Detection Planning of excel format. You can use it for the cost estimation of the leakage survey.

(3) Introduction of the remote monitoring system

(4) Mechanism of Ultrasonic flowmeter

(5) Data management

(6) Practical user’s manuals of equipment

(7) Backfilling reinstatement

(8) Theft Prevention Strategy

Furthermore, this manual is a reference material of the practical training of MDTD programmes. You can learn the real approach to challenge the controlling leakage from experienced persons.

We believe the outcomes of the pilot activities of the project will assist the real active leakage control in Sri Lanka.

1 Outline of this manual

This procedure manual has been developed for engineers and officers who are involved in the maintenance of the distribution network system. Further, this manual is expected to be referred in the development of an action plan for reducing water leakage and its implementation.

Generally, according to the study conducted in Japan, there are several stages of leakage control depending on the level of leakage ratio. Furthermore; effective ways of leakage control may vary with the set target. Major water utilities in Japan have experienced a similar history of leakage reduction and have overcome it over a period of time. Case of Nagoya City is shown in Figure1.1 and Table1.1

For this reason, it is important to firstly assess the current situation of leakage levels.

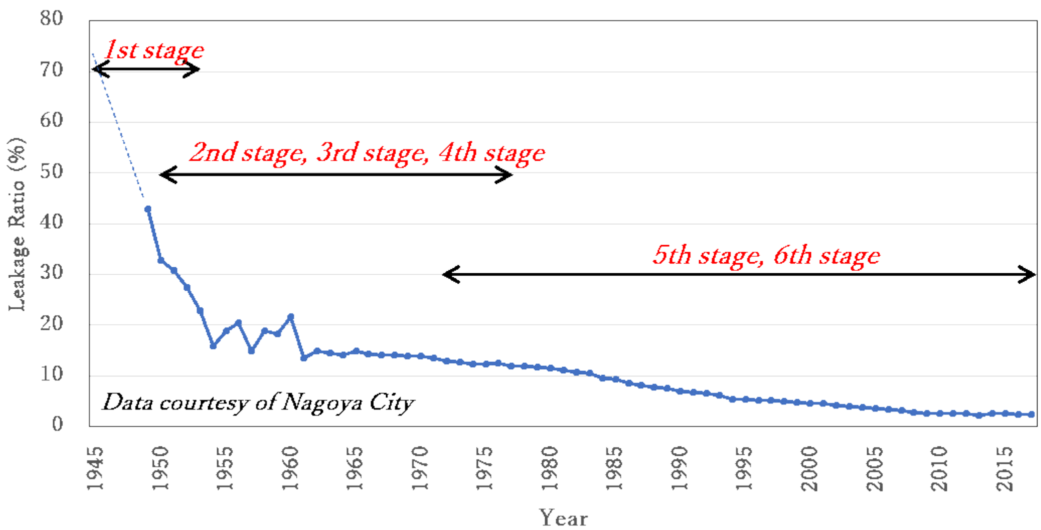


Figure 1.1 History of the leakage ratio of the water utility in JAPAN

Table 1.1 Stages of the leakage control depending on the leakage ratio

<table>
<tr><th rowspan="2">Stage</th><th rowspan="2">Approximate Leakage ratio</th><th colspan="2">Leakage control</th></tr>
<tr><th>Major target</th><th>Types of measure</th></tr>
<tr><td>1</td><td>Larger than 30%</td><td>Visible leakage</td><td>- Just patrolling and repairing.</td></tr>
<tr><td>2</td><td rowspan="2">15% - 30%</td><td rowspan="2">Invisible (unreported) leakage</td><td>- Active Leakage Control (Planned leakage detection work) by sounding equipment targeting all service area.</td></tr>
<tr><td>3</td><td>- Active Leakage Control by sounding equipment targeting particular high-risk area. (To improve the work efficiency.)</td></tr>
</table>

Stage	Approximate Leakage ratio	Leakage control	
		Major target	Types of measure
4			- Combination of Active Leakage Control and planned old pipes' replacement work.
5	Less than 15%	Leakage prevention	- Planned old pipes' replacement work
6			- Improvement of pipe material

Source: Nagoya City Waterworks & Sewerage Bureau

Considering the NRW ratio of RSC-WS being around 20% in 2019, and based on the experiences of the Pilot Activity carried out under *The Project for Enhancement of Operational Efficiency and Asset Management Capacity of Regional Support Center- Western South of NWSDB in Sri Lanka (hereinafter referred to as "JICA project")*, this manual provides the procedure as to how Active Leakage Control (hereinafter referred to as "ALC") is carried out. Main contents of this manual are [Assessment of current situation], [Practice of Active Leakage Control], and [Management of database].

Note that basic information, such as general theories of leakage control and operating principles of leak detection equipment, are out of the scope of this manual as existing manuals of NWSDB have discussed such topics.

Table 1.2 Existing manuals of NWSDB

No.	Title & Contents	Storage location in NWSDB
1	Leak Detection and Repair Procedure	Central Library
2	Pipe Material Selection Process	
3	Service Connection Procedure	
4	Water Meter Selection, Standardization & Installation Process	
5	Meter testing & Calibration Process	
6	Manual on Bench Marking and Monitoring Procedure for NRW Reduction	
7	Manager's Manual for Non-Revenue Water	Design Manual Section
8	Managing Water loss by understanding the reticulation	Central Library
9	Non-revenue water Reduction in Colombo city by adoption of low cost strategies	

In addition, the descriptions as to the usage of equipment, that was utilized in the above-mentioned Pilot Activity, is appended at the end of this manual. However, this is not intended to limit brands, or models of the equipment for implementation of leakage control.

2 Assessment of the current situation

The current situation of leakage level should be grasped first for the effective implementation of ALC. Based on this information, necessary resources, such as budget, manpower, and equipment etc., can be allotted /assigned in a proper manner.

The most convenient mode of obtaining such information is to calculate NRW of target area. Of course, leakage is just one element of NRW, however, leakage volume is considered to occupy most part of the component of NRW in some cases. In other words, NRW can be used as a key indicator for ALC. Leakage volume of the particular area in the Pilot Site was nearly equal to NRW. Therefore, other components of NRW, such as theft water, meter inaccuracy, could be eliminated. Such observations were made during the Pilot Activity conducted by the JICA Project.

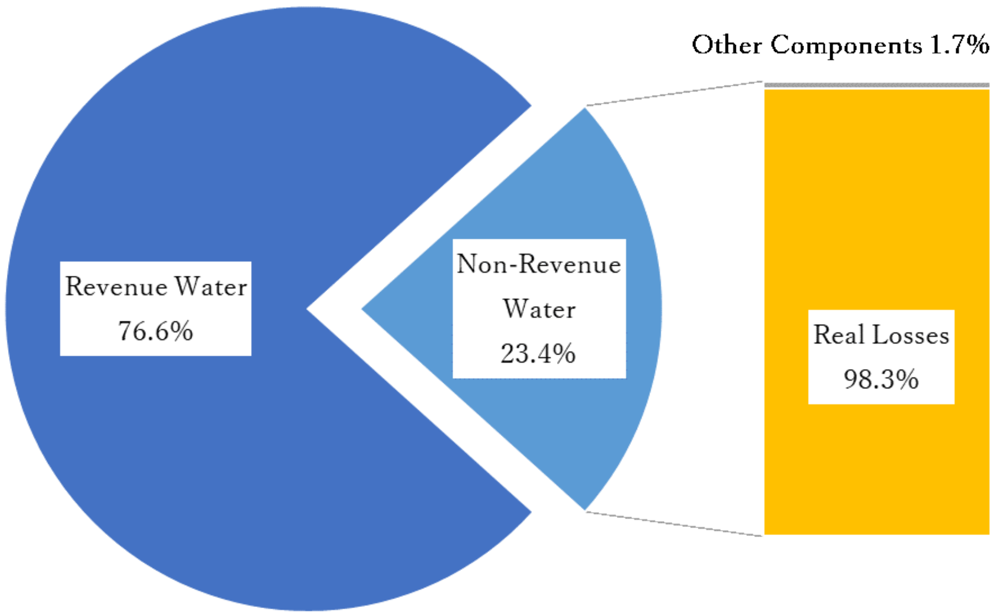


Figure 2.1 NRW components in one area of the Pilot Site under JICA project as of Mar. 2019

On the other hand, theft water, water loss caused by defective meters, water volume used for washout etc., are still parts that form NRW. (**refer to Table 2.1**) Therefore, depending on the area, there are also some cases where leakage volume is relatively small compared to other components. In these cases, it is important to estimate the percentage of leakage volume that exists in total NRW.

Taking these things into account, this chapter discusses the methods of estimating leakage volume in section 2.1 and 2.2. Note: This is a method of mere "estimation" only, as leakage volume cannot be measured directly.

Subsequently, the process for collecting leakage records is described in section 2.3, which contributes towards selecting the target area effectively.

Further, Recurrence of leakage is described in section 2.4.

2.1 Estimating of leakage volume by analysis of water balance

Analyzing water balance is the method of estimating leakage volume. This is done by deducting the total volume of all components except real loss from total input volume into a certain target area.

It will be effective way if each volume except real loss can be measured and recorded accurately. However, in case of several components not being measured, it demands necessary actions, such as establishing the way of measuring and recording them.

Billed metered consumption, which is one of the components of the water balance, is being measured monthly, so that the shortest period of analyzing would be one month.

Table 2.1 Components of Water balance

a) Input volume	Authorized consumption	Billed authorized consumption	b) Metered consumption	Revenue Water
			c) Non-metered consumption	
		Unbilled authorized consumption	b) Metered consumption	Non-Revenue Water
			c) Non-metered consumption	
	Water losses	Apparent losses	d) Unauthorized consumption	
			e) Meter inaccuracy	
		Real losses	f) Leakage	

Source: IWA/AWWA

Definition of items are as follows.

a) Input volume

The volume of water that flows into a target area. Bulk flow meters are required at inlet points to measure this volume.

b) Metered consumption

The volume of usage by a consumer in a target area. This is the total of billed volume and unbilled volume.

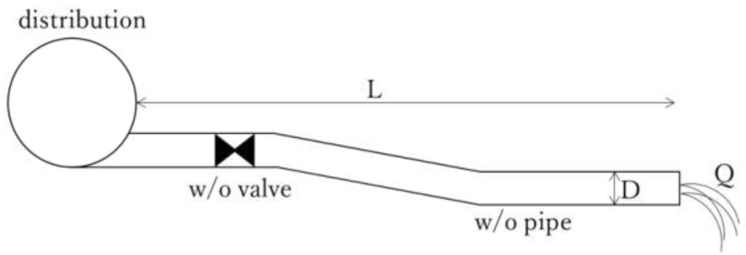
c) Unmetered consumption

The volume for wash out, firefighting, etc. generally. To grasp these volumes, the following actions are required;

- Survey what kinds of unmetered consumption and unmetered water usage exists.
- To establish the way of estimation of those volume.

In NWSDB, w/o has been executed on regular basis, so that the volume is assumed to have been accumulated to a certain amount within a certain period of time. One example of estimating w/o volume consumed is shown below for reference (Source Japan Water Works Association (2012). *The design criteria for water supply facilities*);

In case of the situation mentioned in the figure, quantity of the flow can be calculated by the following based on Bernoulli's equation.



$$P = \left(\zeta e + \zeta e + 2\zeta e + \lambda\frac{L}{D} + 1\right)\frac{v^2}{2g}$$

$$v = \frac{4.43}{\sqrt{1.6 + \zeta v + \lambda\frac{L}{D}}}\sqrt{P}$$

Therefore;

$$Q = \frac{\pi}{4}D^2 \times \frac{4.43}{\sqrt{1.6 + \zeta v + \lambda\frac{L}{D}}}\sqrt{P}$$

where;

Q	flow rate (m^3/sec)
P	water head of water main (m)
L	length of w/o pipe (m)
D	diameter of w/o pipe (m)
ζ **i**	inlet pressure drop coefficient (no dimension) = 0.5
ζ **b**	bend pressure drop coefficient (no dimension) = 0.04
ζ **v**	valve pressure drop coefficient (no dimension) see the table 2.2
λ	friction pressure drop coefficient (no dimension

Table 2.2 Pressure drop coefficient figure of valve with valve opening rate

Valve opening rate	1/8	2/8	3/8	4/8	5/8	6/8	8/8
ζv	90.0	16.0	5.5	2.3	1.0	0.385	0.0

Table 2.3 Pressure drop coefficient figure of friction with diameters of pipe

Diameter of w/o pipe (mm)	100	150	200	250	300	400
λ	0.045	0.040	0.036	0.031	0.027	0.024

Table 2.4 Flow rate of w/o valve opening rate = 8/8, L=50m

Unit in m^3/min

Dia. (mm) / Water pressure of water main (MPa)	100	150	200	250	300	400
0.05	0.95	2.7	6.1	10.5	17.0	34.8
0.10	1.35	3.9	8.1	14.8	24.0	49.2
0.15	1.65	4.7	10.0	18.1	29.4	60.2
0.20	1.90	5.4	11.5	21.2	34.0	69.5
0.25	2.12	6.1	12.8	23.7	38.0	77.7
0.30	2.33	6.6	14.1	26.0	41.6	85.1
0.35	2.52	7.2	15.2	28.1	45.0	92.0
0.40	2.69	7.7	16.3	30.0	48.0	98.3

Source: Japan Water Works Association (2012). *The design criteria for water supply facilities*

d) Unauthorized consumption

The volume of theft water. This can be estimated by applying a discovery rate of illegal connections in a similar area, and the average consumption rate of similar consumer. The table below is the case of the CMC area, which is taken from the database of NWSDB. House to house survey, which is described in section 3.5.1, will contribute to search and sweep these illegal connections.

Table 2.5 Illegal Connections Discovered in the CMC Area Since 2009

AREA	2009		2010		2011		2012		Average	
	No. of premises checked for illegal Connections	Percentage (%)	No. of premises checked for illegal Connections	Percentage (%)	No. of premises checked for illegal Connections	Percentage (%)	No. of premises checked for illegal Connections	Percentage (%)	Total Properties checked	Average Percentage Detected (%)
CC-N	4,509	11.24%	3,919	13.17%	7,469	6.20%	3,862	8.60%	19,759	9.80%
CC-E	4,521	11.83%	4,422	13.32%	8,250	8.52%	3,984	11.35%	21,177	11.26%
CC-S	617	14.42%	1,140	4.12%	3,455	1.24%	1,343	4.91%	6,555	6.18%
CC-W	6,676	5.42%	5,273	7.68%	5,283	2.95%	3,965	5.90%	21,197	5.49%
TOTAL	16,323	9.15%	14,754	10.55%	24,457	5.58%	13,154	8.24%	68,688	8.38%

Source: NWSDB (2013). *NRW ENGINEERING STUDY FOR COLOMBO CITY*

e) Meter inaccuracy

The volume of undermeasured consumption or over measured consumption. This can be estimated by conducting a sampling test using the Meter Test Kit. The number of samples is determined by statistic theory as below.

Table 2.6 The number of samples (Confidence level 95%, Margin of error 5%)

The number of connections	Necessary Samples	Rate
500 or less	220	44% or more
800	260	32.5%
1,000	280	28.0%
2,000	325	16.3%
3,000	345	11.5%
5,000	360	7.2%
10,000	370	3.7%
25,000	380	1.5%
50,000	385	0.8%
100,000 or more	385	0.4% or less

f) Leakage: The volume of the leakage, which is calculated by deducting total volume of all components except the leakage from input volume.

2.2 Estimating of leakage volume by DMA method

2.2.1 Minimum Night Flow Measurement

Minimum Night Flow (hereinafter referred to as "MNF") Measurement is the method for estimating leakage volume of a certain area, by isolating that area hydraulically from other areas except inlet points of the flow. Bulk flow meters are needed at the inlet points to measure the flow into the area.

Those areas are called DMA (Districted Metered Area), the flow and the pressure should be measured at nighttime between midnight to 4 a.m., when water consumption is expected to be the lowest, generally.

If there are consumers who are using large amount of water at nighttime, such as factories, shops, their stop valves should be closed before starting measurement.

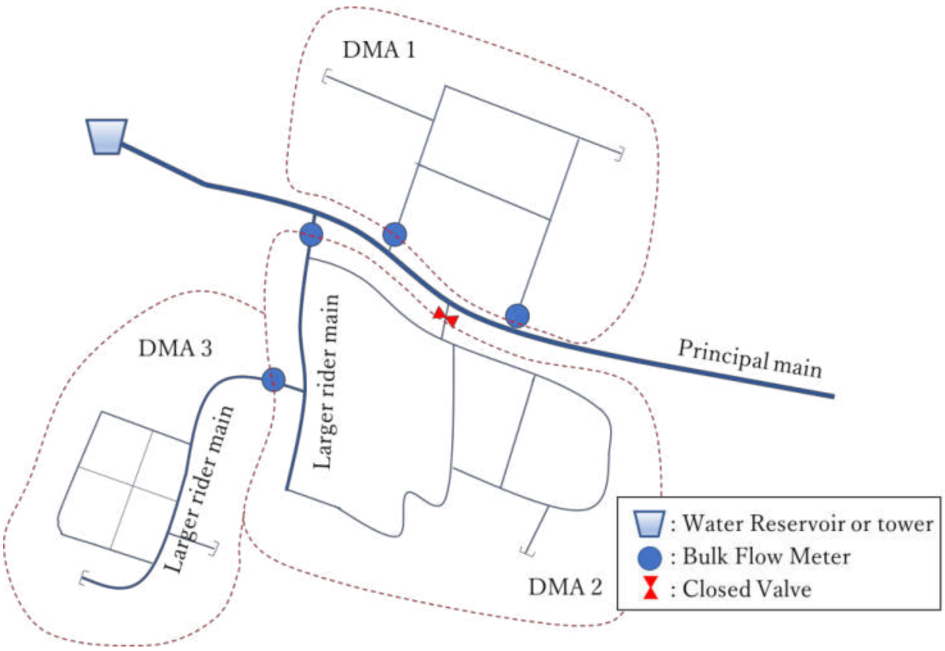


Figure 2.2 Conceptual image of DMAs

MNF is the total volume of Night Leak and Legitimate Night Use.

$$MNF = Night\ Leak + Legitimate\ Night\ Use$$

It is not easy to determine the general value of Legitimate Night Use, because it depends on situations of the area, e.g. whether it is a resident area, commercial area or industrial area. One of the existing manuals of NWSDB, however, can be referred to assume that value, for example.

$$Legitimate\ Night\ Use \approx\ 0.6\ liter/hour/person$$

Source: NWSDB (2013). *NON REVENUE WATER ENGINEERING STUDY FOR COLOMBO CITY VOLUME III PROCEDURES & MANUALS PART 6 OF 6*

Although this calculation is also a mere assumption, Night Leakage can anyhow be calculated for the first trial. Night leakage is the value at nighttime when the system pressure is relatively high. Therefore, it shall be converted to Average Leakage by average pressure. Average Leakage is the Water Losses.

$$Average\ Leakage = Night\ Leak\ \times \sqrt{Average\ Pressure/Night\ Pressure}$$

Source: Bernoulli's equation

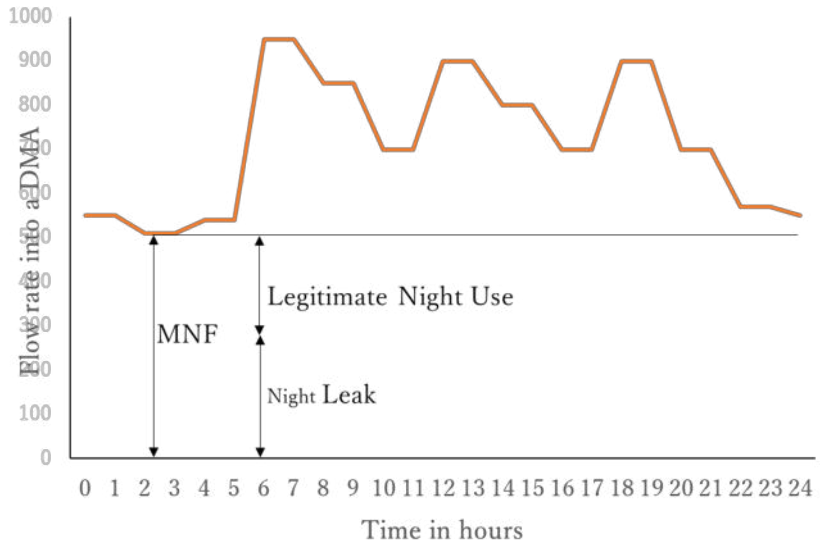
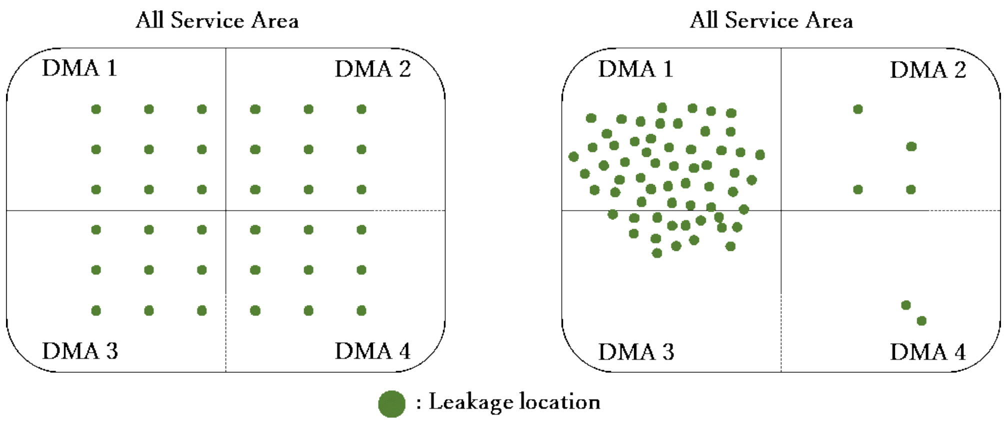


Figure 2.3 Components of MNF

Although it is time consuming and expensive, MNF method can provide the estimate of leakage volume of entire area if it is divided out by DMAs.

It is sometimes possible to take the leakage ratio, which is obtained from one DMA, as the leakage ratio of an entire area. This is an effective method in case the density of leakage by location is considered being uniform, or not so different. (See the figure below.) However, in case that density of leakage point differs by location in an entire area, that figure should not be taken as the figure of an entire area. (For example, leakage record, difference of laid year of pipes, difference of pipe material by location can be referred to check if there is a possibility of the density differing substantially or not.)

Creation of DMA is described in section 3.2.



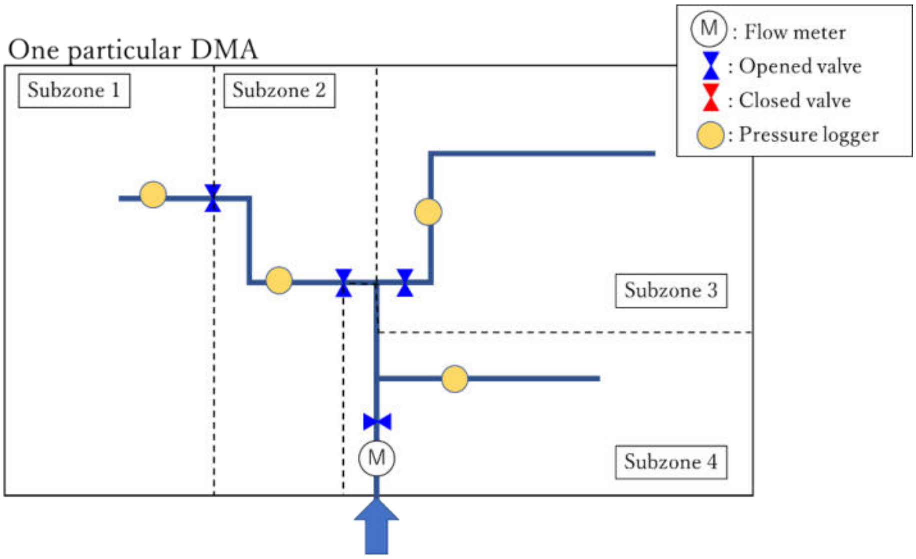
(a) **Uniform density**

(b) **Different density**

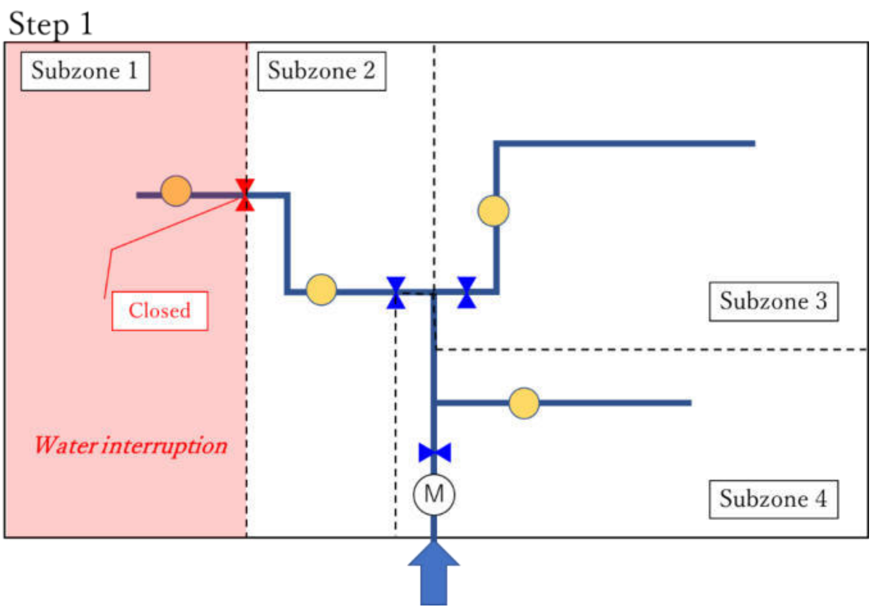
Figure 2.4 **Conceptual diagram of density difference of leakage by location**

2.2.2 Step Test

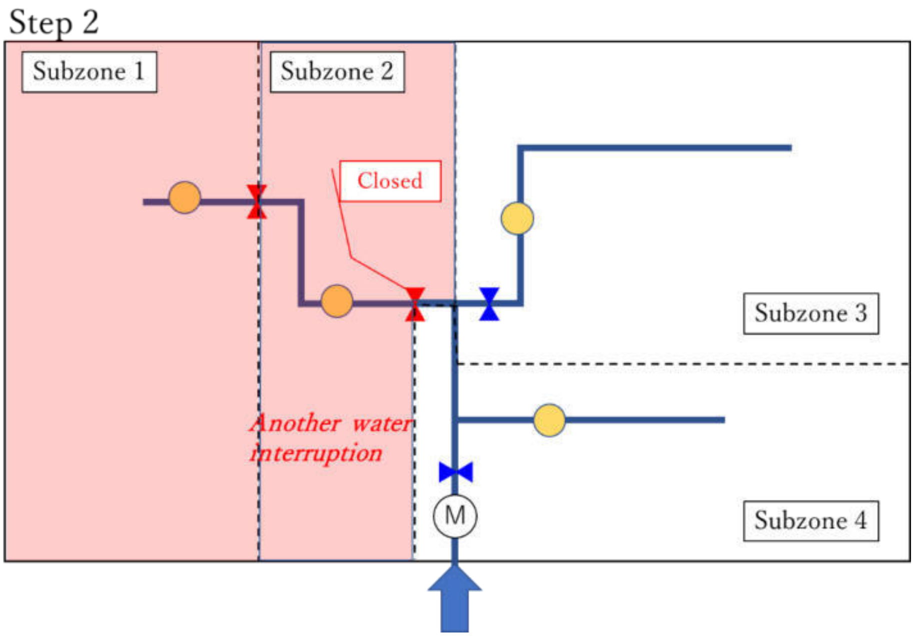
Step Test is the method of localizing areas where larger leakage exists inside the DMA by dividing the DMA into several numbers of smaller areas, which are called "Subzones". If input flow of each subzone is interrupted step by step in certain order, flow rate-drop would be observed. Those each drop can be recognized as the indicators of existing leakage volume that each subzone has. Same as the MNF measurement, step test shall be carried out at nighttime between midnight to 4 a.m., when normal water consumption is expected to be the lowest, generally.



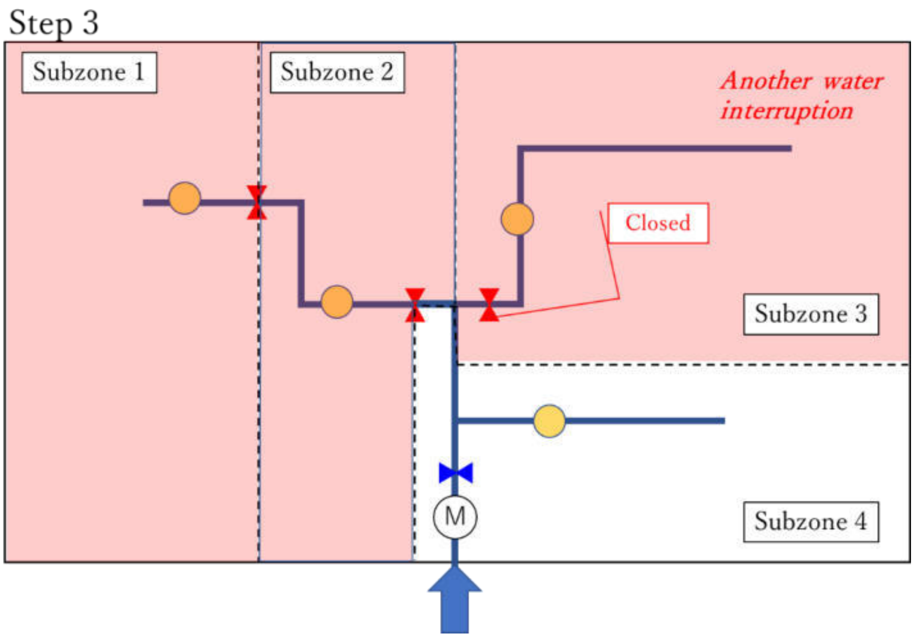
(a) Before the operation of the Step Test



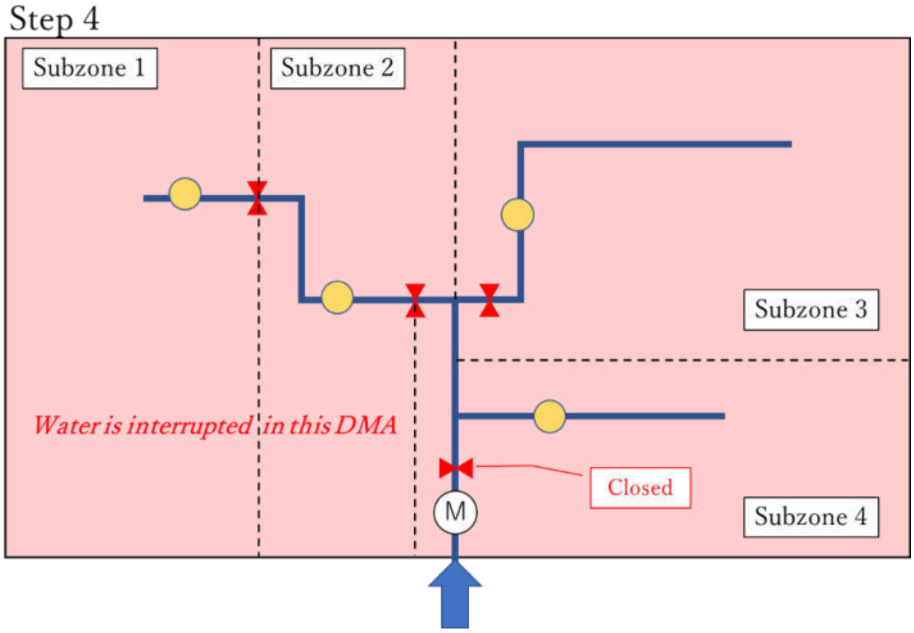
(b) Step 1 of the Step Test (Input Flow of Subzone 1 is interrupted)



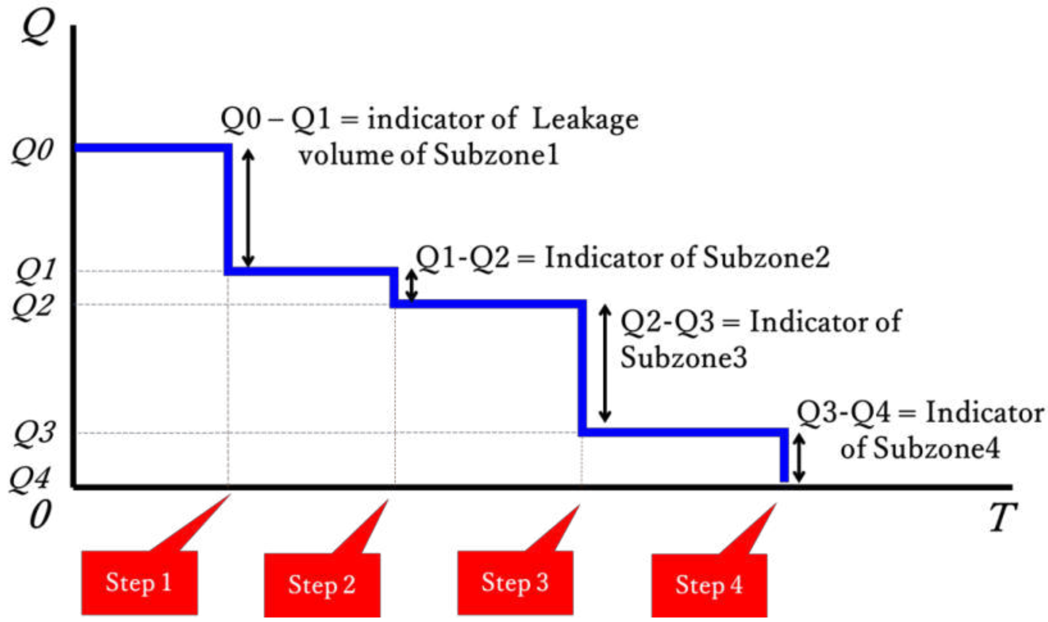
(c) Step 2 of the Step Test (Input Flow of Subzone 2 is interrupted)



(d) Step 3 of the Step Test (Input Flow of Subzone 3 is interrupted)



(e) Step 4 of the Step Test (Input Flow of this DMA is interrupted)



(f) Image of Flow rate change while Step Test

Figure 2.5 Conceptual diagram of flow drop while proceeding with Step Test

2.3 Collecting leakage records

Collecting and accumulating of leakage information help us analyze the tendency of leakage. By doing this, certain areas where leakage may exist can be highlighted, and future plans of ALC can be considered efficiently.

O&M staff should record information regularly while conducting daily activities, such as leakage detection, leakage repair. Further, RSC staff should manage the recorded information intensively.

Information that should be recorded is the following;

a) Category: Visible or Invisible

b) Pipe: Material, Diameter, Age, Depth

c) Circumstance: Road surface, Traffic density, Soil type

d) Leakage: Location, Considerable cause, Leakage volume etc.

Analyzing these records would provide an understanding of which pipes have larger risk of leakage than other pipes. It also enables us to predict the area , which should be prioritized.

Sample of leakage record sheet is shown in **Figure 3.3**.

2.4 Recurrence of leakage

Even if leakage is repaired and leakage ratio decreases once, new leakage may occur and leakage ratio tends to increase again after a certain period. This is because leakage is caused by cyclic load by traffic, ground subsidence, corrosion, poor workman ship, etc.

This phenomenon is called a "Recurrence of leakage". Major water utilities in Japan have experienced it when they reached around 20% of leakage ratio. At a lesser stage of this leakage ratio, effectiveness of ALC tends to become relatively low. Conversely, the existence of recurrence volume of leakage gets prominent more.

It is difficult to determine general figure as recurrence volume of leakage; However, some studies mention that it is 15% to 30% of total NRW.

To break through this situation, a planned pipe replacement work has been carried out in addition to ALC in Japan.

To do a pipe replacement work efficiently in NWSDB, prioritization of pipes that should be replaced preferentially could be considered by the idea based on the accumulated leakage records, mentioned in section 2.3.

3 Practice of Active Leakage Control

ALC is one of the methods for leakage reduction, which is specifically used to detect unreported leakage, to repair detected leakage actively in particular target areas.

Amount of leakage tends to increase with time because of cyclic loads by traffic, ground subsidence, corrosion, poor quality material, poor workman ship, etc. Therefore, this kind of leakage control is demanded to be carried out in a certain cyclic period continuously. All water utilities should expend a steady effort to achieve this.

The flow chart of ALC is as below. Each numbering item is being described in each section of same number.

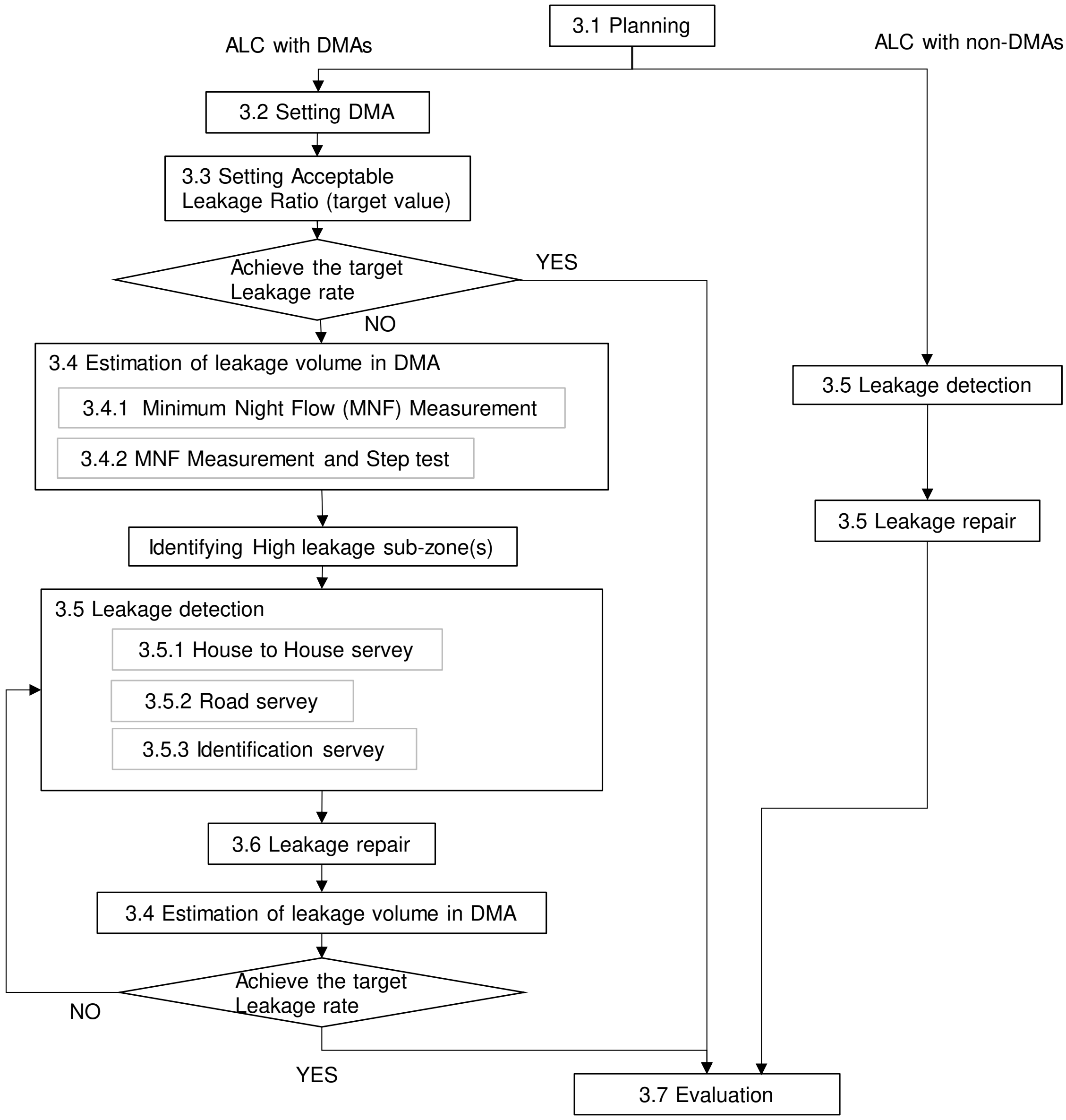


Figure 3.1 Flowchart of ALC

3.1 Planning of the activity

3.1.1 Setting the target area

Basically, all of target areas should be piped water service areas. Moreover, target areas also can be selected from all areas with the result of analysis of the leakage tendency, which can be guessed by past leakage records, pipe age, pipe material, etc.

3.1.2 Selection of Procedure

In implementing the leak reduction plan, candidate areas to be targeted for activities must be selected and identified. The method of DMA creation is only one of various methods of leak management.

Construction a DMA is not a cure-all to reduce leakage and is not required in all water distribution networks. Constructing a DMA, especially in an existing complex water network, requires considerable effort, materials, and time.

In addition, effective activities cannot be carried out without understanding the utilization method after constructing the DMA and the procedure for reducing water leakage.

When applying the DMA method to an existing distribution network, it is of utmost importance to limit it to areas where NRW and water leakage is significant, or the risk of water leakage is high.

Major Factors to be considered

when selecting water supply scheme for DMA creation

- Non-Revenue Water
- Historical record of leakage occurrence and repair
- Age of pipe and pipe installation year
- Type of pipe (Asbestos Cement, Galvanized Iron, PVC, Polyethylene, Ductile)
- Water Supply Pressure
- Topographical condition and land use
- Variation in nodal elevation
- Water demand and number of customers
- Water quality
- Number of sources that feed water to the area

The first factor to be considered is NRW in the area under the jurisdiction of OICs.

It is important to grasp not only the NRW of the entire jurisdiction area but also the NRW in each zone and divide it into three ranks to identify the areas that require countermeasures. As a result, there may be cases where it is not desirable to apply the DMA method.

For example, in an area where pipes have been laid for more than 50 years and the amount of non-revenue water is 40% or more, the pipes should be completely renewed without considering the application of DMA method.

The following shows the basic flow for considering the application of the DMA method.

In this case, NRW is used as an indicator for selection, but it is also possible to use the number of annual leakages, annual repairs, or minimum water inflow rate of nighttime instead of NRW.

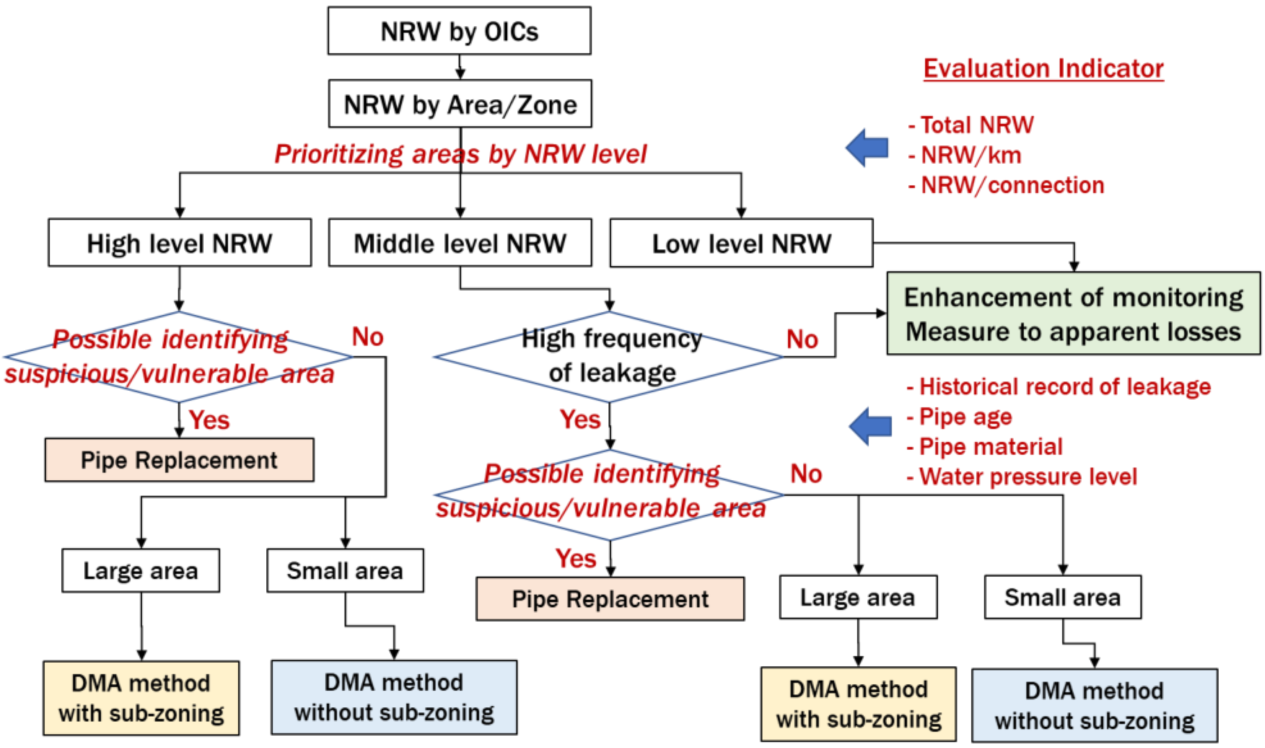


Figure 3.2 Basic flow for considering the application of DMA method

The next table is a summary of Pros and Cons for ALC with DMA and without DMA.

Table 3.1 Comparison of the methods

	Pros	Cons
ALC with DMAs	- It enables grasping of the current situation in detail by the MNF measurement in each DMA. - It enables to localize intensive zones where leakage exists by the Step Test. - It enables the evaluation of effectiveness of the activity.	- Time and expenses are required to set DMAs, to procure flowmeters and valves, to maintain those materials. - Hydraulic analysis would be needed for simulating influences of DMAs, otherwise creating DMAs might affect the existing system in an adverse manner, such as deterioration of water quality, low pressure that are caused by increase of one-way pipe or decrease of inlet points.
ALC without DMAs	- No need to take several actions that are needed to avoid negative repercussions when creating DMAs. - No need to spend time and expenses to create DMAs.	- It is not easy to evaluate the activity because leakage volume cannot be realized directly. - Therefore, existing available NRW would be used as a key indicator of the activity evaluation.

Pros of DMAs-method mentioned above are attractive for those who are dedicated to leakage reduction, on the other hand a large amount of time and money are demanded to divide out all service area into DMAs. Therefore, it might be better to combine both ways first; application of DMAs-method is only to a certain convenient area for creating a DMA.

Creating DMA is described in section 3.2.

3.1.3 Annual plan

Generally, the entire service area is too large to be covered within one year; therefore a particular target area that can be covered in one year should be set. The length of distribution pipe belonging to target area could be used as an indicator of the size of the plan. Those target areas should be covered step by step in every year from the first one to final one. Second cycle should be commenced after completion of the first cycle. Appropriate cyclic period can be determined in several ways. In case of major water utility in Japan that has over 5,000km length of pipe, 3 years is common as a cyclic period.

a) In case of DMAs method, one DMA or multiple DMAs should be selected as a target area of one year, taking into consideration the length of each DMA.

b) In case of non-DMAs method, a target area should be cut out from all areas. On this occasion, taking into consideration geographical features, such as rivers, roads, and the length of pipe in an area, would be convenient.

As mentioned earlier, a target area also can be selected from all areas and prioritized with the result of analysis of leakage tendency, which can be guessed by past leakage records, pipe age, pipe material, etc.

Annual survey length could be set in accordance with the target leakage ratio. However, it also can be set by possible manpower, if necessary, manpower cannot be allocated sufficiently.

Examples of calculations are shown as below;

1) Setting annual survey length **by a possible manpower**

- Unit of leak detection work;

The number of people: 1no. for chief, 2nos. for workers, total 3

The number of people: 3 (1 - chief, 2 – workers)

Equipment: Acoustic bar, Water leak detector (Ground microphone),Pipe locator(Metal/ Non-metal), Metal detector, Boring bar, Hammer drill, Vehicle, 1no. of each

- Conditions of the work considered herein;

i) Considered area: RSC-Western South

ii) The number of people: One-Unit (Unit is mentioned the above.)

iii) The number of working days : 365 - 52×2 - 17=244 days (All working days except weekends and holidays. The number of holidays can be changed as per the actual situation.)

iv) Working hours: half a day in each day mentioned above

v) Average survey length in a day: 0.24 km/day (In accordance with the experience of Pilot Activity in JICA project)

vi) Annual survey length: 244 days × 0.24 km/day = 58.6 km

vii) Cyclic period: Three year

viii) Length of distribution pipe in RSC-WS: 2,852 km

ix) Necessary manpower: 2,852km/ 3years/ 58.6km = 16.2 units

According to the above conditions, annual survey length is guessed as 58.6km per one Unit. As a result of this, annual survey length can be determined by capable manpower. (If it is 1 unit, then 58.6 km. Similarly, if it is 2 units, 117.2 km.)

If it is aimed to cover all area in 3 years, 16.2 units are required for it. (1 to 2 units are required in each OIC of all 13 OICs.)

2) Setting annual survey **by the target leakage ratio**

See the table 3.2.

- Conditions considered herein

i) Considered area: RSC-Western South

ii) Length of distribution pipe in RSC-WS: 2,852 km

iii) Annual production volume: 71,344,743 m^3

iv) Recurrence ratio of leakage: 15%

v) Target leakage ratio: evenly reduced to 15% from 19.6% of current figure in 5 year (In case of RSC-WS, leakage ratio might be replaced by NRW ratio because other components of NRW can be eliminated.)

Table 3.2 Annual survey length depending on target leakage ratio

	Item		Equation	Annual Plan				
				1st year	2nd year	3rd year	4th year	5th year
a	Initial Leakage Ratio of the year	%		**19.40**	**18.52**	**17.64**	**16.76**	**15.88**
b	Target Leakage Ratio after the Activity	%		**18.52**	**17.64**	**16.76**	**15.88**	**15.00**
c	**Approximate Survey Length**	**km**	l/n	**570**	**577**	**585**	**593**	**603**
d	Length of Distribution	km		2,852				
e	Production Volume	m3/year		71,344,743				
f	Initial leakage volume	m3/year	(a/100) *e	13,926,494	13,281,537	12,636,581	11,991,624	11,346,668
g	Initial Leakage Density	m3/hour/km	f/d/365/24	0.56	0.53	0.51	0.48	0.45
h	Recurrence Ratio of Leakage	%		15.00				
i	Increasable Leakage Volume in 1 year	m3/year	f*h/100	2,088,974	1,992,231	1,895,487	1,798,744	1,702,000
j	Target leakage volume	m3/year	(b/100) *d	13,281,537	12,636,581	11,991,624	11,346,668	10,701,711
k	Target Reduction Volume of Leakage	m3/year	f+i-j	2,733,931	2,637,187	2,540,444	2,443,700	2,346,957
l	Target Reduction Volume of Leakage (Unit Conversion)	m3/hour	k/365/24	312.1	301.0	290.0	279.0	267.9
m	Target Leakage Density	m3/hour/km	j/d/365/24	0.53	0.51	0.48	0.45	0.43
n	Average Leakage Density of Initial and Target	m3/hour/km	(g+m)/2	0.54	0.52	0.49	0.47	0.44

- Japan Water Research Center (2013). *Leakage Prevention Manual*

According to the above table, annual survey length can be automatically calculated when Initial Leakage Ratio and Target Leakage Ratio of each year is set.

Points of the table above

- The period of the plan is assumed to be 5 years.
- 19.40 % is being put as an initial leakage ratio of 1st year. (This is the figure of end December of RWC-WS. (source: NWSDB (2018). *KEY PERFORMANCE INDICATORS AS AT END DECEMBER 2018*) This figure should be replaced based on the actual situation.
- 15.00 % is being put herein as final target leakage ratio after 5th year.
- Each target leakage ratio from 1st year to 4th year is being calculated that it would be decreased equally every year.
- The period of the plan and final target leakage ratio should be set by particular responsible section after discussions. It is also better to be linked to the Corporate Plan of NWSDB generally.
- Note that recurrence ratio of leakage is being assumed herein as 15% referring one Japan's water utility. This assumption would be corrected with accumulated experiences and case studies in NWSDB.

Considering necessary maximum number of units under this plan, approximately 10 units are required, because 58.6 km/year is annual survey length per one unit.
$(570{\sim}603\mathrm{km/year} \div 58.6\mathrm{km/unit} = 9.8{\sim}10.4\ \mathrm{units})$

Again, note that this calculation is based on the idea that the density of leakage is equal in each part of the area. Hence if high-density areas or prioritized areas could be picked up with an analysis or experiences, Annual Survey Length can be decreased further.

Generally, features of the area where underground leakage tends to exist more than other areas are the following;

1. A lot of visible leakage
2. Thick road surface
3. Already installed sewerage
4. High water table

In other words, from No.2 to No.4 suggest that leakage hardly appears above ground. This might help consider to select a certain area for the leakage detection.

3.1.4 Preparation of map and record sheet

It is important to understand the current pipe layout properly for the activity. A mapping system is useful for this objective; information shall be updated, shared with staff in the organization regularly.

a) Map of pipe network

Following table shows the examples of the use in accordance with each scale of maps. All these are recommended to be shared with not only the officers of RSC but also O&M for the daily activity. Furthermore, a mapping system should be available in every O&M office, not only RSC office.)

Table 3.3 Use of map with scales

Scale	Description item	Use
1/10,000 -1/50,000	Treatment plant, Reservoir, Tower, Transmission network	Understanding of geographic feature, transmission system
1/2,500 – 1/5,000	Roads, Railroads, Distribution pipe network with diameter and material	For describing target areas for ALC Leakage map
1/500 – 1/1,000	Location of pipe, depth, etc.	Leakage detection work

b) Record sheet of leakage

To help analyze the tendency of leakage, leakage information should be recorded, accumulated, and shared with all staff that is in charge of leakage reduction work. As mentioned before, information that is recorded would be as follows;

1) Category: Visible or Invisible
2) Pipe: Material, Diameter, Age and Depth
3) Circumstance: Road surface, Traffic density, Soil type
4) Leakage: Location, Considerable cause, Leakage volume etc.

This might provide an idea as to which zones may have leakage intensively.

c) Daily work report

To help calculate the cost that are spent for the activity, several information as follows should be added to a daily work report.

1) Number of people in each class
2) Working hours and time
3) Contents of the activity
4) Equipment used

The Project for Enhancement of Operational Efficiency and Asset Management Capacity of Regional Support Center-Western South of NWSDB in Sri Lanka							
Serial Number							
Leak Repair Detail Sheet	National Water Supply & Drainage Board						
	Office						
	OIC			Zone			
	Officer						
Work day	Day			Time			
Attendance day	Day						
Work reason	Complain	Meter reader	Leak detection	Other			
Compainer's name & add							
Leakage location	Adress						
	Meter No.						
	Consumer No.						
	Coordinate						
Type of Leak	Meter	Connection pipe(Joint , pipe)	Ferrule	Distribution pipe			
Cause of Leak							
Nature of repair	Diameter & Material						
Leake repair	Yes		No		Leak volume		M3/h
Material of use							

Machinery Used		Location(Sketch)
(1)	Power Light (1.5.1)Hrs	
(2)	Night work (1.5.2)Hrs	
(3)	Water Pump(Dewatering)Hrs	
(4)	Others	

Measurment						
BOQ Item No.	Description	Unit	L(m)	B(m)	D(m)	Oty
Comment						

Contractor Officer ______________________

Zone Officer ______________________

NWSDB Officer ______________________

Figure 3.3 Sample of leakage record sheet

The information of leakage record sheet for the practical use seems enough for the site persons.

However, it is recommended to leave a report with photographs. The following photographs show the practice to report the construction site in Japan. The contractor took photographs stepwise, such as a full view of the construction site, excavation, connection work, after backfilling, with the blackboard which mentions the date, type of construction, location, name of the contractor, and additional information if necessary.

Photographs of construction site (example)

In case of leak repair, at least the process of the following four photographs is recommended to be taken with the blackboard/ white board indicating the leakage repair information.

- Leka repair point before repair
- After repair
- After backfilling
- After reinstatement

3.2 Setting DMA * Only in case of DMAs method

3.2.1 Concept

Creating a DMA (District Metered Area) is the technic of leakage monitoring. This technic requires the installation of flowmeters at certain points in the distribution network, each meter recording the flows into a discrete area with a defined and permanent boundary.

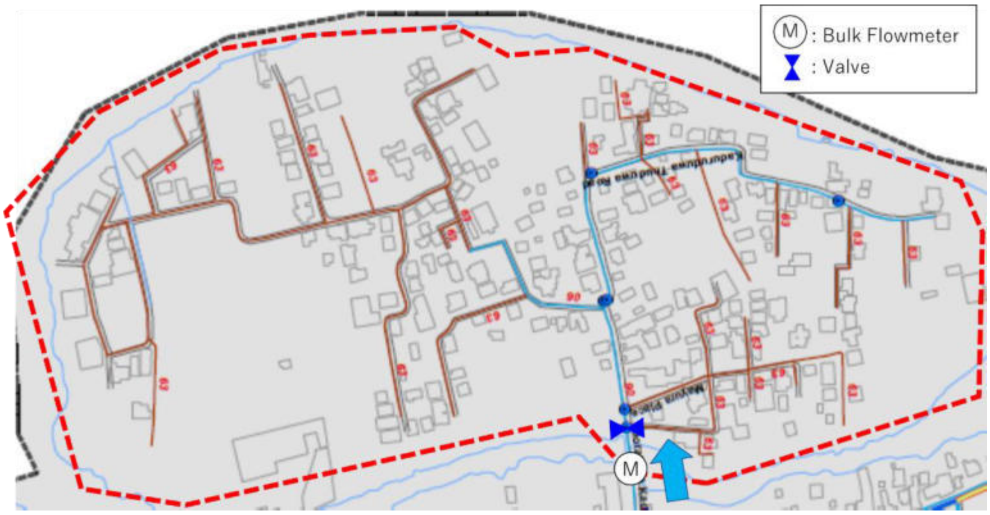


Figure 3.4 One of DMAs in JICA project

3.2.2 Purposes

To divide the distribution network into a number of DMAs, so that night flows into each district can be regularly monitored, enabling the existence of unreported leakage to be identified and located.

3.2.3 Structure of distribution network system

First of all, before designing DMAs, structure of current distribution network system shall be checked. Preparing a schematic drawing would help understand the network system. Simple structure, which is following a simple discipline, is always better for operating and managing the system. For example, distribution pipes can be divided into 2 categories, as a principal main and a rider main. Then, a principal main always shall feed rider mains, where larger rider mains always shall feed smaller rider mains, basically. Besides, principal main shall not feed smaller rider mains, by-passing larger rider mains. Additionally, the following factors should be followed ideally;

- Only rider mains, not a principal main, shall feed service connections.
- Other rider mains on same roads do not front rider mains, therefore old lines should be banned as soon as possible when new lines are laid.
- Exceptionally, 2 lines of rider main would be laid on both sides of wider road, which has pavement on both sides, to avoid service connections crossing long length of the roads.

The factors mentioned above always should be kept in mind when creating the layout of pipes to maintain a good network system.

3.2.4 Design criteria

Several factors should be taken into account when designing a DMA, as follows;

- Size
- Boundary
- Hydraulic modeling
- The number of flowmeters
- Variation of Ground Level

a) Size

DMA size is usually determined by the number of connections or the length of distribution pipe within the DMA. In practical situations, smaller DMAs have several advantages compared to larger DMAs as follows:

- Smaller leaks can be identified against the Legitimate Night Use.
- Survey time can be reduced.
- Survey cost will be reduced

After all, smaller DMA can be maintained in lower level of leakage. If a DMA is larger than 5000 connections, it becomes difficult to discriminate small bursts from night flow data, and it takes longer to locate.

Smaller DMAs, on the other hand, will tend to be costly because larger number of DMA are needed to divide out existing distribution network system, hence establishing a balance between these features is needed.

In practice, the size of an individual DMA will vary, depending on how boundary can be created actually. Hydraulic conditions and economic factors, in general, are the significant keys to determine the size of DMAs.

b) Boundary

Individual DMA has to be independent from other DMAs hydraulically, so that the DMA should be disconnected from the network except feeding points. Physical discontinuity points of the network can be traced as a boundary to avoid any repercussions to the existing service. For this purpose, the boundary valves shall be separately identified using separate marker posts. Otherwise, the closing valve will be needed for making boundary. Normally, it is better to limit the number of closing valves. Hence, a boundary should be designed to cross as few mains as possible.

In any cases, influences should be checked whether decrease of water pressure and increase of travel time of water would be acceptable or not. Testing by hydraulic modeling is always useful for this matter. Or if possible, it can be tested by creating the situation in actual site on a trial basis.

As the **figure 3.5** is showing, if the current pipe layout is the “arborescent type”, natural boundary line (discontinuity points) could be found easily, then, such lines are used as a boundary of the DMAs without any bad repercussions. If it is the “network type”, valve-closings are needed for creating a DMA. At that time, note that larger distribution pipes should be involved as a main line of each DMA. Furthermore valve-closings had better be done in smaller lines to lessen the repercussions.

c) The number of flow meter

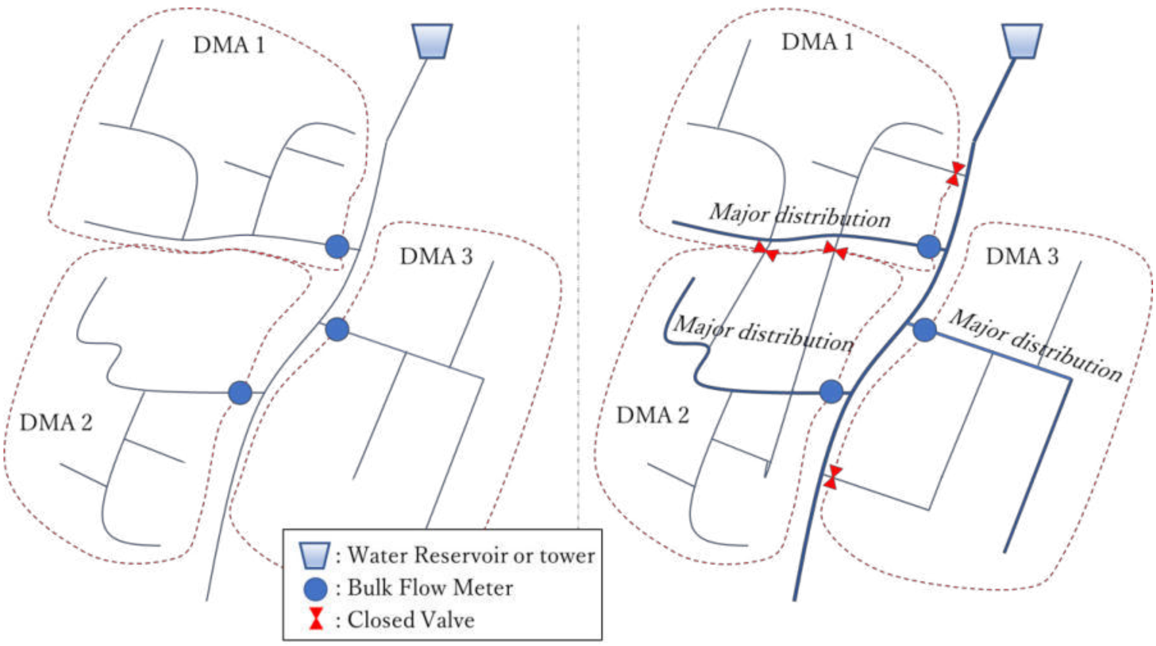
Flow meters must be installed to feeding points (outlet points also, if it cannot avoid having them). Generally, the lesser number of meters is recommended from the viewpoints of accuracy of flow measuring and maintenance cost. If a DMA contains several meters, measuring flows into/out of the district could result in misleading leakage levels because of compounding errors in flow calculations. Thus, it is better to limit the number of flow meters. This means that the number of feeding points should be limited. Negative repercussions that may be caused by this can be checked by hydraulic modeling, if needed.

d) Hydraulic analysis

As mentioned above, closure of valves and limiting of feeder points will influence the existing network system. Hydraulic analysis can simulate how the creation of DMA will influence the existing network. It must be simulated how much water pressure will drop, how long travel time of water will extend. Furthermore, they should be simulated in adverse condition. Then, water pressure should be simulated in the condition of peak time when many people use water service. Travel time should be simulated in the condition of average time.

e) Ground level variation

Minimum variation in ground level across the DMA is recommended. Furthermore, it would be better to take into consideration High/Low pressure problems that certain areas may have, so that those can be managed by installing booster pumps or pressure reduce valves into inlet points. (**Figure 3.6**)



(a) Arborescent type **(b) Network type**

Figure 3.5 Image of DMAs in accordance with differences of pipe layout type

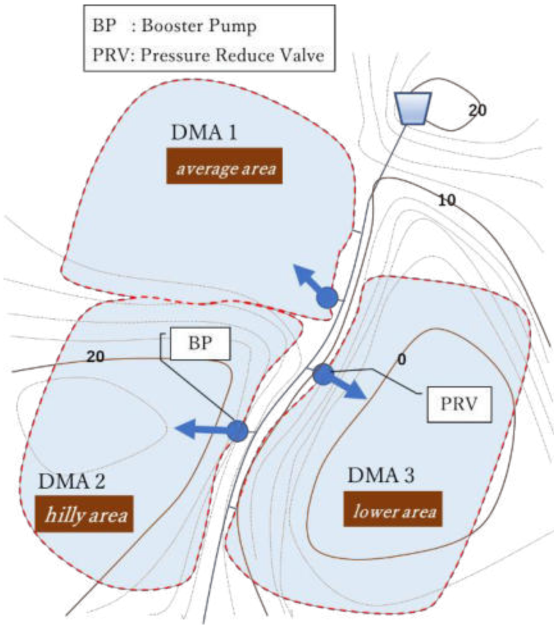


Figure 3.6 Image of DMAs by each elevation

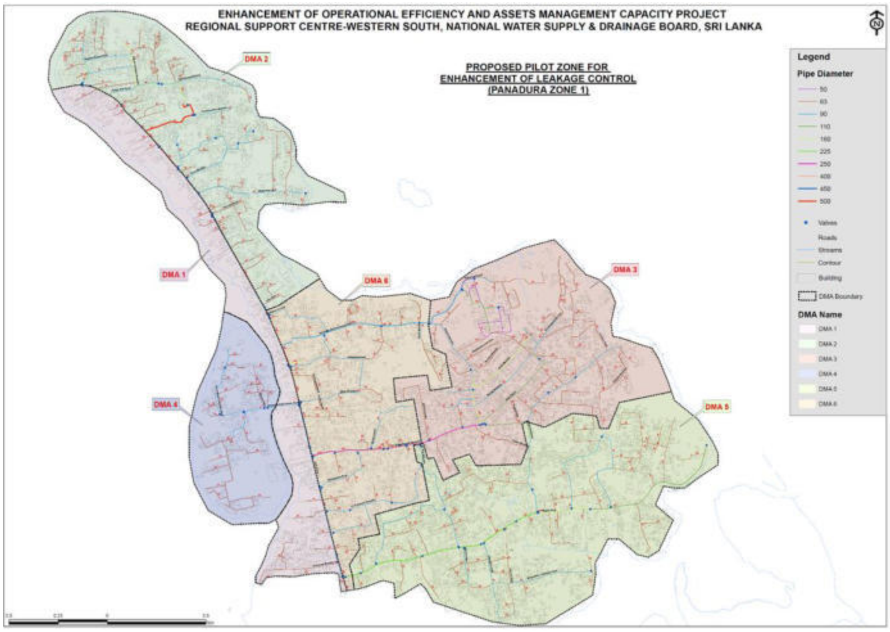


Figure 3.7 Established DMAs under JICA project

3.2.5 Design procedure

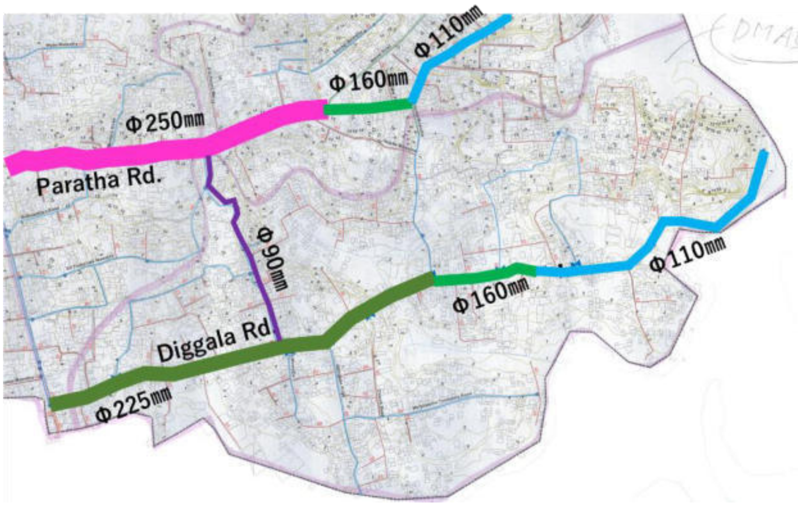
a) Collect local knowledge, available database about a network system

DMA designer must collect and utilize local knowledge from officers who are familiar with a network and available database, such as GIS map, as-built drawing, and contour map, etc. All of those are combined as one pipe network map. Necessary information is as below;

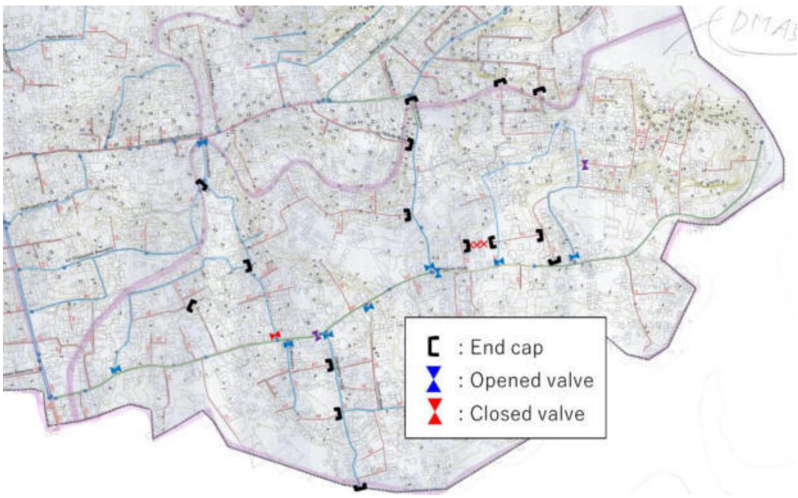
- Pipe-network condition
- Pipe-diameter
- Valve-location
- Local reservoir-location
- Contour

b) Do site survey

Do site survey to check whether accumulated information is correct or not, especially for the pipe network-condition and valve-location. Pipe-tracing and valve-locating should be done as necessary. In case that there are any differences found between accumulated information and actual condition, those should be corrected on the pipe network map. Operability of valves also should be checked in this occasion.



(i) Grasping the outline of major pipe layout structure

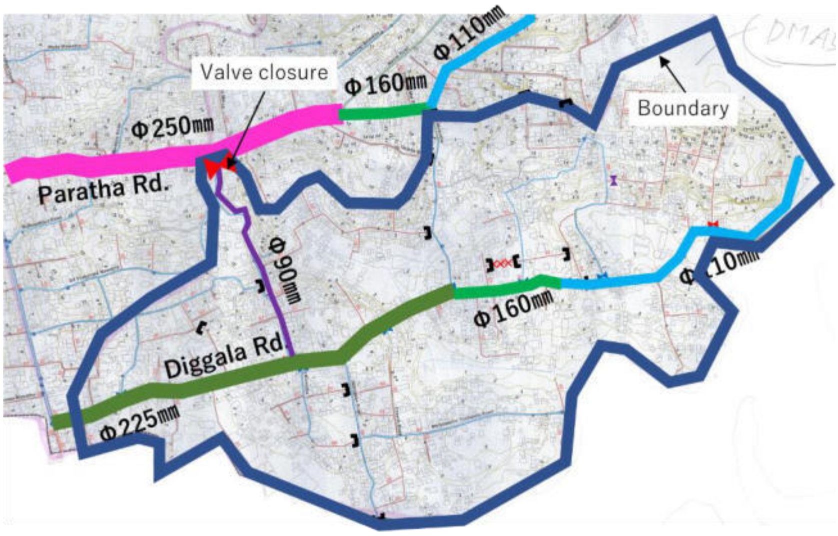


(ii) Grasping pipe network condition and valve location/status

Figure 3.8 Site survey result for one of DMAs in JICA project

c) Design boundaries and feeder points of the DMA

Design boundaries and feeder points of the DMA on the map with the following criteria mentioned in the previous section.



Note: In this case, discontinuity points are traced as much as possible for the boundary to avoid bad repercussions. Only one valve-closure is needed.

Figure 3.9 Boundary of one of DMAs in JICA project

d) Check influences that may be caused by creating the DMA

After the design of the DMA boundaries, trial closure of the boundary valves should be undertaken to verify their effect. Furthermore, the pressure of the highest point inside the DMA also should be monitored if it has the ability to cope with even during peak time. If hydraulic modeling is available, run the modeling to check whether the conditions of the system after creating the DMA are acceptable or not.

A common problem encountered in the actual situation, is the existence of unknown connections or partially closed valves. Therefore, site survey should be carried out to identify problems.

e) Install necessary valves

Once the check is done, necessary valves should be installed and closed to make boundaries.

Note: In this case, boundary valves are not needed

Figure 3.10 Valve Installation

f) Install necessary flow meters into feeder points

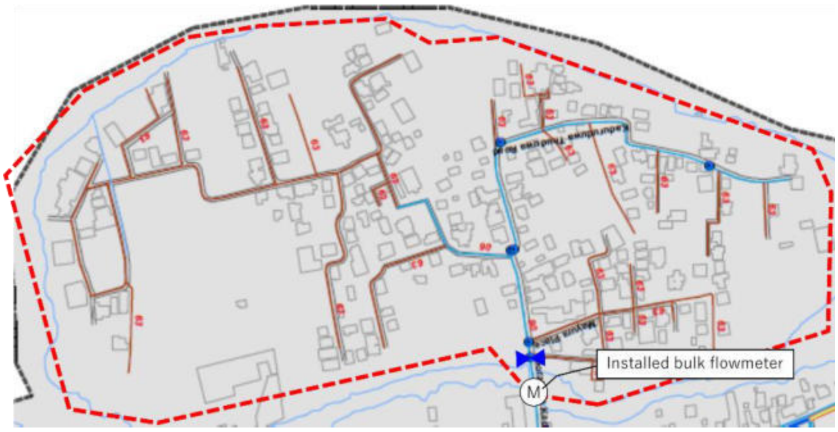


Figure 3.11Flowmeter Installation

See the section 3.2.7 for the detail of meter selection and installation.

g) Check boundary and carry out drop test

Once necessary valves and meters have been installed, valves should be operated to establish the DMA, and then drop test should be carried out. This involves closing the supply to the DMA and checking that the pressure drops towards zero. All boundary and divisional valves should be sounded to check whether the valves are tight. If faulty valves are found these should be rectified and the drop test repeated.

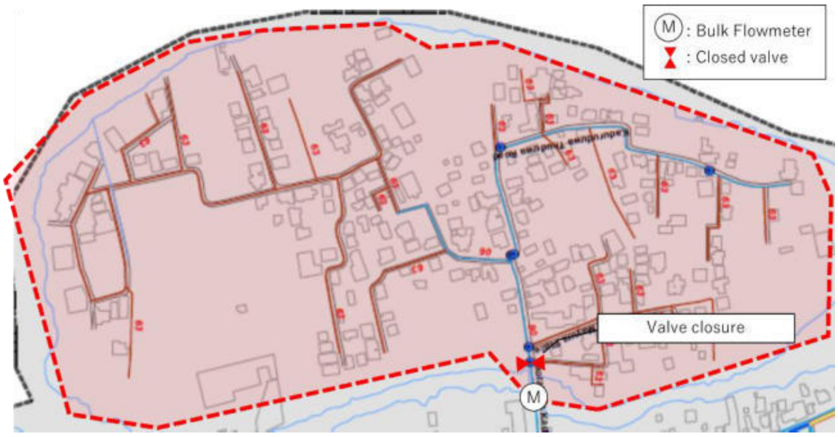


Figure 3.12 Drop test

3.2.6 Setting subzones for Step Test

Step Test is to localize particular zones where larger leakage exists inside the DMA. If Step Test is planned, the DMA should be divided into several numbers of subzones by divisional valves. If needed, new valves could be installed for the test. Hence, this matter should be taken into account in the design stage of DMA.

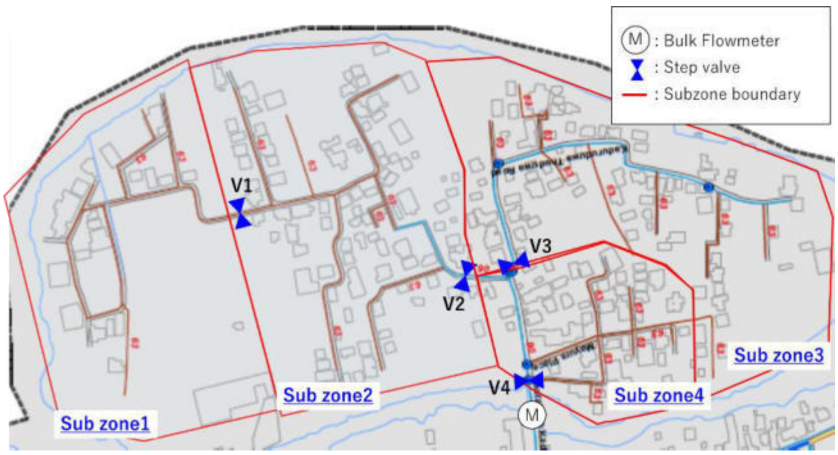


Figure 3.13 Example of subzones

The area of each subzone should not be too large, should not be too partial. It is recommended that the length of distribution pipe should be under 10km at most.

The procedure of Step Test is described in the section of 3.4.2.

3.2.7 Meter selection and installation

a) Bulk meter selection for monitoring NRW

For selecting a bulk meter, size of meter, flow range and head loss should be taken into account. The flow range can be predicted by a hydraulic model if it is available. If not, it can be estimated from information as below;

-The number of connections
-Average consumption per connection
-Exceptional use of over 500 liter per hour (for maximum flow, if it exists.)
-MNF (for minimum flow, it can be measured by ultrasonic/electric-magnetic meter that can be applied temporarily. See the section 2.2.1 for MNF measuring.)

For the correct measurement of flow rate, the full flow condition should be maintained.

The manual named "Leakage management and control", which was compiled by World Health Organization in 2001, can be referred to for both flow range and head loss of a bulk meter. The following tables are given by it.

Table 3.4 Meter size and flow range (in case of KENT Helix 4000 meters)

Meter size(mm)	80	100	150	200
Maximum flow (m^3/h)	200	250	600	1000
Recommended continuous flow (m^3/h)	120	180	450	700
Minimum flow (m^3/h)	0.5	0.6	2	4

Table 3.5 Meter size and the number of connections

No. of connections	Meter size(mm)
Less than 1000	80
1000 to 1500	100
More than 1500	150

Table 3.6 Meter size and head loss

(a) 80mm Dia.

No. of connections	Expected peak flow (liters/sec)	Expected peak flow (m^3/h)	Meter head loss (m)			K value
			80 mm meter	Headless across fittings	Total head loss	
500	7.23	26.04	0.10	0.61	0.71	5.74
1000	14.47	52.08	0.04	2.43	2.47	5.74
1500	21.70	78.13	1.00	5.46	6.46	5.74
2000	28.94	104.17	1.50	9.70	11.20	5.74
2500	36.17	130.21	2.20	15.16	17.36	5.74
3000	43.40	156.25	3.80	21.83	25.63	5.74

(b) 100mm Dia.

No. of connections	Expected peak flow (liters/sec)	Expected peak flow (m^3/h)	Meter head loss (m)			K value
			100 mm meter	Headless across fittings	Total head loss	
500	7.23	26.04	0.10	0.61	0.71	5.74
1000	14.47	52.08	0.04	2.43	2.47	5.74
1500	21.70	78.13	1.00	5.46	6.46	5.74
2000	28.94	104.17	1.50	9.70	11.20	5.74
2500	36.17	130.21	2.20	15.16	17.36	5.74
3000	43.40	156.25	3.80	21.83	25.63	5.74

(c) 150mm Dia.

No. of connections	Expected peak flow (liters/sec)	Expected peak flow (m^3/h)	Meter head loss (m)			K value
			80 mm meter	Headless across fittings	Total head loss	
500	7.23	26.04	0.00	0.05	0.05	5.74
1000	14.47	52.08	0.00	0.20	0.20	5.74
1500	21.70	78.13	0.00	0.44	0.44	5.74
2000	28.94	104.17	0.10	0.79	0.89	5.74
2500	36.17	130.21	0.20	1.23	1.43	5.74
3000	43.40	156.25	0.26	1.77	2.03	5.74

b) Ultrasonic/Electro-magnetic meter selection for MNF measurement and step test

Ultrasonic/Electro-magnetic meter, mostly, have enough repeatability for MNF measurement and step test. These meters would be set temporarily for the specific purposes, such as MNF measurement and step test. An ultrasonic type needs only a certain length of pipe for setting to outside of a pipe. An electro-magnetic type, if it is insertion type, needs a certain tapping point that the meter can be set to. e.g. ferrule

A chamber would be fixed for these meters. Location of these meters can be either upstream of bulk flow meter or downstream of it. However, it should be upstream of first branch or first connection. Furthermore, necessary length of straight pipe shall be taken into account at the installation.

Table 3.7 Necessary straight pipe length

[D: Pipe diameter]

Section	Ultra-sonic flow meter		Insertion type electro-magnetic flowmeter	
	Upstream	Downstream	Upstream	Downstream
90°bend	10D	5D	25D	No need to consider
T bend	50D	10D	25D	
Expanding	30D	5D	-	
Contracting	10D	5D	-	

Note;

- Above information of ultra-sonic flow meter refers to JEMIS032-1987(Standards of Japan Electric Measuring Instruments Manufacturers' Association).
- Above information of electro-magnetic flow meter refers to UNI10727_1998(Italian Organization for Standardization)
- Above values of the electro-magnetic flow meter are valid for a measurement on the axis of the pipe (Means that censor should be set on the center of the pipe.).

c) Installation

A flow meter should be installed to the inlet point. The space for an ultrasonic flow meter or an electro-magnetic flow meter should be also prepared at this occasion.

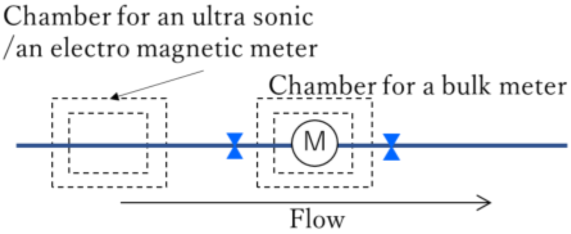


Figure 3.14 Installation of a bulk meter and valves

Further, a bypass line and a wash-out, sometimes, would be advised to be installed around the meter. The site survey should be used to investigate the best site for excavations, using verges in preference to footpaths, and bearing in mind that the area of excavations necessary is considerable. The main advantage of a bypass installation is that the meter can be easily isolated for maintenance without disrupting the supplies. Wash-out is for removing retained water when changing flow line between the main and the bypass.

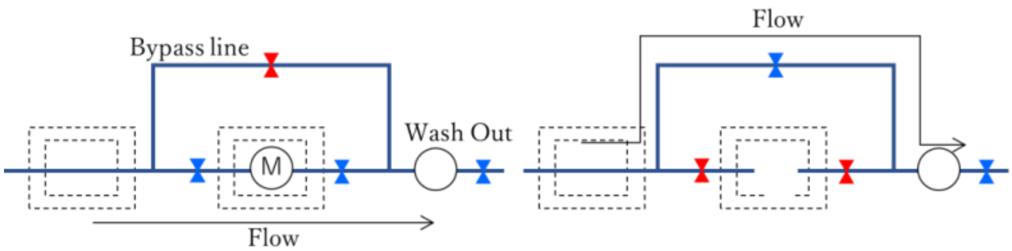
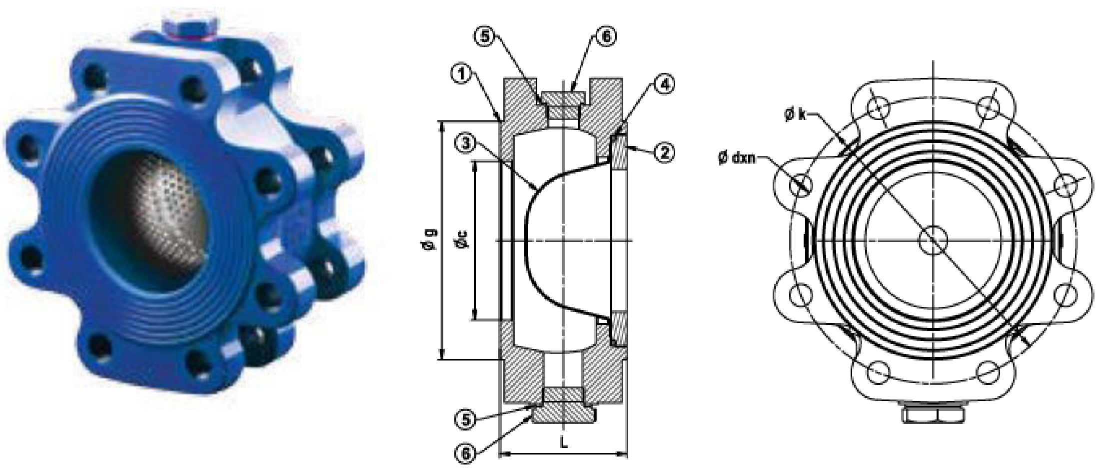


Figure 3.15 Bypass line around a bulk meter

In areas with a history of dirty water problems, it may be necessary to include a strainer in the installation of a bulk meter. An example is provided in the figure below.



Nominal Pressure	PN	16 bar					
Nominal Diameter	DN	40	50	65	80	100	125
Dimension	L	50		65		80	100
	D	84	99	118	132	150	184
	c	40	50	65	80	100	125
	k	110	125	145	160	180	210
	dxn	19x4			19x8		
Weight	Kg	2.5	3	3.8	5.2	6.6	9.8
Filter	Thickness (mm)	1					1.5

Nominal Pressure	PN	16 bar					
Nominal Diameter	DN	150	200	250	300	350	400
Dimension	L	125	150	200	250	300	350
	D	208	266	319	370	429	481
	c	150	200	250	300	350	400
	k	240	295	355	410	470	525
	dxn	23x8	23x12	28x12		28x16	31x16
Weight	Kg	14.7	23.5	38.6	56.6	82.2	106.4
Filter	Thickness (mm)	1.5		2			

Figure 3.16 Example of a strainer (For reference)

d) Remote monitoring

Considering the introduction of remote monitoring, it is recommended the use of Electromagnetic flowmeter. Mechanical type water meter (Waltman type) has an advantage in the initial cost, and it does not need the power supply. However, if you think to introduce the remote monitoring system and put the sensing system on the mechanical flowmeter, the benefit in the cost will be canceled.

Electromagnetic flowmeter uses the theory of Faraday's Law of Electromagnetic Induction, so that it needs power supply but does not need mechanical part which generates head loss.

Appendix 3 explains how to introduce the remote monitoring system in DMA, that carried out in the pilot study of the project. The Electromagnetic flowmeter with pulse signal output was installed with pressure sensors and logger. Components of the system is shown in Figure 3.17.

It is recommended that the pressure also measured at the same time.

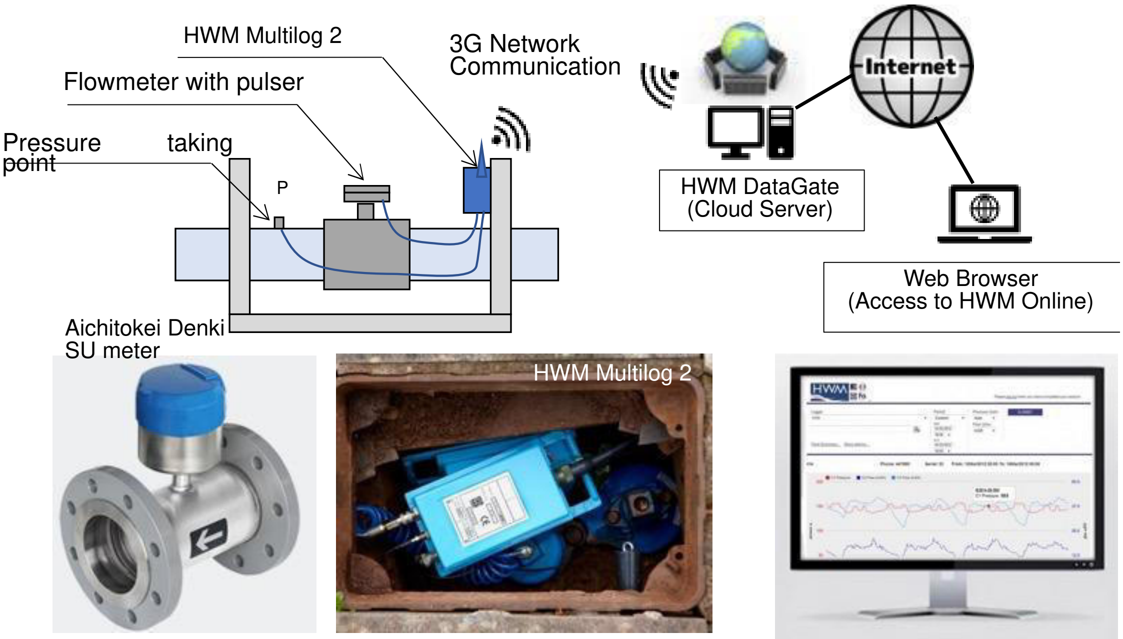


Figure 3.17 Simple remote monitoring system with the Electromagnetic Flowmeter with Pulser

3.3 Setting Acceptable Leakage Rate * Only in case of DMAs method

Acceptable Leakage Rate is the figure of indication to check whether the activity should be carried out or not in a target area.

A particular value of the Acceptable Leakage Rate cannot be defined in general, it depends on the situation. However, the example that is set by a target leakage ratio is shown as below;

- Condition of the calculation - In case of considering whole area of RSC-WS

1) Target Leakage Ratio: 15%
2) Input Volume of Target Area: 71,344,743 m3/year → 8144.38 m3/hour
3) Distribution Pipe Length of Target Area: 2,852km
4) Cyclic Period of the Activity : 3 year
5) Recurrence Leakage Ratio: 15%

$$\begin{aligned} &\mathit{Acceptable\ Leakage\ Rate} \\ &\quad = \mathit{Target\ Leakage\ Ratio} \times \mathit{Input\ volume} \\ &\quad \div (1 + \mathit{Recurrence\ Leakage\ Ratio})^{\mathit{Cyclic\ Period}} \\ &\quad \div \mathit{Distribution\ Pipe\ Length} \end{aligned}$$

$$= 0.15 \times 88{,}144.38\ m^3/hour \div (1 + 0.15)^3 \div 2{,}857\ km$$

$$\underline{= 3.04\ \ m^3/hour/km}$$

<u>This equation means;</u>

If the leakage volume per unit length of a particular target area is less than Acceptable Leakage Rate, it means that leakage volume is not going to grow beyond the target ratio during the period of the Cyclic Year. Therefore, the activity of that target area can be skipped.

The result of the Step Test and the comparison of Acceptable Leakage Rate are shown in section 3.4.2.

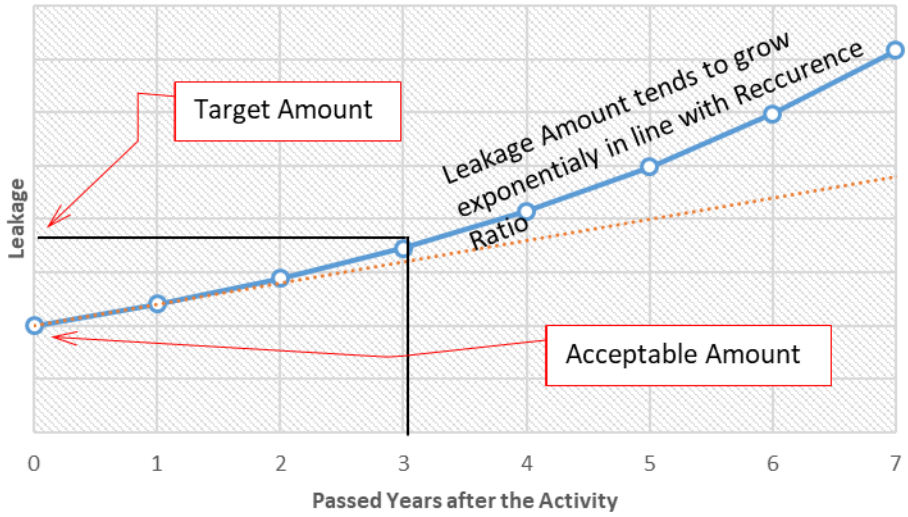


Figure 3.18 Target Leakage Amount and Acceptable Leakage Rate

(In case that Cyclic Period is 3 year)

3.4 Estimating of leakage volume in a DMA method * Only in case of DMAs

This could be done by MNF measurement or step test.

3.4.1 MNF measurement

a) Purpose

To guess the amount of existing leakage volume

b) Preparation

1) Necessary equipment: Ultrasonic/Insertion type flowmeter, Pressure loggers, Valve key, mobile phone

2) Number of people: 1 for chief of the activity, 2 for workers (It depends.)

c) Procedure of MNF measurement

Measurement period should include the period from 12 midnight to 4 a.m. because the least consumption might appear in that period normally. If major consumers are being identified, it is best to close their stop valves beforehand. (Or measure those consumptions separately.)

Table 3.8 Sample procedure of MNF measurement

Before 12 midnight	1) Set the lighting facilities. (If needed.)
↓	2) Set the ultra-sonic/electromagnetic flow meter to the inlet point.
	3) Set the pressure logger to particular point inside the DMA. (Highest point is the best to check whether the pressure reduces or not properly.)
After 4:00 a.m.	4) Remove the flow meter and the pressure logger.
	5) Remove the lighting facilities.

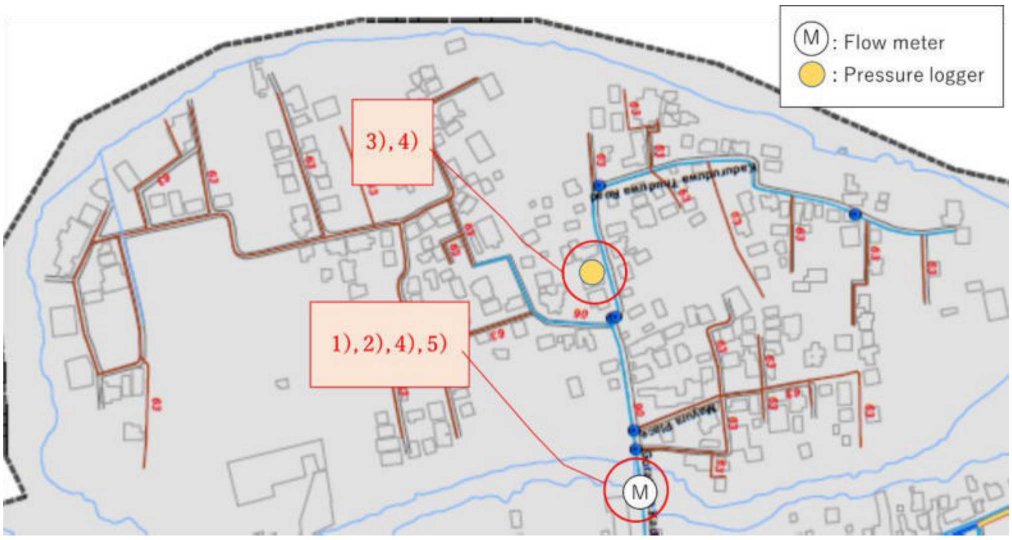


Figure 3.19 Procedure of the MNF measurement

d) After the activity

- Take out recorded data from the flow meter and the pressure logger
- Take a minimum flow rate, which is recorded as the figure of MNF
- Estimate the leakage volume by MNF
- Calculate Acceptable Leakage Rate with the latest average flow rate recorded by installed bulk flow meter and the Target Leakage Ratio set
- Make a decision as to whether the activity is needed or not by comparison of above-mentioned leakage volume and Acceptable Leakage Volume
- Start the leakage survey if needed

Figure 3.20 Setting an Ultra-Sonic Flowmeter

3.4.2 MNF measurement and Step Test

a) Purpose

- To guess the amount of existing leakage volume by MNF measurement.
- To localize particular zones where larger leakage exists by Step Test

b) Preparation

1) Necessary equipment: generator, light facility, ultrasonic/insertion type flowmeter, pressure loggers, valve key, hand torches, mobile phone

2) Number of people: 1 chief of the activity, 3 workers (It depends on the area)

c) Procedure of MNF measurement and Step Test (In case of the DMA that has 4 Subzones)

The table below shows the case under JICA project.

Table 3.9 Sample procedure of MNF measurement and Step Test

12:30 p.m. ↓	1) Set lighting facilities. 2) Set the ultra-sonic/electromagnetic flow meter to the inlet point. 3) Set the pressure loggers to the particular points in each subzone. (The highest point in each subzone are the best to check the pressure reduction after each step) 4) Check the operability of all step valves, and being fully opened.
1:30 a.m.	5) Close the step valve 1 and record the time of the operation.
1:45 a.m.	6) Close the step valve 2 and record the time of the operation.
2:00 a.m.	7) Close the step valve 3 and record the time of the operation.
2:15 a.m.	8) Close the step valve 4 and record the time of the operation.
2:30 a.m.	9) Open the step valves in reverse order. 10) Remove the ultra-sonic flow meter and pressure loggers. 11) Remove lighting facilities.

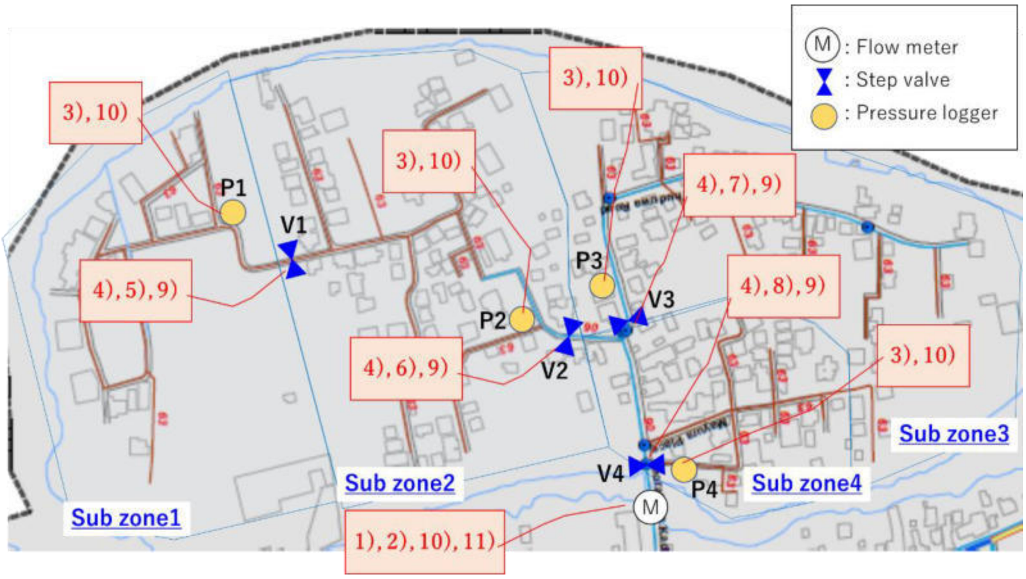


Figure 3.21 Procedure of the Step Test

d) After the activity

1) Take out the recorded data from the flow meter and the pressure loggers

2) Take a minimum flow rate, which is recorded before the first step as the figure of MNF

3) Similarly, take minimum flow rates, which are recorded between each step as flow rates in each step

4) Calculate the Average Drops in each step, using minimum flow rates of each step

5) Estimate the leakage volume of whole DMA from MNF

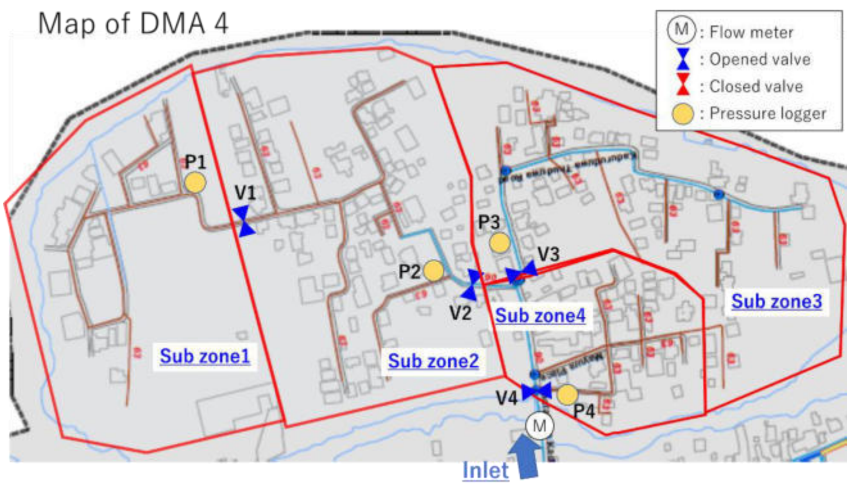
6) Similarly, estimate the leakage volume of each subzone from each Average Drop

7) Calculate Acceptable Leakage Rate with the latest average flow rate recorded by installed bulk flow meter and the Target Leakage Ratio set

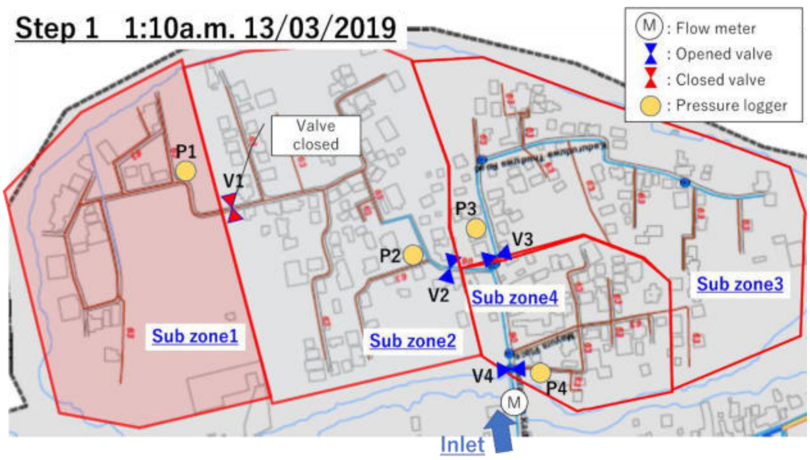
8) Make a decision as to whether the activity is required or not by comparison of the above-mentioned leakage volume and Acceptable Leakage Volume

9) Localize particular zones where larger leakage exists by each Average Drop

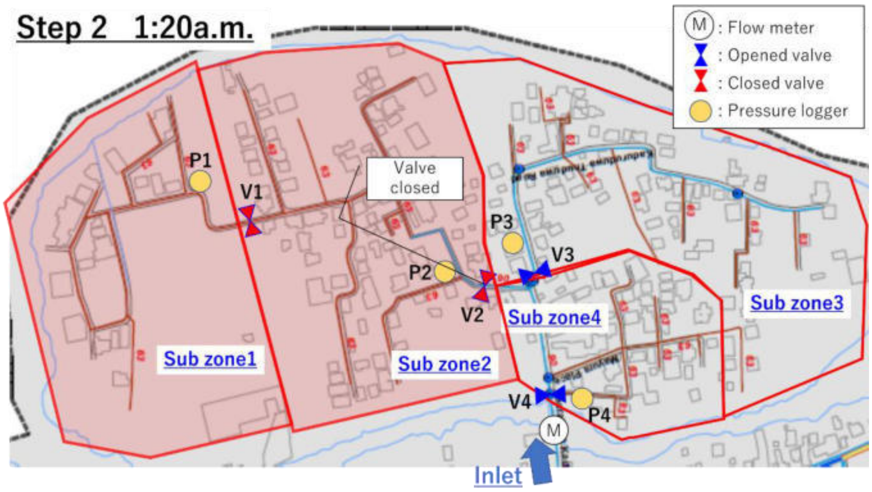
10) Start the leakage survey under the decision



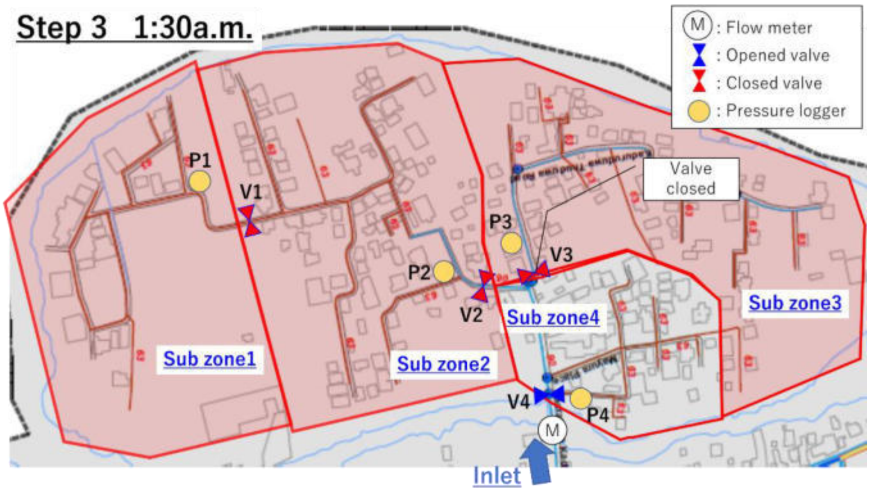
(a) Before the operation



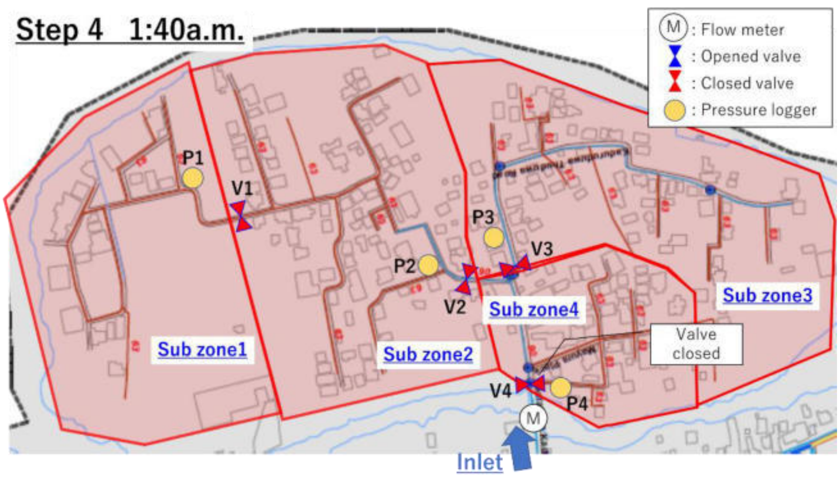
(b) Step 1



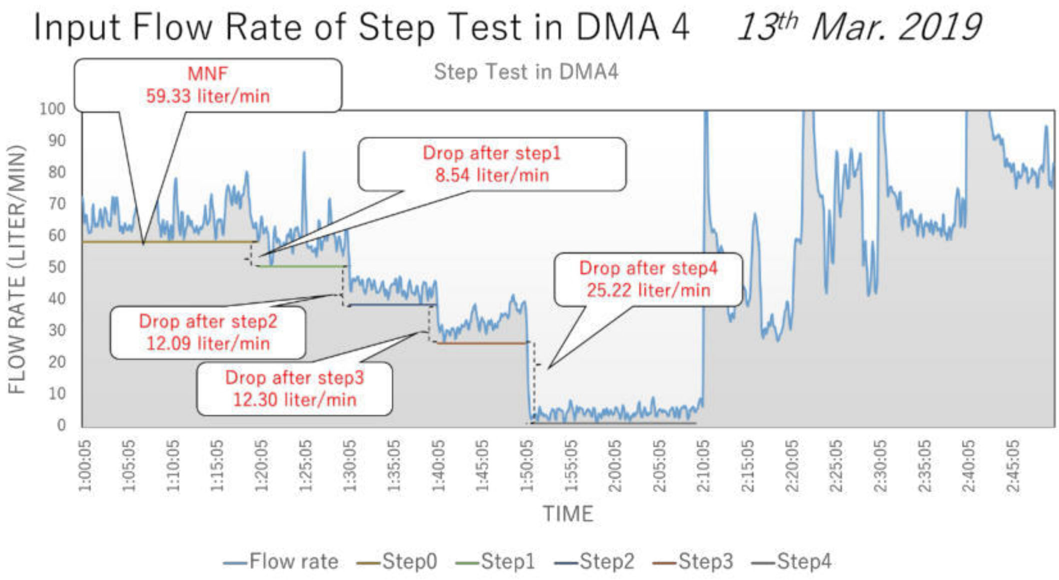
(c) Step 2



(d) Step 3



(e) Step 4



(f) Time series data of the input flow rate while the Step Test

Figure 3.22 Result of the Step Test in the DMA under JICA project

Table 3.10 Summary of the result of the Step Test

Item \ Sub Zone		Equation	Unit	1	2	3	4
a	MNF	From the MNF	*litre/min*	59.33			
b	Average Drop	From the Step Test	*litre/min*	8.54	12.09	12.30	25.22
	Average Drop [Unit conversion]		*m^3/hour*	0.51	0.73	0.74	1.51
c	Connections	Counted while the activity	*nos.*	47	107	89	85
d	Persons	=c*4.8	*nos.*	225.6	513.6	427.2	408.0
e	Legitimate Night Use	=d*0.0006 [Refer to section 2.2.1]	*m^3/hour*	0.14	0.31	0.26	0.24
f	Night Leak	=b-e	*m^3/hour*	0.37	0.42	0.48	1.27
g	Water Losses [Average Leak]	[Refer to section 2.2.1]	*m^3/hour*	0.33	0.37	0.43	1.39
h	Length of distribution pipe	Should be from Mapping	*km*	1.3	1.3	1.2	0.8
i	**Water Losses per Unit Length**	**=g/h**	***m^3/ hour/km***	**0.25**	**0.28**	**0.36**	**1.74**

Herein calculation of Acceptable Leakage Rate and considered conditions for it are as follows;

Conditions:

- Average Input Volume: 257.5 m^3/day $\rightarrow$ 10.73 m^3/hour (From one month data of Mar. 2019)
- Pipe Length: 4.6 km (From GIS map)
- Target Leakage Ratio: 15 % (Assumed figure)
- Recurrence Leakage Ratio: 15% (Assumed figure)
- Cyclic Year: 3 year (Assumed figure)

$$Acceptable\ Leakage\ Rate$$

$$= Target\ Leakage\ Ratio \times Input\ volume \div (1 + Recurrence\ Leakage\ Ratio)^{Cyclic\ Period} \div Pipe\ Length$$

$$= 0.15 \times 10.73\ m^3/hour \div (1 + 0.15)^3 \div 4.6\ km$$

$$= \underline{0.23\ m^3/hour/km}$$

As shown in the above table, there are no subzones where "Water Losses per Unit Length" is less than Acceptable Leakage Ratio. Therefore, leak survey should be carried out in all subzones.

3.5 Leakage detection

Leakage detection is carried out by sounding equipment mainly in the following manner.

3.5.1 House to house survey

↓

3.5.2 Road survey

↓

3.5.3 Identification survey

3.5.1 House to house survey

a) Purpose

House to house survey is carried out to identify leakage sound from exposed parts of pipes, service pipes in particular, using an acoustic bar.

b) Preparation

- Pipe network map of target area
- Acoustic bar
- Marking spray
- Operator, Recorder

c) Procedure

1)	Visit each house to check whether leakage sound exists or not with acoustic bar.	
2)	Before sounding, confirm that the consumer is not using water or water tank is not being filled. If necessary, stop valve should be closed.	
3)	In case that leakage sound may exist, try to guess the leakage location or the distance from the sounding point by the sound volume. Mark nearby ground by a spray so that it can be identified later, when conducting the identification survey. (described in section 3.5.3) If no leak sound exists, move to next.	
4)	Record/Write down the location and other necessary information on the map. (See the figure below.)	

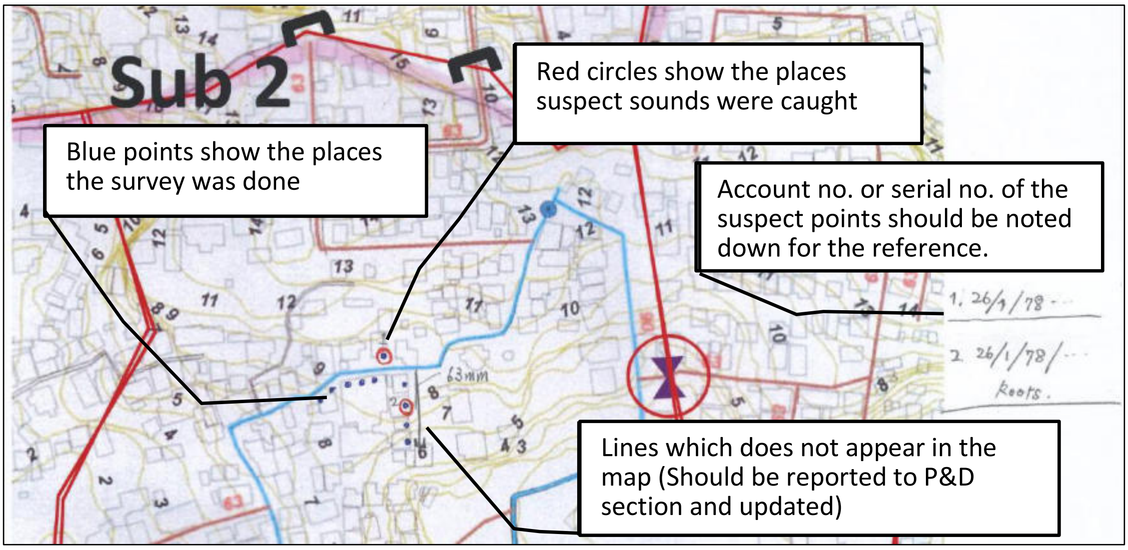


Figure 3.23 Example of Survey Map

Note that there are several features of acoustic bar as follows;

Table 3.11 Particular features of acoustic bar

Propagation of sound	Long	Short
Pressure	High	Low
Leak volume	Large	Small
Pipe Diameter	Small	Large
Pipe Material	Metal	Plastic
Soil Density	High	Low

a

Table 3.12 Sample of audible distance <u>in case of 3 bar - pressure</u>

Propagation of sound	Distance (m)	Dia. of Leak Hole (mm)
Lead (1/2”)	43 - 58	2 – 3
PVC (1/2”)	29 - 32	
Iron with socket joint (100mm)	14 - 26	2 - 10

d) Tips for the use of acoustic bar

- Should not grab the metal part. Should support the rubber part of ear pad when used.
- Should not press your ear to the ear pad strongly. Maintain a slight gap between your ear and the ear pad.
- Flick the stick with your nail to check better position for the listening.
- Checking water flow sounds at an actual site by turning on a particular tap on a trial basis is recommended. Training at the training yard is also useful.
- Don't take more than 10 seconds for the listening. Quick listening, quick judgement is better. (Only pick up clearer sounds.)
- Leak sound tends to be constant in points of pitch and volume. If it is not, it might not be a leak. Sounds of ACs, fans are the most things that are likely to be misidentified.

e) Searching defective meters and illegal connections

On the occasion of the survey, the followings should be checked.

Whether;

- meter locates appropriately
- meter is working properly
- there is no illegal connection (meter bypass, reconnecting of disconnected consumer)

If any of the above are identified to be problematic or abnormal, it should be reported to a responsible officer, and corrected.

Note that possible measures to reduce theft of water is described in the document of NWSDB, which is *NRW ENGINEERING STUDY FOR COLOMBO CITY*. (see Appendix 7)

3.5.2 Road survey

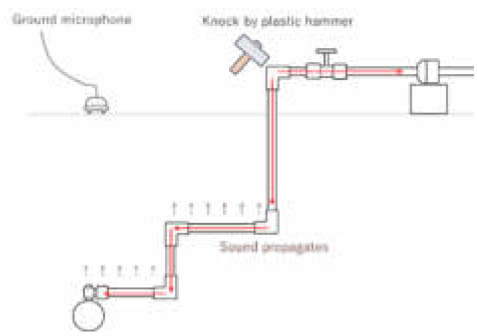
a) Purpose

A road survey is conducted to identify leakage sounds coming from buried parts of pipes, which would be mainly distribution pipes, using a Water Leak Detector (ground microphone).

b) Preparation

- Pipe network Map of target area
- Water leak detector
- Marking spray
- Plastic hammer or Pipe detector (for Meatal or Non-metal)
- Operator, Recorder

c) Procedure

1)	Walk on the road along the top of the pipe line. Then try to identify the existence of leak sounds by putting the microphone on the line in every few meters.	
2)	In case that a location of pipes is not clear, pipe tracing by a pipe detector is needed beforehand.	
3)	Combination of a water leak detector(a ground microphone) and a plastic hammer are also useful for detecting the location of the pipe. Watar leak detector can detect the propagating sounds from the buried distribution pipe when tapping exposed parts of the service pipe by a plastic hammer.	
4)	Once a leak soundis identified, locate the point where the highest level is.	

5)	Record the point on the map.	
6)	Mark the point on the road by a marking spray. Be careful of wind direction to avoid damaging surrounding properties when using a marking spray.	
7)	If highest point cannot be located definitively, the marking point better be checked by identification survey later. Identification survey is described in the next section.	

d) Tips for the use of Water leak detector

- It requires a certain level of experience to identify differences between leak sounds and other noises
- Checking those differences at an actual site by turning on a particular tap on trial is recommended. Training at the training yard also can be useful.
- Leak sound tends to be constant. If there are variations to the sound, such as the pitch and the volume, then it may not be a leak.
- Conducting a road survey with a Water leak detector is a tedious task. It is advisable to take a break every 30 minutes.
- Mostly, water leak detector has a function of sounds frequency filter. This function is aimed at eliminating useless noises. In general, leakage sounds from plastic pipes tend to have lower frequency, where leakage sounds from metal pipe tend to have higher frequency. The filter can be set taking into account those features. However, its sound quality depends on soil, pressure and depth of pipes as well. For this reason, starting without a filter is recommended.
- Lines that have fewer connections are recommended to be picked up for road survey, because h/h survey also covers certain ranges including distribution pipe if density of connection is high.

3.5.3 Identification survey

a) Purpose

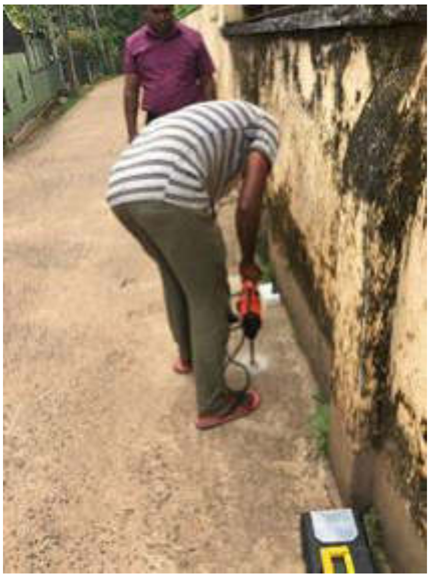
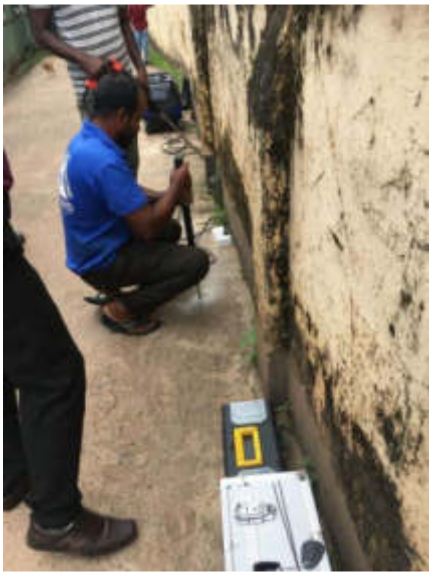
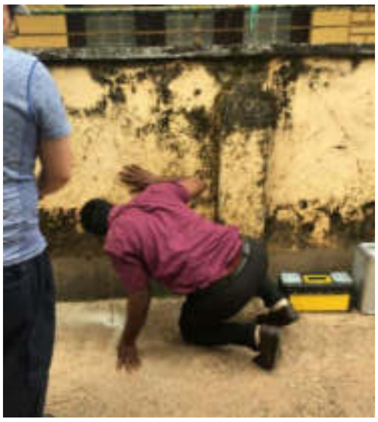
Identification survey is to confirm the exact location of leakage by boring ground and inserting an acoustic rod.

b) Preparation

Boring bar, hammer drill, acoustic bar, water leak detector

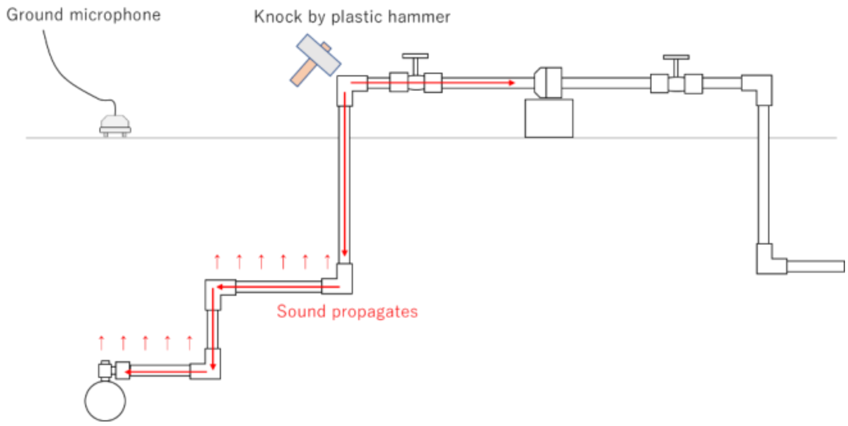
c) Procedure

1)	Visit the points that are marked by h/h survey or road survey.	
2)	Check whether the sound still exists with acoustic bar and water leak detector. If it does not, then eliminate. If it does, try to point out the location.	
3)	If it is difficult to point out, move to boring method. Confirm the pipe location and depth by the applicable pipe locator before boring.	

3)	Bore by hammer drill and boring bar on the marked point up to top of the pipe. (Should be careful not to damage the pipe.)  	
4)	Insert an acoustic bar to the hole to check the volume of leak sound.	
5)	In case that leak sound is clear or water appears, it shows the exact location of the leak. It should be excavated and repaired. If it is still not clear, shift the point slightly, and try again.	

d) Tips for the survey

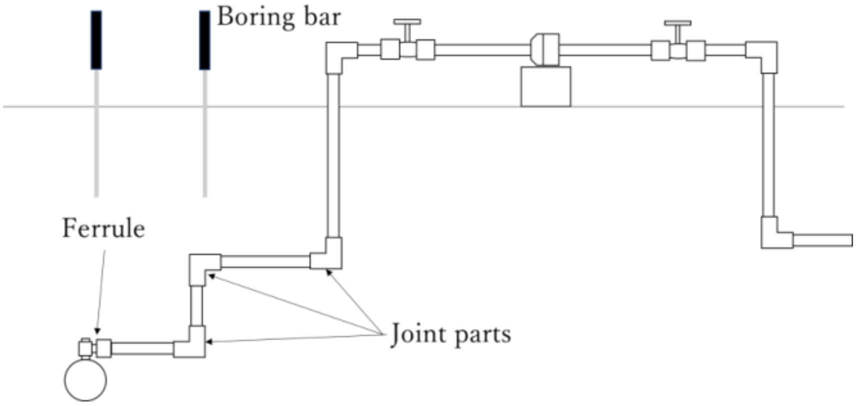
1) Knocking to service pipe exposed by plastic hammer is sometimes useful for tracing buried pipe by ground microphone.



2) For the pipe location and depth, local knowledge should be utilized.

3) Shift slightly from exact top of the pipe when boring. Otherwise, boring can damage pipe.

4) In case of service connections, leakage commonly comes from ferrule or joint parts. Therefore, aim to those points for the bore. (Do not actually shoot)



5) Keep in mind that the following cases are relatively difficult to identify due to less sound propagation. In some cases, waiting for a certain period till leakage grows is needed. (A few weeks or months, or beyond)

In case that

- Flow of leakage is small. (It depends on size of crack, pressure, etc.)
- Thickness of road surface is large.
- Pipe depth is large.
- Leaking point is submerged.
- Leaking point is far from searching point.
- Leakage occurring from the bottom of the pipe towards the underground, not on the surface.

3.6 Leakage repair

Proper leakage repair is done with proper materials, tools, machines, and procedures.

a) Leakage from lead joint

NWSDB has been taking measures to CI pipes with lead joints. It's been replaced to DI pipes with socket joints. However, once leakage occurs, it should be repaired till it is replaced. Repair clamp applicable for a lead joint is provided in an existing manual available in NWSDB. (No.1 in Table 1.2) It is shown as below;

An alternative method to repacking the lead run joints is the use of specially designed CI spigot and socket repair clamps. These clamps compress both the spigot and socket pipe together, with the addition of a gasket which stops the leak. These reduce the need to redo the lead in the joint which can be a messy, labour intensive, tricky job not without its health implications.

Source https://www.cascadeplc.co.uk

b) Points for Backfilling

Some of the leakages are considerably being caused due to poor quality of backfilling. In some cases, large stones come in to contact with the uPVC pipe surface, which cause the pipes to crack due to cyclic loads, eventually resulting in leakage. Based on these observations, following specifications should be followed more strictly to improve current situation.

- Use qualified soil
- Carry out adequate soil compaction

Soil material especially used for surrounding pipes, are required to meet certain standards. Specifically, the maximum particle sizes of soil and particle size distribution are the matters that should be taken into consideration first. Maximum size shall not be greater than 25mm, free from any hard objects and stones. Besides, mass percentage of the particle, which is finer than 75μm, shall not be much more than 25%.

Compaction is advisably carried out in every 200mm thickness of backfill layer to avoid causing any air gaps under the ground. For the same reason, soil should be filled under/side of the pipe sufficiently. Any heavy compacting equipment should not be used for the compaction from the bottom of the trench to 300mm above of top of the pipe. The equipment shown in the figure below is useful for it. Further, beyond 300mm above the top of the pipe, compactor, such as tampers, rammers are recommendable to be used for this.

After all*, SPECIFICATIONS FOR TRENCH EXCAVATION, BACKFILLING & ROAD REINSTATEMENT NWSDB* should be followed in any cases. Standard drawing of road reinstatement from it is shown in Appendix7.

To verify the qualities of contractor's work, NWSDB staff has to visit the sites and supervise it, when repair work is being carried out. To impose a standard of photo-submission on contractors will help the staff save time, if manpower is insufficient. Situations where photos should be taken are as follows (At least, for the work of leakage repair);

- After the completion of the excavation
- The situation of the leakage occurring

- After the completion of the repair

- The situation of the backfilling

- Situation of the compacting

- Situation of the road after completion of all work

Figure 3.24 Equipment for compacting soil by hand

c) Pipe End

In order to close the open pipe end, use of Pipe Plugs is suggested. It prevents both the water losing from the opening and entering the contamination.

Figure 3.25 Example of Pipe Plugs

3.7 Evaluation of the activity

3.7.1 Calculation of the Cost Benefit

Once the activity in one particular target area is finished, it should be evaluated using the Cost-Benefit Calculation. The calculation would be done by comparison of the total cost and the benefit, which were spent on/brought by a series of the activity.

Hereupon, the personnel cost, the machinery cost, and the material cost, which are spent on all the activities, are considered as the "Total Cost".

On the other hand, the value of prevented economic loss by the activity, which could be caused by leakage if the activity would not be carried out, is considered as the "Total Benefit".

a) Total Cost

- Personnel cost: This cost shall be calculated with unit personnel cost of each class, such as engineer, officer, and worker, multiplied by working hours of each activity item. Extra wages of night work etc. should be taken into account.
  - Activity item in one particular target area
    - Map updating, site inspection
    - DMA creation (Valves and flow meters installation)
    - Leak detection (MNF measurement, Step Test, and other surveys)
    - Leak repair
    - Others
- Machinery cost: This cost shall be calculated with unit rate of each machinery or tools multiplied by working hours of each activity item.
  - Machineries, tools
    - Acoustic bar
    - Water leak detector
    - Boring bar
    - Hammer drill
    - Ultrasonic flow meter/Insertion type flow meter
    - Excavator
    - Compactor
    - Others

- Material cost: This is the total cost of the materials used for each activity, including valves and bulk flow meter installed for the creation of the DMA.

> **Note**: The purpose of Cost-Benefit Calculation is to grasp a tendency of the activity efficiency. Hence, it is required to consider the balance of the accuracy and the easiness for the calculation for it. Usually, taking more time to pursue "1 Rs. -accuracy" for the calculation does not serve the purpose. If an easier alternative method of calculation can be performed, then it should be done. For instance, leakage repair cost could be obtained by the number of leakages repaired and "average unit cost". These could be taken from past records, if it is available. This method is easier in comparison to building up by each cost of personnel, machinery, and material of which was spent on the activity.

$$\text{Cost for leakage repair} = \text{Number of repaired leakage} \times \text{Average Unit Cost of the Repair}$$

b) Benefit

The benefit shall be considered as the value of prevented future water losses. Water losses by leakage would keep occurring till the survey is carried out and leakage is repaired someday. If cyclic year period of the activity were 3 years, such water losses would last for 3 years. After all, this value can be defined by the idea that the activity prevents those future losses.

$$\text{The value of prevented future water losses} = \text{Unit Sales Cost} \times \text{Prevented Amount of Leakage} \times \text{The Number of Cyclic Year}$$

Calculation of Prevented Amount of Leakage is as below;

$$(\text{Leakage ratio of before the activity} - \text{Leakage ratio of after the activity}) \times \text{Input Volume to the DMA}$$

3.7.2 Calculation of Cost and Benefit

In this chapter, the calculation of cost and benefit is explained step by step by use of real figures obtained at the DMA4 in the Pilot Site under the JICA project. Note that this is to provide a concept of the calculation, so that it could be modified to a more convenient way, if any.

a) Total Cost calculation

1) Cost for the DMA creation (Valves and Bulk flowmeter installation)

- Personnel and Machinery cost:

This is the cost that is spent for the construction work of the creation of the DMA and the subzones. This cost also could be divided into the personnel cost, the machinery cost, and the material cost as mentioned in the section 3.7.1.

For convenience, however, Average Unit Cost of Repair is being utilized for the calculation. This is because the process and the contents of both construction works are similar. Further, the material cost, such as for a bulk flowmeter, valves, might be relatively high compared to the material cost of Leakage Repair. Hence it will be calculated as other components.

Value of Average Unit Cost of Repair is being obtained herein by referring to the records of Kalutara region. (See Appendix 9)

According to the records, 446 leakage-repairs were done in a certain period from 2018 to 2019. It cost 11,951,022.75 LKR in total. (Note that if there are any other relevant costs, which are not included in this value, it should be added.)

$$Average\ Unit\ Cost\ of\ Leakage\ Repair = 11{,}951{,}022.75\ Rs.\ \div\ 446\ nos.$$
$$= 26{,}797\ Rs./no.$$

As the figure below shows, 4 valves and 1 bulk flowmeter were installed to the particular DMA. In here, one number of valve installation works shall be converted to one number of repair works. On the other hand, meter installation work shall be converted to 5 numbers of repair works, because it includes chamber-casting and installing. It took approximately 5 days in total.

$$\textit{Cost for valve and meter installation}$$
$$= \textit{Converted number} \times \textit{Average Unit Cost}$$
$$= 9\ \textit{nos.} \times 26{,}797\ \textit{Rs./no.}$$
$$= 241{,}173\ \textit{Rs.}$$

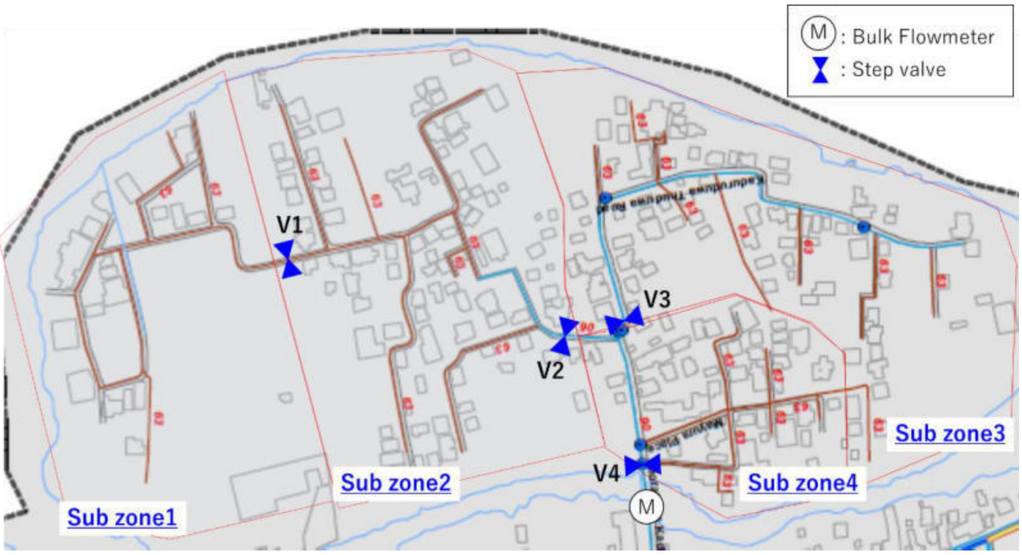


Figure 3.26 Installed flowmeter and valves

- Material cost:

The table below shows the costs of each item that are used for the DMA creation.

These items will keep working not only for the DMA creation but also for other O&M work through their lifetime. Hence, each purchase price itself should not be the cost of material of the DMA creation. What percentage would be equivalent to the cost should be carefully considered.

The values that are provided herein by the cyclic year of the activity and the lifetime of each item. (In other words, “depreciation period” or “life expectancy”)

Table 3.13 Material cost for the DMA creation

Unit of Price and Cost in Rs.

Item	Specs	Nos.	Purchase Price	Depreciation Period	Cyclic Year of the Activity	Cost
		a	b	c	d	e = (a*b/c)*d
Valve	50mm dia.	1	9,850	38	3	778
	80mm dia.	3	49,500	38	3	11,724
Bulk Flowmeter	80mm dia.	1	44,500	38	3	3,514
Surface Box	BS5834 /D400	5	21,500	38	3	8,487
PVC Pipe	110mm dia. As Valve Box	5	11,225	38	3	4,431
Manhole Cover	600mm	1	29,500	38	3	2,329
Chamber	Non casted	1	142,000	38	3	11,211
Necessary Fittings	Flange adaptor, Bolts & Nuts	1	85,340	38	3	6,738
					Total	49,212

Note:

-The number of the depreciation period refers to Japanese law “Government Enterprise Act”

-Assumed herein that the number of cyclic year is 3 year. This refers to the cases of Japan’s major water utility.

2) Cost for the leakage detection

- Personnel cost

The table below shows the amount of time spent for each activity by a person categorically.

Herein, for convenience, it is assumed that the salary rank of the personnel could be divided into 2 categories. Moreover, category 1 would be the rank of Zone Officers or higher, category 2 would be the rank under Zone Officer. (e.g. Skilled Workers, etc.)

Table 3.14 Working hours of each personnel spent for the activity

Unit in hours

Working Item	Personnel Category	Working Hours	
		Daytime	Nighttime
Map updating & Site inspection	1	32	0
	2	0	0
Step Test & MNF Measurement	1	0	35.0
	2	0	60.0
House to House Survey	1	25.0	0
	2	65.5	0
Road Survey	1	10.0	8.0
	2	9.0	8.0
Identification Survey	1	7.5	0
	2	10.0	0
Meter Accuracy Check	1	9.5	0
	2	9.5	0
Data Summarizing, Evaluation	1	42.0	0
	2	0	0
Total Working Hours	1	126.0	43.0
	2	94.0	68.0

Note:

- Source of working hours: the working record of JICA project

- Assumed herein that category1 is the rank of salary of Zone Officers or higher persons, and category2 is the rank of salary of the persons under Zone Officers. (e.g. skilled workers)

Furthermore, the table below shows the personnel cost for the leakage detection. The figures of Unit Rate of each category are a complete conjecture. They should be replaced by more approximate figures. The numbers of working hours are taken from the working record of JICA project. (See Appendix 9)

Table 3.15 Personnel cost for the leakage detection

Unit of Cost in Rs.

Personnel Category	Daytime			Nighttime			Total Cost
	Working Hours	Unit Rate	Cost	Working Hours	Unit Rate	Cost	
1	126.0	247	31,122	43	371	15,932	47,054
2	94.0	182	17,108	68	273	18,564	35,672
						Total	82,726

Note: The unit labour cost is provided by RSC-WS (2021) . 1: Engineer Assistant, 2: Fitter

- Machinery cost:

As with “Material cost of the DMA creation”, which is mentioned in section 3.7.2 a) 1), it needs to be considered what percentage of the purchase-prices of each equipment are worth only for the leakage detection work that was carried out this time.

The table below shows the Unit Rate per Day of each equipment. Particular coefficients are being used for the calculation herein. (Source: Japan leakage survey association)

Table 3.16 Unit Rate of equipment for the leakage detection

Unit of Price and Loss in Rs.

Machinery (Equipment)	Price	Coefficient	Unit Rate per Day
	a	b	c=a*b
Ultra-sonic flow meter	5,300,000	0.0038	20,140
Pressure logger	1,700,000	0.0021	3,570
Acoustic bar	59,148	0.0028	166
Water leak detector	463,266	0.0016	741
Boring bar	45,275	0.012	543
Hammer drill	23,261	0.0019	44
Meter test kit	645,000	0.0038	2,451
Generator	-	-	958

- Source of the coefficients for all the machinery except Generator: Japan Leakage Survey Association

- Source of the coefficient for Generator: Japan Construction Machinery and Construction Association, *Construction machinery unit rate table (Specs - 3kVA)*

The table below shows the material cost of the leakage detection. The number of days spent are obtained from the Working Record of JICA project.

Table 3.17 Material cost of the leakage detection

Unit of Cost in Rs.

Machinery (Equipment)	Unit	Unit Rate per Day	Number of Unit	Cost
		a	b	c=a*b
Ultra-sonic flow meter	day	20,140	3	60,420
Pressure logger	day	3,570	12	42,840
Acoustic bar	day	166	10	1,660
Water leak detector	day	741	7	5,187
Boring bar	day	543	2	1,086
Hammer drill	day	44	2	88
Meter test kit	day	2,451	2	4,902
Generator	day	958	5	4,790
			Total	120,973

3) Cost for the leakage repair

9 leakages were detected and repaired in one particular DMA of the Pilot Site under JICA project. The summary is shown in Table and Figure as below.

Table 3.18 Information of Leakages repaired

ID	Sub Zone	Pipe Category	Material	Dia. (mm)	Ground Surface	Others
1	4	Service	PVC	20	Soil	Occurred under other resident's premises
2	4	Service	PVC	20	Concrete	
3	3	Service	PVC	20	Concrete	
4	2	Service	PVC	20	Concrete	
5	2	Service	PVC	20	Soil	
6	2	Service	PVC	20	-	
7	2	Service	PVC	20	-	
8	4	Distribution	PVC	63	Concrete	
9	2	Distribution	PVC	63	Concrete	

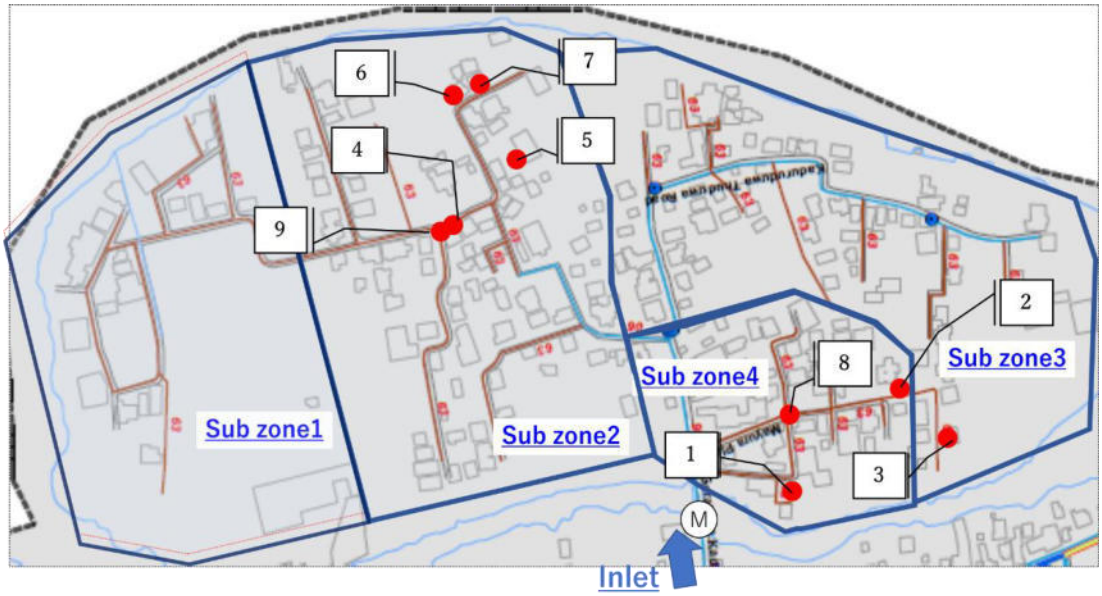


Figure 3.27 Summary of the leakage points

For convenience, Average Unit Cost of Leakage Repair ***26,797 LKR*** is used for the calculation as with the section of 3.7.2 a) 1).

Therefore, cost for the Leakage Repair can be estimated as below.

$$\textit{Cost for Leakage Repair} = \textit{Number of Repaired Leakage} \times \textit{Average Unit Cost}$$

$$= 9\ \textit{nos.} \times 26{,}797\ \textit{Rs./no.}$$

$$= 241{,}173\ \textit{Rs.}$$

b) Total Benefit calculation

There are two assumptions are used.

1) Consideration of leakage recurrences

2) Full use of saved water

Example of a benefit calculation is as below;

Firstly, the Prevented Amount of Leakage shall be estimated by how much the NRW ratio improved.

Table 3.19 Change of key indicators

Status	Average Input Volume		Average Consumption		NRW Ratio
	m^3	m^3/d	m^3	m^3/d	
Before Activity (Mar. 2019)	6,962.0	257.5	6,116	197.3	23.4%
After Activity (Aug. 2019)	6,472.4	223.2	6,067	202.2	9.4%

Source: NWSDB

Prevented Amount of Leakage

$= (Leakage/NRW\ ratio - Leakage/NRW\ ratio) \times Average\ Input\ Volume$

$= 257.5\ m^3/day * 23.4\% - 223.2\ m^3/day * 9.4\%$

$= 39.6\ m^3/day$

$= 14,454\ m^3/year$

It is estimated that the recurrence of water leakage appears in the pattern shown in the schematic image below.

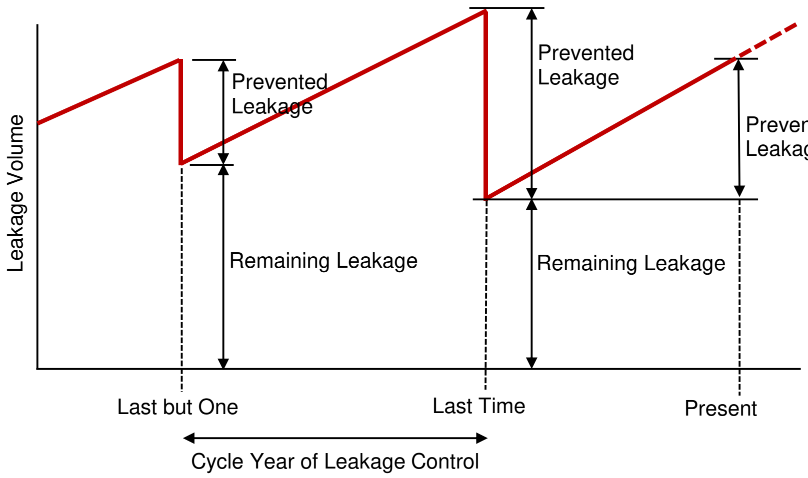


Figure 3.28 Image of Leakage Recurrence

Practically, the costs and human resources available to prevent water leakage are limited. For this reason, it is necessary to set the criteria for determining the allowable amount of water leakage and pipeline renewal while considering the amount of water that has been prevented, the amount of residual water, and the cost spent for prevention activities.

To this end, it is necessary to investigate how quickly the reduced water leakage will be restored, and it is recommended to monitor the water inflow to the DMA and MNF monthly.

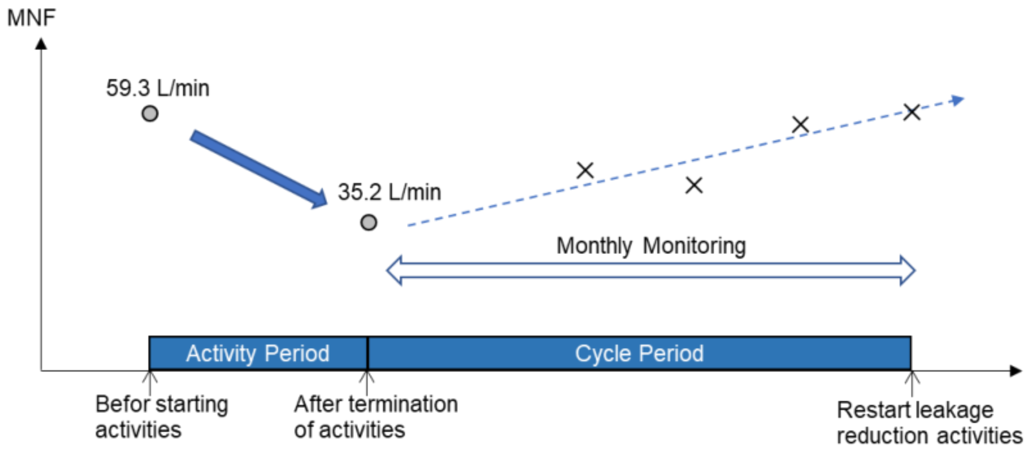


Figure 3.29 Monitoring for Leakage Control

Finally, the Value of Prevented Water Losses shall be estimated by considering the Prevented Amount of Leakage, Unit Sales Cost and Number of Cyclic Year as the benefit of the activity.

The duration of the effect is the number of years until the reduced amount of water leakage returns to the original level, and it is necessary to set this period as the Cyclic Period and repeat the leaked water reduction activities.

In this cost-benefit calculation, the duration of this effect is assumed to be **3 years**.

It is assumed that the leakage volume will increase gradually and become same level in 3 years.

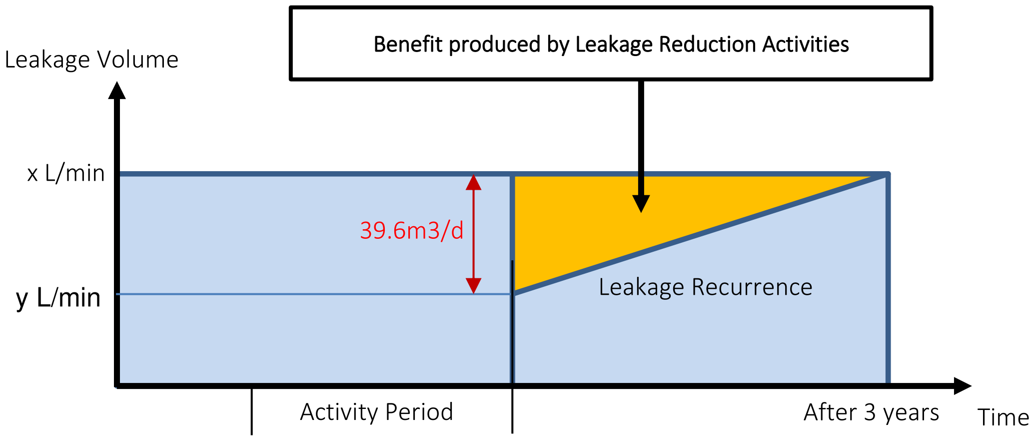


Figure 3.30 Benefit produced by Leakage Reduction Activities

Value of Prevented Water Losses

$$= \textit{Unit Sales Cost} \times \textit{Prevented Amount of Leakage} \times \textit{Number of Cyclic Year}$$

$$= 55\ Rs. \times 14{,}454\ m^3/year \times 3\ years \times 1/2$$

$$= 1{,}192{,}455\ Rs.$$

c) Cost Benefit comparison

As the table below shows, benefit of the activities that were carried out in one particular DMA under JICA project is greater than its cost. It can conclude that the activity was efficient.

Table 3.20 Comparison of Total Cost and Total Benefit

Unit of Value in Rs.

Description			Value
Cost	DMA Creation	Personnel, Machinery	241,173
		Material	49,212
	Leakage Detection	Personnel	82,726
		Machinery	120,973
		Material	0
	Leakage Repair (Personnel, Machine, Material)		241,173
	Total Cost		**735,257**
Benefit	Prevented Water Losses		2,023,560
	Total Benefit		**1,192,455**
Benefit／Cost			**1.62**

The Cyclic period will be monitored, and the benefit shall be re-evaluated. If it becomes less than 1, it will be a time of replacing of pipe.

3.8 Pressure Control

It is very essential for the smooth supply of water to all users to control appropriate water pressure and water volume distribution as much as possible. Further, appropriate pressure control is one of the important measures of ALC.

The relation between pressure and leakage volume is shown as follows. The coefficient N depends on the size and shape of the leak hole and the material of the pipe.

The following Figure shows the relationship between pressure and leakage volume. The higher pressure generates larger amount of leakage.

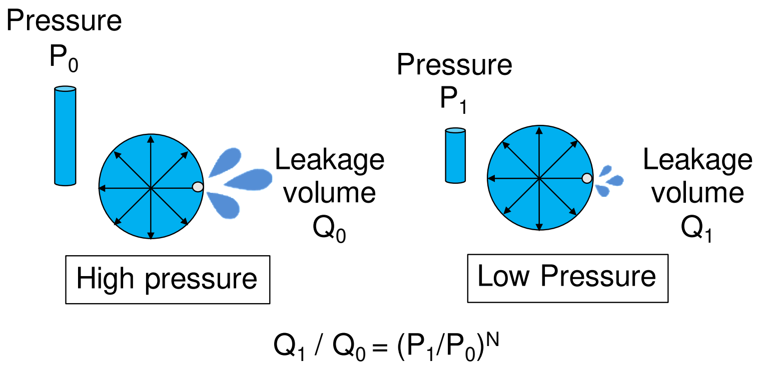


Figure 3.31 Relation between leak volume and pressure

Leak from small orifice :	N=0.5
Leak from crack of pipe or flange joint :	N=1.15

Ideally, the minimum hydrodynamic pressure of the supply network should be maintained at a head of about 15m (0.15MPa) to 20m (0.2MPa). The excessive water pressure brings about higher water leakage beside the risk of making damage to the supply system, therefore, it is desirable to keep the minimum hydrodynamic pressure to 40 m (0.4 MPa) at the maximum. therefore, it is desirable to keep the minimum hydrodynamic pressure to 40 m (0.4 MPa) at the maximum.

There are two major measures for the pressure reduction in distribution network, i.e., valve control and use of pressure reducing valve.

1) Control valve: Change the opening and generate head loss

2) Pressure reducing valve: Use of pressure reducing valve

The

Table 3.21 shows the summary of two kind of pressure controlling method by use of valves.

Table 3.21 Summary of Valves for Pressure Control

	Control valve	Pressure reducing valve
Mechanism	Change opening degree of sluice valve and/or butterfly valve, and generate the pressure difference which reduces the pressure	It works by using the water pressure in the pipeline as a power source, and the pressure on the upstream and the downstream can be controlled.
Characteristic	Simplest method applicable to network with constant flow It completely depends on the downstream side water flow.	Pressure setting is easy. The conditions of pressure and flow rate determines the type of valve.
O&M	Not particular maintenance is required as usual valves.	Periodical maintenance is required.
Operation	When the condition of flow rate and/or pressure change, the setting should be adjusted.	Continuous small flow amount rate will cause the failure. It cannot be installed very near to other pressure reducing valve.

Appropriate setting valves in network and proper operation of them can control the water pressure in proper levels. The examples of necessary locations are given below.

- Distribution Main
  - Upstream of the Location of excessive pressure where changing topography in altitude
  - Location of excessive pressure in nighttime due to low water demand
  - Contacting point to the other network
- Distribution Sub-main
  - Branching point from distribution main
  - Inlet of supply block

The remote monitoring of pressure by sensors will be helpful to control more precisely and timely.

4 Management of database

As mentioned before, understanding the existing situation of pipe network is essential for the daily O&M work. The Mapping system is a useful way to ensure this; information shall be updated and shared with staff in the organization.

NWSDB already has a certain internal rule to accumulate information.

Comprehensive GIS mapping system is developing with the assistance of Greater Colombo Water and Wastewater Management Improvement Investment Program (GCWWMIIP) funded by ADB. The target is to accumulate the existing asset information, and also, they are planning to merge the customer information.

The following table shows main information to be put into the attributes of GIS.

Pipe	Diameter	Material	Type	laid year	status	length
Valve	Diameter	Material	Type	Installation year	status	
Flowmeter	Diameter	Description				
Leakage	location	Leak type				

At present, GIS data is managed by the P&D section of RSC-WS. GCWWMIIP is going to assign GIS data management to the Area Manager Office. Therefore, the internal information sharing will be slightly changed.

However, the data collection is one of important daily works for the field staff members. Furthermore, the daily update of the collected information is essential for the correct data management.

In case of the new scheme of the water supply including the expansion, the drawing with GIS data will be submitted to NWSDB.

NWSDB is collecting and updating the information of pipe laying year into the GIS system. Because these are important basic data for evaluation of the vulnerability of pipeline.

On the other hand, the daily collected information should be updated at the time of repair/ replace of pipe/valve/water hydrant, diversion of the network, excavation work, new connection, etc. The following information can be collected.

- Pipe information: Layout, Location, Depth, Material, Diameter, laid year, location of valves, hydrants, new installation, replacement
- Leakage information: Point, considerable cause, etc.
- Others: Any other differences from existing database

To evaluate the history of the leakage occurrences, it is useful to know the frequency of occurrence in certain pipe. So, NWSDB should request the person who does the leakage repair work at the site must submit the "leakage repair record" and Photograph with geotag.

The following procedure is recommended.

1) NWSDB provides the access information of the e-format to staff/Contactor to take the record.

2) NWSDB staff/Contactor checks the status of the camera/smartphone which must be able to get the coordinate information.

3) NWSDB staff/Contactor shall take photographs to report the working condition with the coordinate information and send it to responsible person in NWSDB.

4) The person in charge in NWSDB compile the photograph with the geotag to the GIS system.

5) This information should be updated regularly, every few months and one year at most.

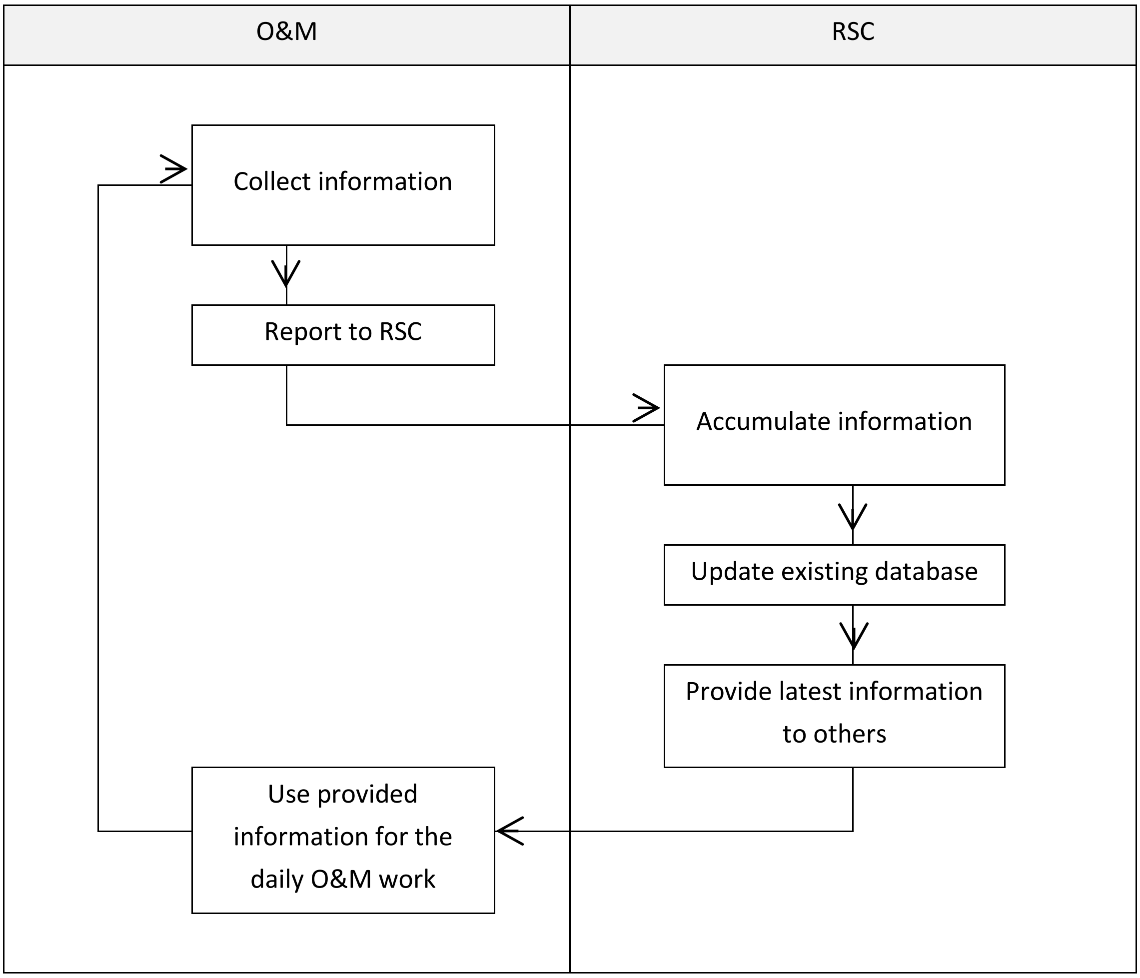


Figure 4.1 Flow of Data

Annex 1: Format of activities schedule of DMA

DMA Activities Schedule

DMA Number:

Number of Connection:

Projected number of subzone:

		Jul-20				Aug-20				Sep-20				Oct-20				Nov-20				Dec-20				Jan-21				Feb-21			
DMA 3																																	
1	Determination of design of sub-zoning																																
2	Procurement of materials																																
3	Arrangement of workers																																
4	Installation of Bulk Flow Meter																																
5	Installation of gate valves for sub-zoning																																
6	Multipoint pressure measurement for 1 week																																
7	Hydraulic isolation check with manometer																																
8	Boundary check with valve operation																																
9	MNF Measurement and 1st Step Test																																
10	Leakage Repair (1st term)																																
11	2nd Step Test																																
12	Updating Customer Data																																
13	Collection of Historical Billing Data for last 12 months																																
14	Calculation of NRW																																
15	Meter Accuracy Test at site																																
16	Analysis of Apparent Losses																																
17	Effect Evaluation of Leakage Repair																																
18	Leakage Repair (2nd term) (if necessary)																										■	■	■				
19	3rd Step Test (if necessary)																													■			
20	Cost-Benefit Analysis																														■	■	■

□ Work to be executed by DWSDB by themselves

▥ Work to be executed by NWSDB under remote assistance by Japanese Experts

■ Collaboration Work with Japanese Experts in Sri Lanka

Annex 2: Format of Step Test Record

Local Recording Format of Step Test

Location	
DMA No.	
Date	

Time	Local reading data at Inflow Point: Valve Operation		Pressure	Cumulative Amount	Increased Amount	Flow Rate	Average Flow Rate	Minimum Flow Rate		Estimated Minimum Inflow in each subzone			Pressure
	Opened	Closed	(m H_2O)	(m^3)	(m^3)	(L/min)	(L/min)	(L/min)			(L/min)	(%)	(m H_2O)
0:45:00	V**	V**		0.000	-		-		-	-	-	-	
0:50:00													
0:55:00									$Q_{mnf-all}$	-	-	-	
1:00:00													
1:05:00									-	-	-	-	
1:10:00													
1:15:00									$Q_{mnf-sub1}$	Inflow Subzone 1			
1:20:00													
1:25:00									-	-	-	-	
1:30:00													
1:35:00									$Q_{mnf-sub2}$	Inflow Subzone 2			
1:40:00													
1:45:00									-	-	-	-	
1:50:00													
1:55:00									$Q_{mnf-sub3}$	Inflow Subzone 3			
2:00:00													
2:05:00									-	-	-	-	
2:10:00													
2:15:00									$Q_{mnf-sub4}$	Inflow Subzone 4			
2:20:00													
2:25:00									-	-	-	-	
2:30:00													
2:35:00									$Q_{mnf-sub5}$	Inflow Subzone 5			
2:40:00													
2:45:00									-	-	-	-	
2:50:00													
2:55:00									$Q_{mnf-sub6}$	Inflow Subzone 6			
3:00:00													
							-		-	-	-	-	

Basic Information

Subzone	No of Connections	Estimated population = 4.8 * connection (persons)	Extension of distribution pipes (km)	Estimated Legitimate Water Use at Night = 0.0006 * connection (m^3/h)
Subzone 1				
Subzone 2				
Subzone 3				
Subzone 4				
Subzone 5				
Subzone 6				

Annex 3: Personnel Work Record for DMA activities

Working Record in DMA4 Work Item: DMA Creation, MNF Measurement, Step Test, Leakage Survey, Meter test, Data Summarizing

Date	Item	Name	Job Status	Morning			Afternoon			Night			Equipment
				Start	End	Hours	Start	End	Hours	Start	End	Hours	
	Map updating & site inspection		Catefory1	8:30	12:30	4:00	13:30	17:30	4:00				
	Map updating & site inspection		Catefory1	8:30	12:30	4:00	13:30	17:30	4:00				
	Map updating & site inspection		Catefory1	8:30	12:30	4:00	13:30	17:30	4:00				
	Map updating & site inspection		Catefory1	8:30	12:30	4:00	13:30	17:30	4:00				
15.02.2019	Valve Installation		Catefory1	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
16.02.2019	Valve Installation		Catefory1	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Valve Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
25.02.2019	Meter Installation		Catefory1	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Meter Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Meter Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Meter Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Meter Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Meter Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
26.02.2019	Chamber Installation		Catefory1	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Chamber Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Chamber Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Chamber Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Chamber Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
	Chamber Installation		Catefory2	9:30	12:30	3:00	14:00	16:30	2:30			0:00	
13.03.2019	MNF, Step Test	1	Catefory1			0:00			0:00	23:00	4:00	5:00	Ultra-sonic flow meter
	MNF, Step Test	2	Catefory1			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	3	Catefory2			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	4	Catefory2			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	5	Catefory2			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	6	Catefory2			0:00			0:00	23:00	4:00	5:00	
	MNF, Step Test	9				0:00			0:00	23:00	4:00	5:00	
	MNF, Step Test	11				0:00			0:00	23:00	4:00	5:00	
14.03.2019	Data summaraizing	9	Catefory1	8:30	12:30	4:00	13:30	16:30	3:00			0:00	
	Data summaraizing	11	Catefory1	8:30	12:30	4:00	13:30	16:30	3:00			0:00	
14.03.2019	House to House Survey	1	Catefory1	10:00	12:30	2:30	14:00	16:30	2:30			0:00	Acoustic bar
	House to House Survey	2	Catefory1	10:00	12:30	2:30	14:00	16:30	2:30			0:00	Acoustic bar
	House to House Survey	3	Catefory2	10:00	12:30	2:30	14:00	16:30	2:30			0:00	
	House to House Survey	4	Catefory2	10:00	12:30	2:30	14:00	16:30	2:30			0:00	
	House to House Survey	7	Catefory2	10:00	12:30	2:30	14:00	16:30	2:30			0:00	
	House to House Survey	8	Catefory2	10:00	12:30	2:30	14:00	16:30	2:30			0:00	
	House to House Survey	9		10:00	12:30	2:30	14:00	16:30	2:30			0:00	
	House to House Survey	11		10:00	12:30	2:30	14:00	16:30	2:30			0:00	
15.03.2019	House to House Survey	1	Catefory1	9:30	13:00	3:30			0:00			0:00	Acoustic bar
	House to House Survey	2	Catefory1	9:30	13:00	3:30			0:00			0:00	Acoustic bar
	House to House Survey	3	Catefory2	9:30	13:00	3:30			0:00			0:00	
	House to House Survey	4	Catefory2	9:30	13:00	3:30			0:00			0:00	
	House to House Survey	7	Catefory2	9:30	13:00	3:30			0:00			0:00	
	House to House Survey	8	Catefory2	9:30	13:00	3:30			0:00			0:00	
	House to House Survey	9		9:30	13:00	3:30			0:00			0:00	
	House to House Survey	11		9:30	13:00	3:30			0:00			0:00	
18.03.2019	Meter Accuracy Check	1	Catefory1			0:00	14:00	17:00	3:00			0:00	Meter test kit
	Meter Accuracy Check	2	Catefory1	10:00	12:30	2:30			0:00			0:00	
	Meter Accuracy Check	3	Catefory2	10:00	12:30	2:30	14:00	17:00	3:00			0:00	
	Meter Accuracy Check	11		10:00	12:30	2:30	14:00	17:00	3:00			0:00	
19.03.2019	Meter Accuracy Check	2	Catefory1	10:00	12:30	2:30	15:00	16:30	1:30			0:00	Meter test kit
	Meter Accuracy Check	3	Catefory2	10:00	12:30	2:30	15:00	16:30	1:30			0:00	
	Meter Accuracy Check	11		10:00	12:30	2:30	15:00	16:30	1:30			0:00	
26.03.2019	House to House Survey	2	Catefory1	10:00	12:30	2:30			0:00			0:00	Acoustic bar
	House to House Survey	3	Catefory2	10:00	12:30	2:30			0:00			0:00	Acoustic bar
	House to House Survey	4	Catefory2	10:00	12:30	2:30			0:00			0:00	

Date	Item	Name	Job Status	Morning			Afternoon			Night			Equipment
				Start	End	Hours	Start	End	Hours	Start	End	Hours	
	House to House Survey	5	Catefory2	10:00	12:30	2:30			0:00			0:00	
	House to House Survey	6	Catefory2	10:00	12:30	2:30			0:00			0:00	
	House to House Survey	7	Catefory2	10:00	12:30	2:30			0:00			0:00	
	House to House Survey	8	Catefory2	10:00	12:30	2:30			0:00			0:00	
	House to House Survey	10		10:00	12:30	2:30			0:00			0:00	
	House to House Survey	11		10:00	12:30	2:30			0:00			0:00	
	House to House Survey	other				0:00			0:00			0:00	
	House to House Survey	other				0:00			0:00			0:00	
28.03.2019	House to House Survey	1	Catefory1	9:45	12:30	2:45			0:00			0:00	Acoustic bar
	House to House Survey	2	Catefory1	9:45	12:30	2:45			0:00			0:00	Acoustic bar
	House to House Survey	3	Catefory2	9:45	12:30	2:45			0:00			0:00	
	House to House Survey	4	Catefory2	9:45	12:30	2:45			0:00			0:00	
	House to House Survey	5	Catefory2	9:45	12:30	2:45			0:00			0:00	
	House to House Survey	6	Catefory2	9:45	12:30	2:45			0:00			0:00	
	House to House Survey	7	Catefory2	9:45	12:30	2:45			0:00			0:00	
	House to House Survey	8	Catefory2	9:45	12:30	2:45			0:00			0:00	
	House to House Survey	10		9:45	12:30	2:45			0:00			0:00	
	House to House Survey	11		9:45	12:30	2:45			0:00			0:00	
01.04.2019	Road survey	1	Catefory1	10:00	14:00	4:00			0:00			0:00	Water leak detector
	Road survey	2	Catefory1	10:00	13:00	3:00			0:00			0:00	
	Road survey	3	Catefory2	10:00	14:00	4:00			0:00			0:00	
	Road survey	10		10:00	14:00	4:00			0:00			0:00	
	Road survey	11		10:00	14:00	4:00			0:00			0:00	
04.04.2019	Road survey	2	Catefory1	10:00	12:00	2:00			0:00			0:00	Water leak detector
	Road survey	3	Catefory2	10:00	12:00	2:00			0:00			0:00	
	Road survey	4	Catefory2	10:00	12:00	2:00			0:00			0:00	
	Road survey	10		10:00	12:00	2:00			0:00			0:00	
	Road survey	11		10:00	12:00	2:00			0:00			0:00	
05.04.2019	Road survey	1	Catefory1	10:00	11:00	1:00			0:00			0:00	Water leak detector
	Road survey	3	Catefory2	10:00	11:00	1:00			0:00			0:00	
	Road survey	10		10:00	11:00	1:00			0:00			0:00	
	Road survey	11		10:00	11:00	1:00			0:00			0:00	
10.04.2019	Identification survey	1	Catefory1	10:00	12:30	2:30			0:00			0:00	Hammer drill
	Identification survey	3	Catefory2	10:00	12:30	2:30			0:00			0:00	Boring bar
	Identification survey	4	Catefory2	10:00	12:30	2:30			0:00			0:00	Generator
	Identification survey	10		10:00	12:30	2:30			0:00			0:00	Acoustic bar
	Identification survey	11		10:00	12:30	2:30			0:00			0:00	Water leak detector
12.04.2019	Identification survey	1	Catefory1	10:30	13:00	2:30			0:00			0:00	Hammer drill
	Identification survey	2	Catefory1	10:30	13:00	2:30			0:00			0:00	Boring bar
	Identification survey	3	Catefory2	10:30	13:00	2:30			0:00			0:00	Generator
	Identification survey	4	Catefory2	10:30	13:00	2:30			0:00			0:00	Acoustic bar
	Identification survey	10		10:30	13:00	2:30			0:00			0:00	Water leak detector
	Identification survey	11		10:30	13:00	2:30			0:00			0:00	
01.05.2019	Road survey	1	Catefory1			0:00				22:00	0:00	2:00	Water leak detector
	Road survey	2	Catefory1			0:00				22:00	0:00	2:00	
	Road survey	3	Catefory2			0:00			0:00	22:00	0:00	2:00	
	Road survey	4	Catefory2			0:00			0:00	22:00	0:00	2:00	
10.05.2019	Road survey	1	Catefory1			0:00				22:00	0:00	2:00	Water leak detector
	Road survey	2	Catefory1			0:00				22:00	0:00	2:00	
	Road survey	3	Catefory2			0:00			0:00	22:00	0:00	2:00	
	Road survey	4	Catefory2			0:00			0:00	22:00	0:00	2:00	
10.07.2019	MNF, Step Test	1	Catefory1			0:00			0:00	23:00	4:00	5:00	Ultra-sonic flow meter
	MNF, Step Test	2	Catefory1			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	3	Catefory2			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	4	Catefory2			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	5	Catefory2			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	6	Catefory2			0:00			0:00	23:00	4:00	5:00	
	MNF, Step Test	11				0:00			0:00	23:00	4:00	5:00	
11.07.2019	Data summaraizing	9	Catefory1	8:30	12:30	4:00	13:30	16:30	3:00			0:00	
	Data summaraizing	11	Catefory1	8:30	12:30	4:00	13:30	16:30	3:00			0:00	
05.08.2019	MNF, Step Test	1	Catefory1			0:00			0:00	23:00	4:00	5:00	Ultra-sonic flow meter
	MNF, Step Test	2	Catefory1			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	Mr. Ajith	Catefory1			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	3	Catefory2			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	4	Catefory2			0:00			0:00	23:00	4:00	5:00	Pressure logger
	MNF, Step Test	5	Catefory2			0:00			0:00	23:00	4:00	5:00	
	MNF, Step Test	6	Catefory2			0:00			0:00	23:00	4:00	5:00	
	MNF, Step Test	9				0:00			0:00			0:00	
	MNF, Step Test	11				0:00			0:00			0:00	
07.08.2019	Data summaraizing	9	Catefory1	8:30	12:30	4:00	13:30	16:30	3:00			0:00	

Date	Item	Name	Job Status	Morning			Afternoon			Night			Equipment
				Start	End	Hours	Start	End	Hours	Start	End	Hours	
	Data summaraizing	11	Catefory1	8:30	12:30	4:00	13:30	16:30	3:00			0:00	
						0:00			0:00			0:00	
						0:00			0:00			0:00	
						0:00			0:00			0:00	
						0:00			0:00			0:00	
						0:00			0:00			0:00	
						0:00			0:00			0:00	
						0:00			0:00			0:00	
						0:00			0:00			0:00	
						285:30			127:30			126:00	

Working Hours

Category	Daytime	Nighttime
1	126	43
2	94	68
JET		

Excluding Chamber, Meter, Valve Installation

Appendix-1

Case Study of Pilot Site Activity in Panadura RSC-WS

2018- 2021

The Appendix-1 shows the real practice with the strategic method to control the leakage.
The practice has been done by the project members of RSC-WS, Panadura-Horana manager area staff members with the assistance of Japanese Experts.
It is useful to learn how to do the active leakage control with the concept of PDCA cycle.

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1 Introduction

1.1 Objective of the Pilot Activities

National Water Supply and Drainage Board (NWSDB) was established in 1975 as a principal authority providing safe drinking water and facilitating the provision of sanitation in Sri Lanka, presently under the Ministry of Urban Development. NWSDB has been improving water supply facilities throughout the country for the realization of a stable water supply. Currently, although coverage of the water supply system of densely populated Colombo district has reached 94.5 %, that of the whole country is still 48.1 %. Therefore, NWSDB will continue to enhance water supply capacity and improve its service.

Enhancement of efficiency of its business operation and expanding water supply system is required to achieve its goal. NWSDB has been considering the introduction of Asset management to (1) improve its business operation by effective distribution of O&M and investment costs and (2) formulate a business plan based on prioritized of renewal demand of aging facilities.

Enhancement of its capacity for leakage control as that of their daily O&M work directly leads to reduction of non-revenue water (NRW) and an improvement of business operation and finance.

Improving the quality of pipe installation not only prevents leakages but also promotes prolonging the lifetime of water supply facilities.

The purpose of this pilot activity is to acquire the knowledge, technology, and skills necessary for leakage control through practical On-the-Job Training in the actual water distribution network.

These tasks must be undertaken under the initiative of NWSDB staff in Sri Lanka, utilizing the equipment, experience and knowledge provided by Japanese experts.

1.2 Pilot activity strategy

Pilot activities are an extremely important opportunity to acquire practical skills such as leak detection and repair.

The results of activities conducted by NWSDB staff can be confirmed from quantitative data through a series of tasks such as estimating the area of water leakage, taking countermeasures, and measuring the results

1.2.1 Selection of target area

The NRW ratio in RSC-WS is not so high in the average of the whole area. It was 19.5 % for the 12-month average from September 2017 to October 2018, at the starting of the Project. That is to say, this area was suitable for the study of Active Leakage Control.

1.2.2 Construction of DMA

District Metered Area (DMA) means "Hydraulically isolated area where flow meter can control water inflow volume". The DMA method is generally adopted to manage leakage reduction in the pilot area. The DMAs are created in the existing supply network by installing valves and bulk flow meters.

1.2.3 Evaluation of Non-Revenue Water (NRW)

The amount of leakage reduced by a series of activities is a very important indicator for measuring performance.

In this study, the drop of MNF is used for the immediate evaluation of effectiveness of countermeasures. However, MNF is not a perfect indicator, because it consists of not only leakage but also the used water. NRW has also been monitored, but the single month NRW is not stable, in addition, the meter reading was not appropriately done due to the lock-down or else caused by the COVID-19 pandemic. Therefore, if the continuous monitoring data were available, NRW is also good indicator for measuring the effectiveness of activity.

1.3 PDCA Cycle

For future leakage reduction activities to be effective and sustainable, PDCA cycle-conscious efforts are necessary.

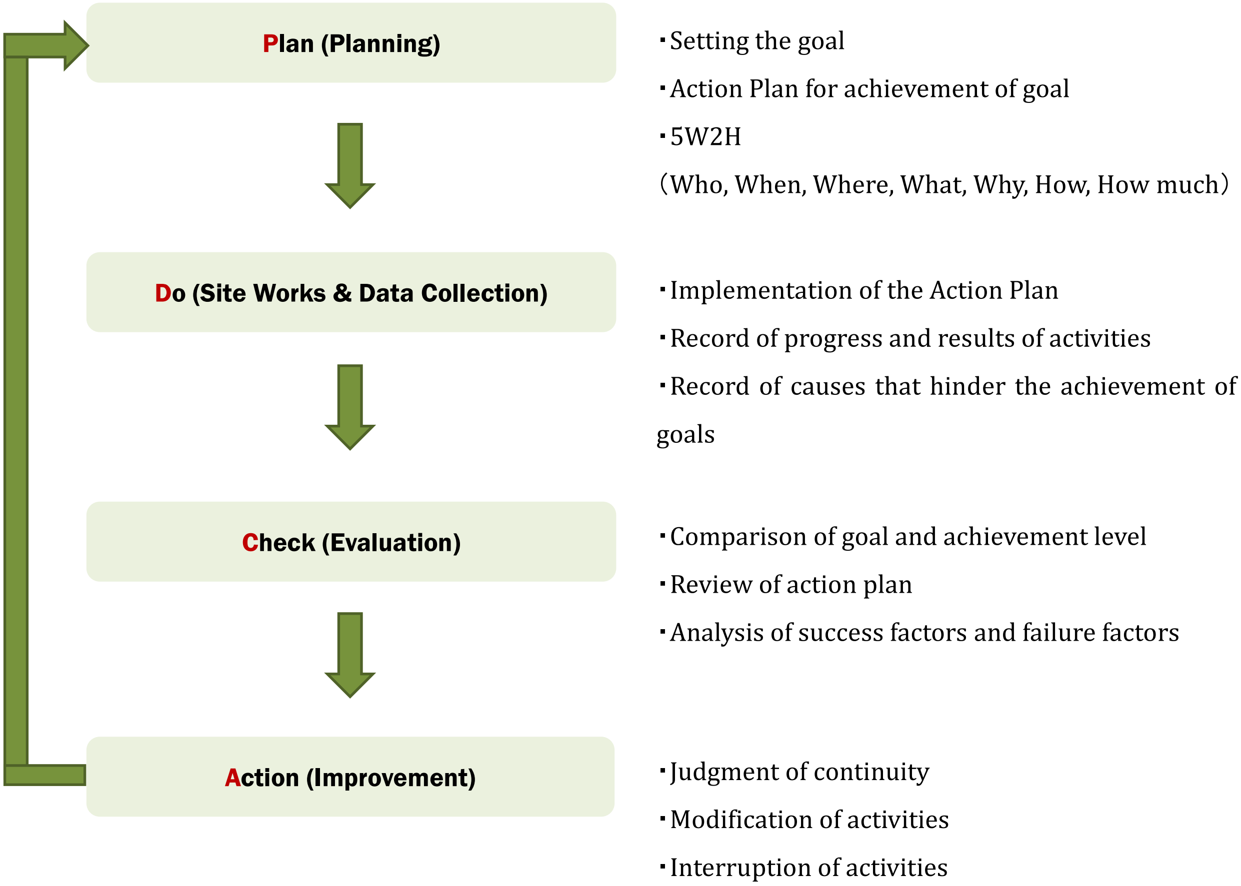


Figure 1.1 PDCA Cycle

There are four points to effectively operate the PDCA cycle:

- To show targets numerically and to plan concretely activities
- To appoint a responsible person and to execute as planned
- To Make a comfortable schedule
- To check and evaluate progress periodically

1.4 Pilot activity flow

1.4.1 Activity implementation system

The pilot activities will proceed under the following system.

Since the selected pilot site belongs to OIC Panadura, the leakage reduction activities will be carried out by the engineers and staff of OIC.

The leader of the pilot project will be the P&C manager of RSC W-S, and will be responsible for securing the equipment and materials necessary for the activities, obtaining the license, and coordinating with other departments within NWSDB, while receiving reports from OIC Panadura.

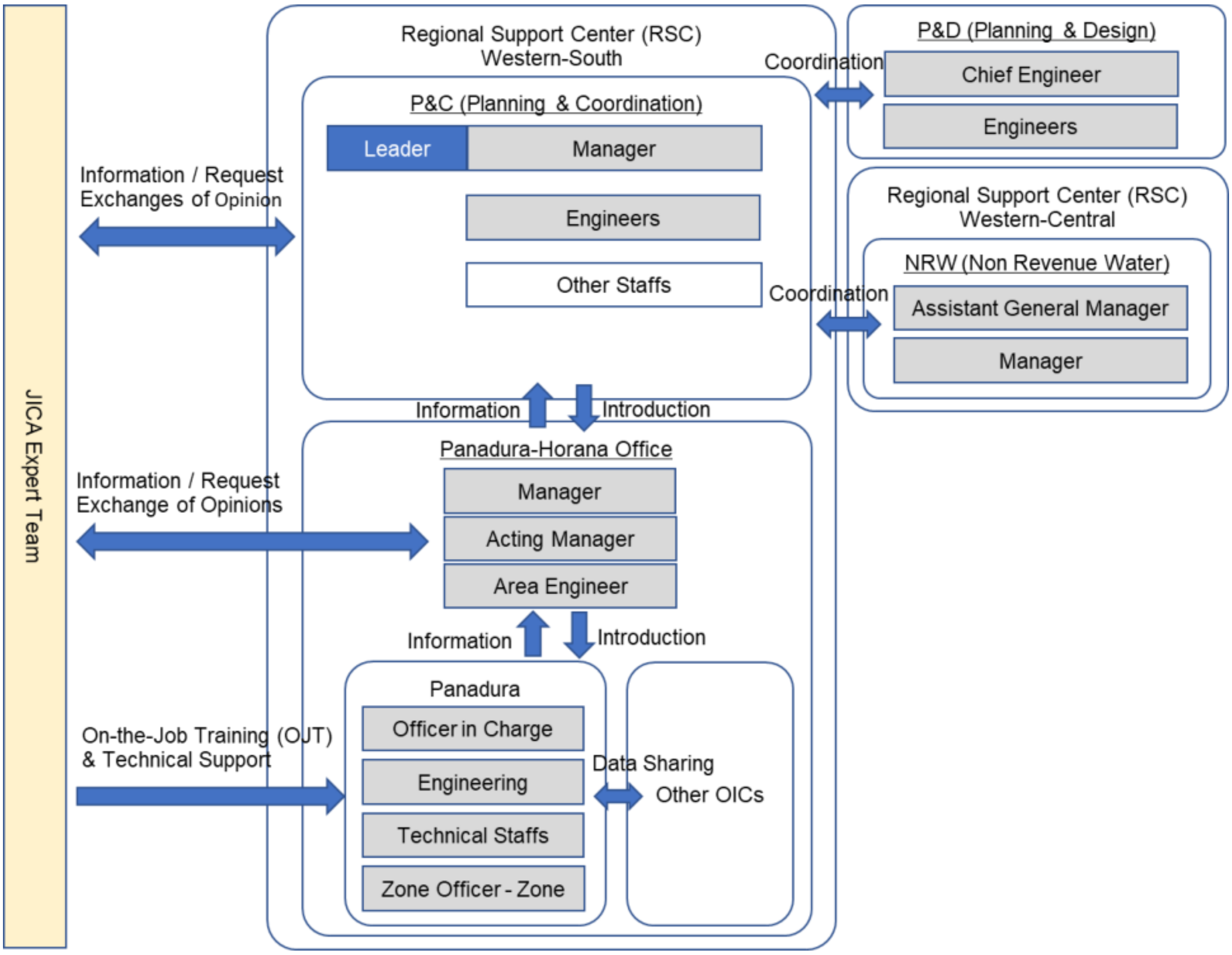


Figure 1.2 Activity implementation system

1.4.2 Implementation Steps of Pilot Activities

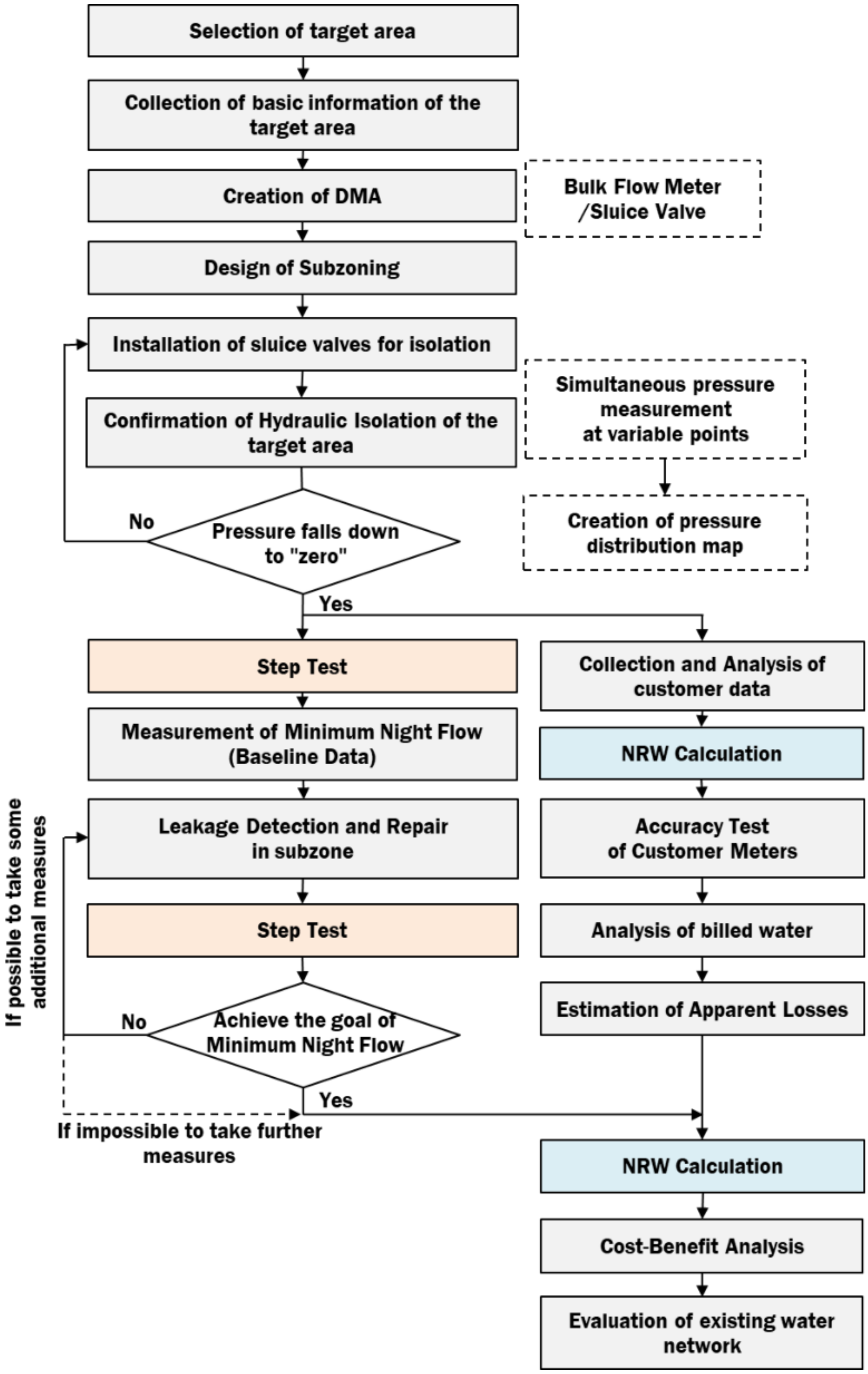


Figure 1.3 Implementation Steps of Pilot Activities

2 PLAN Planning for water leakage reduction measures

This chapter explains the PLAN of PDCA cycle.

2.1 Setting goals and evaluation indicators

For all activities, it is necessary to determine the target area and achievement goals in advance. In general, the goals that can be set as pilot activities are as follows.

- To learn techniques to detect underground leakage

  Through practical training in field work, learn leak detection methods and equipment operation.

- To clarify the components of NRW.

  Quantitatively show the components of NRW in the pilot area and propose the most effective and efficient measures to reduce NRW.

- To improve NRW rate

  Implement the proposed measures and improve the NRW ratio.

This project assumes that most of NRW in the pilot area is dominated by underground leakages that are difficult to detect, and NWSDB staff aims to acquire the knowledge, technology, and skills necessary for underground leakage control.

The effectiveness of the measures will be evaluated by monitoring the following data.

- Minimum Night Flow (MNF)
- NRW ratio (%)

In case that, after activities, it is found that activities other than leak control are effective in reducing non-revenue water, we propose measures to be taken.

2.2 Evaluation of real losses (leakage)

The dynamic scheme of real losses (leakage) is shown below.

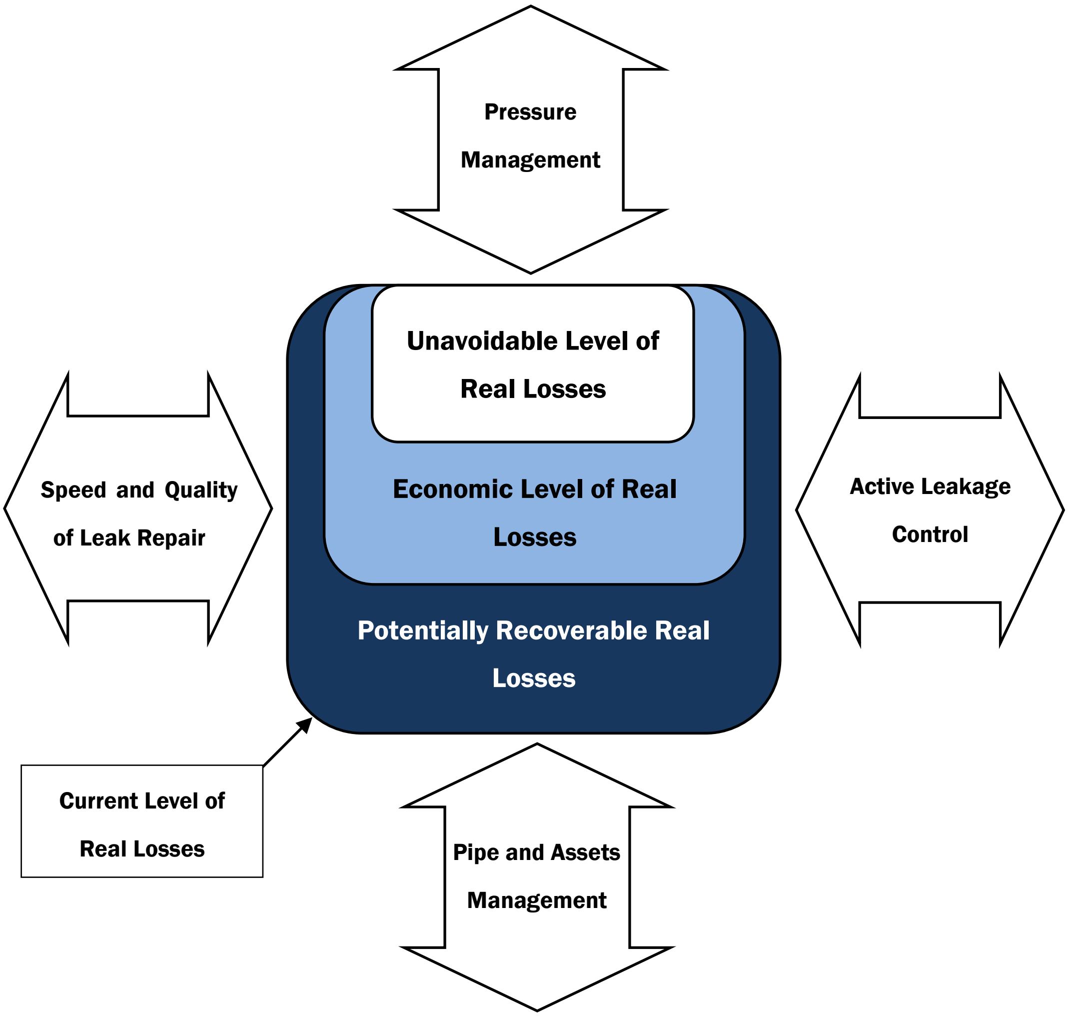


Figure 2.2.1 Dynamic scheme of real losses

To reduce water leakage, it is necessary to take measures from four directions, however, the priority of which depends on the characteristics of the district.

Therefore, in the pilot activities, the leakage repair will be carried out first and the effect will be confirmed. In addition, if a large amount of residual water leakage is observed, additional measures such as water pressure management and pipeline renewal will be taken, and measures will be continued until the amount of water leakage can be reduced from an economical point of view.

There is a level of leakage that is physically difficult to reduce. They call this level "Unavoidable Annual Real Losses (UARL)". The performance indicators of real losses are as follows.

2.2.1 Current Annual Volume of Real Losses (CARL)

$$\textbf{CARL (L/day)} = \frac{\textbf{Annual Volume of Real Losses } (m^3/year) \times 1000}{\textbf{Number of Water Service Days}}$$

2.2.2 Real Losses per connection

$$\textbf{Real Losses (L/connection/day)} = \frac{\textbf{Current Annual Volume of Real Losses (CARL)}}{\textbf{Number of Service Connection}}$$

The IWA recommends an index (L/km/day) that uses the total length of water distribution pipes instead of the number of connections for areas where the density of water pipes is less than 20 cases/km.

2.2.3 Infrastructure Leakage Index (ILI)

ILI is a value recommended by IWA as an indicator of the vulnerability of distribution pipes. To calculate this value, calculate UARL (Unavoidable Annual Real Losses) in advance with the following formula.

UARL (L/day) = (18×Lm + 0.8×Nc + 25×Lc) × P

Lm	: Total length of distribution pipes (km)
Nc	: House Connection Number
Lc	: Total length of service connection pipes (km)
	= Average length per connection (km/connection) × Ns. of connection
P	: Average water supply pressure (m H_2O)

UARL is the amount of water that cannot be expected to be further reduced no matter what water leakage measures are taken. It is said that this value will be about 2 to 4% of the total amount of water distributed by any water utility, and it can be understood as the allowable amount of leakage.

ILI is the value obtained by dividing the amount of water leakage (CARL) shown above by this UARL and is used to judge how appropriately the distribution network is maintained.

$$\textbf{Infrastructure Leakage Index (ILI)} = \frac{\textbf{Current Annual Volume of Real Losses (CARL)}}{\textbf{Unavoidable Annual Real Losses (UARL)}}$$

The IWA Working Group reports that when comparing ILI values, they can be applied in relatively large systems at the national, city, and zone levels. The conditions are as follows.

Number of connection : more than 3,000 (no limit for density)

Average water supply pressure : more than 25m as water head

In the case of an ideal water distribution network with no problems, ILI=1.0, which is a purely technical ultimate indicator. However, it is a value that is practically impossible, ignoring cost-effectiveness, and it is not necessary to target this level.

If the current ILI and target value can be set in this way, the real losses to be targeted can be determined using the following matrix according to the ILI value and the average water supply pressure.

Table 2.2.1 Target value of real losses

Technical Performance Category		ILI	Physical Losses (L/connection/day) (when the system is pressured) at an average pressure of:				
			10m	20m	30m	40m	50m
Developed Countries	A	1 - 2		< 50	< 75	< 100	< 125
	B	2 - 4		50 – 100	75 – 150	100 – 200	125 – 250
	C	4 - 8		100 – 200	150 – 300	200 – 400	250 – 500
	D	> 8		> 200	> 300	> 400	> 500
Developing Countries	A	1 - 4	< 50	< 100	< 150	< 200	< 250
	B	4 - 8	50 – 100	100 – 200	150 – 300	200 – 400	250 – 500
	C	8 - 16	100 – 200	200 – 400	300 – 600	400 – 800	500 – 1000
	D	> 16	> 200	> 400	> 600	> 800	> 1000

Source: Roland Liemberger, IWA Leakage 2005 Conference

Category A   Good。Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost-effective improvement

Category B   Potential for marked improvements; consider pressure management; better active leakage control practices, and better network maintenance

Category C   Poor leakage record; tolerable only if water is plentiful and cheap; even then, analyze level and nature of leakage and intensify leakage reduction efforts

Category D   Highly inefficient; leakage reduction programs imperative and high priority

2.3 Data Collection

In carrying out the pilot activities, the following information should be organized.

2.3.1 Basic data

Table 2.3.1 Data to be collected before commencement of activities

No	Items	No	Items
1	Number of connections	6	Distribution Network Drawing
2	Number of effective customer meter	7	Extension of pipes by type of material
3	Billing data during last 12 months	8	Extension of pipes by diameter
4	Meter reading data during last 12 months	9	Pipe laying year
5	Number of users by category	10	History of accident/repair

2.3.2 Updating commercial data

While conducting the activity, check the consistency between the data base of billing status and the current water users, so that NRW and real losses can be calculated accurately.

Table 2.3.2 Commercial data to be updated

No	Items	No	Items
1	ID Code of region	16	Sewerage service
2	Region	17	Status of meter box
3	Zone	18	Operating condition of meter
4	Registration number	19	Manufacturer of meter
5	Customer number for billing	20	Nominal diameter of meter
6	Direction	21	Serial number of meters
7	Type of connection	22	Type of service pipe
8	Water usage status	23	Diameter of service pipe
9	Contact number	24	
10	Customer name	25	
11	Type of building	26	
12	Economic status	27	
13	Type of commercial activities	28	
14	Water source	29	
15	Connection date	30	

2.4 Design of DMA

Determine the range where hydraulic independence is possible according to the distribution network map of the activity area.

2.4.1 Definition of DMA

In this activity, DMA is defined as follows.

Definition of DMA

DMA is the smallest leak management area constructed in the distribution network.
It is used to estimate the amount of water loss occurring in the sector by making it hydraulically independent at night when water demand is low and measuring the Minimum Night Flow (MNF).

【Complementary conditions】

- Water communication between adjacent distribution networks is allowed, but valves must be installed in place to allow the distribution network to be independent (separate from surrounding distribution networks) when needed.
- Multi point Inflow is permitted.
- It is not an absolute requirement to install a flow meter at the inflow point, but it must be possible to install a portable flow measurement device and measure the inflow water amount at night.

Scale of DMA

DMA will be set in consideration of distribution network conditions, water demand, customer density, etc.
For efficient control of water leakage reduction activities, it is desirable that the number of water supply connections for one DMA is about 500 to 3,000.

The ideal DMA is a system that is always disconnected from the surrounding water distribution network 24 hours a day and allows you to compare the amount of water supplied to the sector with the amount of water consumed within a certain period.

In order to construct DMA with perfect condition, it is necessary to perform hydraulic calculation based on distribution pipe data, and to develop a pipe network that does not cause a significant shortage of water demand, which requires a great deal of cost and time.

2.4.2 Purpose of constructing a DMA

The purpose of constructing a DMA is as follows.

- After limiting the boundary of distribution network from the surroundings at night, measure the Minimum Night Flow (MNF) to roughly understand the level of water leakage occurring in the area.
- Divide MNF by the number of customers existing in the area to calculate the Minimum Night Flow rate per connection (MNF/connection).
- Divide MNF by the pipeline extension in the area to calculate the Minimum Night Flow rate per km (MNF/km).
- Compare the MNF of different DMAs to identify areas with high levels of water leakage and NRW, and take efficient and effective water leakage reduction measures considering priority.
- It is recommended that the effect of the measures should be regularly confirmed in the DMA that has taken measures against water leakage, at least once a month.
- By installing a remote monitoring system in DMA, we can monitor daily inflow water volume and water pressure and respond to sudden leaks and water distribution network accidents.

2.4.3 Information needed for DMA design

The following information needs to be confirmed when designing a DMA.

- Location, diameter and actual status of existing valves and its diameter
- Location and diameter of Inlet pipe of a target area
- Information of distribution pipes near the expected boundary
- In case of sub-zoning, detail of pipeline of its boundary
- Water supply pressure

2.4.4 Preliminary design of DMA

Based on the information obtained in advance, the following preliminary design will be performed.

After that, the boundary may be modified while referring to the data of the water distribution network found by making the area hydraulically isolated and measuring the water pressure.

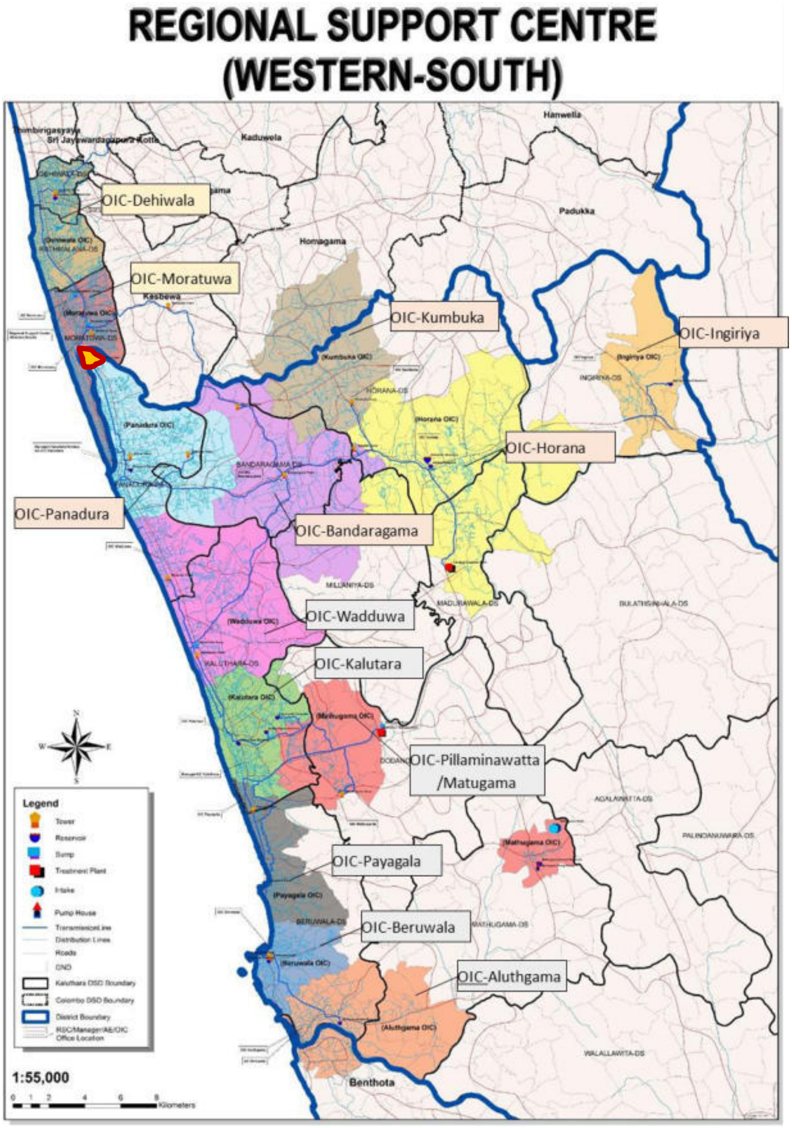


Figure 2.1 Location of Pilot Area

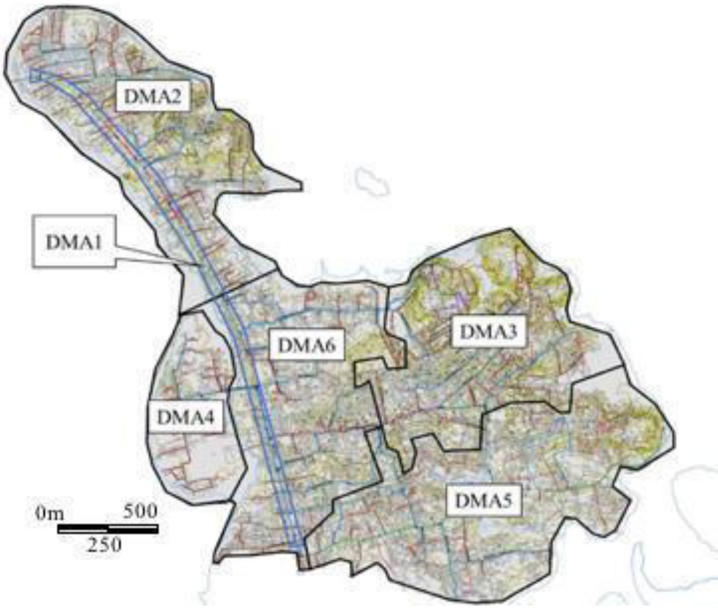


Figure 2.2 Plan of DMA creation at beginning stage 2018

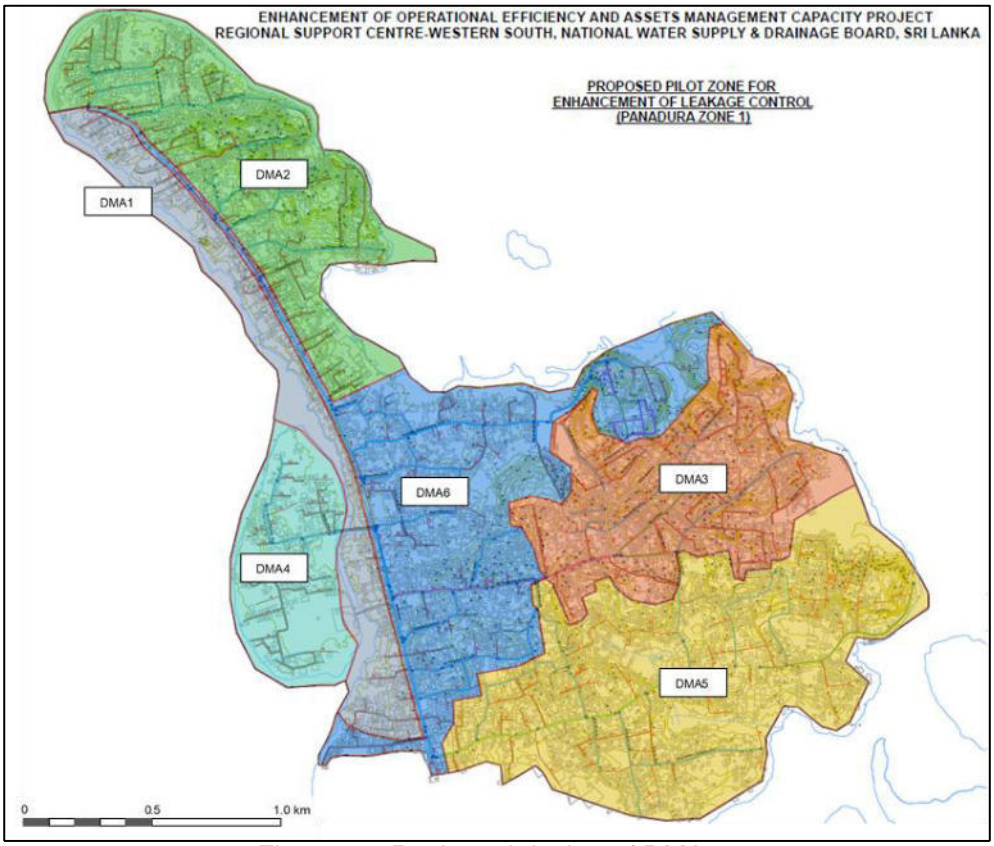


Figure 2.3 Reviewed design of DMA

After the practical survey at the site, plan shown in Figure 2.2 was changed as Figure 2.3.

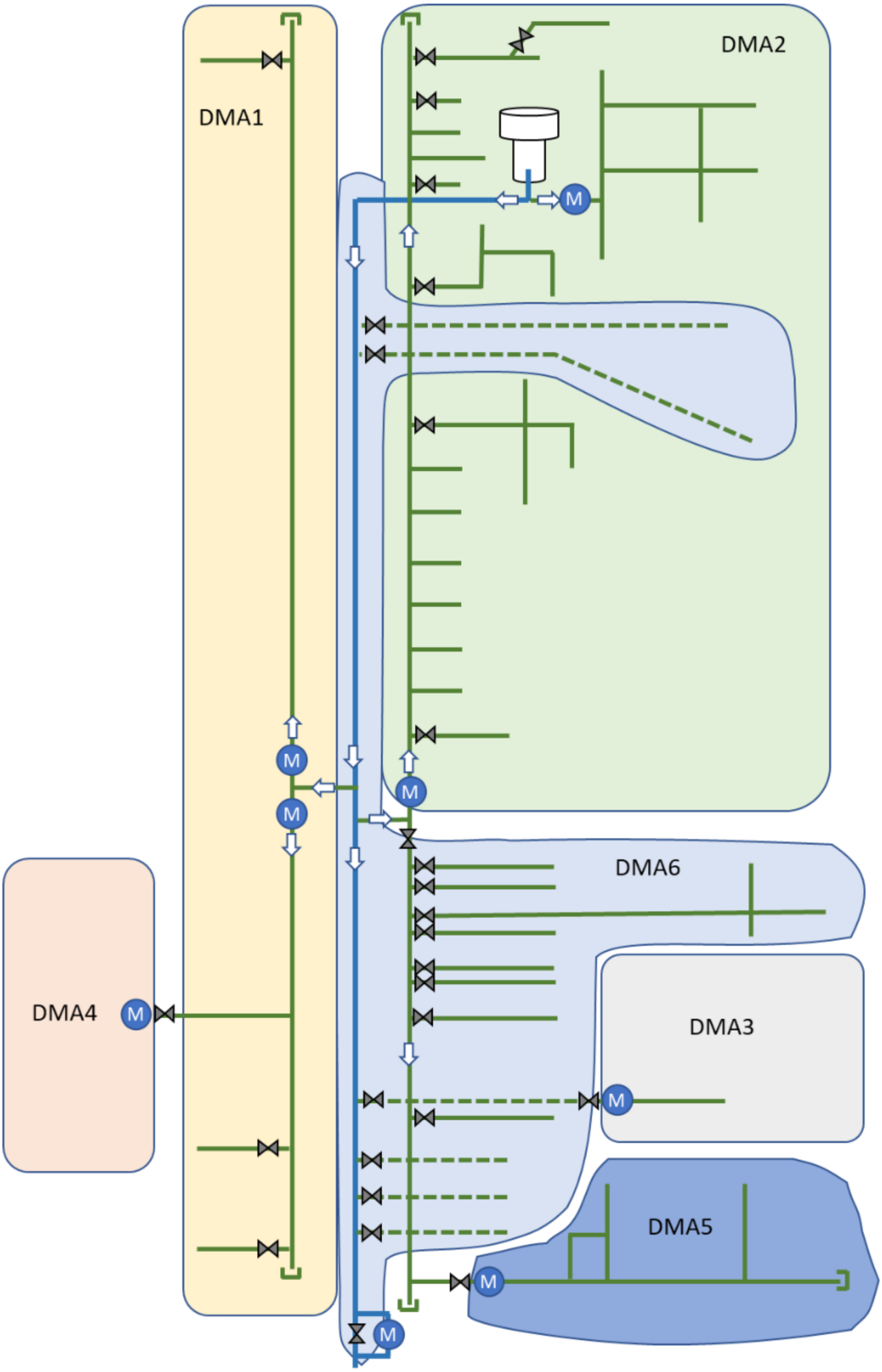
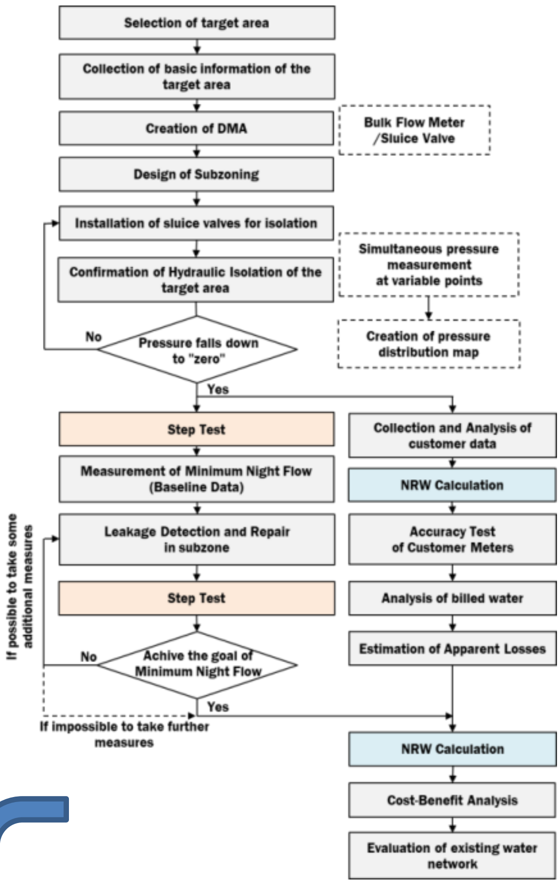


Figure 2.4 Schematic image of distribution pipes of DMA

2.5 Determination of activity schedule

The person responsible for implementing the activity sets the activity schedule based on the basic workflow described in Section 1.4.2.

- Implementation system and determination of activity members
- Secure activity budget
- Site survey and confirmation of construction conditions in the DMA target area
- Collection of customer information and billed water volume data in the area
- Procurement of materials and equipment necessary for hydraulic independence
- Construction of hydraulic isolation
- Measurement of inflow water and minimum flow rate at night
- Calculation of NRW rate
- Accuracy test of customer meters
- Detection and repair of leakage



Activities	January				February				March			
	1w	2w	3w	4w	1w	2w	3w	4w	1w	2w	3w	4w
1.												
2.												
3.												
4.												
5.												

3 DO Practice of leakage control measures

This chapter explains the DO of PDCA cycle in the Pilot project site and real practices at 6 DMAs.

The practice of water leakage control using DMA is carried out according to the following flow.

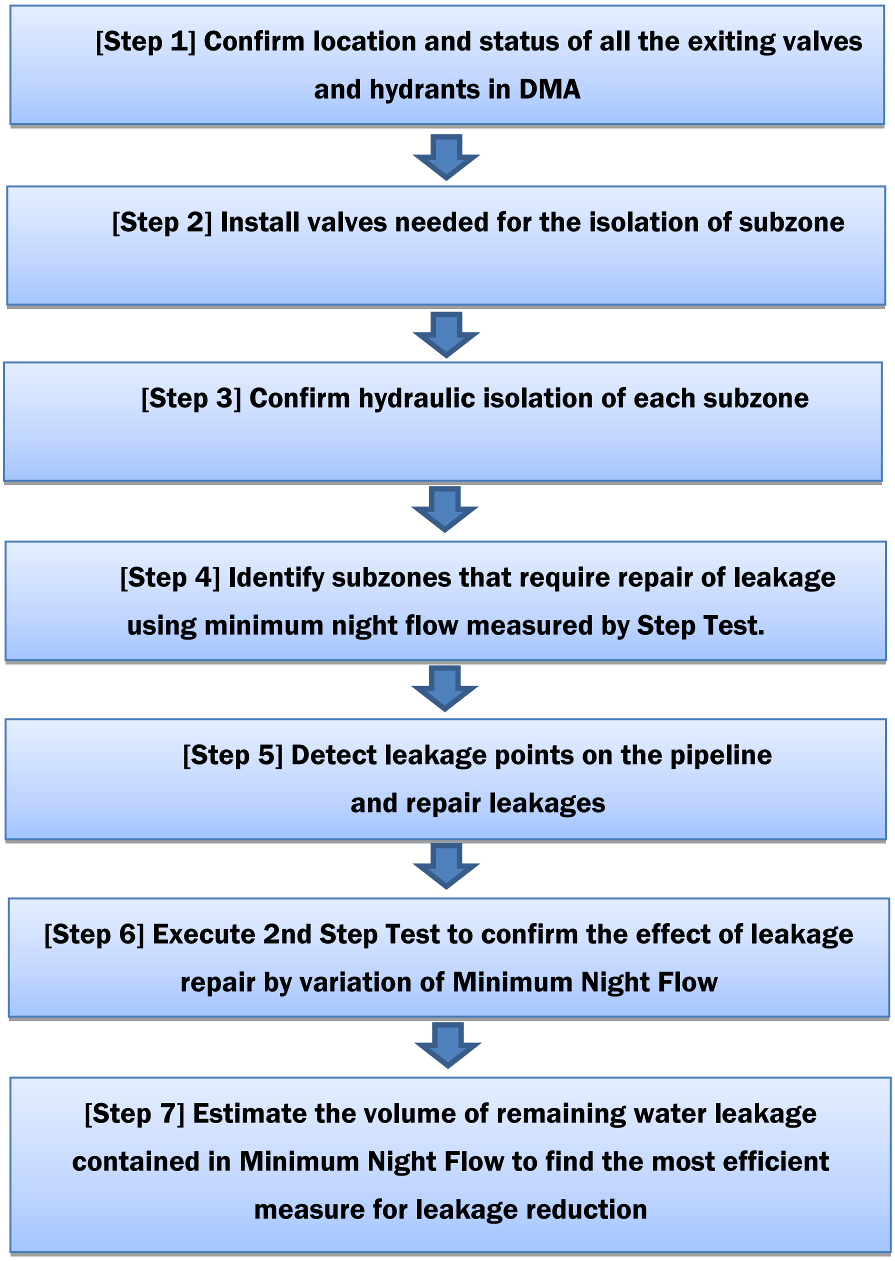


Figure 3.1 Steps of leakage reduction activities

3.1 Leakage Reduction Activity of each DMA

To proceed with the construction of the DMA, a field survey should be conducted based on the preliminary design created in advance. The distribution pipe, distribution status, the presence or absence of dead-end pipes, and the connection status with adjacent areas should be confirmed and should be reflected to updating work of pipeline network drawing.

After that, the changes from the preliminary design will be clarified and the boundaries for hydraulic independence will be set.

If the water pressure gauges are installed at multiple points in the area, the valves at the inflow points are closed, and the water supply pressure becomes zero after a certain period of time, it means that hydraulic independence has been achieved.

	
Measurement of pressure at the water tap	Equipment of pressure measurement at a certain point of distribution pipe.

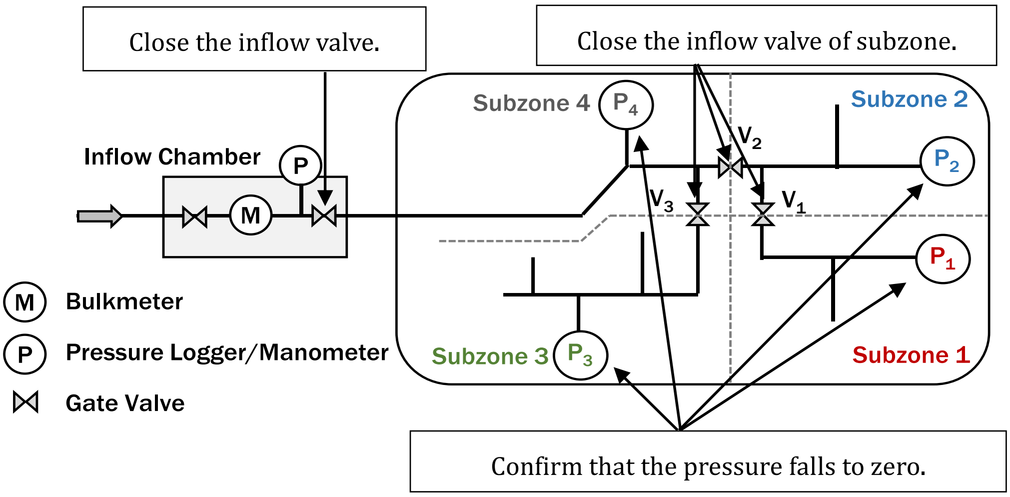


Figure 3.2 Image of pressure measurement in DMA

The following sub chapters shows the practice at the three typical DMAs out of 6 DMAs.

3.1.1 DMA 5

The features of DMA 5 are as follows. It is a simple and basic example.

- There is only one inflow pipe to the area.
- Since there are many existing valves in the area, it is easy to set the DMA boundary.
- There are multiple types of road pavement.
- There is a difference in elevation, and it is necessary to select an appropriate leak detection method according to the water pressure condition for each subzone.

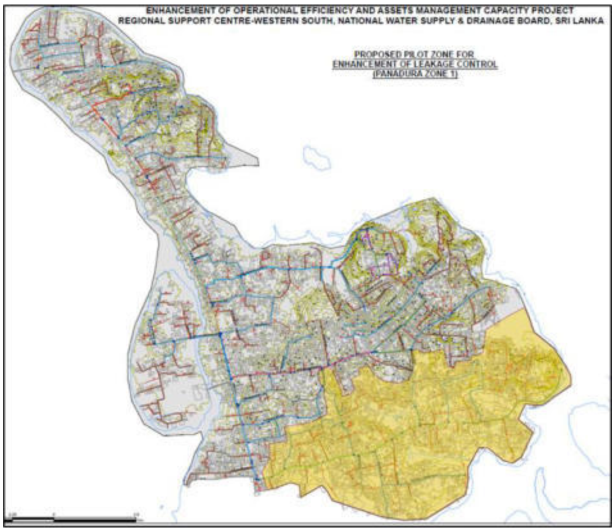


Figure 3.1.8 Location of DMA 5

There is only one inflow pipe to the area. Establish a separation plan for subzones (hydraulicly separated subdivisions) with sluice valves so that inflow of each subzone can be measured by flow meters installed at the inlet point of DMA.

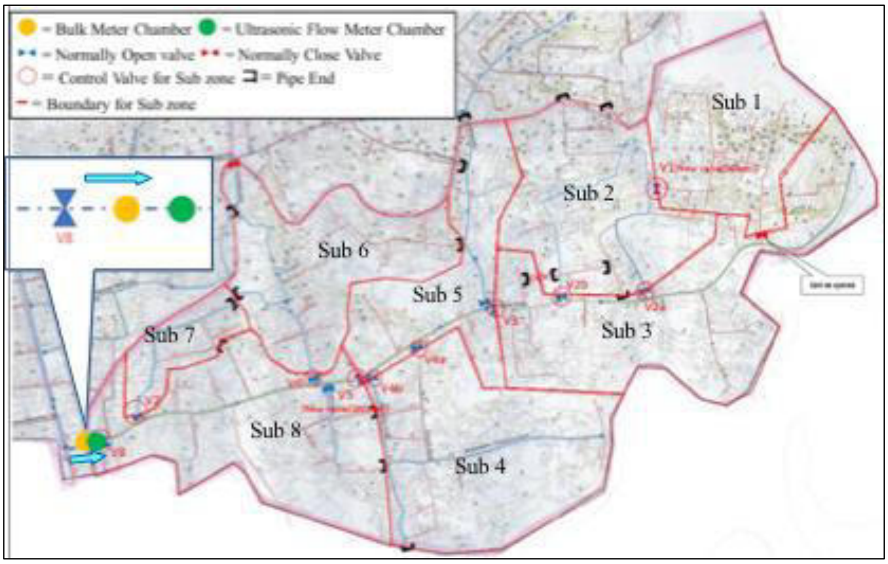


Figure 3.1.9 Sub-zoning of DMA5

The materials required for the construction of DMA 5 and subzones are as follows.

Table 3.1.8 Material for hydraulic isolation of DMA5

Items	Qty
Bulk Flow Meter (DN200)	1
Sluice Valve (DN200)	1
Sluice Valve (DN50)	1
Flanges, Manhole cover, Valve key etc.	1 set

Table 3.1.9 Basic Information of subzone in DMA 5

Subzone No.	Number of connections	Extension of distribution pipes (km)	General situation
1	159	1.9	Quiet residential area, good survey environment. The difference of ground elevation is large.
2	184	2.1	Quiet residential area, good survey environment. The difference of ground elevation is large.
3	721	2.5	Divided into noisy areas facing avenue and quiet residential areas Attention should be paid to noise on traffic road.
5		1.3	Divided into noisy areas facing avenue and quiet residential areas Attention should be paid to noise on traffic road.
4	299	1.7	Quiet residential area, good survey environment. The difference of elevation in the area is small, but it becomes lower as it goes to the end of the pipeline.
6	316	1.9	Quiet residential area, good survey environment. The difference of ground elevation is large.
7	197	1.0	Quiet residential area, good survey environment. There are some small factories, etc. The elevation at the valve V7 point is low and gradually increases toward the end of the pipe.
8	365	2.5	This area is facing the main road. There are many shops, and noise continues to occur during the day. The difference of elevation is small
Total	2,241	14.9	-

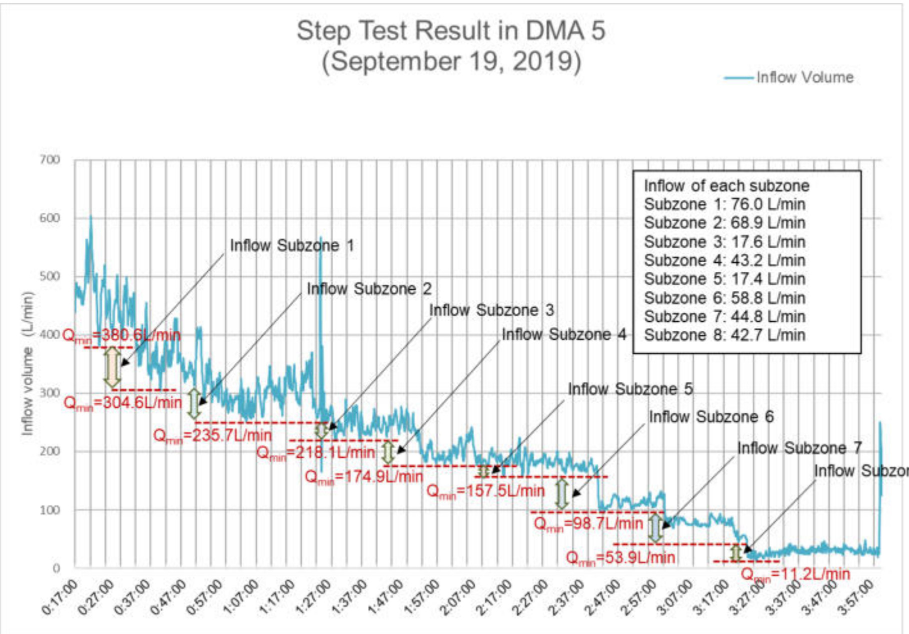


Figure 3.1.10 Result of 1st Step Test in DMA 5

Table 3.1.10 Evaluation of subzone with MNF/km in DMA 5 (Before activities)

Zone ID	Inflow Volume	Pipe Length	Evaluation Indicator	Prioritization
Subzone 1	76.0 L/min	1.9 km	40.00 L/min･km	2
Subzone 2	68.9 L/min	2.1 km	32.81 L/min･km	3
Subzone 3	17.6 L/min	2.5 km	7.04 L/min･km	8
Subzone 4	43.2 L/min	1.7 km	25.41 L/min･km	5
Subzone 5	17.4 L/min	1.3 km	13.38 L/min･km	7
Subzone 6	58.8 L/min	1.9 km	30.95 L/min･km	4
Subzone 7	44.8 L/min	1.0 km	44.80 L/min･km	1
Subzone 8	42.7 L/min	2.5 km	17.08 L/min･km	6

Table 3.1.11 Evaluation of subzone with MNF/connection in DMA 5 (Before activities)

Zone ID	Inflow Volume	No. Customer	Evaluation Indicator	Prioritization
Subzone 1	76.0 L/min	159	0.48 L/min･con	1
Subzone 2	68.9 L/min	184	0.37 L/min･con	2
Subzone 3	17.6 L/min	721	0.05 L/min･con	7
Subzone 4	43.2 L/min			
Subzone 5	17.4 L/min	299	0.14 L/min･con	5
Subzone 6	58.8 L/min	316	0.19 L/min･con	4
Subzone 7	44.8 L/min	197	0.23 L/min･con	3
Subzone 8	42.7 L/min	365	0.12 L/min･con	6

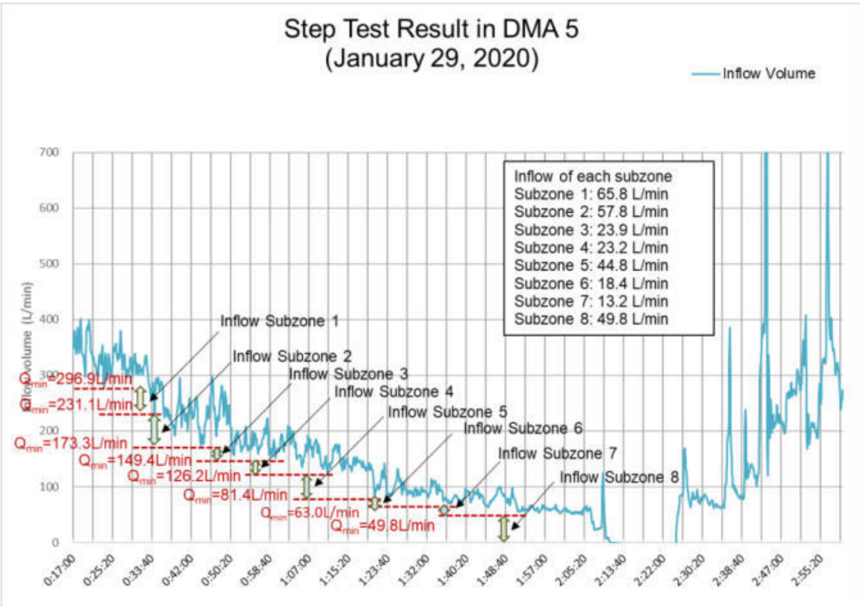


Figure 3.1.11 Result of 2nd Step Test in DMA 5

Table 3.1.12 Evaluation of subzone with MNF/km in DMA 5 (After activities)

Zone ID	Inflow Volume	Pipe Length	Evaluation Indicator	Prioritization
Subzone 1	65.8 L/min	1.9 km	34.63 L/min･km	1
Subzone 2	57.8 L/min	2.1 km	27.52 L/min･km	3
Subzone 3	23.9 L/min	2.5 km	9.56 L/min･km	7
Subzone 4	23.2 L/min	1.7 km	13.65 L/min･km	5
Subzone 5	44.8 L/min	1.3 km	34.46 L/min･km	2
Subzone 6	18.4 L/min	1.9 km	9.68 L/min･km	8
Subzone 7	13.2 L/min	1.0 km	13.20 L/min･km	6
Subzone 8	49.8 L/min	2.5 km	19.92 L/min･km	4

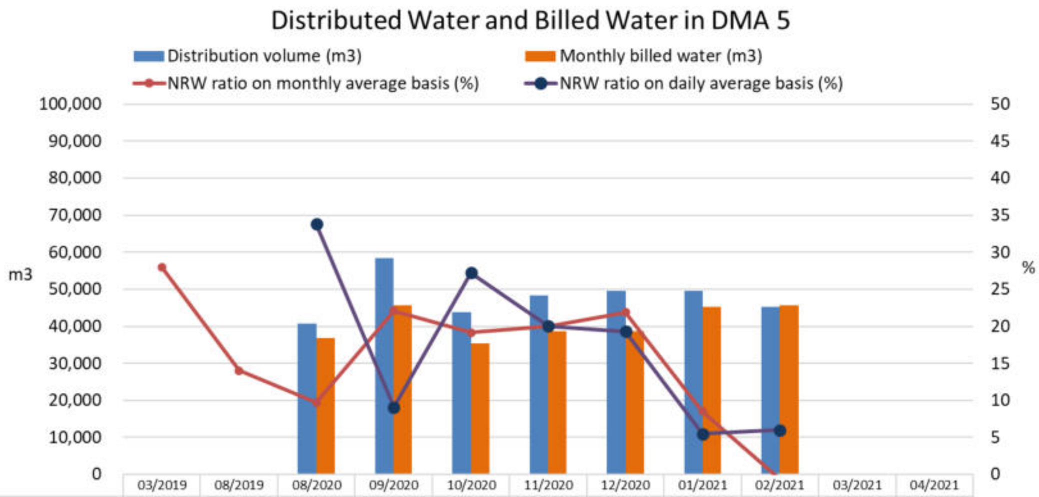
Table 3.1.13 Evaluation of subzone with MNF/connection in DMA 5 (After activities)

Zone ID	Inflow Volume	No. Customer	Evaluation Indicator	Prioritization
Subzone 1	65.8 L/min	159	0.41 L/min･con	1
Subzone 2	57.8 L/min	184	0.31 L/min･con	2
Subzone 3	23.9 L/min	721	0.10 L/min･con	4
Subzone 4	23.2 L/min			
Subzone 5	44.8 L/min	299	0.08 L/min･con	5
Subzone 6	18.4 L/min	316	0.06 L/min･con	7
Subzone 7	13.2 L/min	197	0.07 L/min･con	6
Subzone 8	49.8 L/min	365	0.14 L/min･con	3

Table 3.1.14 Result of Leakage Control Activities in DMA 5

Zone ID	Unit	Result	
		Sept. 19, 2019	Jan 29, 2020
Subzone 1	L/min	76.0	65.8
Subzone 2	L/min	68.9	57.8
Subzone 3	L/min	17.6	23.9
Subzone 4	L/min	43.2	23.2
Subzone 5	L/min	17.4	44.8
Subzone 6	L/min	58.8	18.4
Subzone 7	L/min	44.8	13.2
Subzone 8	L/min	42.7	49.8
MNF	L/min	380.6	296.9
NRW	%	28	14

The changes in non-revenue water since September 2020 is shown following figure. The NRW seems fluctuating. The system input is measured the reading of bulk meter and consumption is sum of domestic meter reading values. The duration between two readings is not the same. Therefore, we suggest the use of daily average value of NRW. It cancels the difference of duration of meter reading



	03/2019	08/2019	08/2020	09/2020	10/2020	11/2020	12/2020	01/2021	02/2021	03/2021	04/2021
Distribution volume (m3)			40,834	58,476	43,750	48,400	49,500	49,550	45,350	0	0
Monthly billed water (m3)			36,869	45,567	35,364	38,716	38,664	45,332	45,669		
Monthly NRW (m³/month)			3,965	12,909	8,386	9,684	10,836	4,218	-319		
NRW ratio on monthly average basis (%)	28.0	14.0	9.7	22.1	19.2	20.0	21.9	8.5	(0.7)		
NRW ratio on daily average basis (%)			33.8	9.1	27.3	20.0	19.3	5.5	6.0		

Figure 3.1.12 NRW ratio in DMA 5

3.1.2 DMA 3

(1) Outline of DMA 3

The features of DMA 3 are as follows. Remote monitoring system was introduced for continuous monitoring to take immediate countermeasures to leakage.

- There are two inflow pipes to the area.
- The north area is supplied from the distribution pipe from DMA6 on the west side, and the distribution network is separated from the south area.
- For smooth and effective implementation of leakage control activities, it is recommended that the southern area indicated below should be included in DMA 3 and the north area be included in DMA 6.

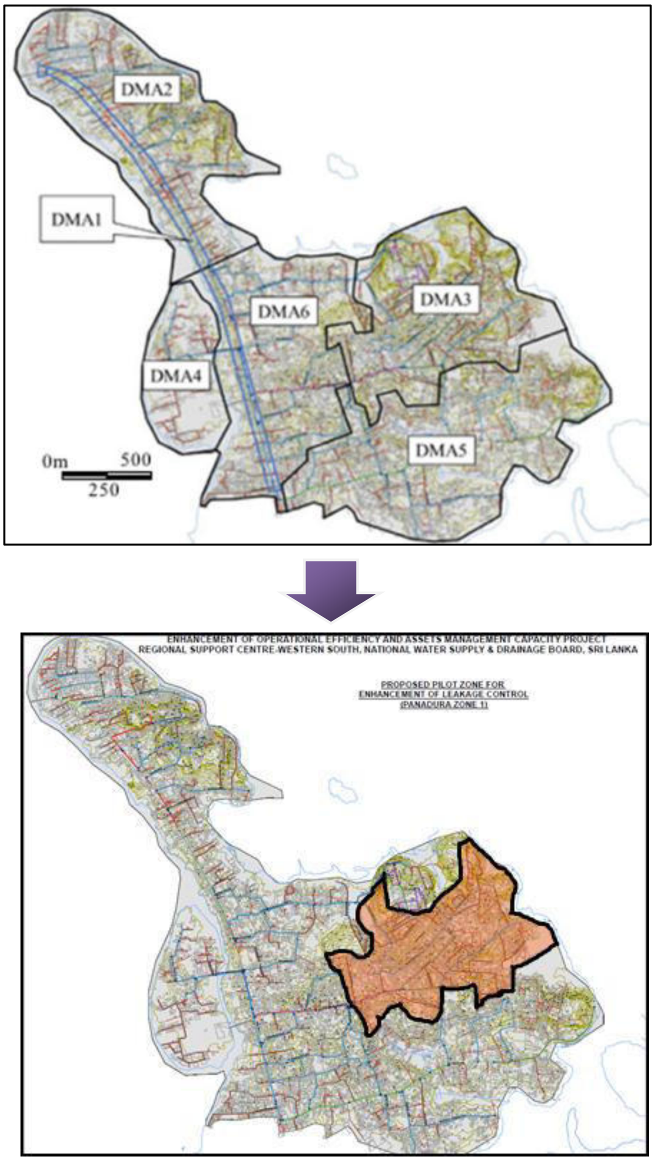


Figure 3.1.13 Change of Design of DMA 3

(2) Sub-zoning Plan and Hydraulic Isolation Work of DMA 3

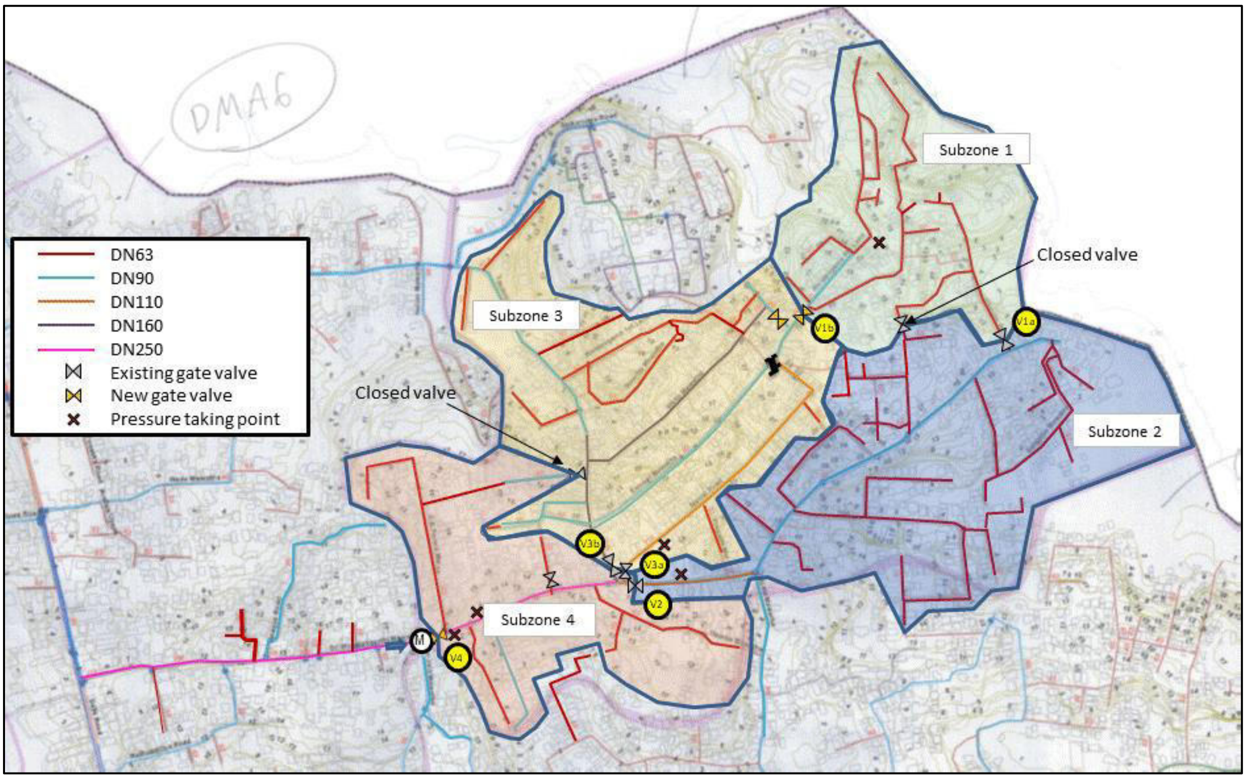


Figure 3.1.14 Sub-zoning of DMA 3

The materials required for the construction of DMA3 and subzones are as follows.

Table 3.1.15 Material for hydraulic isolation of DMA 3

Items	Qty
Bulk Flow Meter (DN250)	1
Sluice Valve (DN250)	2
Sluice Valve (DN150)	2
Sluice Valve (DN80)	3
Flange Adaptor (DN250)	4
Flange Adaptor (DN150)	4
Flange Adaptor (DN80)	6
PVC Pipe DN160 (for Valve DN80)	3 mts
PVC Pipe DN160 (for Valve DN150)	1 mts
Surface Box 150x150x100 (for Valve DN80)	3
Surface Box 150x150x100(for Valve DN150)	2
Precast Chamber Set	2

Table 3.1.16 Basic Information of subzone in DMA 3

Subzone No.	Number of connections	Extension of distribution pipes (km)	General situation
1	657	2.2	
3		3.5	
2	250	3.7	
4	216	2.1	
Total	1,123	11.5	-

(3) 1st Step Test

The 1st Step Test in DMA 3 was conducted on October 8th, 2020.

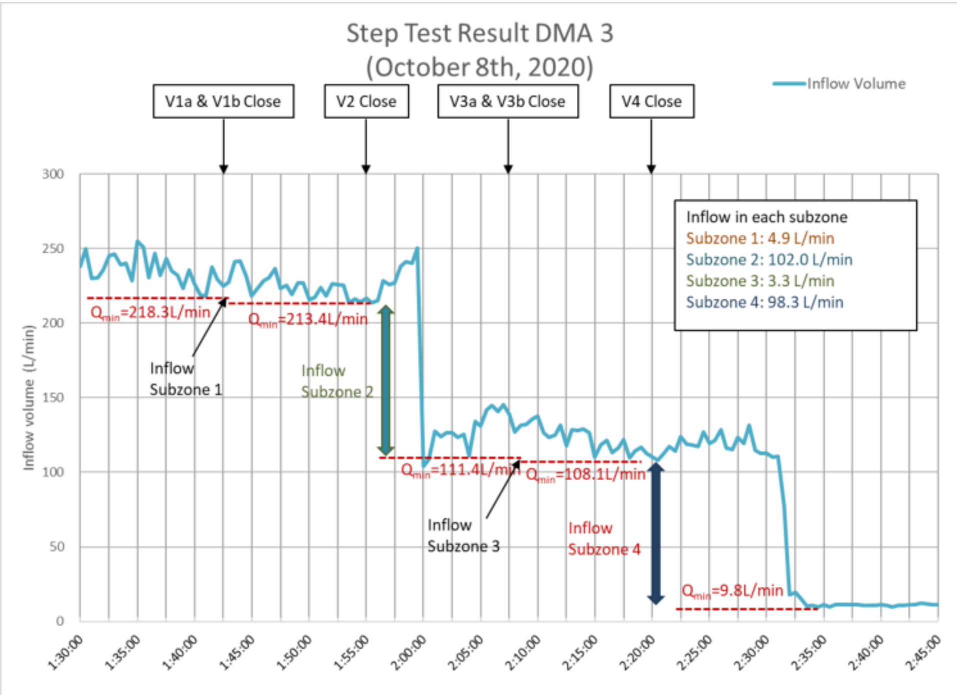


Figure 3.1.15 Result of 1st Step Test in DMA3

Table 3.1.17 Evaluation of subzone with MNF/km in DMA 3 (Before activities)

Zone ID	Inflow Volume	Pipe Length	Evaluation Indicator	Prioritization
Subzone 1	4.9 L/min	2.18 km	2.25 L/min･km	3
Subzone 2	102.0 L/min	3.67 km	27.79 L/min･km	2
Subzone 3	1.9 L/min	3.51 km	0.54 L/min･km	4
Subzone 4	99.4 L/min	2.04 km	48.73 L/min･km	1

Table 3.1.18 Evaluation of subzone with MNF/connection in DMA 3 (Before activities)

Zone ID	Inflow Volume	No. Customer	Evaluation Indicator	Prioritization
Subzone 1	6.8 L/min	657	0.01 L/min･con	3
Subzone 3				
Subzone 2	102.0 L/min	250	0.41 L/min･con	2
Subzone 4	99.4 L/min	216	0.46 L/min･con	1

(4) Leak Detection and Repair Work

Table 3.1.19 HH Survey & Road Surface Survey in DMA3

Items	Result	
	Subzone 4	Subzone 2
No of customer targeted by H-H Survey	216	250
Suspicious leak point detected by H-H Survey	19	8
Suspicious leak point detected by Road Surface Survey	9	12
Total point of suspicious leakage	28	20
Comparison	High	Middle
Number of repaired leak	13	12

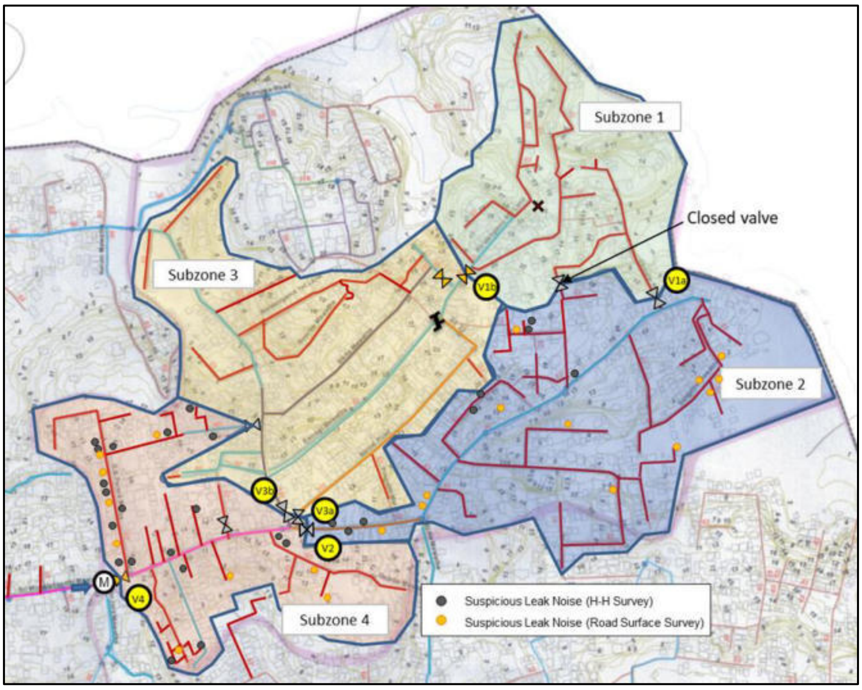


Figure 3.1.16 Map of Suspicious Leakage Points

(5) Monitoring of Minimum Night Flow

The materials required for the construction of DMA 3 and subzones are as follows.

In DMA 3, an electromagnetic flow meter is installed in the inflow section, and the flow rate can be monitored by counting the electric signal transmitted every 100L of water flow.

The installed system records the number of pulse signals generated during a certain period of time in a data logger and sends it to a Web server via a 3G network.

The transmitted data can be confirmed on the Internet by the service provided by the manufacturer of the data logger.

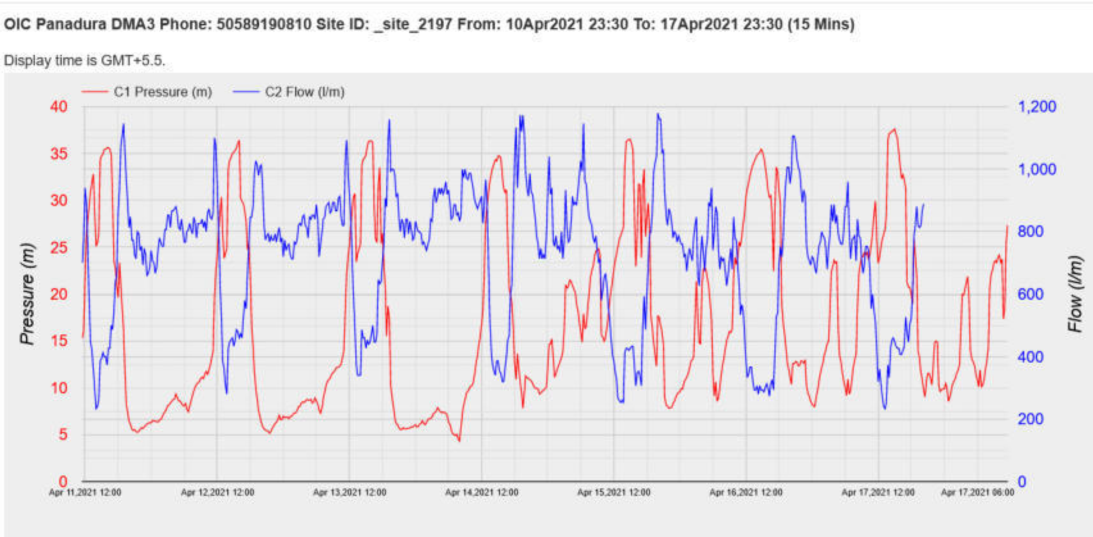


Figure 3.1.18 Monitoring Screen of Web Browser

(6) 2nd Step Test in DMA 3

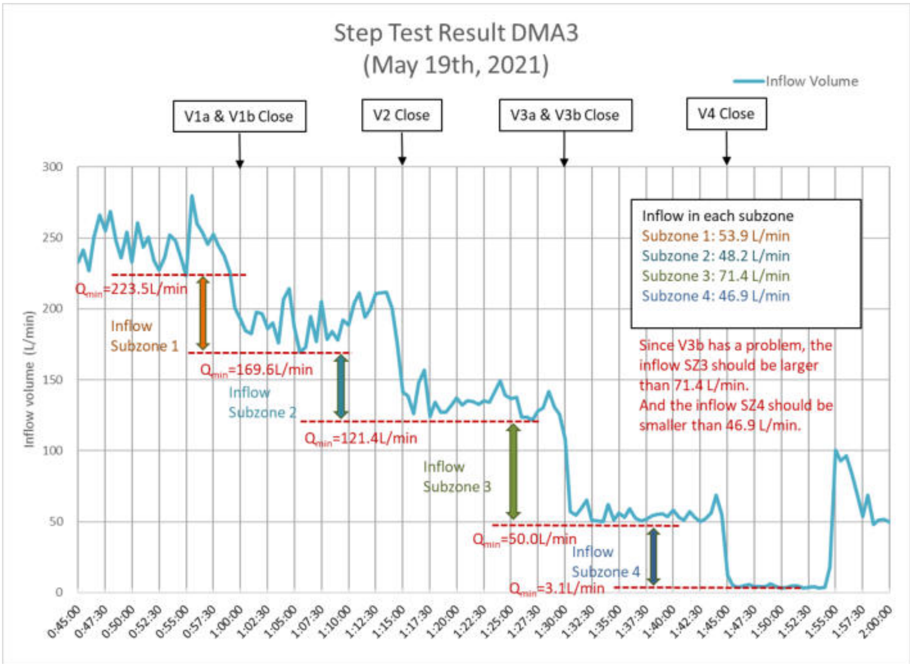


Figure 3.1.19 Result of 2nd Step Test in DMA3

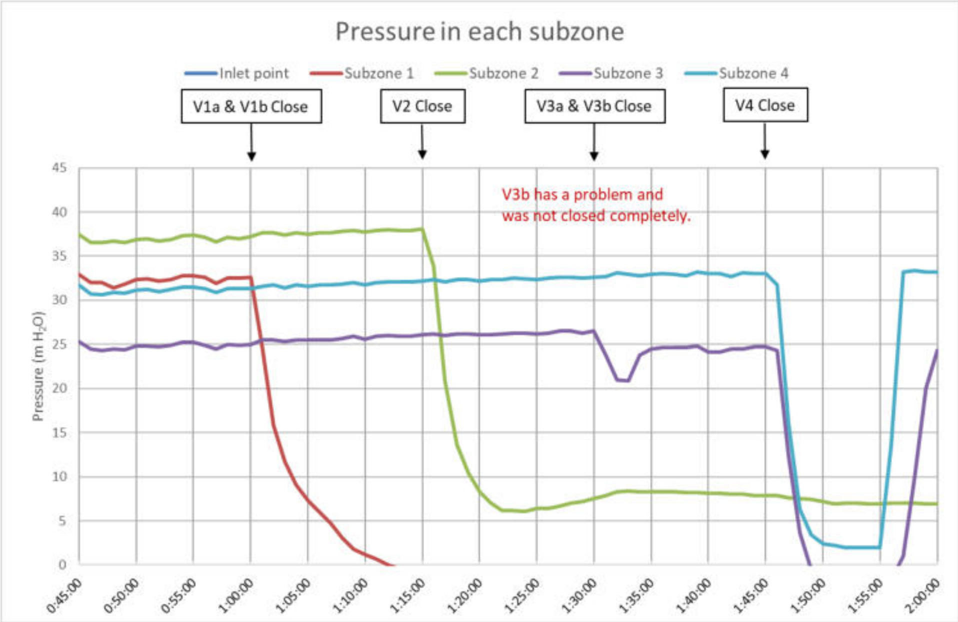


Figure 3.1.20 Pressure Monitoring during the 2nd Step Test in DMA

Table 3.1.20 Evaluation of subzone with MNF/km in DMA 3 (After activities)

Zone ID	Inflow Volume	Pipe Length	Evaluation Indicator	Prioritization
Subzone 1	53.9 L/min	2.18 km	24.72 L/min･km	1
Subzone 2	48.2 L/min	3.67 km	13.13 L/min･km	4
Subzone 3	71.4 L/min	3.51 km	20.34 L/min･km	3
Subzone 4	46.9 L/min	2.04 km	22.99 L/min･km	2

Table 3.1.21 Evaluation of subzone with MNF/connection in DMA 3 (After activities)

Zone ID	Inflow Volume	No. Customer	Evaluation Indicator	Prioritization
Subzone 1 Subzone 3	125.3 L/min	657	0.19 L/min･con	3
Subzone 2	48.2 L/min	250	0.19 L/min･con	2
Subzone 4	46.9 L/min	216	0.22 L/min･con	1

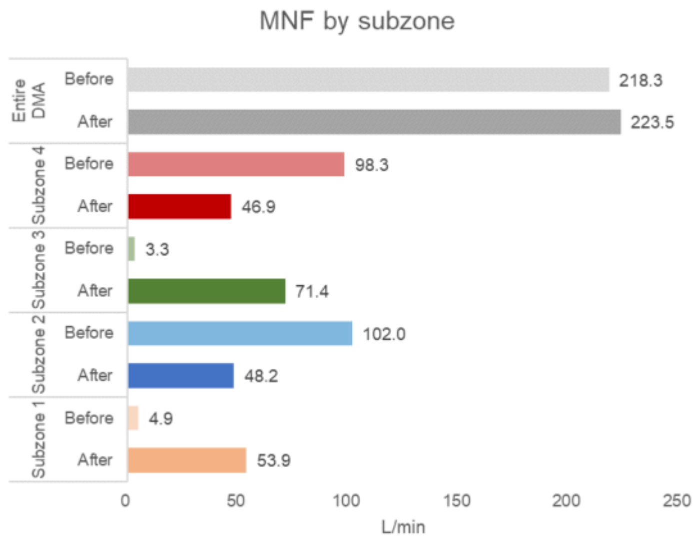


Figure 3.1.21 Difference of MNF in DMA 3 (Before/After)

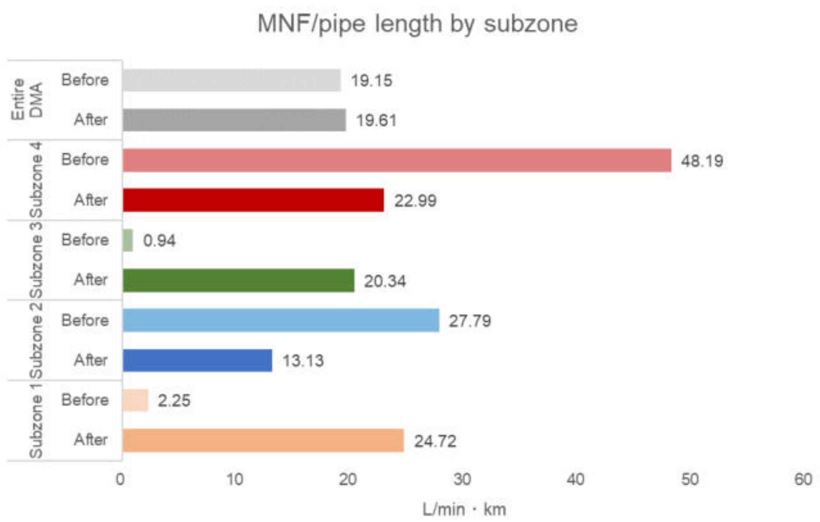


Figure 3.1.22 Difference of MNF/pipe length in DMA 3(Before/After)

(7) Evaluation of Leakage Reduction Activity

1) Analysis of Leakage Reduction

From the results of the step test conducted on October 8, 2020, it was found that the priority of water leakage countermeasures in subsectors 1 and 3 was low. On the other hand, it was considered necessary to focus on measures against water leakage in sub-sector 2 and sub-sector 4.

After implementing leak reduction activities in these two subzones, the minimum night flow (inflow of each subzone) has been reduced to 47% in both subzones. This is considered to be the result of focusing on leak detection and leak repair.

However, from the time of the 2nd step test, the increasing tendency of water inflow in subzone 1 and subzone 3 was observed on the monitoring data.

In subzone 1 and subzone 3, it was initially evaluated that the suspicion of water leakage was low, so no water leakage countermeasures were implemented. However, in all of these subzones, the MNF rate has increased significantly.

As a result of a patrol survey immediately after the step test, a new leak was confirmed in subzone 3.

The second step test was conducted approximately 7 months after the first implementation date. After such a long period of time, new water leaks and changes in nighttime water usage due to seasonal changes appear.

2) Necessity of Additional Leakage Reduction

Leakage is considered to be a major factor in the increase of MNF rate in subzone 1 and subzone 3. Therefore, the severity can be judged by comparing the entire DMA using the evaluation index "MNF / pipe length ".

The indicator (L/min･km) of the entire DMA is almost unchanged before and after the activity, and is in the range of 18 to 20 L/min･km.

At the start of the activity, the indicator value in subzone 2 and subzone 4 was 46.81 L/min･km and 27.57 L/min･km respectively, which greatly exceeded the average value of the entire DMA. Therefore, it is clear that the need for water leakage countermeasures in these two subzones was extremely high.

On the other hand, the current MNF rates of subzone 1 and subzone 3 have increased significantly from October 2020, and its value of L/min･km also exceeds the value of entire DMA.

Although the excess width based on the overall average of entire DMA is not as large as that of subzones 2 and 4 before the start of activities, at the time of the step test, it was confirmed that water leakage occurred in subzone 3. Therefore, it is recommended to investigate the remaining subzones by road surface sound survey.

3) Analysis of Minimum Night Flow

The changes in MNF rate from April 1st, 2021 to May 31st, 2021 are as follows.

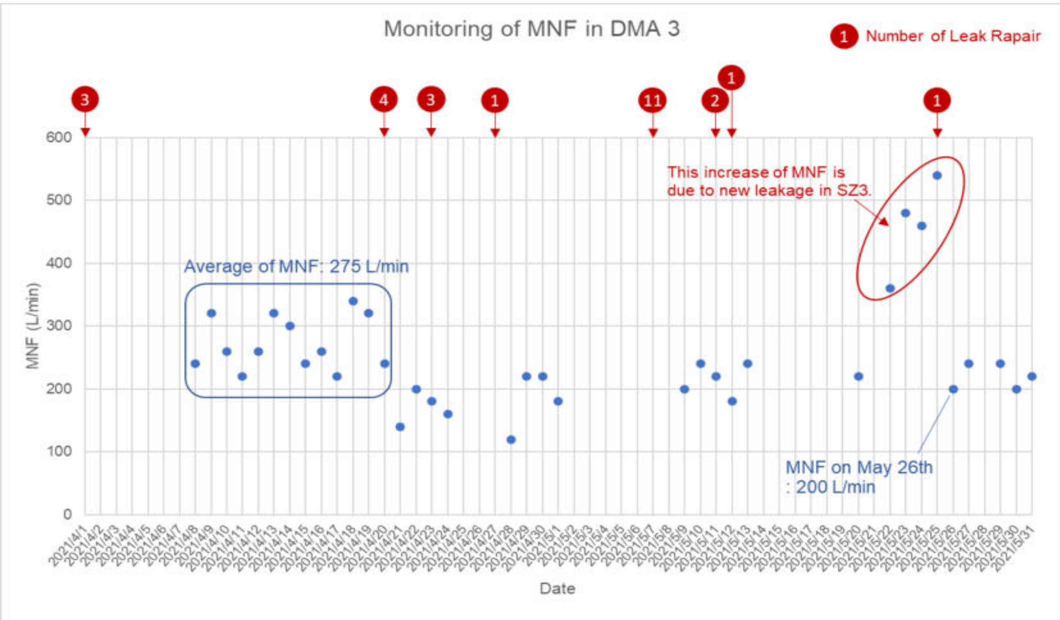


Figure 3.1.23 Fluctuation of MNF in DMA 3

The MNF in early April 2021, when full-scale leak repairs began, fluctuates greatly from day to day. In addition, while the leak repair was carried out in subzone 2 and subzone 4, it was considered that a new leak might occur in other subzones. And it is extremely difficult to estimate the amount of water leakage reduction from MNF rate of the entire DMA.

4) Estimation of reduced volume of leakage

Considering the above-mentioned result, in this pilot activity, the effect of leakage reduction activity should be evaluated only from the results of step test in subzone 2 and subzone 4.

Comparing the MNF rates for each subzone from the results of the step test, it can be confirmed that the inflow rate decreased by 53.8 L/min in subzone 2 and 51.4 L/min in subzone 4, for a total of 105.2 L/min.

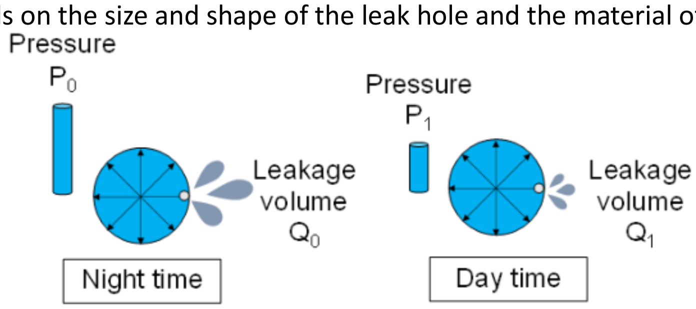
We assume that this reduction in MNF of 105.2 L/min corresponds to the amount of leak reduction in the two subzones where the leak repair was performed, and analyze the cost effectiveness from this value.

(8) Calculation of Reduced Leakage Volume

The amount of water obtained in the Step Test is the value at midnight when the water pressure is the highest, so in order to convert it into the daily average value, it is necessary to take into account the fluctuations in water pressure during the day and correct it.

The amount of water leaking from a single hole is highest at midnight when the water pressure is high, and is low during the day when the water pressure is low. This relationship is shown as follows. The coefficient N depends on the size and shape of the leak hole and the material of the pipe.

The relation between pressure and leakage volume is shown as follows. The coefficient N depends on the size and shape of the leak hole and the material of the pipe.



$$Q_1 / Q_0 = (P_1/P_0)^N$$

Leak from small orifice : N=0.5
Leak from crack of pipe or flange joint : N=1.15

Figure 3.1.24 Relation between leak volume and pressure

In DMA3, the water pressure can be monitored remotely. The pressure fluctuation between May 1st and 7th is as shown below:

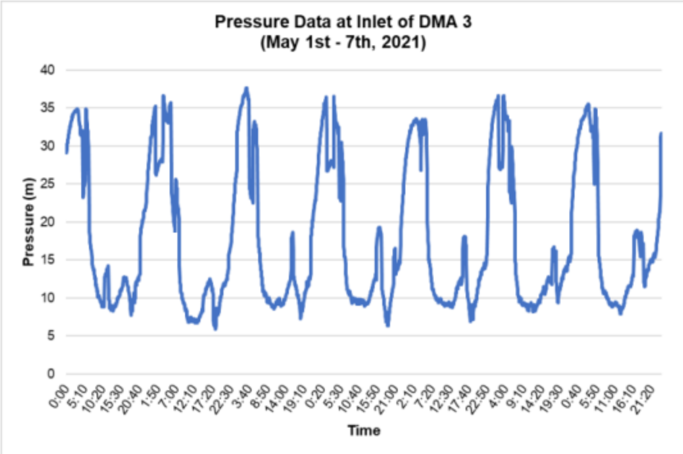


Figure 3.1.25 Pressure Fluctuation in DMA 3 (Inlet Point, May 2021)

The results of arranging this change in water pressure by the average value every 6 hours are as follows.

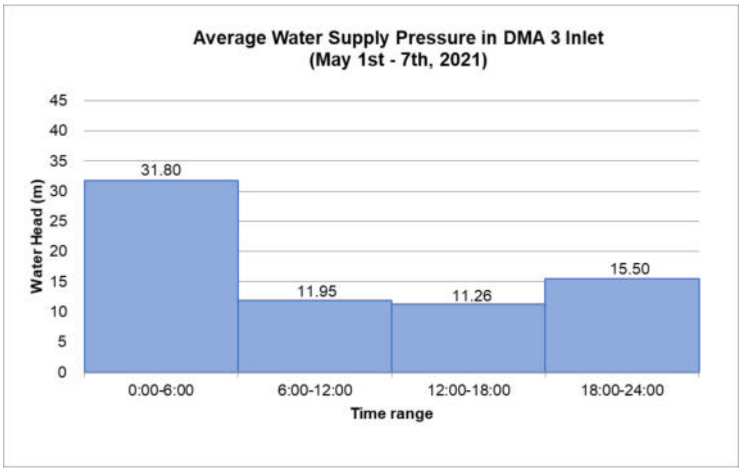


Figure 3.1.26 Fluctuation of Water Pressure in DMA3 Inlet (Average by time range)

The results of converting 105.2 L/min, which is the amount of water leakage reduction confirmed by the step test, into the daily average value are as follows. The effect of water leakage reduction was 76 L/min.

Table 3.1.22 Calculation of leak volume as an daily average value

Items	Time Range				Average
	0:00-6:00	6:00-12:00	12:00-18:00	18:00-24:00	
Pressure (m)	31.80	11.95	11.26	15.50	17.63
Proportion (P_x/P_o)	1.00	0.376	0.354	0.487	
$(P_x/P_0)^{0.5}$	1.00	0.613	0.595	0.698	
Flow rate (L/min)	105.20	64.49	62.59	73.43	76.43

P_x: Pressure at base time range

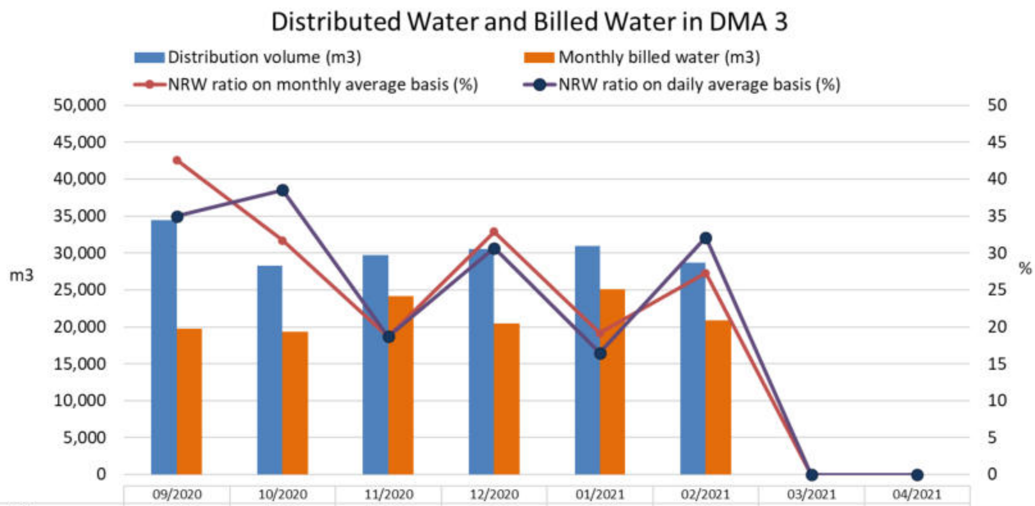
P_0: Pressure at target time range

Leakege volume = Flow rate at base time range x $(P_x/Po)^{0.5}$

However, the above value is a value estimated from the change in the MNF rate. In order to confirm the certainty of the estimation, it is necessary to compare the actual decrease in the amount of non-revenue water. Therefore, continuous monitoring of non-revenue water is important.

(9) NRW Monitoring in DMA 3

The changes in non-revenue water since September 2020 are as follows.



	09/2020	10/2020	11/2020	12/2020	01/2021	02/2021	03/2021	04/2021
Distribution volume (m3)	34,420	28,260	29,700	30,500	30,990	28,720		
Monthly billed water (m3)	19,748	19,299	24,150	20,466	25,049	20,885		
Monthly NRW (m³/month)	14,672	8,961	5,550	10,034	5,941	7,835	0	0
NRW ratio on monthly average basis (%)	42.6	31.7	18.7	32.9	19.2	27.3	0.0	0.0
NRW ratio on daily average basis (%)	35.0	38.5	18.7	30.7	16.5	32.1	0.0	0.0

Figure 3.1.27 NRW ratio in DMA 3

Since it is difficult to accurately match the meter reading interval of the customer meter with the meter reading interval of the bulk meter, the average value of NRW for the past 5 months is calculated as follows:

Assuming that leak repairs in subzones 2 and 4 reduced an average daily leak of about 76.4 L/min, future NRW is expected to be about 174.1 L/min (7,521 m^3/month).

Table 3.1.23 Distribution volume and NRW

Item	Cumulative value	Average value	Remarks
Before Repair Work			
Distributed water	182,590 m^3	700.5 L/min	181 days
Billed water	129,597 m^3	450.0 L/min	180 days
NRW volume	52,993 m^3	250.5 L/min	
NRW ratio	-	35.8 %	
After Repair Work (Hypothetical Estimation)			
Distributed water	-	524.1 L/min	Expected value
Billed water	-	450.0 L/min	
NRW volume	-	174.1 L/min	Expected value
NRW ratio	-	27.9 %	

3.1.3 DMA 6

The input volume was determined by the difference between inflow in this area and outflow from this area measured simultaneously. Prior to conducting the step test, it was confirmed to perform well. Since there are 500mm distribution main and many branch pipes in DNA 6, each branch line is considered as a sub-zone. Step test was carried out by closing valves at branch lines. The suspicious areas were identified.

(1) Outline of DMA 6

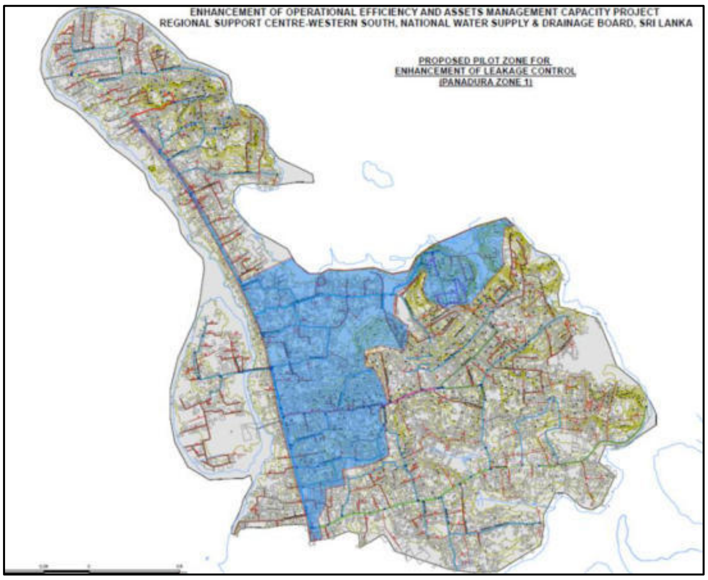


Figure 3.1.42 Location of DMA 6

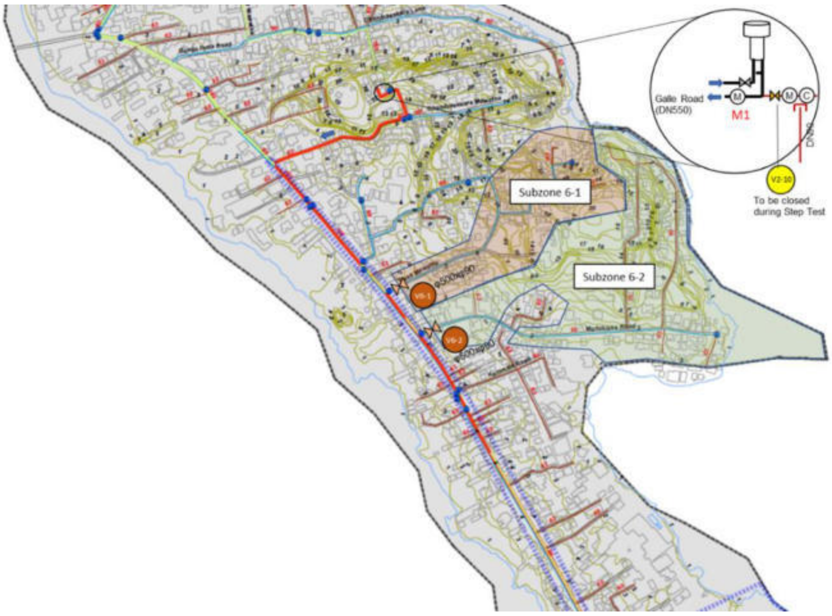


Figure 3.1.43 Sub-zoning of DMA 6 (1 of 3)

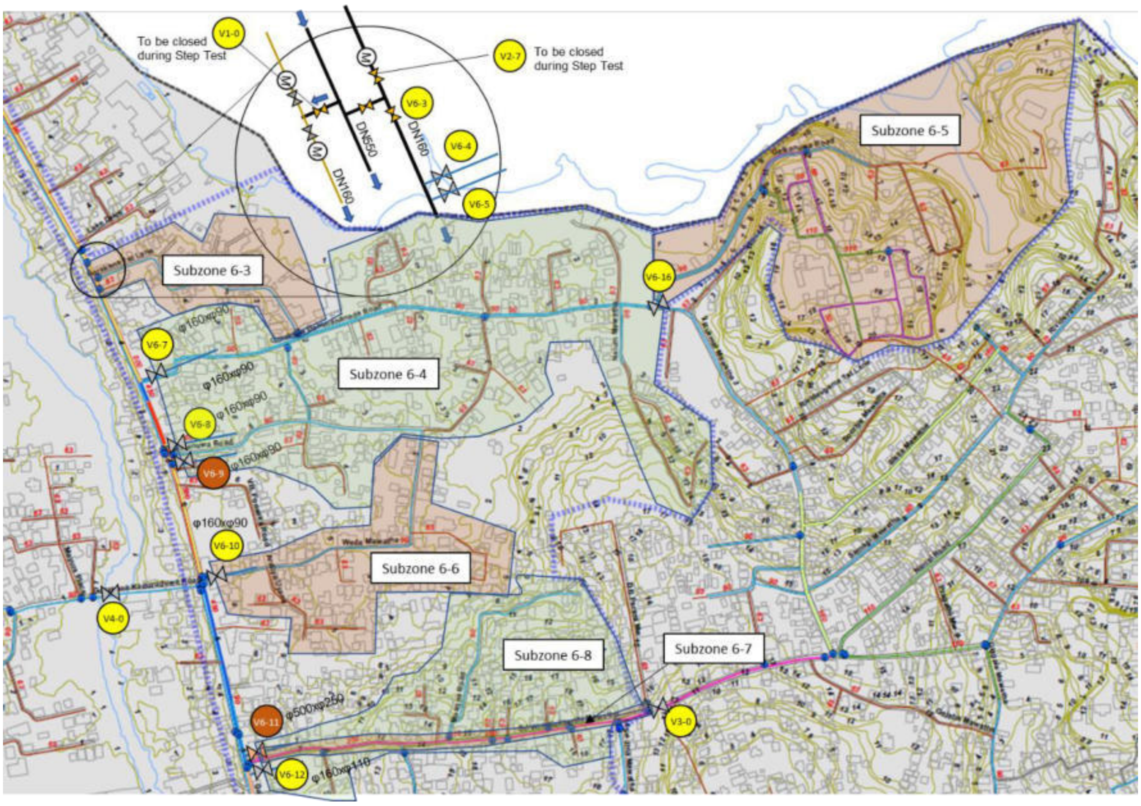


Figure 3.1.44 Sub-zoning of DMA 6 (2 of 3)

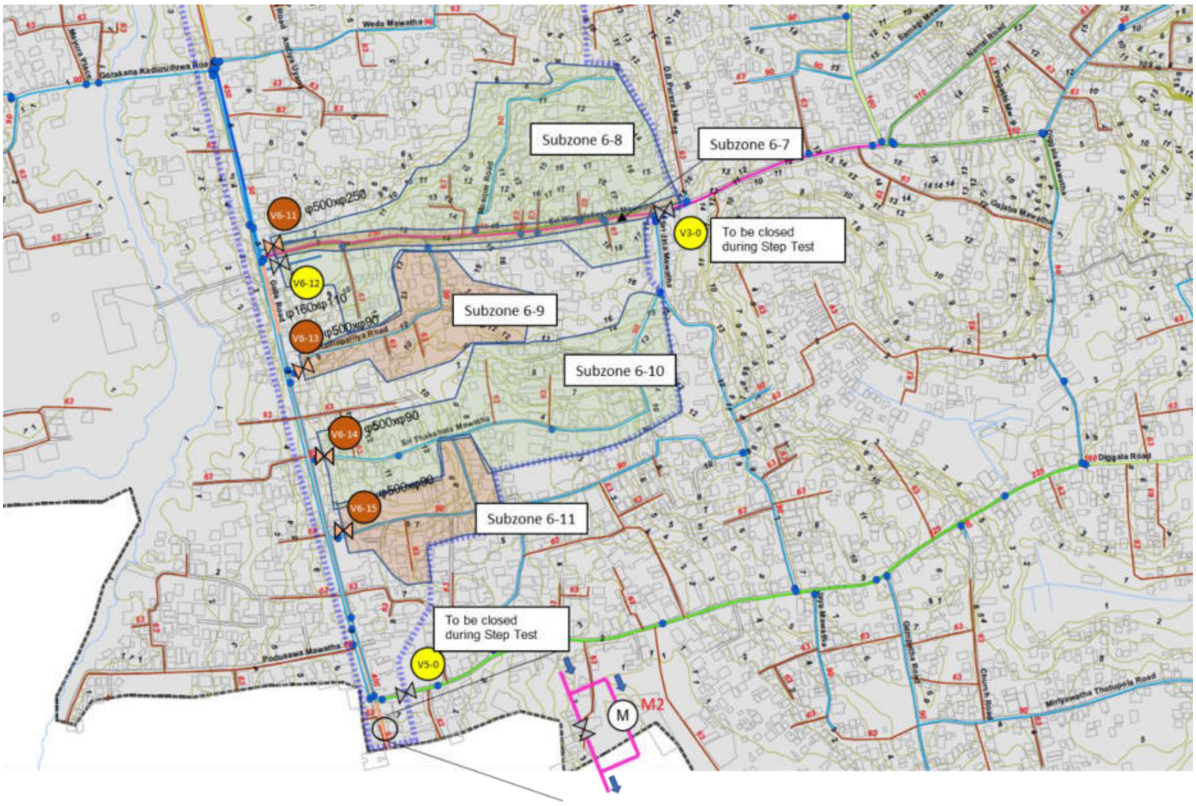


Figure 3.1.45 Sub-zoning of DMA 6 (3 of 3)

Table 3.1.34 Basic Information of subzone in DMA 6

Subzone ID.	Number of connections	Valve ID to isolate subzone	Extension of distribution pipes (km)	General situation
Subzone 6-1	-	V6-1	0.818	
Subzone 6-2	-	V6-2	1.717	
Subzone 6-3	-	V6-4	0.444	Subzone 6-3 is isolated by closing 2 valves.
		V6-5	0.521	
Subzone 6-4	-	V6-7	1.228	Subzone 6-3 is isolated by closing 3 valves.
		V6-8	0.617	
		V6-9	1.102	
Subzone 6-5	-	V6-16	2.305	
Subzone 6-6	-	V6-10	1.024	
Subzone 6-7	-	V6-11	0.620	
Subzone 6-8	-	V6-12	1.343	
Subzone 6-9	-	V6-13	0.835	
Subzone 6-10	-	V6-14	0.884	
Subzone 6-11	-	V6-15	0.468	
Galle Road DN160 Main	-	V6-3	1.475	
Tank-Galle Road DN500 Main		None	1.320	
Total	-		15.401	-

(3) 1st Step Test

The 1st Step Test in DMA 6 was conducted on May 21th, 2021.

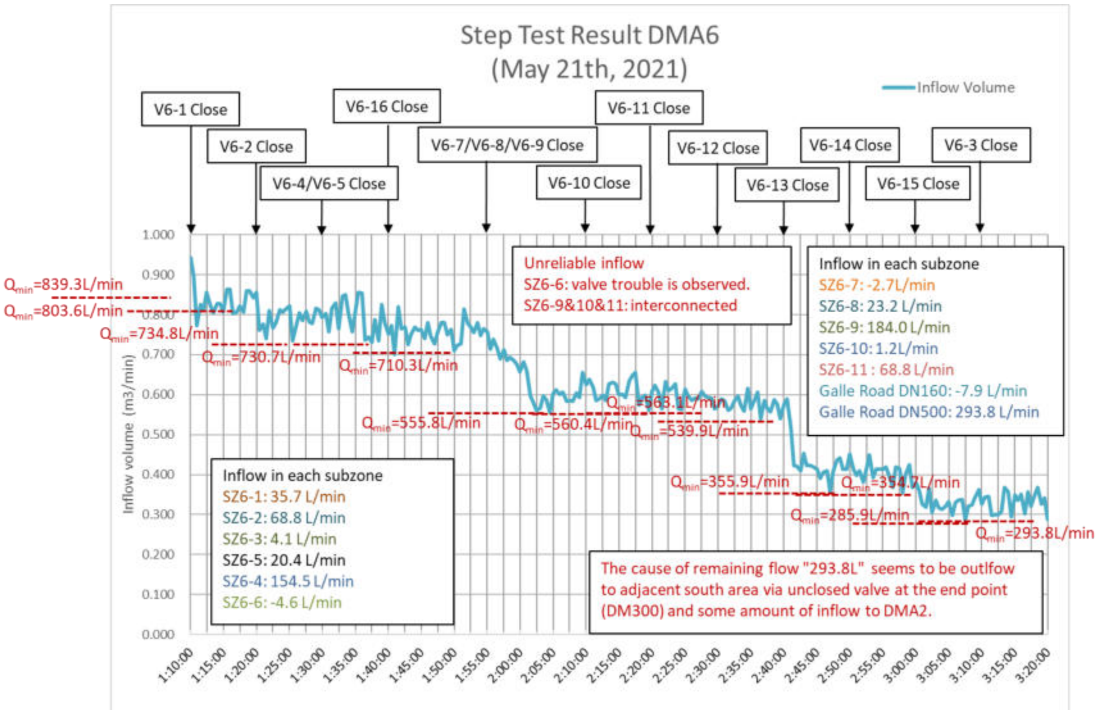


Figure 3.1.46 Result of 1st Step Test in DMA 6

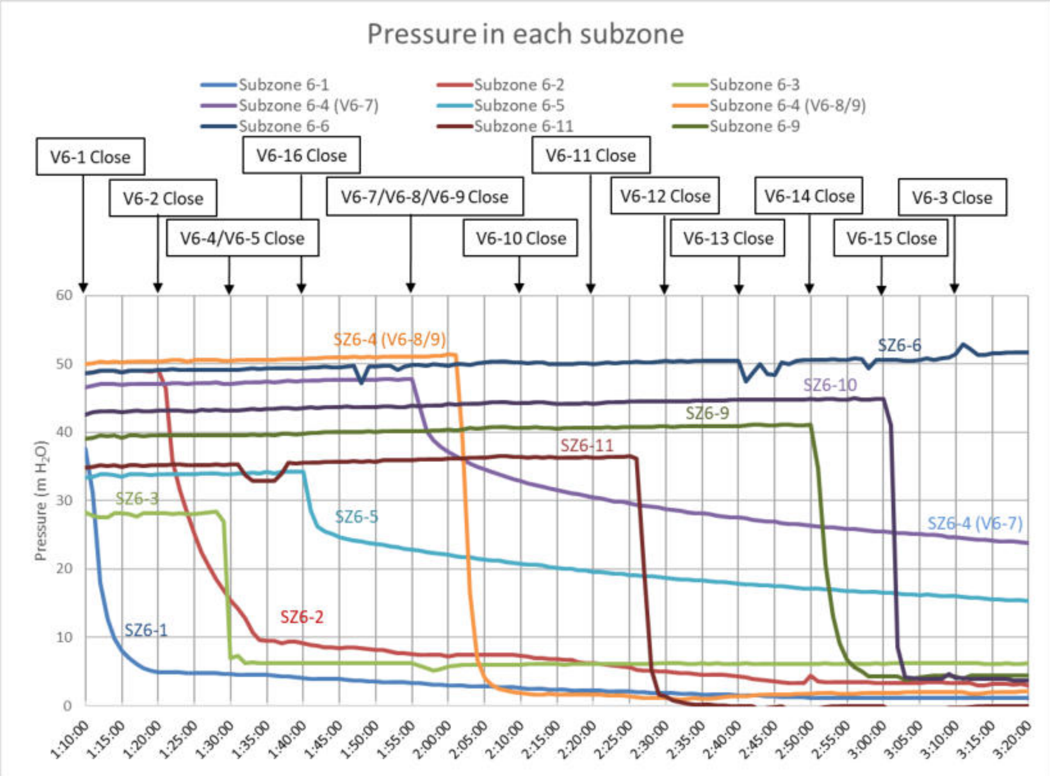


Figure 3.1.47 Pressure drop in DMA 6

[Observation]

- Valve V6-10 to isolate the subzone 6-6 was not closed completely, so the inflow value to the subzone 6-6 is not reliable.
- The cause of remaining flow (293.8 L/min) seems to be outflow to the adjacent southern area, since the existing valve of the endpoint may not be closed completely.
- The pressure drop after closing the valves V6-13 and V6-14 is observed with 10 minutes of delay. This means that the sub-zone 6-9, 6-10 and 6-11 are mutually interconnected.

Table 3.1.35 Evaluation of subzone with MNF/km in DMA 6 (Before activities)

Zone ID	Inflow Volume	Pipe Length	Evaluation Indicator	Prioritization
Initial				
Subzone 6-1	35.7 L/min	0.82 km	43.5 L/min･km	Middle
Subzone 6-2	68.8 L/min	1.72 km	40.0 L/min･km	Middle
Subzone 6-3	4.1 L/min	0.96 km	4.3 L/min･km	Low
Subzone 6-4	154.5 L/min	2.95 km	52.4 L/min･km	Middle
Subzone 6-5	20.4 L/min	2.31 km	8.8 L/min･km	Low
Subzone 6-6	-4.6 L/min	1.02 km	-4.5 L/min･km	Low
Subzone 6-7	-2.7 L/min	0.62 km	-4.4 L/min･km	Low
Subzone 6-8	23.2 L/min	1.34 km	17.3 L/min･km	Low
Subzone 6-9	184.0 L/min	0.84 km	116.0 L/min･km (See Note 1)	High
Subzone 6-10	1.2 L/min	0.88 km		
Subzone 6-11	68.8 L/min	0.47 km		
Galle Road DN160	-7.9 L/min	1.32 km	-5.34 L/min･km	Low
Galle Road DN500	293.8 L/min	1.45 km	See Note 2	Low

Note 1: Subzone 6-9, 6-10 and 6011 were interconnected.

Note 2: The cause of remaining flow (293 L/min) seems to be outflow to adjacent southern area.

3.2 Collection of customer information

Once the DMA has been hydraulically separated and sub-sectors have been constructed, the customer information in each sub-zone should be clearly indicated in the drawing.

The information arranged here is not only indispensable for the calculation of non-revenue water, but also important for estimating the apparent loss that is a loss other than water leakage.

- Customer number
- Customer category
- Date of meter installation
- Serial Number of meters
- Nominal diameter of meter
- Manufacturer of meter
- Diameter and material of service connection pipe
- Meter reading record during last 12 months (Monthly water use, Accumulated reading value)
- Billing record during last 12 mouths

Regarding the amount of billed water, the department in charge shall adjust this so that the data can be shared monthly with the leakage reduction activity team.

3.3 Measurement of water distribution and water pressure

3.3.1 Measurement of Minimum Night Flow (MNF)

An ultrasonic flow meter and a water pressure data logger shall be installed at the target DMA inflow point, and the flow rate and water pressure will be measured for at least 24 hours. The MNF Measurement Method is a method of grasping the consumption water volume in the network at night when the water use on the user is small. This measured volume will be an approximate value of the leakage that has occurred in the network.

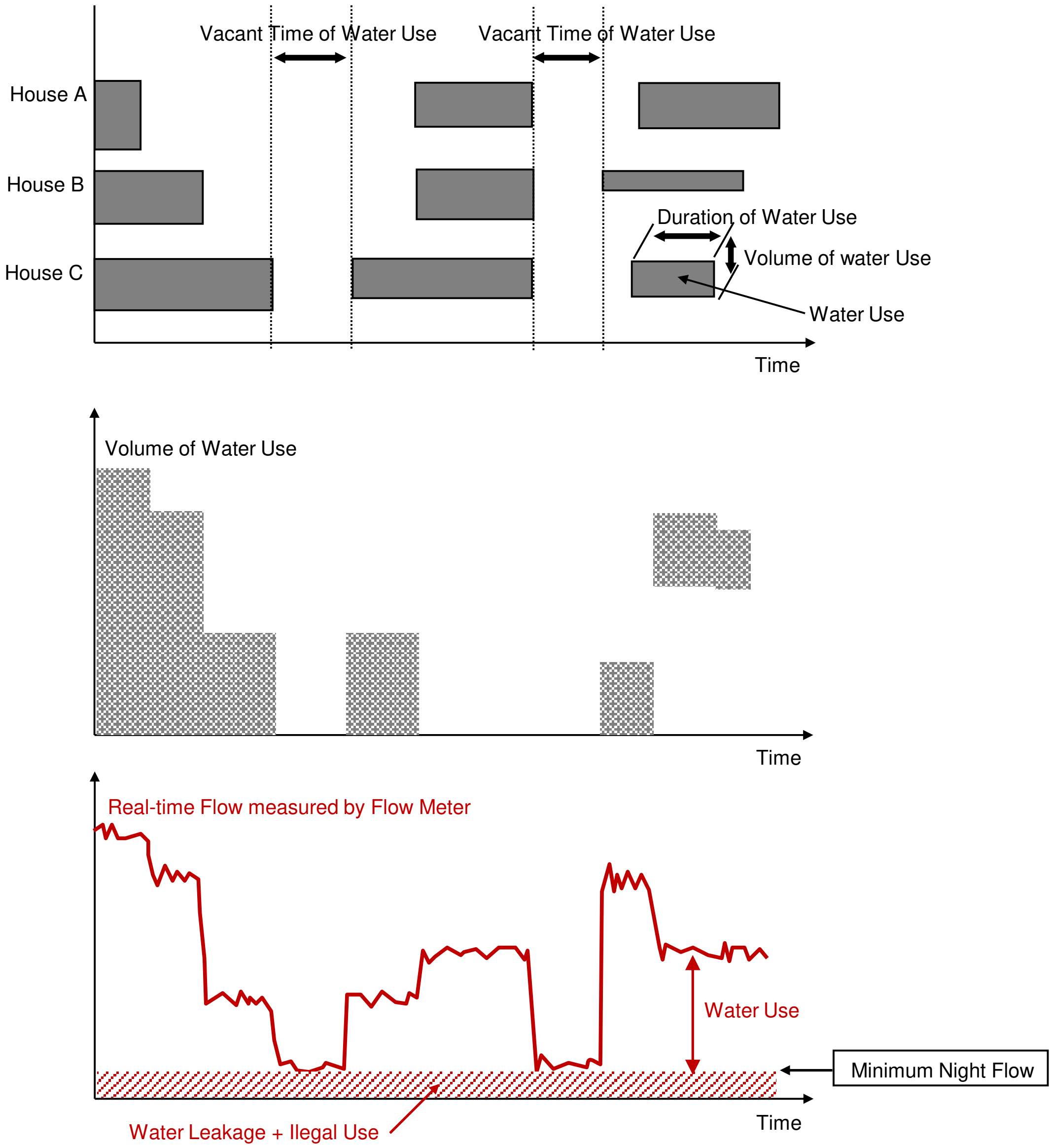


Figure 3.3.1 Minimum night flow and vacant time of water use

3.3.2 Step Test

The work of grasping how the amount of water distribution in the DMA is distributed and estimating the degree of deterioration of the pipeline that produces many leaks is called “Step Test”.

The step test has the effect of running out of water in the entire DMA, so it must be performed during the time when water use is the least.

Generally, the core time of measurement is from 1:00 to 4:00 midnight, and the time before and after is also used for measurement depending on the actual conditions of water use in the area.

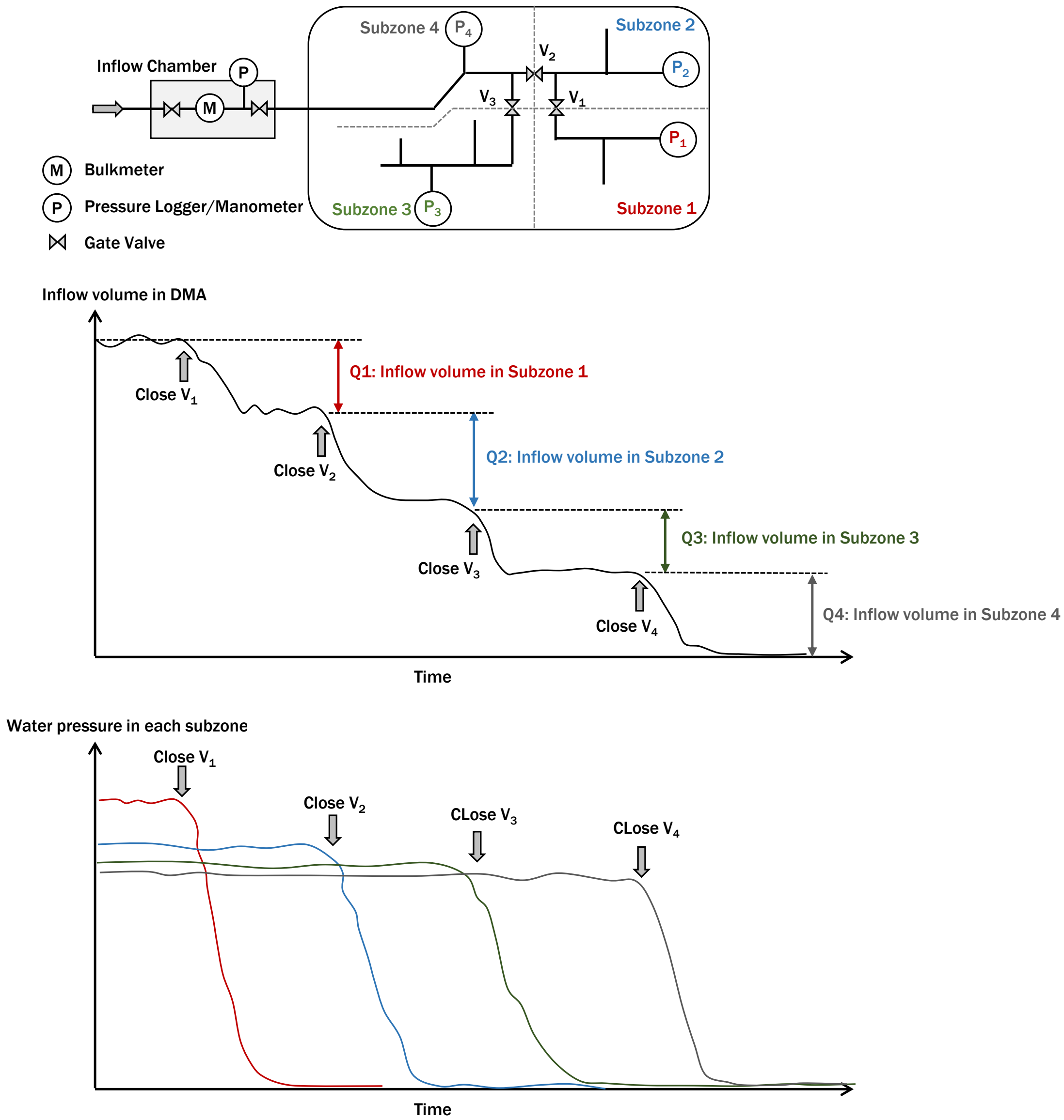


Figure 3.3.2 Imagen of Step Test procedure

In MNF measurement and Step Test, flow rate fluctuations must be recorded at minimum 10-

second intervals, so a flow meter with the following functions is required, such as "Ultrasonic Flowmeter" or "Electromagnetic Flowmeter (with pulse generator)".

Flow rate can be measured at intervals of at least 10 seconds.

Being capable of logging instantaneous flow rate and cumulative flow rate.

Being capable of measuring in the low flow rate band.

In the case of an ultrasonic flow meter, the accuracy may be greatly reduced at a minute flow rate of 0.3 m/sec or less.

A general bulk flow meter with impeller cannot measure an instantaneous flow rate, and has a slow response speed to a flow rate fluctuation, so that it is impossible to determine a vacant time of water use. Therefore, this type of flow meter is used for long-term monitoring of water distribution and for analysis of daily or monthly fluctuation of inflow rate.

In the step test, an ultrasonic flow meter is installed in the inflow chamber, and the valve operation of each sub-sector is performed while monitoring the MNF rate (Q_{mnf}). It is necessary to record the valve operating time and the measuring time required for the judgment.

In addition, the unit of flow rate should be unified so that the analysis will not be confused even if the measurer is different.

Secure a connection for water pressure measurement on the inflow pipe, and record the water pressure at the time of testing with a data logger.

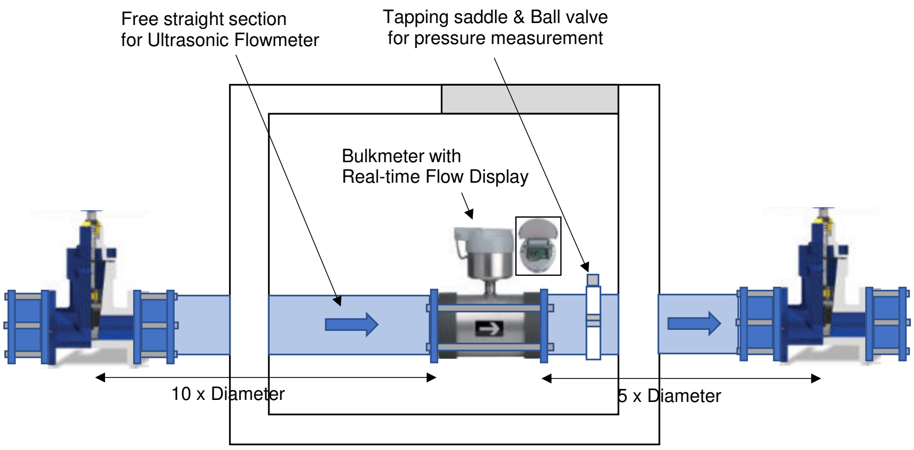


Figure 3.3.3 General equipment at Inlet of DMA

The timing of closing the subzones must be carefully considered in advance, but the measurement time of one subzone should be maintained for 10 minutes or more.

One or more water pressure data loggers should be installed in each subzone to record water pressure fluctuations during the step test.

The sub-sector where the water pressure does not reach zero after the valve is closed indicates that hydraulic independence is incomplete.

3.3.3 Measurement of water supply pressure

When performing water pressure measurement at multiple points in the area, record the continuous water pressure fluctuation for about one week including the step test period.

By grasping water pressure fluctuations during normal times over a long period of time, it is possible to judge whether there occurs an abnormality of water pressure during a step test.

In the water pressure survey, data loggers are used to simultaneously measure water pressure changes at multiple points. By showing the result as a water pressure distribution map, it is possible to grasp the area where the water pressure is insufficient in the area and to estimate whether there is a problem in the capacity of the pipeline.

In addition, the amount of water leakage estimated from the minimum flow rate at night is the value in the late-night hours, so it is necessary to consider the daily water pressure fluctuations and correct it in order to calculate the amount of water leakage of the average daily value

Water pressure surveys are important because they enable such a wide variety of analyses.

(1) Pressure measurement with data logger

A port for pressure measurement should be provided in the DMA inflow pipe using a tapping saddle and a ball valve (incorporation valve).

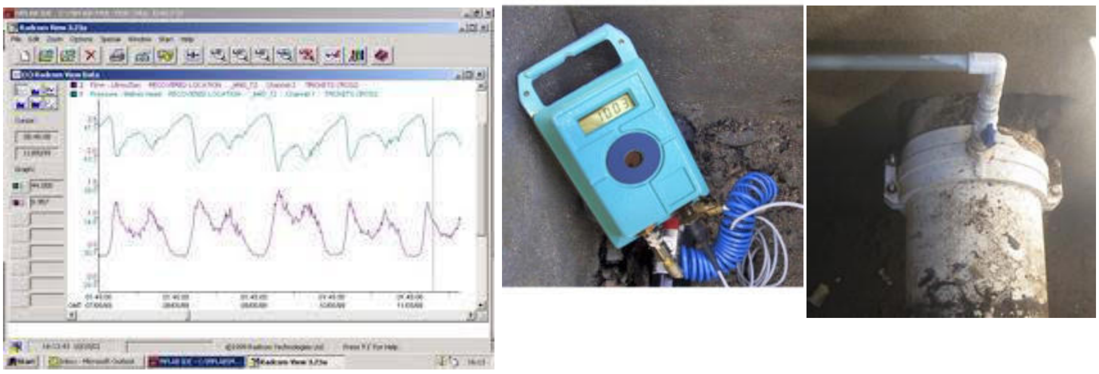


Figure 3.3.4 Installation of pressure data logger

(2) Logging interval

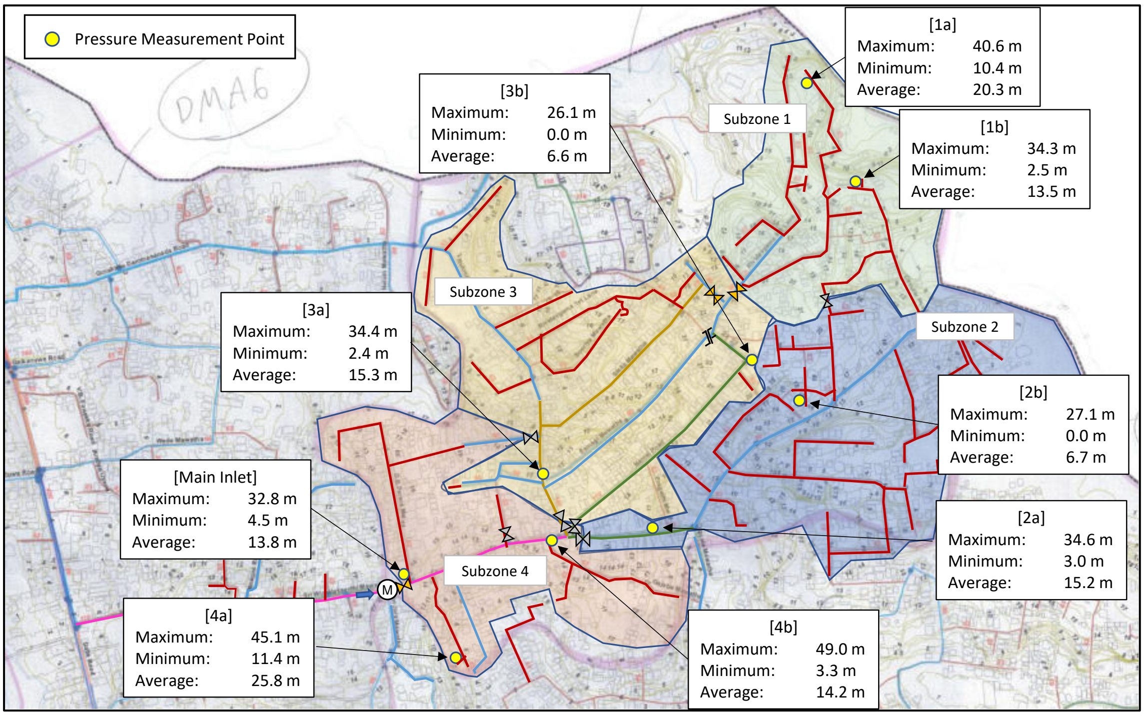
Since the water pressure fluctuates according to changes in the amount of water in the distribution network, it is necessary to set an appropriate interval according to the purpose of measurement.

Table 3.3.1 Recommended interval for each purpose

Logging Interval	Purpose
1sec	Suitable for observing instantaneous water pressure fluctuations. Especially analysis of water pressure fluctuations and water hammer pressure in pump water pipes, etc. There is also a high-precision Logger that can record in 1/100 second.
10sec	Suitable for detailed analysis of water supply pressure in DMA. It is also possible to estimate the household use hours and usage patterns from water pressure fluctuations, and it will be the basic data for considering the renewal of the pipe network.
1min	Suitable for monitoring water pressure fluctuations in the distribution network. If there is a large fluctuation in units of 1 min, shorten the interval and measure again.

(3) Drawing of water pressure measurement results

The measured value is visually displayed as follows.



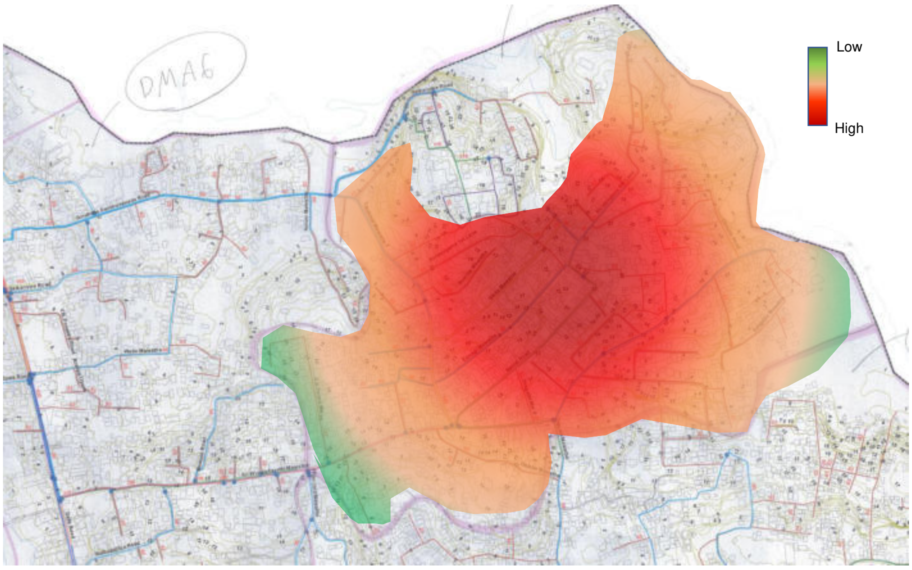


Figure 3.3.5 Pressure distribution map (Example)

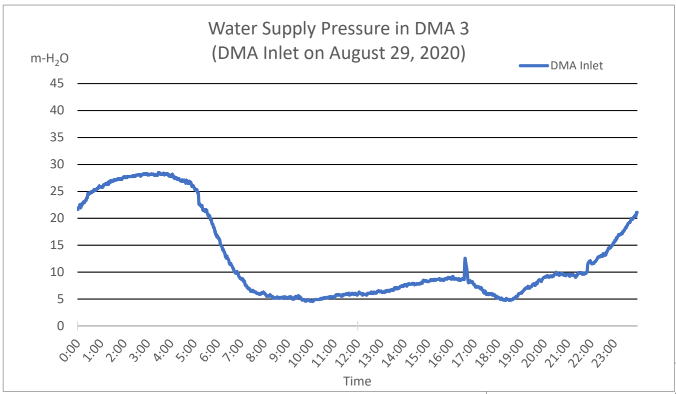
The pressure distribution map allows us to understand the following situation:

- Where is the water pressure during the daytime less than 10 bar?
- Which route has a high maximum water pressure and a high risk of water leakage?
- Where is the area where the water pressure is low even though the pipe diameter is sufficient?
- Where is the area where the water pressure fluctuation during daytime and nighttime is large and the water supply demand is large?

3.3.4 Trend analysis of water pressure fluctuation

Using the measured water pressure data, the water pressure fluctuation for each time zone is summarized as follows.

This is the key data used to estimate the actual amount of leak reduction



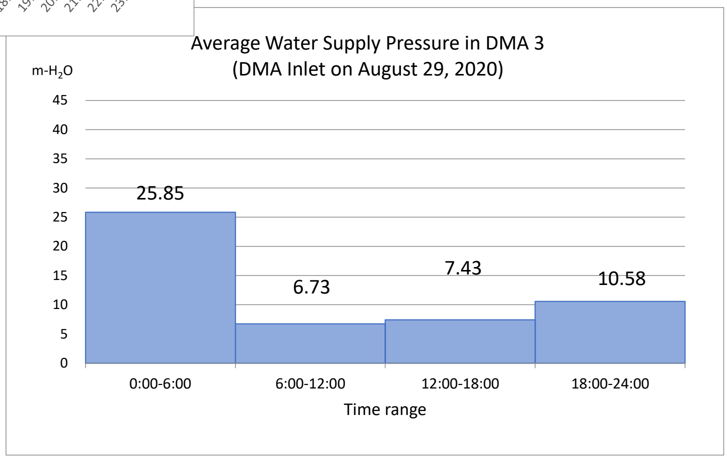


Figure 3.3.6 Water pressure fluctuation pattern (DMA 3)

3.4 Setting the base line data

Based on the results of the Step Test and the MNF measurement, set the baseline data before starting water leakage reduction measures.

The results of the step test and baseline data for DMA5, which has already been conducted, are as follows. New DMA activities will be performed in the same procedure.

Table 3.4.1 Result of Step Test in DMA5

Subzone	Time	Flow		Average value of drop-down (L/min)	Length of pipe (km)	Average volume of drop-down / km (L/min･km)
		L/min	m^3/h			
MNF (Base Line)	**:** am	380.64	22.84			
Step 1	**:** am	304.60	18.28	76.04	1.9	40.0
Step 2	**:** am	235.70	14.14	68.90	2.1	32.8
Step 3	**:** am	218.13	13.09	17.57	2.5	7.0
Step 4	**:** am	174.93	10.50	43.20	1.7	25.4
Step 5	**:** am	157.51	9.45	17.42	1.3	13.4
Step 6	**:** am	98.70	5.92	58.81	1.9	31.0
Step 7	**:** am	53.95	3.24	44.75	1.0	44.8
Step 8	**:** am	0.00	0.00	53.95	2.5	21.6
					14.9	

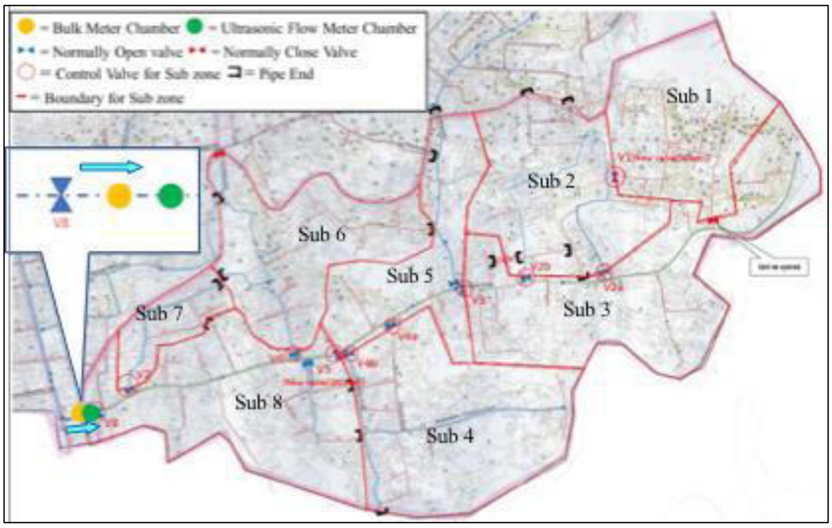


Figure 3.4.1 Sub zoning of DMA5

Here, if the current potential leakage is close to Q_{mnf}, consider what level should be targeted for reduction.

【Unavoidable Annual Real Losses in DMA 5】

UARL (L/day)

= (18×Lm + 0.8×Nc + 25×Lc) × P = (268.2 + 1792.8 + 168.075) x 25

= 55726 (L/day) = 38.7 (L/min)

Lm : Total extension of distribution pipe (km) = 14.9 km

Nc : Number of service connection = 2,241

Lc : Total extension of service connection pipe (km)

= 0.003 km/connection × 2241 = 6.723

P : Average pressure (m H_2O) = 25 m as water head

In the above calculation, the allowable water leakage of DMA5 is 38.7L/min, and the recorded Q_{mnf} is equivalent to 10 times the allowable water leakage.

Distributing this allowable amount of water leakage at the rate of extension of pipelines in each subzone is as follows.

Table 3.4.2 Leakage amount and priority of subzone

Subzone	Inflow volume (L/min)	Length of pipe		UARL (L/min)	"Inflow volume" / "UARL"	Criteria 10≦e: High 5<e<10: Middle e≦5: Low
		(km)	(%)			
	a	b	c	d=a*c	e=a/d	
Sub 1	76.04	1.9	12.8	4.9	15.5	High
Sub 2	68.90	2.1	14.1	5.5	12.5	High
Sub 3	17.57	2.5	16.8	6.5	2.7	Low
Sub 4	43.20	1.7	11.4	4.4	9.8	Middle
Sub 5	17.42	1.3	8.7	3.4	5.1	Low
Sub 6	58.81	1.9	12.7	4.9	12.0	High
Sub 7	44.75	1.0	6.7	2.6	17.2	High
Sub 8	53.95	2.5	16.8	6.5	8.3	Middle
MNF (Q_{mnf})	380.64	14.9	100.0	38.7	9.8	

When setting the priority of each subzone, pay attention to the ratio of the current inflow to UARL, and evaluate it as high if 10 times or more and low if 5 times or less.

However, since the measured Q_{mnf} includes the amount of water used at night to some extent, it is difficult to uniformly set the above evaluation criteria.

Therefore, it is necessary to individually consider the evaluation criteria and activity target values based on the results of the step test of each DMA.

3.5 Estimation of apparent losses

The apparent loss mainly consists of the following three, but this project deals only with the error of the meter body.

- Illegal water use
- Error of meter reading and data input
- Error caused by inaccuracy of meter

3.5.1 Instrumental error of water meter

The instrumental error of a water meter is the value obtained by subtracting the true value that should be indicated from the value indicated by the measuring instrument, and is expressed as a percentage by the following calculation formula.

$$\mathbf{E\,(\%)} = \frac{V_{MBP} - V_{PC}}{V_{PC}} \times 100$$

V_{MBP} : Water volume recorded by water meter

V_{PC} : Water volume measured by a standard tank

As an example, the instrumental error of a water meter DN15mm is explained below using ISO-4064 Class B and Class C as an example.

Table 3.5.1 Class of meter and standard flow rate for accuracy test

Symbol	Description	Classification by ISO 4064 for DN15mm	
		Class B	Class C
Q_1	Minimum flow	30 L/h	15 L/h
Q_2	Transitional flow	120 L /h	22,5 L/h
Q_3	Permanent flow	1.5 m^3/h	1.5 m^3/h
Q_4	Overload flow	3.0 m^3/h	3.0 m^3/h

The numerical values and units in the above table are the values set for each reference flow rate, and the accuracy is confirmed by conducting a test in this flow rate band at the time of manufacturer shipment.

3.5.2 Allowable meter error

Performance requirements are set for water meters.

The maximum flow rate that is guaranteed to be accurately measured is Q_3, the minimum flow rate is Q_1, and the measurement range is expressed as $R=Q_3/Q_1$.

A meter with R=100 indicates that there is a 100-fold difference from a small flow rate to a large flow rate, and if the meter has the same diameter, the larger the R value, the more accurately the small flow range can be measured.

If the meter complies with the ISO4064 standard, it guarantees an instrumental error of +/-5% when $Q_1 \leqq Q < Q_2$ and +/-2% when $Q_2 \leqq Q \leqq Q_4$ as the inherent error of the meter.

In other words, in the case of a Class B meter, if the error is within ±5.0% when the flow rate range is between Q_1 and less than Q_2 and within ±2.0% when the flow range is between Q_2 and Q_4, the meter is approved as a shipped product.

On the other hand, for a meter that is in use by customer, twice the above error is allowed.

Therefore, if $Q_1 \leqq Q < Q_2$ is within +/−10% and $Q_2 \leqq Q \leqq Q_4$ is within +/−4%, it is determined that the meter in use does not have any problem.

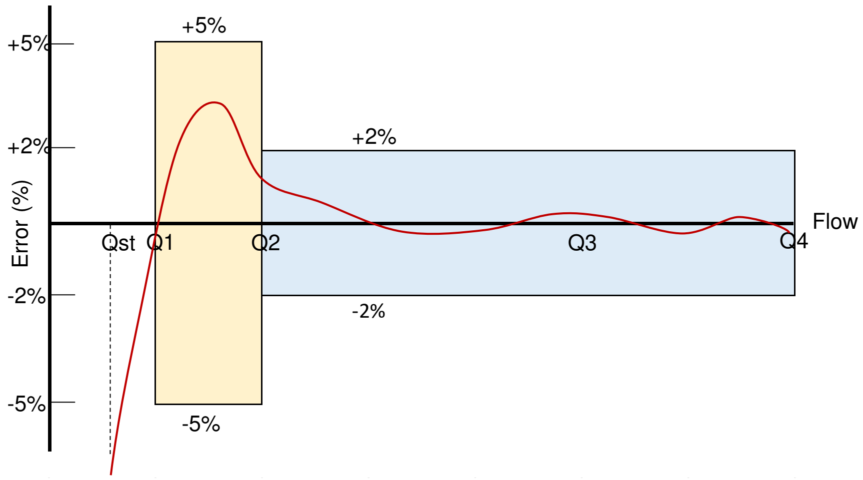


Figure 3.5.1 Instrumental Error Curve

3.5.3 Accuracy inspection of customer meter using electrical test meter

(1) Survey plan and equipment preparation

First, the target area and the number of cases, the number of investigators, and the approximate survey period should be decided. For equipment, a portable electronic test meter and standard tank (20 liters) will be prepared.

Figure 3.5.2 Example of a test meter and a standard tank

(2) Type of inspection method

There are two methods for on-site meter inspection, but this Work Plan describes a simple method.

It should be noted that all water meters have a permissible error, so a predetermined error will occur even when inspected with an electronic test meter.

In order to perform meter inspection with higher accuracy, it is recommended to prepare a standard tank whose volume is accurately measured with officially appropriate method in advance, instead of using a potable reservoir, and compare the amount of water accumulated in the reference tank with the meter reading. ..

【Simple method】

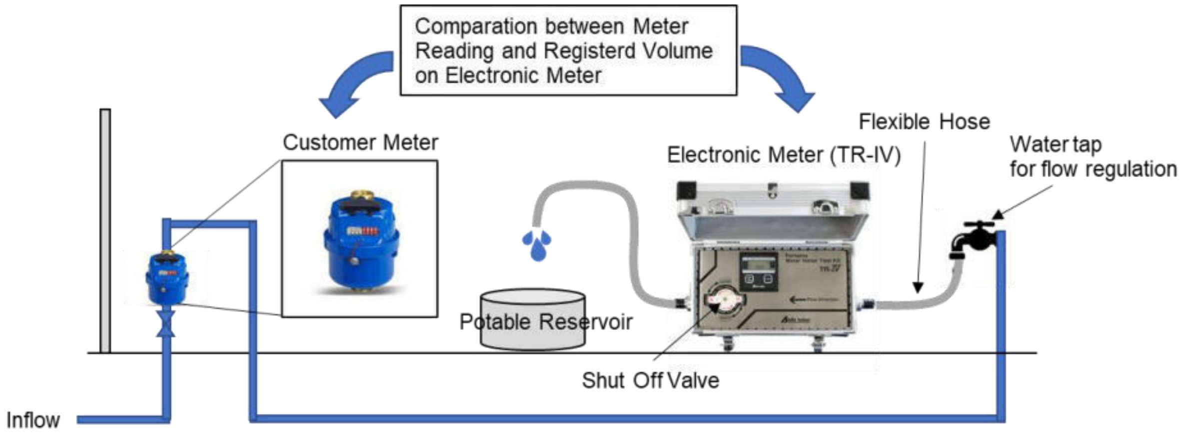


Figure 3.5.3 Method of Inspection with Test Meter

The allowable error of the water meter is determined by the flow rate band.. Therefore, it is necessary to adjust the amount of water for each flow rate zone for inspection, and an electronic test meter is used to set this flow rate zone.

The meter body inside the test meter has the following specifications.

Aichitokei-Denki Electronic Meter: Model EDS-20 (DN20)

Q_1: 0.040 m^3/h (0.67 L/min)

Q_2: 0.064 m^3/h (1.07 L/min)

Q_3: 4m^3/h (66.67 L/min)

Q_4: 5m^3/h (83.33 L/min)

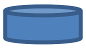
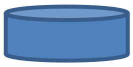
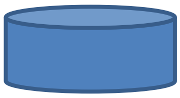
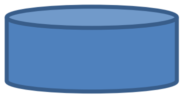
The error table of the instrument difference of the test meter shows the error at three points: large flow rate (1,000 L/h), medium flow rate (200 L/h), and small flow rate (100 L/h), in the factry pre-shipment inspection. Refer to the test result certificate in the meter box.

Table 3.5.2 Instrumental Error of Test Meter

Model: TR-IV Serial No.	Instrumental error by flow rate		
	1000L/h (16.67L/min)	200L/h (3.33L/min)	100L/h (1.67L/min)
***	**%	**%	**%

When confirming the accuracy of the meter in use, it is desirable to perform a test in the following multiple flow rate bands, make corrections using errors close to the flow rate bands, and perform a comprehensive evaluation.

Table 3.5.3 Example of meter test pattern

	Step 1 Starting Flow Q_{st}	Step 2 Between Q_1 & $1.1*Q_1$	Step 3 Between Q_2 & $1.1*Q_2$	Step 4 Approx. Q_3	Step 5 Between $0.9*Q_3$ & Q_3
Image					
Flow rate	3L/h～10L/h	27～33 L/h	108～132 L/h	Approx.600L/h	1350～1500 L/h
	0.05～ 1.66L/min	0.45～0.55L /min	1.8～2.2 L /min	Approx.10 L /min	22.5～25 L /min
Total Test Volume		5L 	10L 	20L 	20L 

(3) Test Procedure

1) Preparation of the Test Meter

1a. Remove the air from the meter so that the meter is filled with water.

1b. Secure a higher place than the main body in the middle of the outlet hose so that air does not enter the hose when water is stopped.

1c. Close the test meter valve and check that there is no water leakage from the piping or hose joint.

1d. Switch the LCD counter display to "Instantaneous Flow Rate Mode".

In instantaneous flow mode, a U is displayed to the left of the number. 4-digit display, unit is L/min

1e. Fully open the Shut Off Valve of the test meter body and adjust it so that it is within the flow rate range of the inspection target while changing the opening of the Water Tap.

1f. After adjusting the flow rate to the specified range, fully close the Shut Off Valve on the test meter body.

1g. Use of water from other taps in the residential area is prohibited during the inspection.

2) Test procedure

Since the counter display was set to ”Instantaneous Flow Rate Mode” during flow rate adjustment in the preparation stage, change the display mode to “Trip Mode” or “Cumulation Mode” before starting the test.

- The display of the counter changes when the L/min button is pressed for about 3 seconds.
- Press the Total/Trip button to display zero reset in Trip Mode.

2a. Record the reading on the water meter before starting the test.

2b. Determine the amount of test water for each flow rate band. (Small flow: 10 Lts, Medium flow: 10 Lts, Large flow: 20 Lts).

2c. Set the counter of the test meter to “Cumulation Mode” and reset to zero

2d. Simultaneously with the start of the test, open the valve of the test meter body and start passing water.

2e. While checking the display on the test meter, close the valve on the test meter main body at the moment when the predetermined amount of test water is reached to stop water flow.

2f. Record the amount of water passing through with a test meter.

2g. Check the instrumental error (%) in the flow rate range indicated in the test meter instrumental error report.。

2h. Check the reading on the water meter and record the amount of water measured within the above time.

2i. Calculate the instrumental error of the water meter by the following formula.

$$\text{Error (\%)} = \frac{\text{Water Volume measured by Customer Meter} - \text{Water Volume registered by Test Meter}}{\text{Water Volume registered by Test Meter}} \times 100$$

+ Instrumental Error of Test Meter

3.5.4 Aggregate meter accuracy inspection results

The test results are recorded in the table below.

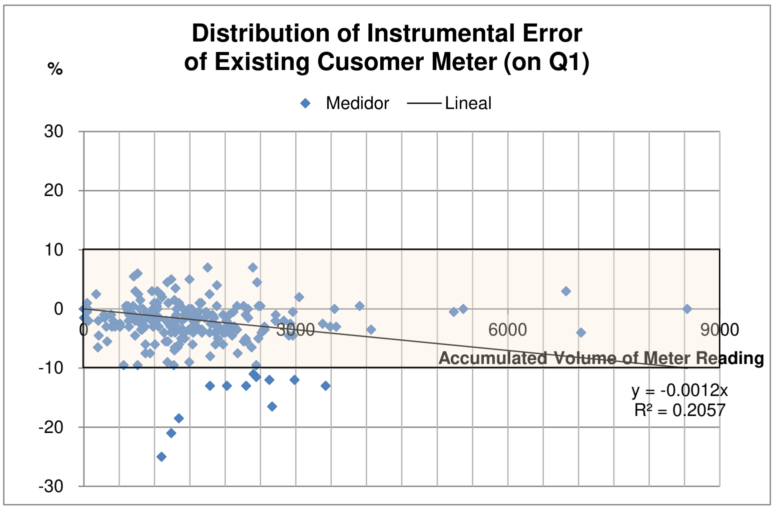
Table 3.5.4 Format of test record

Meter ID					
Step	1	2	3	4	5
Target test flow rate	Starting Flow	30 L/h (0.5 L/min)	120 L/h (2.0 L/min)	600 L/h (10 L/min)	100%
Total test volume	Variable	5 L	10 L	20 L	20 L
Initial reading of customer meter					
Final reading of customer meter					
Registered volume of customer meter "A" (L)					
Registered volume of Electrical Test Meter "B" (L)					
Test time (min)					
Test flow rate of TR-IV (L/min)					
Difference of volume between A & B ("A"-"B")					
Error ((A-B)-B)*100 (%)					

3.5.5 Meter reliability evaluation

Generally, the larger the cumulative cumulative value of the meter, the longer the years of use, so that it tends to be aged and malfunction. By plotting the cumulative water volume of the meter on the horizontal axis and the meter instrument error on the vertical axis, you can read the accumulated meter value of the meter and the tendency of the generator difference.

If there is a high correlation between the accumulated flow rate value and the occurrence of instrumental error, it is possible to determine when it is desirable to update the existing meter.



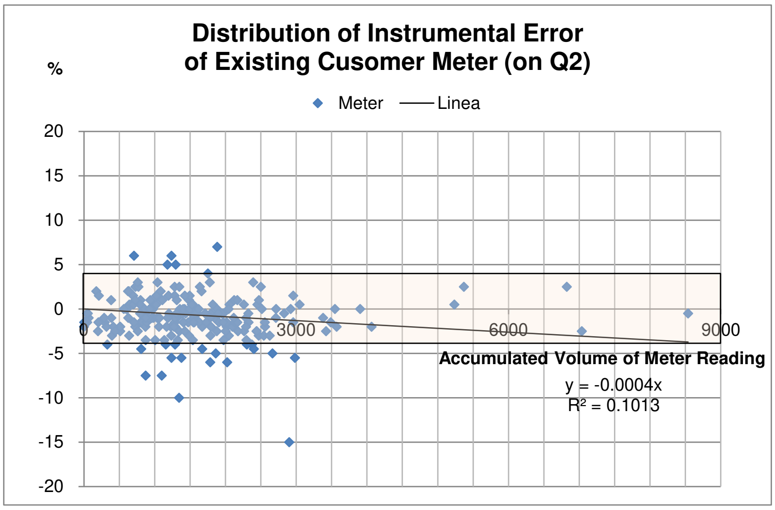


Figure 3.5.4 Relation between cumulative water volume and instrumental error

3.5.6 Estimation of apparent losses

If all test results are plotted on a graph, it can be shown as follows.

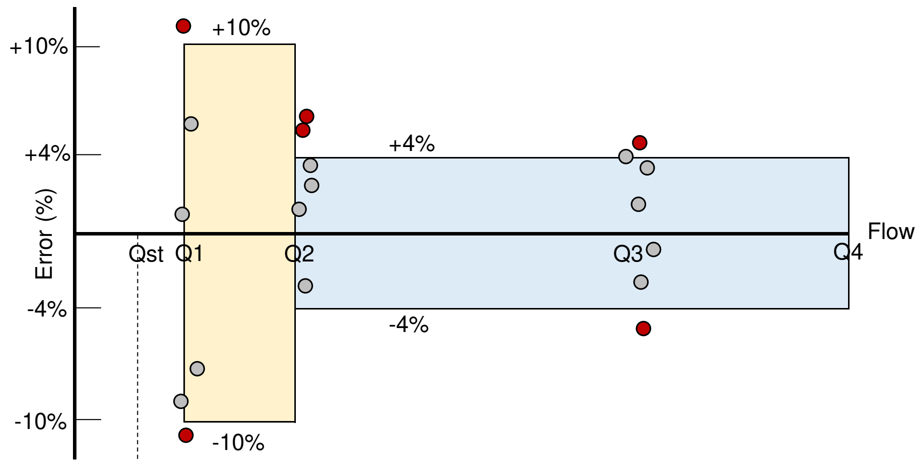


Figure 3.5.5 Distribution of instrumental error of customer meter

The error of the existing meter differs depending on each flow rate band.

For households that use water in a large flow rate, the error near Q_3 has a large effect on the amount of billed water. On the other hand, for low-income households who often use water in a small flow rate, the error near Q_1 to Q_2 greatly affects the billed water.

As mentioned above, since the measurement error occurs depending on the band and frequency of the actual water consumption of the household, it is necessary to investigate the water consumption band of the household in order to estimate the influence of the meter error on the billed water amount.

Therefore, when calculating the apparent loss of water due to meter error using a simple method, use an error in the vicinity of Q2 (100 to 120 L/h), which is the band, for the typical amount of water usage flow band.

Once the monthly NRW is calculated, the ratio of apparent loss and actual loss can be estimated by the following formula.

By comparing the calculated actual water loss and the MNF rate, it becomes possible to grasp the amount of water leakage remaining more accurately in the DMA.

$$\text{Apparent Losses (L/min)} = \frac{\text{Billed Water (m}^3\text{/month)} \times \text{Error (\%)} / 100}{\text{Billing Interval (days)} \times 24 \times 60 \times 1000}$$

$$\text{Real Losses (L/min)} = \text{Non-Revenue Water (L/min)} - \text{Apparent Losses (L/min)}$$

3.5.7 Determination of sample size

When considering the sample size under the following conditions, the statistical size is as shown in the table below.

- Allowable error: 5%
- Confidence level: 95%

Table 3.5.5 Table of sample size

Total number of customer meter in DMA	Sample size (Number of meter)	Percentage against total number of meters
250	152	60.8%
300	169	56.3%
400	196	49.0%
500	220	44.0%
800	260	32.5%
1,000	280	28.0%
2,000	325	16.3%
3,000	345	11.5%
5,000	360	7.2%
10,000	370	3.7%
25,000	380	1.5%
50,000	385	0.8%
> 100,000	385	< 0.4%

3.6 Leakage detection and repair

From the results of MNF measurement and Step Test, we can identify subzones that should be prioritized in countermeasures, and proceed to leak detection and repair.

The general procedure for water leak detection is as follows.

[Step 1] House-to-house survey

↓

[Step 2] Road surface survey

↓

[Step 3] Pinpoint survey

3.6.1 Record of the leakage points

The surveyed locations should be shown in the drawings as follows.

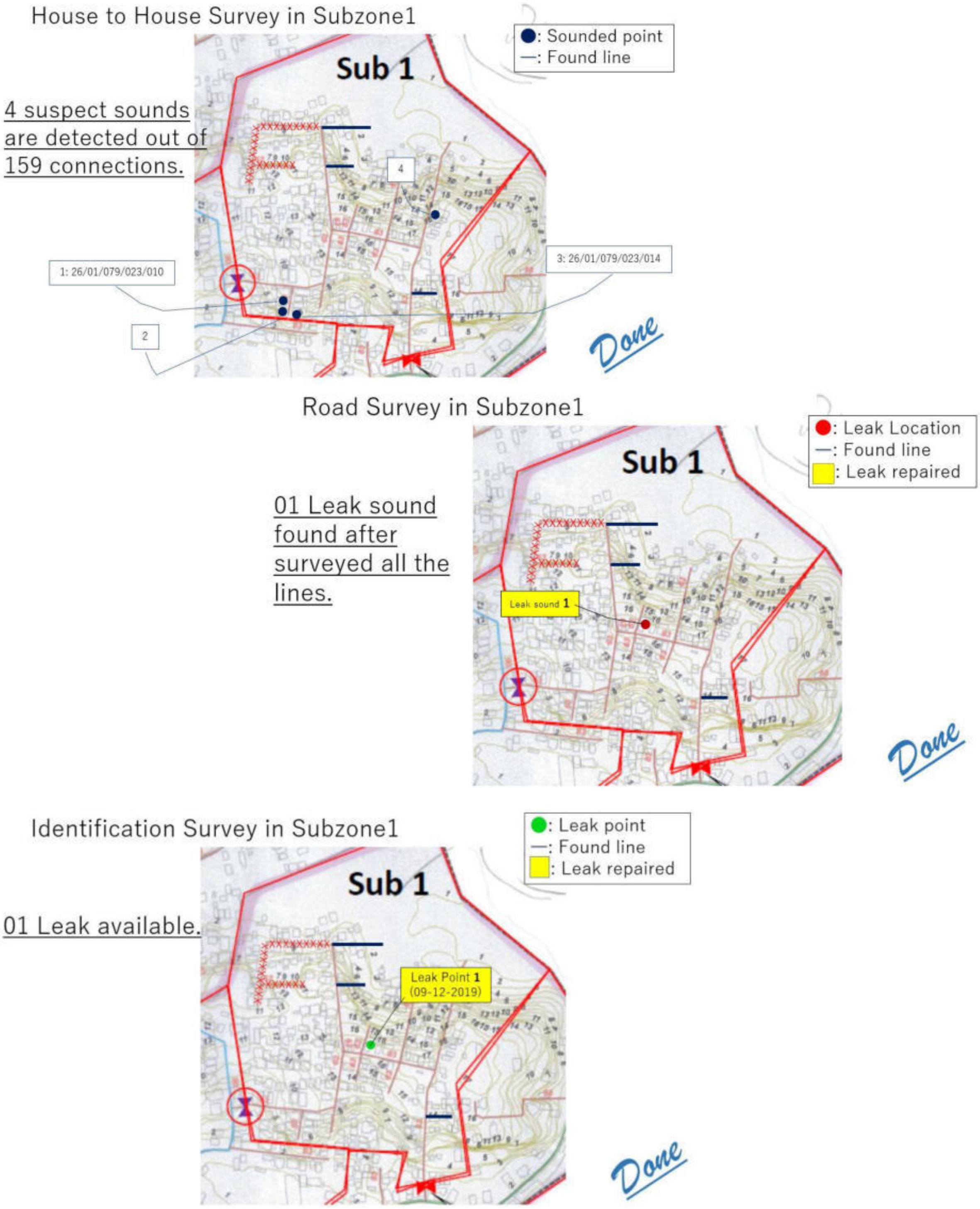


Figure 3.6.8 Example of record of leakage detection

3.6.2 Leakage repair work

(1) Preparation

- Confirm the pipeline information of the leakage point found in the survey.
- Investigate valves that can stop water flow on the target route.
- Notify customers along the target route before repair.
- Procure materials and equipment needed for repairs

(2) Repair work

- When a leak is repaired, the supervisor should check it and record the repair result.
- Prepare a measurement bucket so that workers can directly measure the amount of water leakage
- If leaked water can be collected from the leak hole, measure the leak rate per minute.
- Record items are as follows.
  Location, Type of pavement, Diameter and material of pipe, Installation depth of pipe, Detail of leakage, Estimated cause, Amount of leaked water, Material used to repair, Person responsible for repair, etc.

3.7 Measuring the effects of water leak repair

3.7.1 Minimum Night Flow (MNF)

An effective method for estimating the amount of water leakage existing in a certain area and its severity is to measure the amount of water flowing into a hydraulically independent zone and analyze the minimum night flow (MNF).

Although there is a certain amount of water used at night, it is considered that most of Q_{mnf} is due to the amount of water leakage occurring in the sector, since the water demand of users is the smallest.

The measurement time period is from midnight to 6:00 in the early morning, and the core time of MNF analysis is generally between 1:00 and 4:00.

The MNF rate is often measured for the number of connections of about 500 to 1,000 according to the size of DMA. As an example, if the DMA can be divided into 5 sub-zones as follows, a sub-zone with a large potential leakage can be identified by performing a step test.

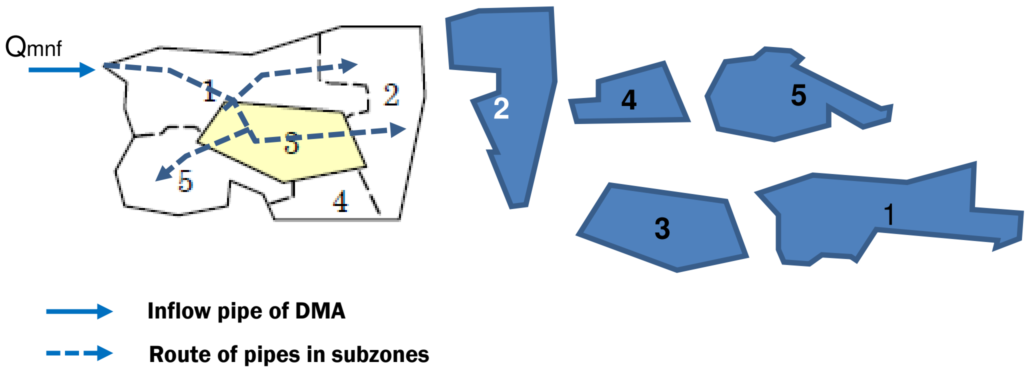


Figure 3.7.1 Image of DMA and sub zoning

3.7.2 Calculation of amount of leaked water

The MNF rate measured in DMA includes the amount of water used at night and the amount of illegal water used in addition to water leakage.

Especially when each household has a water storage tank and water is continuously stored at night, MNF contains a considerable amount of water used, it is necessary to notify residents in advance or secure closure of meter valves.

The breakdown of the amount of water contained in the MNF is shown below.

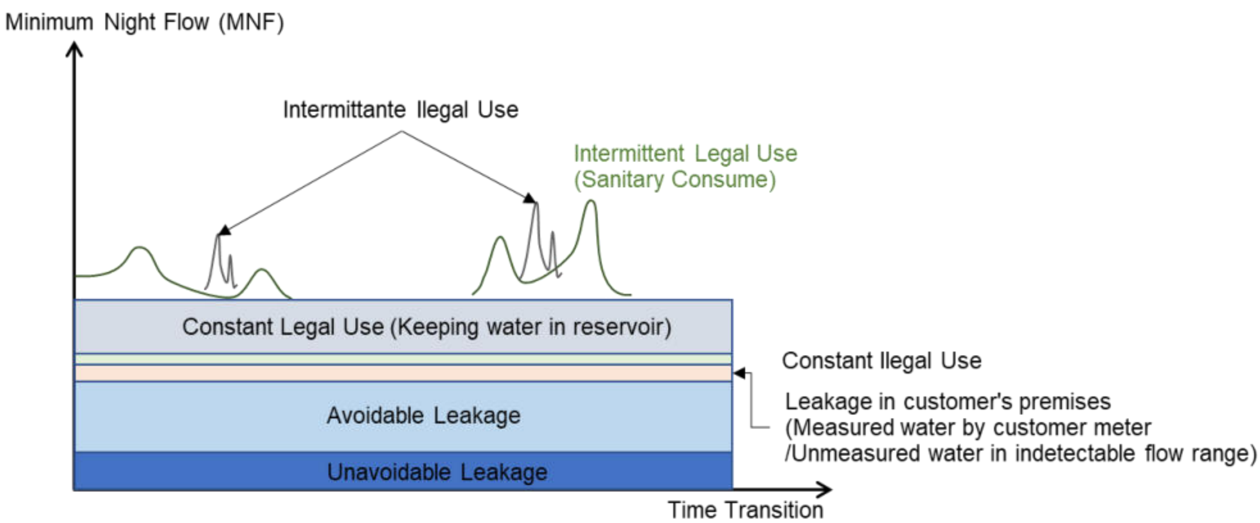


Figure 3.7.2 Breakdown of MNF

The value of MNF will be gradually lowered by the leak detection and repair.

The reduced amount of water leakage can be calculated by performing MNF measurement and step test again when all the measures for water leakage have been completed.

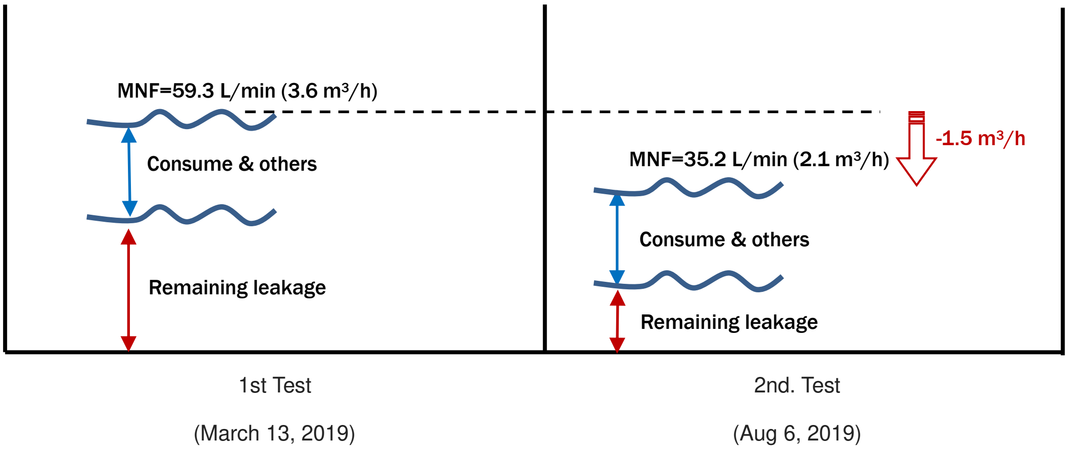


Figure 3.7.3 Monitoring of Minimum Night Flow

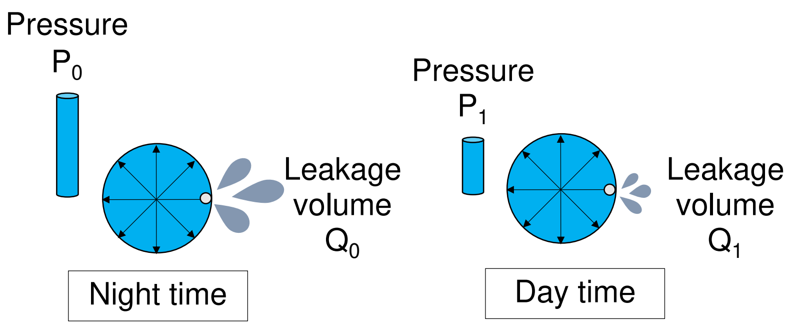
In the example of DMA4, Q_{mnf} has decreased by 1.5 m^3/h due to the leak detection/repair work, and if the amount of water used does not fluctuate, it can be considered as the reduced amount of leak.

However, this amount of water is the value at midnight when the water pressure is the highest, so in order to convert it into the average amount of water per day, it is necessary to take into account the fluctuations in water pressure during the day and correct it.

The relation between pressure and leakage volume is shown as follows. The coefficient N depends on the size and shape of the leak hole and the material of the pipe.

Leak from small orifice : N=0.5

Leak from crack of pipe or flange joint : N=1.15



$$Q_1 / Q_0 = (P_1/P_0)^N$$

Figure 3.7.4 Relation between leak volume and pressure

Here, assuming that the average water pressure of DMA is changing as follows, the daily average value of the leakage reduction amount is calculated as follows.

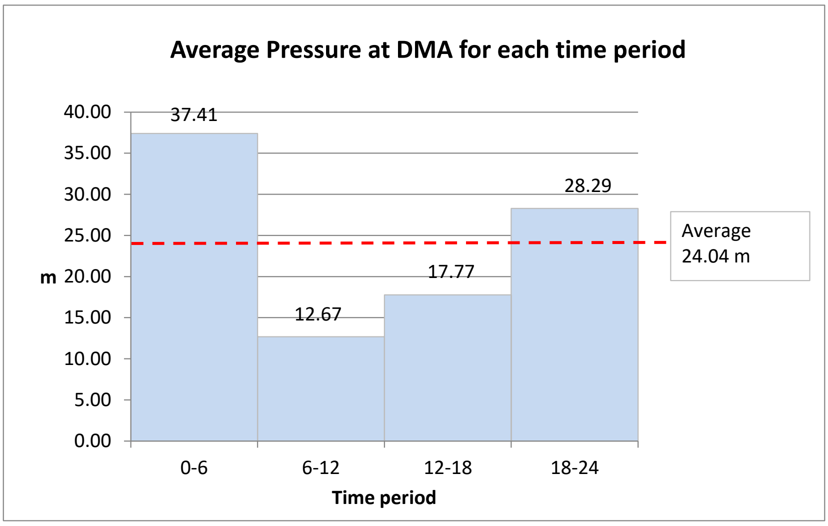


Figure 3.7.5 Average water pressure by time period

Table 3.7.1 Calculation of prevented water leak

Items	Time period				Average
	0:00-6:00	6:00-12:00	12:00-18:00	18:00-24:00	
Pressure (m H_2O)	37.41	12.67	17.77	28.29	24.04
Ratio (P_x/P_o)	1.00	0.339	0.475	0.756	
$(P_x/P_0)^{0.5}$	1.00	0.582	0.689	0.869	
Flow (m^3/h)	1.50	0.87	1.03	1.30	1.18

Reduction of Q_{mnf}

Average volume of avoided leakage

$$Q_x = (P_x/P_0)^{0.5} \times Q_0$$

Q_0: Water flow at a reference time band

P_0: Pressure at a reference time band

P_x: Pressure at a target time band

Calculating in the above example,

Prevented leakage at midnight : 1.50 m^3/h (at pressure of 37.41m H_2O)

Average volume of prevented leakage : 1.18 m^3/h (at pressure 24.04m H_2O)

4 CHECK Evaluation of Pilot Activities

This chapter explains the CHECK of PDCA cycle. The activities done in the "DO" part are analyzed, and its effectiveness and efficiency are evaluated.

4.1 Calculation of Cost-Benefit as a test case of DMA 3

This procedure is another test case in DMA 3.

4.1.1 Total Cost

Total cost consists of the following items.

(1) Personnel costs and machine costs related to DMA construction

LKR. 176,470

Table 4.2.1 Breakdown of Personnel Cost

Class	Spent hour		Unit Cost	Total Cost	Remarks
	Daytime	Nighttime			
DN250 Valve Installation					
EA	-	18	604	10,872	
Fitter	-	9	300	2,700	
Un-skilled	-	45	250	11,250	
Operator	-	9	250	2,250	
			Sub total	27,072	
DN80 Valve Installation					
EA	-	18	604	10,872	
Fitter	-	9	300	2,700	
Un-skilled	-	36	250	9,000	
Operator	-	9	250	2,250	
			Sub total	24,822	
DN150 Valve Installation					
EA	-	18	604	10,872	
Fitter	-	9	300	2,700	
Un-skilled	-	45	250	11,250	
Operator	-	9	250	2,250	
			Sub total	27,072	
DN250 Flowmeter Installation					
EA	6	-	247	1,482	
Fitter	6	-	182	1,092	
Un-skilled	18	-	159	2,862	
Operator	6	-	159	954	
			Sub total	6,390	
Chamber Installation for Flowmeter					
EA	-	36	604	21,744	
Fitter	-	18	300	5,400	
Un-skilled	-	216	250	54,000	
Operator	-	18	250	4,500	
			Sub total	85,644	
Pressure Drop Test					
EA	4	-	247	988	
Fitter	2	-	182	364	
Un-skilled	4	-	159	636	
			Sub total	1,988	

Class	Spent hour		Unit Cost	Total Cost	Remarks
	Daytime	Nighttime			
Data Logging 7 days					
EA	6	-	247	1,482	
Fitter	4	-	182	728	
Un-skilled	5	-	159	795	
Operator	3	-	159	477	
			Sub total	3,482	

(2) Machinery cost for DMA construction

LKR. 208,324

Table 4.2.2 Breakdown of Machinery Cost

Class	Spent hour		Unit Cost	Total Cost	Remarks
	Daytime	Nighttime			
DN250 Valve Installation					
Backhoe		2	2,370	4,740	
DI Pipe Cutter		1	1,095	1,095	
Water Pump		1	450	450	
Generator 3kVA		9	958	8,622	
Vehicle		1 day	2,500	2,500	
			Sub total	17,407	
DN80 Valve Installation					
Backhoe		2	2,370	4,740	
Water Pump		2	450	900	
Generator 3kVA		18	958	17,244	
Vehicle		2 days	2,500	5,000	
			Sub total	27,884	
DN150 Valve Installation					
Water Pump		1	450	450	
Generator 3kVA		9	958	8,622	
			Sub total	9,072	
DN250 Flowmeter Installation					
Backhoe		9	2,370	21,330	
DI Pipe Cutter		1	1,095	1,095	
Vehicle		1 day	2,500	2,500	
			Sub total	24,925	
Chamber Installation for Flowmeter					
Backhoe		18	2,370	42,660	
Generator 3kVA		18	958	17,244	
Vehicle		2 days	2,500	5,000	
Boom Truck		2 days	12,800	25,600	
			Sub total	90,504	
Pressure Drop Test					
Data Logger		1 day	3,570	3,570	
Acoustic bar		1 day	166	166	
Vehicle		0.5 day	2,500	1,250	
			Sub total	4,986	
Data Logging 7 days					
Data Logger		9 days	3,570	32,130	
Acoustic bar		1 day	166	166	
Vehicle		0.5 day	2,500	1,250	
			Sub total	33,546	

(3) Material Cost for DMA construction

Initial Cost: LKR. 826,788

Depreciation Period: 38 years

Cyclic year of leakage reduction activity: 3 years (as assumption)

Cost: LKR.826,788/38*3=LKR.65,272

Table 4.2.3 Breakdown of Material Cost

Material	Qty	Unit Cost	Total Cost	Remarks
DN250 Valve Installation				
Sluice Valve DN250	1	84,700	84,700	
Flange Adaptor DN250	2	24,596	49,192	
Nuts & Bolts	1	5,145	5,782	
Mastic Material	1	3,034	3,034	
PVC Pipe DN160	1	2,354	2,354	
Surface Box 150x150x100	1	6,630	6,630	151,692
DN80 Valve Installation				
Sluice Valve DN80	3	17,400	52,200	
Flange Adaptor DN80	6	7,142	42,852	
Nuts & Bolts	3	717	2,151	
Mastic Material	3	1,096	3,288	
PVC Pipe DN160	3	2,354	7,062	
Surface Box 150x150x100	3	7,061	21,183	128,736
DN150 Valve Installation				
Sluice Valve DN150	2	33,500	67,000	
Flange Adaptor DN150	4	12,695	50,780	
Nuts & Bolts	2	2,875	5,750	
Mastic Material	2	2,105	4,210	
PVC Pipe DN160	1	2,354	2,354	
Surface Box 150x150x100	2	7,061	14,122	144,216
DN250 Flowmeter Installation				
Waltman Flow Meter DN250	1	78,800	78,800	
Flange Adaptor DN250	2	25,391	50,782	
Nuts & Bolts	2	5,781	11,562	
Mastic Material	1	2,900	2,900	144,044
Chamber Installation for Flowmeter				
Precast Chamber Set	2 Nos	123,950	247,900	
Quarry Dust	1 Cu	8,400	8,400	
Cement	2 bags	900	1,800	258,100

(4) Personnel cost related to water leakage detection

LKR. 332,314

Table 4.2.4 Breakdown of Personnel Cost

Class	Spent hour		Unit Cost	Total Cost	Remarks
	Daytime	Nighttime			
Initial Step Test					
EA	-	36	604	21,744	
Fitter	-	12	300	3,600	
Un-skilled	-	48	250	12,000	
			Sub total	37,344	

Class	Spent hour		Unit Cost	Total Cost	Remarks
	Daytime	Nighttime			
House to House Survey in Subzone 2					
EA	-	45	247	11,115	
Fitter	-	5	182	910	
Un-skilled	-	11	159	1,749	
			Sub total	13,774	
House to House Survey in Subzone 4					
EA	-	24	247	5,928	
Fitter	-	6	182	1,092	
Un-skilled	-	24	159	3,816	
			Sub total	10,836	
Road Surface Survey in Subzone 2					
EA	-	120	604	72,480	
Fitter	-	120	300	36,000	
Un-skilled	-	120	250	30,000	
			Sub total	138,480	
Road Surface Survey in Subzone 4					
EA	-	84	604	50,736	
Fitter	-	84	300	25,200	
Un-skilled	-	84	250	21,000	
			Sub total	96,936	
Final Step Test					
EA	-	36	604	21,744	
Fitter	-	24	300	7,200	
Un-skilled	-	24	250	6,000	
			Sub total	34,944	

(5) Machinery cost related to water leakage detection

LKR. 172,433

Table 4.2.5 Breakdown of Machinery Cost

Class	Spent hour		Unit Cost	Total Cost	Remarks
	Daytime	Nighttime			
Initial Step Test					
Ultrasonic Flow Meter		1 days	20,140	20,140	
Datalogger		9 days	3,570	32,130	
Acoustic bar		3 days	166	498	
Vehicle		1 day	2,500	2,500	
Generator 3KVA		12 hours	958	11,496	
			Sub total	66,764	
House to House Survey in Subzone 2					
Acoustic bar		15 days	166	2,490	
Vehicle		2.5 days	2,500	6,250	
			Sub total	8,740	
House to House Survey in Subzone 4					
Acoustic bar		6 days	166	996	
Vehicle		0.5 day	2,500	1,250	
			Sub total	2,246	
Road Surface Survey in Subzone 2					
Acoustic bar		10 days	166	1,660	
Leak Detector		10 days	741	7,410	
Vehicle		3 days	2,500	7,500	
			Sub total	16,570	
Road Surface Survey in Subzone 4					
Acoustic bar		7 days	166	1,162	

Class	Spent hour		Unit Cost	Total Cost	Remarks
	Daytime	Nighttime			
Leak Detector		7 days	741	5,187	
Vehicle		2 days	2,500	5,000	
			Sub total	11,349	
Final Step Test					
Ultrasonic Flow Meter		1 days	20,140	20,140	
Datalogger		9 days	3,570	32,130	
Acoustic bar		3 days	166	498	
Vehicle		1 day	2,500	2,500	
Generator 3KVA		12 hours	958	11,496	
			Sub total	66,764	

(6) Cost for leakage repair

It is the procurement cost of the materials used for leakage prevention.

Procurement Cost of Valves and meters for DMA Creation

&

Material Cost for leakage repairing

If it is difficult to add up all material costs, calculate the material costs using the unit cost for leak repair per location.

【Reference data from Kalutara region】

Number of repair from 2018 to 2019 : 446 points

Cost of repair from 2018 to 2019 : LKR 11,951,022.75

Unit cost of repair work: LKR 26,797 / point

【In case of 25 points of leakage work】

Estimated cost of repair : LKR 26,797 × 25 points = LKR 669,925

Table 4.2.6 Cost of Leakage Repair

Items	Result	
	Subzone 4	Subzone 2
No of customer targeted by H-H Survey	216	250
Suspicious leak point detected by H-H Survey	19	8
Suspicious leak point detected by Road Surface Survey	9	12
Total point of suspicious leakage	28	20
Repaired Leakage Point	13	12
Unit Cost (LKR)	26,797	26,797
Total Cost (LKR)	348,361	321,564

4.1.2 Effectiveness

The effectiveness of reducing the amount of water leakage can be confirmed by a step test.

1st Step Test before implementing activities: October 8th, 2020

2nd Step Test after implementing activities: May 19th, 2021

In DMA4 and DMA5, the amount of water leakage reduction was calculated based on the decrease in the non-revenue water ratio.

During the activity period of DMA3, the COVID-19 infection has spread throughout the country, and it affected the meter reading work of customers.

Therefore, in DMA3, the amount of water leakage reduction should be evaluated analyzing the decrease in the Minimum Night Flow rate after leak repair work instead of the evaluation using the non-revenue water ratio.

As mentioned in the Clause 3.1.3 (8), the reduced water volume of leakage was calculated in 76 L/min as a daily average rate.

The use of MNF has advantages as follows.

- The result can be observed instantly.
- The meter reading error and/or meter reading duration gap are ignorable.
- It is applicable for the DMA which is not completely isolated.

4.1.3 Concept of duration of effect

In DMA3 activities, leak repairs were intensively carried out from the middle to the end of April 2021,

The amount of water leakage that decreased at this stage will gradually recur and will return to the value at the start of the activity in a few years. This is called the leakage recurrence phenomenon of the amount of water leakage.

The period required for the amount of water leakage to return to the original level cannot be easily estimated because various factors such as deterioration of pipelines, aging, water pressure load, and external force due to road traffic affect.

However, it is possible to predict the recurrence speed of the amount of water leakage by monitoring the Minimum Night Flow rate change for about one year by utilizing the electromagnetic flow meter and remote monitoring system installed in the project.

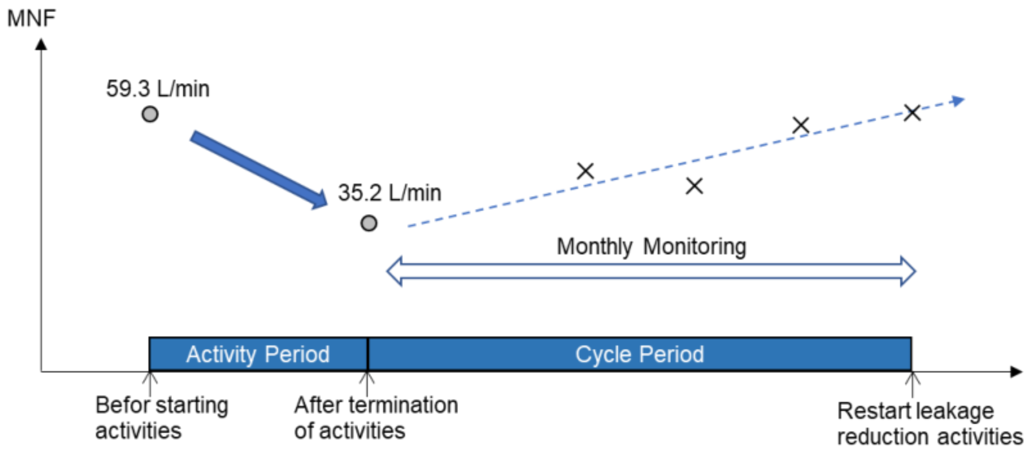


Figure 4.2.4 Monitoring of Leakage Recurrence

The duration of the effect is the number of years until the reduced amount of water leakage returns to the original level, and it is necessary to set this period as the Cyclic Period and repeat the leaked water reduction activities.

In this cost-benefit calculation, the duration of this effect is assumed to be 3 years, as same as that of DMA4 and DMA5.

Since the leak repair of DMA3 was intensively carried out from the middle to the end of April 2021, the effect obtained by the recurrence of water leakage amount after 3 years can be shown in the figure below.

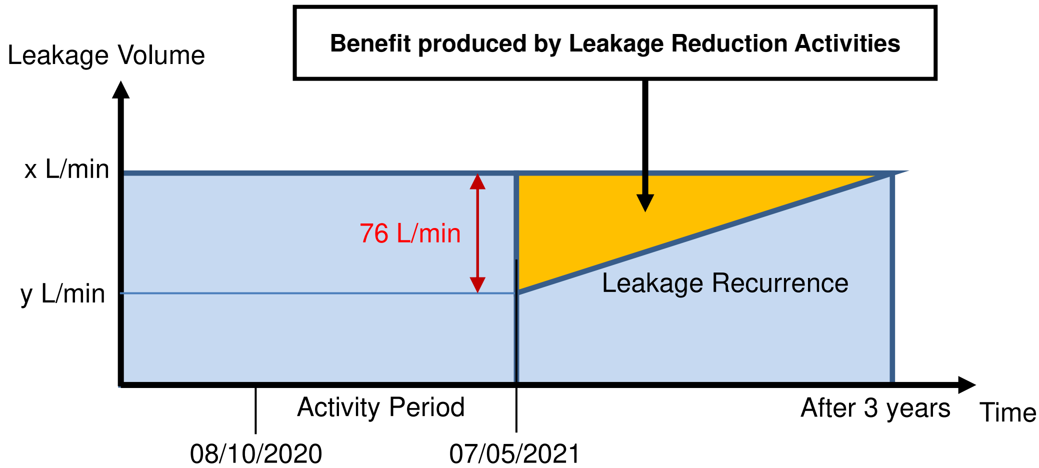


Figure 4.2.5 Benefit produced by Leakage Reduction Activities

In DMA3, the leakage repair work was started following the Road Surface Survey that was finished on May 12th, 2021. Therefore, the effect of leakage repair work can be evaluated from reduction of Minimum Night Flow which has been monitored from April 8th, 2021.

As mentioned before, since the reduced volume of water leakage in Subzone 2 and Subzone 4 is calculated in 76 L/min as a daily average rate, the effect obtained in 3 years can be calculated as follows:

$0.076\ m^3/min \times 60\ min \times 24\ hours \times 365\ day \times 3\ years \div 2 = 59{,}918\ m^3$

As mentioned in the Procedure Manual of Leakage Control, the unit sale cost of water is LKR55/m^3. Therefore, the monetary benefit will be calculated as follows:

$59{,}918\ m^3 \times$ LKR55 = LKR3,295,490

This result is an estimate using the sales cost per 1 m^3, and it is assumed that the total amount of reduced water leakage will be effectively utilized in the DMA or the adjacent area.

Even if the reduced leaks were allocated to water supply in other areas, some of them would actually be lost as non-revenue water. Therefore, it should be noted that the above monetary effect is just a theoretical result.

4.1.4 Comparison of Cost/Benefit

Table 4.2.9 Cost/Benefit of Leakage Reduction Activities in DMA 3

Items	Type of work	Details	Value (LKR)
Cost			**1,624,738**
Cost	DMA Creation	Labor Cost	176,470
		Machinery Cost	208,324
		Material Cost	65,272
	Leakage Detection	Labor Cost	332,314
		Machinery Cost	172,433
	Leakage Repair		669,925
Benefit			**3,295,490**
Benefit/Cost			2.03

4.2 Setting the target level of leakage management

Water pipes deteriorate over time due to various factors such as deterioration, corrosion, and traffic load, and this deterioration causes water leakage.

Also, unless the deteriorated pipeline is completely renewed, a new leak will occur soon after the repair.

This phenomenon is called "Leakage Recurrence"

There are only two methods to reduce the amount of residual water leakage.

- Continue water leakage prevention work at a pace that exceeds the amount of water leakage recurrence.
    - ・Increase the amount of water leakage prevention work. (Investment of human resources)
    - ・Improve water leak detection technology. (Training and accumulation of experience)
    - ・Adopt efficient leak detection and repair technology. (New technology)
- Erasure of restoration itself by renewing dilapidated pipelines
    - ・Use a pipe that does not easily leak water. (Change of material)
    - ・Shorten the length of the pipe to make an efficient piping route. (Improved efficiency)
    - ・Adopt appropriate piping technology. (New technology)

One way to efficiently carry out this monitoring is to build a remote communication system.

The following is the content to be proposed assuming the situation where Japanese experts cannot resume their local travels early.

【Work in Japan】

- Procure data loggers with built-in communication modems, electronic water meters, etc., and prepare training materials for remote monitoring systems.
- Utilizing the Japanese mobile phone communication network, transmit the pulse signal of the test meter to the data server and perform the operation test of the monitoring system using the Web browser.
- If the operation test is successful, purchase the electromagnetic flowmeter to be installed in DMA3 and DMA5.
- One candidate of Data Server will be the Online Service named “HWM DataGate” with 1 year-license contracted between HWM and Japanese Experts Team.
- Collect the theory of pulse measurement of flow rate, detailed work required for system construction, equipment selection, monitoring method and its utilization as a manual, and share it with the C/P of the Output 2 team.
- The members of Output 2 team access the monitoring system constructed in Japan and understand the monitoring method through the manual and the remote instruction.

【Work in Sri Lanka】

- Replace the Bulk Flow meter in DMA3 and DMA5 with Electromagnetic Flowmeters (with pulse output).
- In case of monitoring DMA3, the target area to be monitored will be the southern area whose water is provided by DN250mm pipe.
- Transport and install the monitoring system equipment from Japan.
- Use the SIM card of the local communication company to set the communication modem.
- The monitoring system is operated by the C/P, and daily fluctuations in water distribution are monitored under the guidance of Japanese experts to understand the tendency of water leakage recurrence.

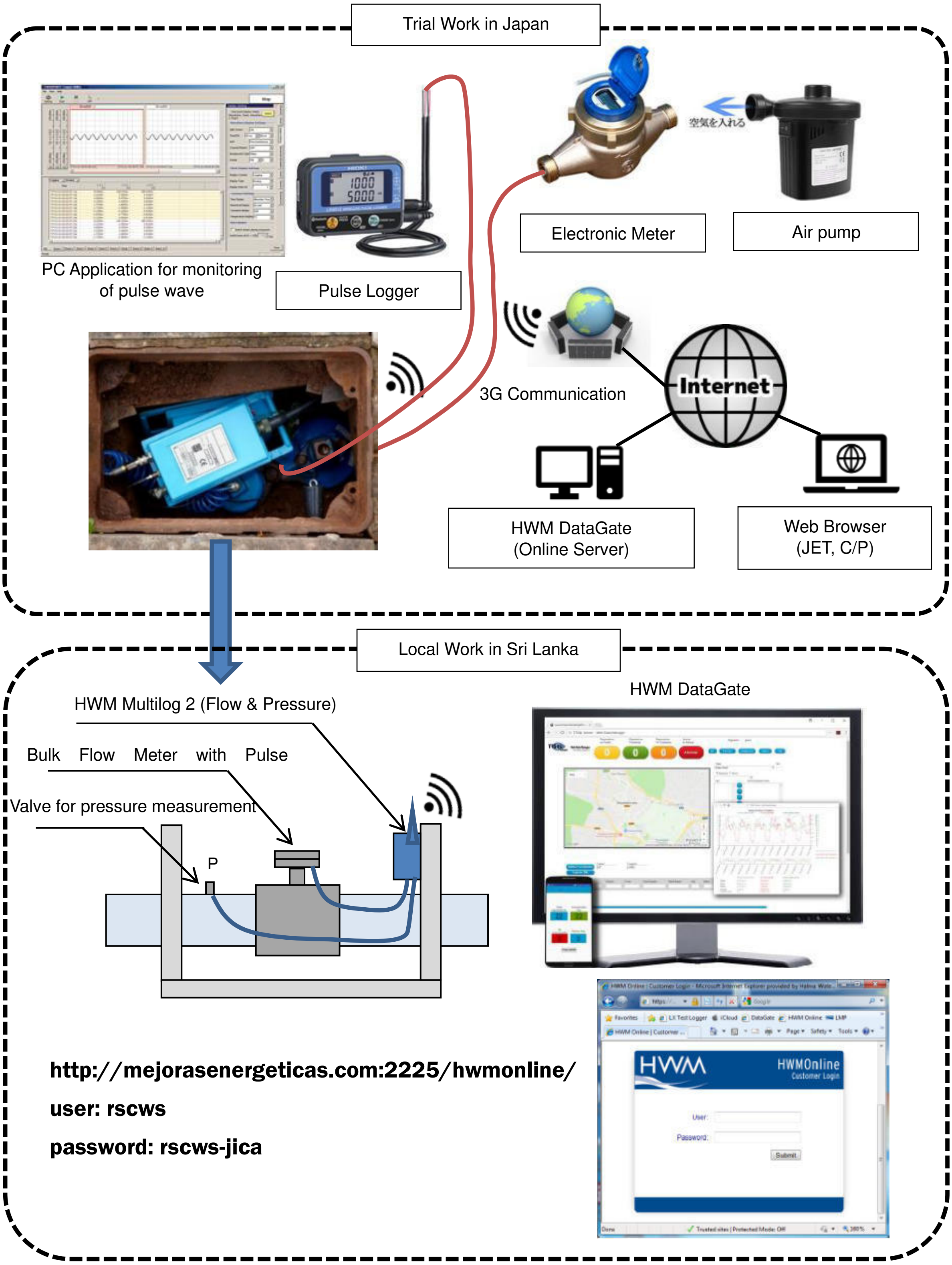


Figure 4.3.3 Remote Monitoring System for Leakage Control

CLEAN WATER

HWM

Multilog 2

Multi-channel Data Logger

Multilog 2 is the highly advanced and versatile multi-channel data logger designed to monitor any combination of digital and analogue signals.

Multilog 2 is ideal for a wide variety of specialised applications, including monitoring PRV flow and/or pressure in a district or zone to assess demand, leakage and conformance.

Accurate, powerful and robust, Multilog 2 is an effective data logging solution.

Key Features and Benefits

- **Telemetry:** integral SMS/GPRS/3G/NBIoT/LTE-M (Cat-M1) cellular options
- **Serial input option:** for connection to digital meters, SonicSens level sensor, Modbus, SDI12, RS232, Badger/Sensus/Neptune serial meter interfaces
- **4 channel logging:** 8 or 16 channels available on request
- **Fast logging:** primary logging to 1 second as standard - 25hz for transient events
- **Alarm:** full alarm functionality
- **Robust:** rugged die cast aluminium case
- **True readings:** true max and min flow and investigation of pressure spikes
- **Pulse interval timing:** smooths reading of infrequent pulses
- **External antennas:** support improved signal strength - contact HWM for more information
- **Local data download:** 10 pin military plug connected to laptop or desktop PC
- **Fully waterproof:** the IP68 rating has been tested at 10m depth over a 24 hour period
- **Optional outputs:** replicate inputs or trigger on alarm, allows operation of third party sensors, e.g. water samplers
- **Long-term monitoring:** 5 year battery life

Applications

After installation, all firmware upgrades and programming changes are made remotely. As well as ensuring that changes are made efficiently, this is also cost-effective, as it removes the need for site visits.

An innovative feature of Multilog 2 is a secondary channel, enabling additional fast logging down to 25Hz.

Secondary logging can be triggered on time schedule and/or in response to an alarm condition being triggered. This is invaluable when more detailed investigation is required, such as pressure spikes and 'true' minimum night flow.

AUTOMATED
METER READING

DataGate

Remote data management

DataGate is HWM's web hosted data server that provides a fast, convenient and secure remote data management solution via the internet. Information can be received from all mobile networks via several different methods including FTP, VMN and modem.

DataGate currently processes over 1.7 million messages received from HWM telemetry devices every day. This rapid transmission is possible because data is sent in a file format which is converted to a secure data stream. This eliminates the problem of sending data as an email which can be blocked by IT firewalls and spam filters. No host modem is required, which is another weak point of a traditional remote handling system as all data transfer now takes online.

Key Features and Benefits

- **Manage large data volumes quickly:** Designed to handle large volumes of SMS/GPRS data traffic
- **Compatible:** Works on all mobile networks
- **Fast data transmission:** Enables rapid data transmission
- **Eliminates data blockages:** Caused by IT firewalls and SPAM filters.
- **No host modem:** No modem required to receive data.
- **Secure Servers:** Data can be archived indefinitely on secure servers
- **Detailed message transmission:** To enable diagnostic investigation if required
- **Logger alarms:** Automatically sent to multiple users to enable prompt action
- **Data accepted from multiple sources:** FTP, VMN and modem
- **Data can be viewed online:** HWM Online or other corporate system
- **DataGate LS:** Option for customers outside the UK to transmit data to a data server in their own country
- **Real time data:** 99.99% uptime and real time data back

Applications

Data can be viewed in graphical or table format from any internet enabled device using our web viewer HWM Online or seamlessly integrated into a third party corporate system.

On receipt of an alarm DataGate can send automatic alerts to multiple users to enable action to be taken promptly. The system will even store data from loggers it does not recognise, and then add this information to the logger's history when it is registered on the system. Multiple accounts can be set up and configured to ensure that users only see data from the specific loggers they require.

HWM Water Limited

Ty Coch House
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5 ACTION Improvement and expansion of pilot activities

This chapter explains the ACTION of PDCA cycle. It explains how to promote the result of "PDC" for the further improvement. To promote water leakage reduction activities more effectively and efficiently, the activities of the next DMA will be started, reflecting the points to be improved from the evaluation results of the pilot activities.

5.1 Target of leakage prevention at RSC Western-South

This pilot activity has been conducted for NWSDB Staff to understand the actual state of water leakage in some DMAs and to acquire the technology to reduce it effectively and efficiently.

After that, the activity to be carried out by NWSDB is the formulation of a water leakage prevention plan in the RSC Western-South

Usually, when formulating a water leakage prevention plan, a basic investigation is first conducted, an analysis of the current situation is conducted, and the water leakage prevention target is set after a thorough understanding of the actual state of water leakage.

And, it is necessary for the entire organization to work to achieve those goals efficiently and effectively.

As a result of the pilot activities, it was revealed that most of the non-revenue water was due to leakage, so the leakage prevention target in the case of NWSDV may be replaced with the non-revenue water reduction target value.

Table 5.1.1 Target value of NRW in NWSDB

RSC	Target value of NRW (%)					Future Target	
	2016	2017	2018	2019	2020	2025	2030
Western-Central	34.8	34.1	33.5	32.8	32.1		
(Colombo)	45.0	44.0	43.0	42.0	41.0		
(Other)	18.0	17.5	17.0	16.5	16.0		
Western-South	27.3	26.4	25.5	24.6	23.5	???	???
Western-North	23.5	23.0	22.5	22.0	21.5		
South	26.5	26.0	25.5	25.0	24.5		
Uva	21.2	20.3	19.4	18.5	17.6		
Central	23.0	22.0	21.0	20.0	19.0		
Sabaragamuwa	24.6	23.8	23.0	22.2	21.4		
Western-North	10.0	10.0	10.0	10.0	10.0		
Eastern	15.4	13.3	11.0	10.0	10.0		
North-Central	16.1	15.2	14.3	13.4	13.0		
North	23.0	21.0	19.0	18.0	17.0		
National	27.8	27.3	26.7	26.0	25.3		

Source: NWSDB Corporate Plan 2016-2020

5.2 Formulation of water leakage prevention plan

This work is a matter that NWSDB should carry out after the project.

The formulation of the plan is based on the results of the pilot activities, NWSDB's strategic plan, the target values of other regions, etc. are set, and the target values are set. From the long-term (10 years) and the medium-term (3 to 5 years) Plan.

5.2.1 Setting of target area

- Basically, all target areas should be selected from the areas served by the distribution network. Since the target area should be selected based on the trend analysis of water leakage, the following information is indispensable as the basic data necessary for selecting this area.
- Historical record of leakage and repair
- Installation year of pipeline
- Material of pipeline

If such information is not sufficiently prepared, it is possible to identify the area where leakage control should be prioritized using the following data collected in each zone or water supply area within RSC.

Table 5.2.1 Example of indicator for selection of target area

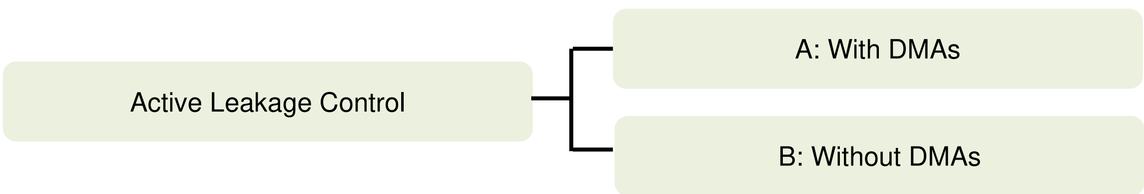
Indicator	Description
1. NRW (%)	This is the NRW rate for each DMA. When comparing non-revenue water rates (NRW) of different DMAs, due to differences in the length of the network, the density of the number of water taps, and the amount of water used per connection, the evaluation results of the network are different even among sectors with the same NRW rate.
2. NRW (L/connection/day)	This is the total amount of non-revenue water converted into the amount of water per user and per day. Strictly speaking, since it is calculated by the number of branches from the water distribution pipe, it is not necessary to consider the total number of users in the case of apartment houses and condominiums. This is highly linked to physical loss. If there is little leakage in the distribution pipe, this indicator can be used to evaluate the amount of water loss.
3. NRW (L/km/min)	This is the total amount of non-revenue water is converted into the amount of water per 1 km of distribution pipe, and it is highly linked to physical loss as in (2). If there are more leaks in the distribution pipe than in the service connection pipe, this indicator can be used to evaluate the amount of water loss.
4. UARL	Unavoidable Annual Real Losses (UARL) is the amount of water that cannot be reduced any further, and is a theoretical value calculated using a formula. However, if cost-effectiveness is ignored, it can be reduced to zero, but it is difficult in reality. The unit is L/connection/day.
5. NRW/UARL	The indictor based on (4) is the ILI (Infrastructural Leakage Index), which is known as an index recommended by IWA. ILI is a value calculated as Current Annual Real Losses (CARL) / UARL, and if this value is large, it indicates that the problem of water leakage in the distribution network is prominent and that the degree of deterioration is progressing. CARL: Current physical real losses UARL: Unavoidable Annual Real Losses that cannot be reduced any further. Since an accurate survey is required to accurately grasp the amount of water leakage (CARL), here we propose an index in which CARL is replaced with non-revenue water only for the purpose of comparing the degree of deterioration of distribution networks.
6. MNF/URL	If data on minimum nighttime flow (MNF) is available, “MNF/UARL” using MNF instead of NRW is effective in determining the degree of pipe network deterioration.

5.2.2 Determination of DMA construction

This pilot project adopted the method of building DMA to detail the regional distribution of actual leak occurrences and to find the most efficient and effective measures.

However, in the water distribution network, there are areas where it is difficult to construct a DMA and areas where leakage can be prevented without constructing a DMA.

Normally large initial investment is required to build DMA, and a huge budget and period are required to manage all areas with DMA. Therefore, the necessity of DMA must be judged according to the regional characteristics.



5.2.3 Annual plan

Generally, the entire water supply area is vast and it is impossible to take measures against water leakage within one year.

Therefore, it is necessary to plan the leakage control of the water supply area so that one cycle can be completed within several years, and the size of the target area to be covered in one year should be considered according to the capacity of the water board.

When one cycle is completed, start the second cycle activity from the first target area.

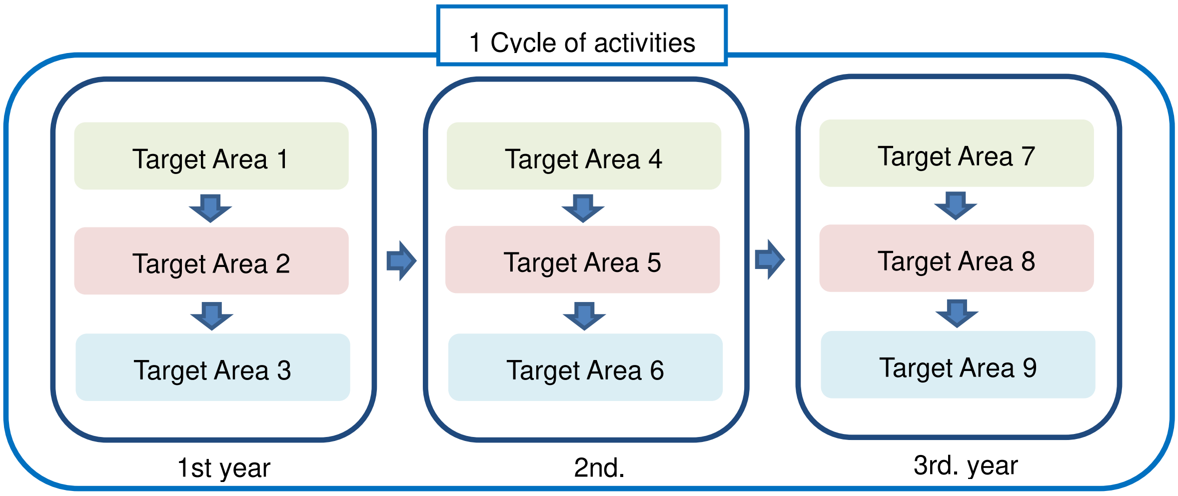


Table 5.2.2 Relation between 1 cycle of activities and target areas

The extension of water pipes in the target area is one of the effective indicators for determining the scale to be covered in one year.

In case of major water utilities in Japan that has over 5,000km length of pipeline, 3 years is commonly applied for 1 cycle period.

【In case of DMAs method】

One or more DMAs will be selected as the target area for one year, taking into consideration the extension of the distribution pipe of each DMA.

【In case of Non-DMAs method】

The target area is extracted from the whole area in consideration of topographical features (river, road, pipeline length).

5.2.4 Example of annual planning

The pipeline length to be investigated in one year can be determined according to the target leakage rate (or non-revenue water rate).

However, if the number of personnel engaged in the survey cannot be secured, it can be decided according to the capacity of the water business utilities.

(1) Calculation of annual survey extension from the number of staff that can be invested

- Unit of leak detection work

  3 persons per 1 unit (1 chief and 2 workers)

  Equipment: Acoustic listening stick, Water leak detector, Pipe locator, Metal detector, Boring bar, Hammer Drill, Vehicle

- Conditions of the work considered herein

  Considered area: RSC Western-South

  Number of work unit： 1 unit (1 chief and 2 workers)

  Number of working date: 244 days per year

  (365days - Saturday and Sunday×52 weeks - Other holidays 17 日)

  Working hours: half a day in each day

  Average survey extension of pipeline： 0.24km/day

  (In accordance with the experience of pilot activities in JICA project)

  Annual survey extension of pipeline: 0.24km/day×244day=58.6km/year

  Cyclic period: 3 years

  Extension of existing pipeline: 2,852km (data provided by RCS-WS)

  Necessary input of manpower: 2,852 / 3 / 58.6 = 16.2 units

  According to above mentioned calculation, if you secure 16 units of manpower, you will be able to conduct surveys of all regions at the pace of one cycle for three years.

(2) Calculation of annual survey extension from target leakage rate

- Conditions of the work considered herein

  Considered area: RSC Western-South

  Extension of existing pipeline: 2,852km (data provided by RCS-WS)

  Annual production volume: 71,344,743 m^3/year

  Leakage recurrence ratio: 15% of leakage volume

  Target leakage ratio: The leakage rate in the first year (19.4%) will be reduced evenly every year, and will decrease to 15% after 5 years.

  In this case, annual reduction rate

  = (19.4-15.0)/5 = 0.88%

- Necessary input of manpower

  When completing the 2,852km survey in 5 years, it is necessary to input about 10 units because the survey distance is 58.6km per unit per year.

(3) Supplementary notes

The above estimation case is based on the assumption that the water leakage is widely dispersed in the area and the density of the water leakage is evenly distributed.

However, many leaks concentrate in areas where pipes have deteriorated and where water pressure is excessive.

For example, areas and routes that have only been in the pipeline for a few years can be excluded from the first cycle. In addition, the priority of measures will be lowered in areas where the water supply pressure is relatively low.

Therefore, it is essential to analyze existing data and narrow down the target area for efficient and effective water leakage reduction.

Table 5.2.3 Annual survey extension of pipeline calculated with the target leakage ratio

Id	Items	Unit	Formula	Annual plan				
				1st year	2nd year	3rd year	4th year	5th year
a	Initial leakage ratio by year	%		19.40	18.52	17.64	16.76	15.88
b	Target reduction value by year (equally set)		(19.4-15.0)/5	0.88	0.88	0.88	0.88	0.88
c	Target leakage ratio after activities	%	a-b	18.52	17.64	16.76	15.88	15.00
d	Approximate survey length of pipe	km	m/o	570	577	585	593	603
e	Extension of distribution pipe	km		2,852	2,852	2,852	2,852	2,852
f	Water production volume	m^3/year		71,344,743	71,344,743	71,344,743	71,344,743	71,344,743
g	Initial leakage volume	m^3/year	(a/100)*f	13,840,880	13,213,046	12,585,213	11,957,379	11,329,545
h	Initial leakaga dentity	m^3/hour/km	f/d/365/24	0.55	0.53	0.50	0.48	0.45
i	Recurrence ratio of leakage	%		15.00	15.00	15.00	15.00	15.00
j	Increasable leakage volume by year	m^3/year	f*i/100	2,076,132	1,981,957	1,887,782	1,793,607	1,699,432
k	Target leakage volume	m^3/year	(c/100)*f	13,213,046	12,585,213	11,957,379	11,329,545	10,701,711
l	Target reduction volume of leakage	m^3/year	g+j-k	2,703,966	2,609,791	2,515,616	2,421,441	2,327,266
m		m^3/hour	l/365/24	308.7	297.9	287.2	276.4	265.7
n	Target leakage density	m^3/hour/km	k/e/365/24	0.53	0.50	0.48	0.45	0.43
o	Average leakage density between Initial & Target values	m^3/hour/km	(h+n)/2	0.54	0.52	0.49	0.47	0.44

Appendix-2

Guideline for Cost and Working Days Calculation Sheet for Leakage Detection Planning

Appendix-2 is a guideline for utilizing a calculation sheet (Excel), which enables estimation of the necessary costs and duration of leakage detection surveys and planning of the financial aspects of active leakage control.

1 Background and Aim of Making Cost and Working Days Calculation Sheet

1.1 Background of Making Cost and Working Days Calculation Sheet

A JICA project has been transferring technology and skills for detecting water leaks since 2018. NWSDB intends to expand the leak survey over a wide area to reduce the leak rate. To this end, it is necessary to accurately estimate the budget and investigation period for leak investigation and formulate an efficient plan. Therefore, the project team, JET, in collaboration with the counterpart, prepared a calculation sheet to enable such budgetary and working period considerations to be more effectively and easily understood.

1.2 Aim of Making Cost and Working Days Calculation Sheet

The aim of making the cost and working days calculation sheet is to understand:

- the necessary budget,
- the required survey period, and
- the required number of personnel.

1.3 Scope and Applicability

The calculation sheet has been developed to estimate the required cost and labor force for leak surveys—which consist of flow measurements, house-to-house surveys, road surveys and identification surveys.

1) The calculation sheet will be used by:

- the non-revenue water (NRW) section of RSC to create survey plans and to understand budgetary requirements, and
- OIC offices to grasp survey schedules.

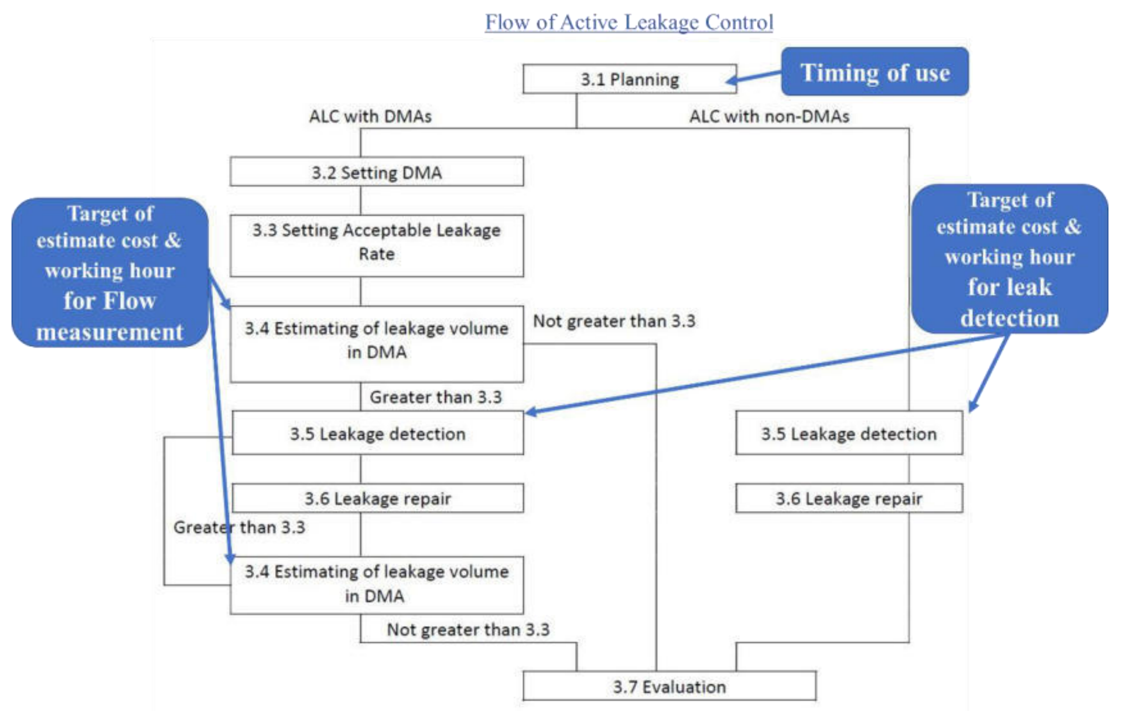
2) Timing of use and target of estimate

The timing of the use of the calculation sheet will be in:

- the planning phase of surveys.

The target of the cost and working hour estimates produced by the calculation sheet are for:

- estimating leakage volumes in DMAs for flow measurements.
- leakage detection phases of the surveys.



3) Condition of use

- A calculation sheet can be used throughout Sri Lanka.
- The working speed depends on the density of houses per 1 km of pipeline in the target area. The average value is to be used if there is variation in density of houses within a target area. If the areas within a target area are far apart, calculate separately for each area.
- The work speed is the workload, as shown in the table below. Set this workload in tables 2, 3, 4, and 5 of the calculation sheets.

Standard workloads of calculation sheet (work speed)		
Survey item	Less than 100 houses per 1 km of pipeline	Over 100 houses per 1 km of pipeline
Flow measurement	4.0 hours per operation	6.0 hours per operation
House-to-house survey	13.6 houses per hour	28.7 houses per hour
Road surface survey	235 m per hour	
Identification survey	3.6 locations per hour	XX locations per hour

1.4 Required data for calculations

The following data is required for use in the calculation sheet.

- Pipeline length in the target area,
- Number of houses in the target area,
- The density of houses in the target area, and
- The number of equipment required for the survey and the number of equipment that RSC can prepare.

2 Overview and Structure of Calculation Sheet

2.1 Overview

- The calculation sheet is the sheet for calculating the working hours of leak detection work and survey costs.
- The calculation sheet organizes expenses including ordering costs such as labor costs and work costs, and clearly shows the methods of calculation.

2.2 Structure of Calculation Sheet

- Table 1. Total survey cost and working hours table for leak detection
- Table 2. Cost table of flow measurements (minimum night flow and step test)
- Table 3. Cost table of house-to-house surveys
- Table 4. Cost table of road surface surveys
- Table 5. Cost table of identification surveys
- Basis of labor costs in each table
- Basis of equipment prices in each table (purchase and ownership prices per day)

3 How to Calculate

3.1 Flow of Calculation

The below figure is a standard calculation flow. Whether all steps from 2 to 5 need to be implemented depends on the survey plan. For example, Step 2 can be skipped if you do not perform flow measurement.

Step 1 Create a leak detection plan

↓

Step 2 Set up the survey team and necessary equipment for the flow measurement survey including step test and drop test in Table 2

↓

Step 3 Set up the survey team and necessary equipment for the house-to-house survey in Table 3

↓

Step 4 Set up the survey team and necessary equipment for the road survey in Table 4

↓

Step 5 Set up the survey team and necessary equipment for the identification survey in Table 5

↓

Step 6 Enter the survey quantities planned in Step 1 in Table 1

↓

Step 7 Evaluate the plan

* In flow measurement survey, one team will consist of a main team and a valve team.

3.2 Details of Calculation Steps

The various quantities for the calculations need to be entered into the yellow-colored cells (a drop down list of quantity options will appear once clicked on) of the sheet following the steps described below.

1) Step 1

Plan and confirm the following three points.

1)-1 Plan the quantities of items to be conducted in each survey.

Times of flow measurements, quantity of house-to-house survey, distance of road surface survey, distance of identification survey.

1)-2 Consider the number of personnel to be assigned to each of the teams for the various surveys.

1)-3 Check the availability of equipment required for each survey.

* Each survey mentioned in 1) - 3) are the following. Flow measurement, house-to-house survey, road surface survey, identification survey.
* The distance of the road surface survey and identification survey is the length of the pipeline.
* The equipment required for each survey is shown in Table 2-5.

2) Step 2

Set the number of survey teams and equipment required for the flow measurement survey in Table 2. Follow the instructions below to operate with Table 2.

Table 2	Cost Table of Flow Measurement (Minimum Night Flow & Step Test)			workload =	4.0 hours/operation/team			Workload
Item	Description		Unit	Quantity	Unit cost (Rs.)	Total cost (Rs.)	Note	
Labor cost	Main Team	EA(Chief)	Person /hour	1.0	247	247	1 Person in 1 Team	Section A
		Fitter	Person /hour	2.0	182	364	2 Persons in 1 Team	
		Un Skilled	Person /hour	1.0	159	159	1 Person in 1 Team	
	Valve Control Team	EA(Chief)	Person /hour	1.0	247	247	1 Person in 1 Team	
		Fitter	Person /hour	2.0	182	364	2 Persons in 1 Team	
		Un Skilled	Person /hour	1.0	159	159	1 Person in 1 Team	
	Daytime hourly cost		Hour			1,540	Main Team + Valve Team cost	
	Nighttime hourly cost		Hour	0.50	Daytime cost*0.5	770	Night work premium	Section B
	Total labor cost		Hour			2,310	Daytime + Nighttime hourly cost	
	1 Operation Labor cost (1 Operation = Workload hours)					9,240	Total Labor cost*Workload	Section C
Equipment cost	Item		Unit	Quantity	Unit price Purchase (Rs.)	Total price (Rs.)	Note	
	Equipment Purchase cost	Flow Meter (Portable type)	Each	1.0	5,300,000	5,300,000	Depends on number of Inlet point 1 unit in 1 inlet point	
		Pressure Logger	Each	4.0	1,700,000	6,800,000	Depends on number of subzone 1 unit in 1 subzone	
		Generator	Each	1.0	290,000	290,000	1 unit in 1 Main team	
							Add equipment cost if need	
	Total Purchase cost					12,390,000		Section D
	Item		Unit	Quantity	Unit price Ownership (Rs.)	Total price (Rs.)	Note	
	Equipment Ownership cost	Flow Meter (Portable type)	Each	1.0	20,140	20,140	Depends on number of Inlet point 1 unit in 1 inlet point	
		Pressure Logger	Each	4.0	3,750	15,000	Depends on number of subzone 1 unit in 1 subzone	
		Generator	Each	1.0	958	958	1 unit in 1 Main team	
		Vehicle	Each	1.0	2,500	2,500	1 unit in 1 Main team	
	Total Ownership cost for 1 day					38,598		

Section A: Labor cost

- Select the appropriate quantities in the yellow cells (drop down lists). Select the quantity of labor according to the number of teams you planned in Step 1.

Section B: Nighttime work premium cost

- Select the appropriate quantity in the yellow cell (drop down list). Select 0 for daytime work, select 0.5 for nighttime work.

Section C: Unit cost of each operation

- This section is calculated automatically.

Section D: Equipment purchase and ownership cost

- Select the appropriate quantities in the yellow cells (drop down lists). Select the quantity of equipment you need that you confirmed in Step 1.

  No equipment in the office: Add purchase cost.

  Own equipment in the office or can be prepared: Add equipment ownership cost.

Workload: Time required for each operation

➢ Refer to Guideline 1.3 3) select the correct workload.

* In flow measurement survey, one team will consist of a main team and a valve team.
* The times of flow measurements are twice the number of DMAs.

3) Step 3

Set the number of survey teams and equipment required for the house-to-house survey in Table 3. Follow the instructions below to operate Table 3.

Table 3	Cost Table of House to House survey					workload =	10.18 house/hour/team	Workload
Item	Description		Unit	Quantity	Unit cost (Rs.)	Total cost (Rs.)	Note	
Labor cost	Labor	EA(Chief)	Person /hour	2.0	247	494	1 Person in 1 Team	Section A
		Fitter	Person /hour	2.0	182	364	1 Person in 1 Team	
		Un Skilled	Person /hour	2.0	159	318	1 Person in 1 Team	
	Daytime hourly cost		Hour			1,176		Section B
	Total labor cost		Hour			1,176		
	1 house survey cost					116	Total Labor cost/Workload	Section C
Equipment cost	Item		Unit	Quantity	Unit price/Purchase (Rs.)	Total price (Rs.)	Note	Section D
	Equipment Purchase cost	Acoustic Rod	Each	1.0	59,148	59,148	1 unit in 1 Team	
							Add equipment cost if need	
	Total Purchase cost					59,148		
	Item		Unit	Quantity	Unit price/Ownership (Rs.)	Total price (Rs.)	Note	
	Equipment Ownership cost	Acoustic Rod	Each	1.0	166	166	1 unit in 1 Team	
		Vehicle	Each	1.0	2,500	2,500	1 unit in 1 Team	
	Total Ownership cost for 1 day					2,666		

Section A: Labor cost

➢ Select the appropriate quantities in the yellow cells (drop down lists). Select the quantity of labor according to the number of teams you planned in Step 1.

Section B: Nighttime work premium cost

➢ This survey will be conducted during the daytime, therefore the cells in this section cannot be changed.

Section C: Unit survey cost of per house

➢ This section is calculated automatically.

Section D: Equipment purchase and ownership cost

➢ Select the appropriate quantities in the yellow cells (drop down lists). Select the quantity of equipment you need that you confirmed in Step 1.

No equipment in the office: Add purchase cost.

Own equipment in the office or can be prepared: Add equipment ownership cost.

Workload: Work speed per hour

➢ Refer to Guideline 1.3 3) and select the correct workload.

4)Step 4

Set the number of survey teams and equipment required for the road survey in Table 4. Follow the instructions below to operate with Table 4.

Table 4	Cost Table of Road Surface survey					workload =	235.0m/hour/team	Workload
Item	Description		Unit	Quantity	Unit cost (Rs.)	Total cost (Rs.)	Note	
Labor cost	Labor	EA(Chief)	Person /hour	1.0	247	247	1 Person in 1 Team	Section A
		Fitter	Person /hour	2.0	182	364	2 Persons in 1 Team	
		Un Skilled	Person /hour	1.0	159	159	1 Person in 1 Team	
	Daytime hourly cost		Hour			770		
	Nighttime hourly cost		Hour	0.5	Daytime cost*0.5	385	Night work premium	Section B
	Total Labor cost		Hour			1,155	Daytime + Nighttime hourly cost	
	1 meter road survey cost					4.91	Total Labor cost/Workload	Section C
Equipment cost	Item		Unit	Quantity	Unit price/Purchase (Rs.)	Total price (Rs.)	Note	
	Equipment Purchase cost	Leak Detector	Each	1.0	463,266	463,266	1unit in 1 Team	
		Acoustic Rod	Each	0.0	59,148	0	1unit in 1 Team	
						0	Add equipment cost if need	
	Total Purchase cost					463,266		Section D
	Item		Unit	Quantity	Unit price/Ownership (Rs.)	Total price (Rs.)	Note	
	Equipment Ownership cost	Leak Detector	Each	1.0	741	741	1 unit in 1 Team	
		Acoustic Rod	Each	1.0	166	166	1 unit in 1 Team	
		Vehicle	Each	1.0	2,500	2,500	1 unit in 1 Team	
	Total Ownership cost for 1 day					3,407		

Section A: Labor cost

➢ Select the appropriate quantities in the yellow cells (drop down lists)Select the quantity of labor according to the number of teams you planned in Step 1.

Section B: Nighttime work premium cost

➢ Select the appropriate quantities in the yellow cell (drop down list). Select 0 for daytime work, select 0.5 for nighttime work.

Section C: Unit survey cost of per m

➢ This section is calculated automatically.

Section D: Equipment purchase and ownership cost

➢ Select the appropriate quantities in the yellow cells (drop down lists). Select the quantity of equipment you need (to either newly purchase or for which is already available) that you confirmed in Step 1.

No equipment in the office: Add purchase cost.

Own equipment in the office or can be prepared: Add equipment ownership cost.

Workload: Work speed per hour

➢ Refer to Guideline 1.3 3) and select the correct workload.

5) Step 5

Set the number of survey teams and equipment required for the identification survey in Table 5.

Follow the instructions below to operate Table 5.

Table 5	Cost Table of Identification survey				workload =	3.6 Location/hour/team		Workload
Item	Description		Unit	Quantity	Unit cost (Rs.)	Total cost (Rs.)	Note	
Labor cost	Labor	EA(Chief)	Person /hour	1.0	247	247	1 Person in 1 Team	Section A
		Fitter	Person /hour	2.0	182	364	2 Persons in 1 Team	
		Un Skilled	Person /hour	1.0	159	159	1 Person in 1 Team	
	Daytime hourly cost		Hour			770		
	Nighttime hourly cost		Hour	0.0	Daytime cost*0.5	0	Night work premium	Section B
	Total Labor cost		Hour			770	Daytime + Nighttime hourly cost	
	1 suspected leakage survey cost		Location			213.89	Total Labor cost/Workload	Section C
Equipment cost	Item		Unit	Quantity	Unit price/Purchase (Rs.)	Total price (Rs.)	Note	
	Equipment Purchase cost	Leak Detector	Each	0.0	463,266	0	1unit in 1 Team	
		Generator	Each	0.0	290,000	0	1unit in 1 Team	
		Hammer Drill	Each	1.0	23,261	23,261	1unit in 1 Team	
		Boring Bar	Each	1.0	45,275	45,275	1unit in 1 Team	
		Acoustic Rod	Each	1.0	59,148	59,148	2 units in 1 Team	
						0	Add equipment cost if need	
	Total Purchase cost					127,684		Section D
	Item		Unit	Quantity	Unit price/Ownership (Rs.)	Total price (Rs.)	Note	
	Equipment Ownership cost	Leak Detector	Each	0.0	741.00	0	1unit in 1 Team	
		Generator	Each	0.0	958.00	0	1unit in 1 Team	
		Hammer Drill	Each	1.0	44.00	44	1unit in 1 Team	
		Boring Bar	Each	1.0	543.00	543	1unit in 1 Team	
		Acoustic Rod	Each	1.0	166.00	166	2 units in 1 Team	
		Vehicle	Each	1.0	2,500.00	2,500	1unit in 1 Team	
	Total Ownership cost for 1 day					3,253		

Section A: Labor cost

- Select the appropriate quantities in the yellow cells (drop down lists). Select the quantity of labor according to the number of teams you planned in Step 1.

Section B: Nighttime work premium cost

- Select the appropriate quantities in the yellow cell (drop down list). Select 0 for daytime work, select 0.5 for nighttime work.

Section C: Unit survey cost of number of locations

This section is calculated automatically.

Section D: Equipment purchase and ownership cost

- Select the appropriate quantities in the yellow cells (drop down lists). Select the quantity of equipment you need that you confirmed in Step 1.
  No equipment in the office: Add purchase cost.
  Own equipment in the office or can be prepared: Add equipment ownership cost.

Workload: Work speed per hour

- Refer to Guideline 1.3 3) and select the correct workload.

6) Step 6

Set the quantities of each survey in Table 1. Follow the instructions below to operate Table 1.

Table 1	Total Survey Cost & Working hour Table of Leak Detection						
	Item	Unit	Quantity	Unit cost (Rs.)	Total cost (Rs.)	Note	
Survey Cost 1 Labor cost	Flow Measurement	Operation	2.0	2,310.00	4,620	See the Table 2 for basic data	Section A
	House to House Survey	House	7,700.0	115.52	889,509	See the Table 3 for basic data	
	Road Surface Survey	Km	62.0	4.91	304,723	See the Table 4 for basic data	
	Identification Survey (Suspected leak location)	Km	62.0			See the Table 5 for basic data	
		Location	341.0	213.89	72,936	Quantity of Location= Km (Pipe length)* 5.5 Location/Km	
	Total Labor cost				1,271,788		
	Item	Unit			Total price (Rs.)	Note	
Survey Cost 2-1 Equipment Purchase cost	Flow Measurement	Each			12,390,000	See the Table 2 for basic data	Section B
	House to House Survey	Each			59,148	See the Table 3 for basic data	
	Road Surface Survey	Each			463,266	See the Table 4 for basic data	
	Ientification Survey	Each			127,684	See the Table 5 for basic data	
	Total Puechase Cost				13,040,098		
	Item	Unit	Quantity	Unit cost (Rs.)	Total cost (Rs.)	Note	
Survey Cost 2-2 Equipment Ownership cost	Flow Measurement	Operation	2.00	38,598	77,196	Same as the number of flow measurement	
	House to House Survey	Days	54.03	2666.00	144,037	The daily working hour is 7 hours. Quantity=Working hours team/7hours	Quantity=F27/7hours
	Road Surface Survey	Days	18.84	3407.00	64,205		Quantity=F28/7hours
	Ientification Survey	Days	13.53	3253.00	44,019		Quantity=F29/7hours
	Total Ownership Cost				329,457		
Total Survey Cost					14,641,343	Total Labor Cost + Total Equipment cost	Section C
	Item	Unit	Working hours	No. of survey team	Working hours/Team		
Working hour	Flow Measurement	Each	8.00	2.0	4.00		Section D
	House to House Survey	Each	756.39	2.0	378.19		
	Road Surface Survey	Each	263.83	2.0	131.91		
	Ientification Survey	Each	94.72	1.0	94.72		
	Total Working Hour		1,122.94			Working hour for all teams	
Working hour required to complete the survey					608.8		

Section A: Total labor cost

- Select the appropriate quantities in the yellow cells (drop down lists). Enter the quantities of each survey planned in Step 1.

Section B: Total equipment purchase and ownership cost

- This section is calculated automatically.

Section C:

Total survey cost (labor + equipment)

- This section is calculated automatically.

Section D: Working hours for leak detection work

- Select the appropriate quantities in the yellow cells (drop down lists). Select the same number of teams as in tables 2,3,4 and 5.

Flow measurement: Table 2; House-to-house survey: Table 3; Road surface survey: Table 4; Identification survey: Table 5

7) Step 7

Examine whether the cost and working hours calculated in Step 6 are feasible or not. If it is difficult to implement, return to Step 1 and review the plan.

4 Basis for Setting

4.1 Setting the Basic Data in Tables 2, 3, 4 and 5

A: This section has adopted the track records of pilot activities. The unit prices are mentioned in the basis of labor cost in each table of the calculation sheet.

B: A bonus of 0.5 will be added for nighttime work.

C: This section is the sum of sections A and B divided by workload. The survey cost is calculated by multiplying this number by the survey quantity of Table 1.

D: This section has adopted the equipment prices for pilot activities. The unit prices mentioned are based on the equipment purchase and ownership prices in each table.

Table 4	Cost Table of Road Surface survey				workload =	235.0 m/hour/team		Workload
Item	Description		Unit	Quantity	Unit cost (Rs.)	Total cost (Rs.)	Note	
Labor cost	Labor	EA(Chief)	Person /hour	1.0	247	247	1 Person in 1 Team	Section A
		Fitter	Person /hour	2.0	182	364	2 Persons in 1 Team	
		Un Skilled	Person /hour	1.0	159	159	1 Person in 1 Team	
	Daytime hourly cost		Hour			770		
	Nighttime hourly cost		Hour	0.5	Daytime cost*0.5	385	Night work premium	Section B
	Total Labor cost		Hour			1,155	Daytime + Nighttime hourly cost	
	1 meter road survey cost					4.91	Total Labor cost/Workload	Section C
Equipment cost	Item		Unit	Quantity	Unit price/Purchase (Rs.)	Total price (Rs.)	Note	Section D
	Equipment Purchase cost	Leak Detector	Each	1.0	463,266	463,266	1unit in 1 Team	
		Acoustic Rod	Each	0.0	59,148	0	1unit in 1 Team	
						0	Add equipment cost if need	
	Total Purchase cost					463,266		
	Item		Unit	Quantity	Unit price/Ownership (Rs.)	Total price (Rs.)	Note	
	Equipment Ownership cost	Leak Detector	Each	1.0	741	741	1 unit in 1 Team	
		Acoustic Rod	Each	1.0	166	166	1 unit in 1 Team	
		Vehicle	Each	1.0	2,500	2,500	1 unit in 1 Team	
	Total Ownership cost for 1 day					3,407		

4.2 Setting the Labor Unit Costs and Equipment Unit Costs

These costs are mentioned in the tables below.

1) Basis of Labor Cost in Each Table

These prices are the same as B / C of DMA3 in the 2021 pilot activities.

Basis of Labor Cost in Each Table			
Position	Unit	Unit cost (Rs.)	Note
EA (Chief)	Person/hour	247	Change the labor cost if needed
Fitter	Person/hour	182	Change the labor cost if needed
Un Skilled	Person/hour	159	Change the labor cost if needed

2) Basis of Equipment Price in Each Table (Purchase and Ownership Prices per Day)

2)-1 Price list of equipment

These prices are the same as the equipment prices in pilot activities.

Basis of Equipment Price in Each Table Purchase and Ownership Prices per Day			
Item	Purchase price (Rs.)	Ownership price per day (Rs.)	Note
Leak detector	463,266	741	*1 The purchase price of the equipment is the amount procured by the pilot activity in Panadura, WSC-WS. *2 The equipment's ownership price is the same as B/C calculation costs by the pilot activity
Generator	290,000	958	
Hammer drill	23,261	44	
Acoustic rod	59,148	166	
Boring bar	45,275	543	
Pressure logger	1,700,000	3,750	

Flow meter (portable type)	5,300,000	20,140	in Panadura, WSC-WS. Change the equipment purchase and ownership if needed
Vehicle	-	2,500	

2)-2 Ownership price settings

The table below shows the unit rate per day of each equipment. Coefficients are being used for the calculations herein.

Equipment	Price	Coefficient	Unit rate per day
	a	b	C=a*b
Leak Detector	463,266	0.0016	741
Generator	290,000	-	958
Hammer Drill	23,261	0.0019	44
Acoustic Rod	59,148	0.0028	166
Boring Bar	45,275	0.012	543
Pressure Logger	1,700,000	0.0021	3,750
Flow Meter (Portable Type)	5,300,000	0.0038	20,140
Vehicle	-	-	2,500

*Source of the coefficients for all the machinery except generators and vehicles: Japan Leakage Survey Association

*Source of the coefficient for generators: Japan Construction Machinery and Construction Association, construction machinery unit rate table (Specs -3kVA)

* Source of the coefficient for Vehicle: RSC-WS

4.3 Types of Equipment Use for Each Survey

This table is a list of equipment and surveys used in pilot activities. This list is reflected in tables 2, 3, 4 and 5.

Types of equipment use for each survey		Item of survey			
		Flow Measurement	House to House Survey	Road Surface Survey	Identification Survey (Suspected leak location)
Equipment	Leak Detector			✓	✓
	Generator	✓			✓
	Hammer Drill				✓
	Acoustic Rod		✓	✓	✓
	Boring Bar				✓
	Pressure Logger	✓			
	Flow Meter (Portable type)	✓			
	Vehicle	✓	✓	✓	✓

4.4 Setting the Workload

1) How to Set the Workload

The basic data for workload are the working records and the results of the pilot activities in DMA 3, 4 and 5. The working records are analyzed to calculate the respective working hours. After that, JET compares the survey quantity of each DMA and calculates the survey quantity conducted by one team in one hour.

2) DMA3 Workload Analysis

Under analysis.

3) DMA4 Workload Analysis

- The workload of flow measurement is 4.0 hours per operation.
  The flow measurement was conducted by one team consisting of a main team and a valve team, and the total working hours was 8 hours. Within this time, two flow measurements were taken, and the workload per flow measurement was estimated to be 4 hours.
- The workload of the house-to-house survey is 10.18 houses per hour.
  Two teams conducted the house-to-house survey, and the total working hours was 27.6 hours. Within this time, 281 houses were able to be surveyed. Therefore, the workload per hour by one team was estimated to be 10.18 houses.
- The workload of the road surface survey is 235.71 m per hour.
  Two teams conducted the road surface survey, and the total working hours was 14.0 hours. Within this time, 3,300 m was able to be surveyed. Therefore, the workload per hour by one team was estimated to be 235.71 m.
- The workload of the identification survey is 3.6 locations per hour.

One team conducted the identification survey, and the total working hours was 5.0 hours. Within this time, 18 locations were able to be surveyed. Therefore, the workload per hour by one team was estimated to be 3.6 locations.

Workload of DMA 4			
Customer density per 1km : 85.15 (Number of costomer 281/Pipelength 3.3km)			
Survey item	Working hours in 1 team	Quantity of survey by 1 team	Workload of 1 team per hour
Flow measurement &Step test	4.0	1.0	4.0 / operation
House to House	13.8	140.5	10.18 / houses
Road surface	7.0	1650.0	235.71 / meter
Identification(Pinpoint)	5.0	18.0	3.60 / location

) DMA5 Workload Analysis

- The workload of flow measurement is 6.0 hours per operation.
  The flow measurement was conducted by one team consisting of a main team and a valve team, and the total working hours was 12 hours. Within this time, two flow measurements were taken, and the workload per flow measurement was estimated to be 6 hours.
- The workload of the house-to-house survey is 28.67 houses per hour.
  Two teams conducted the house-to-house survey, and the total working hours was 24.0 hours. Within this time, 668 houses were able to be surveyed. Therefore, the workload per hour by one team was estimated to be 28.67 houses.
- The workload of road surface surveys is 155.65 m per hour.
  Two teams conducted the road surface survey, and the total working hours was 37.5 hours. Within this time, 5,837 m was able to be surveyed. Therefore, the workload per hour by one team was estimated to be 155.65 m.
- The workload of identification survey
  In DMA5, the road survey and the identification survey were conducted at the same time. Therefore, unlike DMA4, it is not possible to separate the two working hours.

Workload of DMA 5			
Customer density per 1km : 123.96 (Number of costomer 1376/Pipelength 11.1km)			
Survey item	Working hours in 1 team	Quantity of survey by 1 team	Workload of 1 team per hour
Flow measurement &Step test	6.0	1.0	6.0 / operation
House to House	24.0	688	28.67 / houses
Road surface	18.8	2918.5	155.65 / meter
Identification(Pinpoint)	-	100.0	- / location

5) Setting Standard Workload Required for Water Leak Detection Activities

1) Summary of analysis

The following table summarizes the analysis results of DMAs 3, 4, and 5, which formed the basis for how we set the various workloads.

DMA	DMA3	DMA4	DMA5
Customer density per 1 km	81.75	85.15	123.96
Workload of all flow measurement activities		4.0 hours/operation	6.0 hours/operation
Workload of all house-to-house survey activities		10.18 houses/hour	28.67 houses/hour
Workload of all road surface survey activities		235.71m/hour	155.65m/hour
Workload of all identification survey activities		3.6 locations/hour	-

2) Setting standard workload

The workload set two patterns based on the density of houses per km of pipeline. These two patterns were decided by exchanging opinions with the pilot activity workers based on the analysis results. For the workload of each survey, refer to: Guideline 1.3 3) Conditions of use.

5 Make a Test Calculation

In this chapter, we will make a trial calculation using the following hypothetical numbers. Please refer to the conditions under which the amounts are calculated. This calculation is using the normal flow in Guideline Chapter 3.

1) Step 1. Create a leak detection plan

1)-1 Plan the quantity of items to be conducted in each survey

- Number of households: 4,000 (surveyed in the house-to-house survey)
- Pipe length: 50.0 km (surveyed in both the road surface survey and the identification survey)
- Number of DMAs: 3 (flow measurements undertaken six times)

1)-2) Consider the number of teams to be assigned to each survey

- All surveys are to be conducted by one team each (flow measurement is conducted by one team (split into a main team and a valve team))

1)-3 Check the availability of equipment required for each survey

- Purchase all equipment required for each survey
- The vehicle figure is the ownership cost for each survey

1)-4 Workload settings

- The density of the houses per 1km of pipeline in the target is 80.0 houses per km (4,000 house/50.0 km = 80 houses per km) Therefore, Set the workload as follows in Table 2,3,4 and 5:

  Flow Measurement is 4.0 hours per operation.

  House-to-house survey is 13.6 houses per hour.

  Road surface survey is 235 m per hour

  Identification survey is 3.6 locations per hour

2) Step 2. Set up the survey team and necessary equipment for the flow measurement survey in Table 2

Table 2	Cost Table of Flow Measurement (Minimum Night Flow & Step Test)					workload =	4.0 hours/operation/team
Item	Description		Unit	Quantity	Unit cost (Rs.)	Total cost (Rs.)	Note
Labor cost	Main Team	EA(Chief)	Person /hour	1.0	247	247	1 Person in 1 Team
		Fitter	Person /hour	2.0	182	364	2 Persons in 1 Team
		Un Skilled	Person /hour	1.0	159	159	1 Person in 1 Team
	Valve Control Team	EA(Chief)	Person /hour	1.0	247	247	1 Person in 1 Team
		Fitter	Person /hour	2.0	182	364	2 Persons in 1 Team
		Un Skilled	Person /hour	1.0	159	159	1 Person in 1 Team
	Daytime hourly cost		Hour			1,540	Main Team + Valve Team cost
	Nighttime hourly cost		Hour	0.50	Daytime cost*0.5	770	Night work premium
	Total labor cost		Hour			2,310	Daytime + Nighttime hourly cost
	1 Operation Labor cost (1 Operation = Workload hours)					9,240	Total Labor cost*Workload
Equipment cost	Item		Unit	Quantity	Unit price Purchase (Rs.)	Total price (Rs.)	Note
	Equipment Purchase cost	Flow Meter (Portable type)	Each	1.0	5,300,000	5,300,000	Depends on number of Inlet point 1 unit in 1 inlet point
		Pressure Logger	Each	4.0	1,700,000	6,800,000	Depends on number of subzone 1 unit in 1 subzone
		Generator	Each	1.0	290,000	290,000	1 unit in 1 Main team
							Add equipment cost if need
	Total Purchase cost					12,390,000	
	Item		Unit	Quantity	Unit price Ownership (Rs.)	Total price (Rs.)	Note
	Equipment Ownership cost	Flow Meter (Portable type)	Each	0.0	20,140	0	Depends on number of Inlet point 1 unit in 1 inlet point
		Pressure Logger	Each	0.0	3,750	0	Depends on number of subzone 1 unit in 1 subzone
		Generator	Each	0.0	958	0	1 unit in 1 Main team
		Vehicle	Each	1.0	2,500	2,500	1 unit in 1 Main team
	Total Ownership cost for 1 day					2,500	

Workload

Section A

Section B

Section C

Section D

Section A: Labor cost

- 1 Main team (1 EA (Engineer (Chief)), 2 fitters, 1 unskilled), 1 Valve team (1 EA (chief), 2 fitters, 1 unskilled)

Section B: Nighttime work premium cost

- Select 0.5 for nighttime work.

Section C: Unit cost of 1 operation

- This section is calculated automatically.

Section D: Equipment purchase and ownership cost

- Select the quantity of equipment needing to be purchased (1 flow meter, 4 pressure loggers, 1 generator)

Select the quantity of equipment ownership (1 vehicle)

3) Step 3. Set up the survey team and necessary equipment for the house-to-house survey in Table 3

Table 3	Cost Table of House to House survey					workload =	10.18 house/hour/team	Workload
Item	Description		Unit	Quantity	Unit cost (Rs.)	Total cost (Rs.)	Note	
Labor cost	Labor	EA(Chief)	Person /hour	1.0	247	247	1 Person in 1 Team	Section A
		Fitter	Person /hour	1.0	182	182	1 Person in 1 Team	
		Un Skilled	Person /hour	1.0	159	159	1 Person in 1 Team	
	Daytime hourly cost		Hour			588		Section B
	Total labor cost		Hour			588		
	1 house survey cost					58	Total Labor cost/Workload	Section C
Equipment cost	Item		Unit	Quantity	Unit price/Purchase (Rs.)	Total price (Rs.)	Note	Section D
	Equipment Purchase cost	Acoustic Rod	Each	1.0	59,148	59,148	1 unit in 1 Team	
							Add equipment cost if need	
	Total Purchase cost					59,148		
	Item		Unit	Quantity	Unit price/Ownership (Rs.)	Total price (Rs.)	Note	
	Equipment Ownership cost	Acoustic Rod	Each	0.0	166	0	1 unit in 1 Team	
		Vehicle	Each	1.0	2,500	2,500	1 unit in 1 Team	
	Total Ownership cost for 1 day					2,500		

Section A: Labor cost

- 1 team (1 EA (chief), 1 fitter, 1 unskilled)

Section B: Nighttime work premium cost

- This section does not operate.

Section C: Unit survey cost of per house

- This section is calculated automatically.

Section D: Equipment purchase and ownership cost

- Select the quantity of equipment needing to be purchased (1 acoustic rod)
- Select the quantity of equipment already owned (1 vehicle)

4) Step 4. Set up the survey team and necessary equipment for the Road survey in Table 4

Table 4	Cost Table of Road Surface survey					workload =	235.0 m/hour/team
Item	Description		Unit	Quantity	Unit cost (Rs.)	Total cost (Rs.)	Note
Labor cost	Labor	EA(Chief)	Person /hour	1.0	247	247	1 Person in 1 Team
		Fitter	Person /hour	2.0	182	364	2 Persons in 1 Team
		Un Skilled	Person /hour	1.0	159	159	1 Person in 1 Team
	Daytime hourly cost		Hour			770	
	Nighttime hourly cost		Hour	0.5	Daytime cost*0.5	385	Night work premium
	Total Labor cost		Hour			1,155	Daytime + Nighttime hourly cost
	1 meter road survey cost					4.91	Total Labor cost/Workload
Equipment cost	Item		Unit	Quantity	Unit price/Purchase (Rs.)	Total price (Rs.)	Note
	Equipment Purchase cost	Leak Detector	Each	1.0	463,266	463,266	1unit in 1 Team
		Acoustic Rod	Each	0.0	59,148	0	1unit in 1 Team
						0	Add equipment cost if need
	Total Purchase cost					463,266	
	Item		Unit	Quantity	Unit price/Ownership (Rs.)	Total price (Rs.)	Note
	Equipment Ownership cost	Leak Detector	Each	0.0	741	0	1 unit in 1 Team
		Acoustic Rod	Each	0.0	166	0	1 unit in 1 Team
		Vehicle	Each	1.0	2,500	2,500	1 unit in 1 Team
	Total Ownership cost for 1 day					2,500	

Workload

Section A

Section B

Section C

Section D

Section A: Labor cost

- 1 team (1 EA (chief), 2 fitters, 1 unskilled)

Section B: Nighttime work premium cost

- Select 0.5 for nighttime work.

Section C: Unit survey cost of per m

- This section is calculated automatically.

Section D: Equipment purchase and ownership cost

- Select the quantity of equipment needing to be purchased (1 leak detector, 0 acoustic rods). Note: Acoustic rod is set to zero as an acoustic rod was already purchased for the house-to-house survey in Step 3.
- Select the quantity of equipment already owned (1 vehicle)

5) Step 5. Set up the survey team and necessary equipment for the Identification survey in Table 5

Table 5	Cost Table of Identification survey					workload =	3.6 Location/hour/team
Item	Description		Unit	Quantity	Unit cost (Rs.)	Total cost (Rs.)	Note
Labor cost	Labor	EA(Chief)	Person /hour	1.0	247	247	1 Person in 1 Team
		Fitter	Person /hour	2.0	182	364	2 Persons in 1 Team
		Un Skilled	Person /hour	1.0	159	159	1 Person in 1 Team
	Daytime hourly cost		Hour			770	
	Nighttime hourly cost		Hour	0.0	Daytime cost*0.5	0	Night work premium
	Total Labor cost		Hour			770	Daytime + Nighttime hourly cost
	1 suspected leakage survey cost		Location			213.89	Total Labor cost/Workload
Equipment cost	Item		Unit	Quantity	Unit price/Purchase (Rs.)	Total price (Rs.)	Note
	Equipment Purchase cost	Leak Detector	Each	0.0	463,266	0	1unit in 1 Team
		Generator	Each	0.0	290,000	0	1unit in 1 Team
		Hammer Drill	Each	1.0	23,261	23,261	1unit in 1 Team
		Boring Bar	Each	1.0	45,275	45,275	1unit in 1 Team
		Acoustic Rod	Each	1.0	59,148	59,148	2 units in 1 Team
						0	Add equipment cost if need
	Total Purchase cost					127,684	
	Item		Unit	Quantity	Unit price/Ownership (Rs.)	Total price (Rs.)	Note
	Equipment Ownership cost	Leak Detector	Each	0.0	741.00	0	1unit in 1 Team
		Generator	Each	0.0	958.00	0	1unit in 1 Team
		Hammer Drill	Each	0.0	44.00	0	1unit in 1 Team
		Boring Bar	Each	0.0	543.00	0	1unit in 1 Team
		Acoustic Rod	Each	0.0	166.00	0	2 units in 1 Team
		Vehicle	Each	1.0	2,500.00	2,500	1unit in 1 Team
	Total Ownership cost for 1 day					2,500	

Workload
Section A
Section B
Section C
Section D

Section A: Labor cost

- 1 team (1 EA (chief), 2 fitters, 1 unskilled)

Section B: Nighttime work premium cost

- Select 0 for daytime work.

Section C: Unit survey cost of number of locations

➢ This section is calculated automatically.

Section D: Equipment purchase and ownership cost

➢ Select the quantity of equipment needing to be purchased (0 leak detectors, 0 generators, 1 hammer drill, 1 boring bar, 1 acoustic rod). Note: various equipment was already purchased for other surveys in steps 2 to 4 (1 leak detector, 1 generator, and 1 acoustic rod).

  ➢ Select the quantity of equipment already owned (1 vehicle)

6) Step 6. Enter the survey quantities planned in Step 1 in Table 1

Table 1	Total Survey Cost & Working hour Table of Leak Detection						
	Item	Unit	Quantity	Unit cost (Rs.)	Total cost (Rs.)	Note	
Survey Cost 1 Labor cost	Flow Measurement	Operation	6.0	2,310.00	13,860	See the Table 2 for basic data	
	House to House Survey	House	4,000.0	57.76	231,041	See the Table 3 for basic data	
	Road Surface Survey	Km	50.0	4.91	245,745	See the Table 4 for basic data	
	Identification Survey (Suspected leak location)	Km	50.0			See the Table 5 for basic data	
		Location	275.0	213.89	58,819	Quantity of Location= Km (Pipe length)*	5.5 Location/Km
	Total Labor cost				549,465		
Survey Cost 2-1 Equipment Purchase cost	Item	Unit			Total price (Rs.)	Note	
	Flow Measurement	Each			12,390,000	See the Table 2 for basic data	
	House to House Survey	Each			59,148	See the Table 3 for basic data	
	Road Surface Survey	Each			463,266	See the Table 4 for basic data	
	Ientification Survey	Each			127,684	See the Table 5 for basic data	
	Total Puechase Cost				13,040,098		
Survey Cost 2-2 Equipment Ownership cost	Item	Unit	Quantity	Unit cost (Rs.)	Total cost (Rs.)	Note	
	Flow Measurement	Operation	6.00	2,500	15,000	Same as the number of flow measurement	
	House to House Survey	Days	56.13	2500.00	140,331	The daily working hour is 7 hours. Quantity=Working hours team/7hours	Quantity=F27/7hours
	Road Surface Survey	Days	30.40	2500.00	75,988		Quantity=F28/7hours
	Ientification Survey	Days	10.91	2500.00	27,282		Quantity=F29/7hours
	Total Ownership Cost				258,601		
Total Survey Cost					13,848,164	Total Labor Cost + Total Equipment cost	
Working hour	Item	Unit	Working hours	No. of survey team	Working hours/Team		
	Flow Measurement	Each	24.00	2.0	12.00		
	House to House Survey	Each	392.93	1.0	392.93		
	Road Surface Survey	Each	212.77	1.0	212.77		
	Ientification Survey	Each	76.39	1.0	76.39		
	Total Working Hour		706.08			Working hour for all teams	
Working hour required to complete the survey					694.1		

Section A (Survey Cost 1)
Section B (Survey Cost 2-1 and 2-2)
Section C (Total Survey Cost)
Section D (Working hour)

Section A: Enter the quantities of each survey planned in Step 1.

➢ Flow measurement: 3 times

➢ House-to-house survey: 4,000 houses

➢ Road surface survey: 50.0 km

➢ Identification survey: 50.0 km

Section B: This section is calculated automatically.

Section C: This section is calculated automatically.

Section D: Select the same number of teams as in tables 2,3,4 and 5.

- Flow measurement: 2 teams (Main team + Valve team)
- House-to-house survey: 1 team
- Road surface survey: 1 team (as in Table 4)
- Identification survey: 1 team (as in Table 5)

7) Step 7 Evaluate the plan

7)-1 Result of Calculations

[Survey Cost]

Item	Cost (Rs)
Labor cost	549,465
Equipment purchase cost	13,040,098
Equipment ownership cost	258,601
Total survey cost	**13,848,164**

[Working hours]

Item	Working hours/Team
Flow measurement	12.0
House-to-house survey	392.93
Road surface survey	212.77
Identification survey	76.39
Total Working Hours for leak detection	**694.1**

Table 1	Total Survey Cost & Working hour Table of Leak Detection						
	Item	Unit	Quantity	Unit cost (Rs.)	Total cost (Rs.)	Note	
Survey Cost 1 Labor cost	Flow Measurement	Operation	6.0	2,310.00	13,860	See the Table 2 for basic data	
	House to House Survey	House	4,000.0	57.76	231,041	See the Table 3 for basic data	
	Road Surface Survey	Km	50.0	4.91	245,745	See the Table 4 for basic data	
	Identification Survey (Suspected leak location)	Km	50.0			See the Table 5 for basic data	
		Location	275.0	213.89	58,819	Quantity of Location= Km (Pipe length)*	5.5 Location/Km
	Total Labor cost				549,465		
Survey Cost 2-1 Equipment Purchase cost	Item	Unit			Total price (Rs.)	Note	
	Flow Measurement	Each			12,390,000	See the Table 2 for basic data	
	House to House Survey	Each			59,148	See the Table 3 for basic data	
	Road Surface Survey	Each			463,266	See the Table 4 for basic data	
	Ientification Survey	Each			127,684	See the Table 5 for basic data	
	Total Puechase Cost				13,040,098		
Survey Cost 2-2 Equipment Ownership cost	Item	Unit	Quantity	Unit cost (Rs.)	Total cost (Rs.)	Note	
	Flow Measurement	Operation	6.00	2,500	15,000	Same as the number of flow measurement	
	House to House Survey	Days	56.13	2500.00	140,331	The daily working hour is 7 hours. Quantity=Working hours team/ 7hours	Quantity=F27/7hours
	Road Surface Survey	Days	30.40	2500.00	75,988		Quantity=F28/7hours
	Ientification Survey	Days	10.91	2500.00	27,282		Quantity=F29/7hours
	Total Ownership Cost				258,601		
Total Survey Cost					13,848,164	Total Labor Cost + Total Equipment cost	
Working hour	Item	Unit	Working hours	No. of survey team	Working hours/Team		
	Flow Measurement	Each	24.00	2.0	12.00		
	House to House Survey	Each	392.93	1.0	392.93		
	Road Surface Survey	Each	212.77	1.0	212.77		
	Ientification Survey	Each	76.39	1.0	76.39		
	Total Working Hour		706.08			Working hour for all teams	
Working hour required to complete the survey					694.1		

7)-2 Evaluation of plan

Examine whether the cost and working hours calculated in Step 7)-1 are feasible or not. If it is difficult to implement, return to Step 1 and review the plan.

6 Points of Attention for Using the Calculation Sheet

6.1 When Calculating

- Do not change any cell quantities in sheets 1-5 besides the yellow cells.
- Consider in advance whether the equipment required for the survey can be prepared. It takes

time to procure equipment. Therefore, the planner needs to have some spare time in the planning schedule before the actual survey begins.

6.2 When changing the basic cost data of labor and equipment in the calculation sheet

The basis of labor cost and the basis of equipment cost in each table is based on the results of pilot activities as of 2021. When planning in the future, if the labor cost and equipment cost do not reflect the current price, NWSDB can change the unit price. However, it should be noted that the calculation result will not reflect the actual situation unless the correct basis is used. The planner must make this change on the right evidence and be approved by the budget and NRW section in RSC.

6.3 When changing the workload

The workloads in Sheets 2-5 reflect the pilot activity performance of 2019-2021, as explained in chapter 4 of this Guideline. NWSDB can change the workload in the future. However, it should be noted that the calculation results will not reflect the actual situation unless the correct basis is used. The planner must make this change on the right evidence and be approved by the budget section, NRW section, and chief of site survey in RSC.

Observe the following conditions when changing the workload.

1) Refer to the precedents of surveys conducted under the same survey conditions or conduct test surveys.
2) Determine the workload (work per hour) based on precedents and test results. Let this workload be A.
3) Conduct survey workload in the setting of A.
4) When the survey is complete, calculate the actual workload from the survey records. Let this workload be B.
5) In subsequent surveys, workload B will be used to develop the plan.
6) However, it is necessary to record the survey conditions under which the workload was decided and leave it as basic data.

Appendix-3

Introduction of Remote Monitoring System

The Appendix-3 is a guidance of convenient monitoring system. It was installed in DMAs in RSC-WS.
It realized the real time monitoring from anywhere.
Considering the remote work and reducing the chance of contact with infectious disease, the remote monitoring was very much welcomed.

1 Mechanism of Remote Monitoring System

In DMA 5 the remote monitoring system was installed on site as mentioned below:

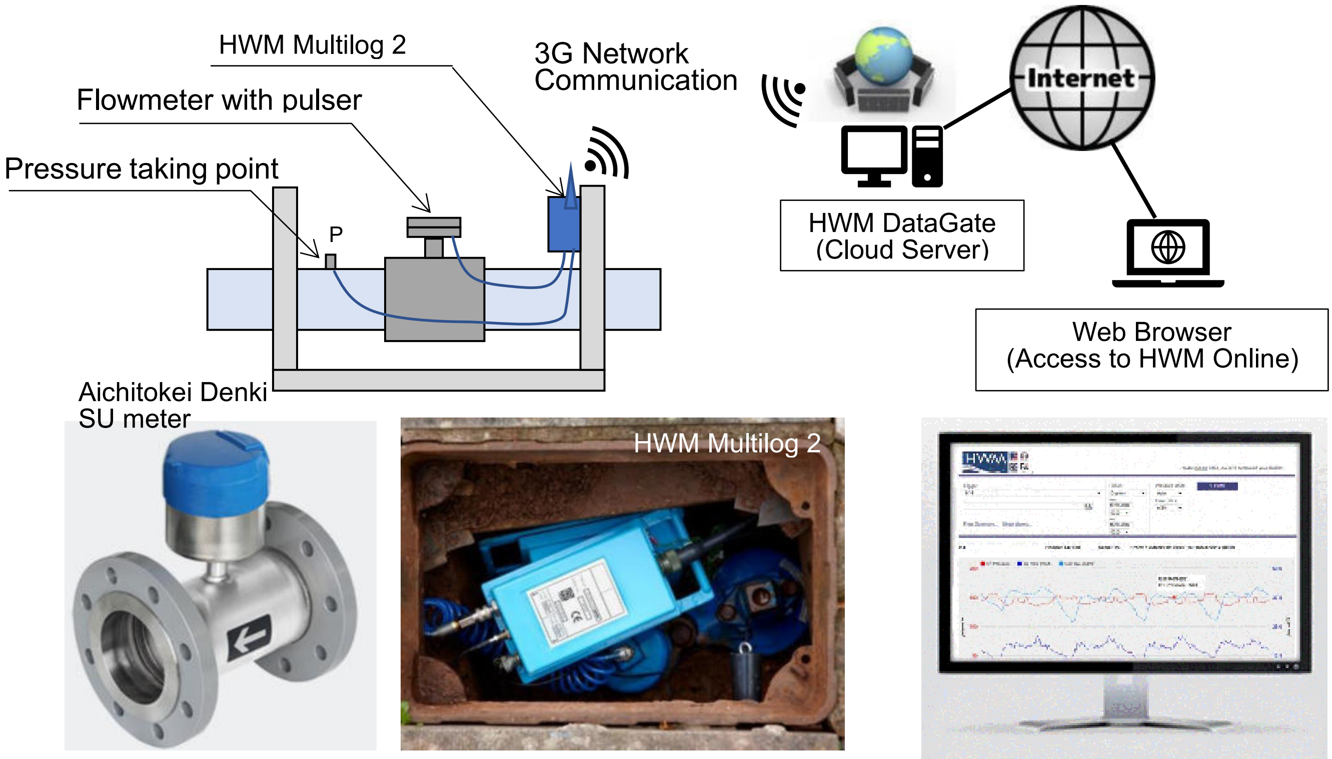


Figure 1.1 Image of Remote Monitoring System

Table 1.1 Necessary basic data of water supply system

No	User's responsibility	HWM's service
1	Installation of 3G Modem Datalogger	Data saving in Cloud Server
2	Preparation of Data SIM card	Data sharing by HWM Online
3	3G Modem Configuration	Maintenance of Cloud Server
4	3G Network Fee	Security measures against illegal access
5	Mobile tablet or PC	Provision of access key
6	Internet Access from PC	
7	DataGate Hosting fee	
8	Flowmeter with pulse signal output	
9	Connection cable for digital signal	
10	Pressure taking point on pipe	
11	Pressure taking cable with quick coupler	
12	External battery (if necessary)	

The monitoring system introduced on a trial basis this time is a service provided by a data logger manufacturer (Halma Water Management). The user can easily check the measurement data anywhere on the earth simply by preparing a SIM card using the mobile phone communication network and paying the service usage fee.

Data can be viewed in graphical or table format from any internet enabled device using web viewer HWM Online or seamlessly integrated into a third-party corporate system.

On receipt of an alarm DataGate can send automatic alerts to multiple users to enable action to be taken promptly. The system will even store data from loggers it does not recognize, and then add this information to the logger's history when it is registered on the system.

Multiple accounts can be set up and configured to ensure that users only see data from the specific loggers they require.

Figure 1.2　Monitoring Screen on Web Browser

2 Use of Pulse Signal

Pulse signals are used in various measurement sites such as automobile speed, water flow rate, and electricity usage.

However, even if we look only at the pulse signal, we do not know the specific value.

Since a pulse signal is a digital signal converted from mechanical changes such as velocity and flow rate, it becomes valuable only by analyzing the data.

2.1 Basic Calculation Method of Pulse Signal

In the case of flowmeter, a preset pulse signal is output according to the rotation speed of the impeller or its passed water volume detected by internal electrical device. Therefore, the flow that has passed can be measured by counting the pulse signals generated within a certain period of time.

(1) Frequency of Pulse Signal

“Frequency” indicates the number of vibrations generated per second, that is, how many times the pulse signal is output.　The time required for a pulse signal to make one round trip is called “Period”.

“Frequency” and “Period” have a reciprocal relationship, and once one is known, the other value can be calculated.

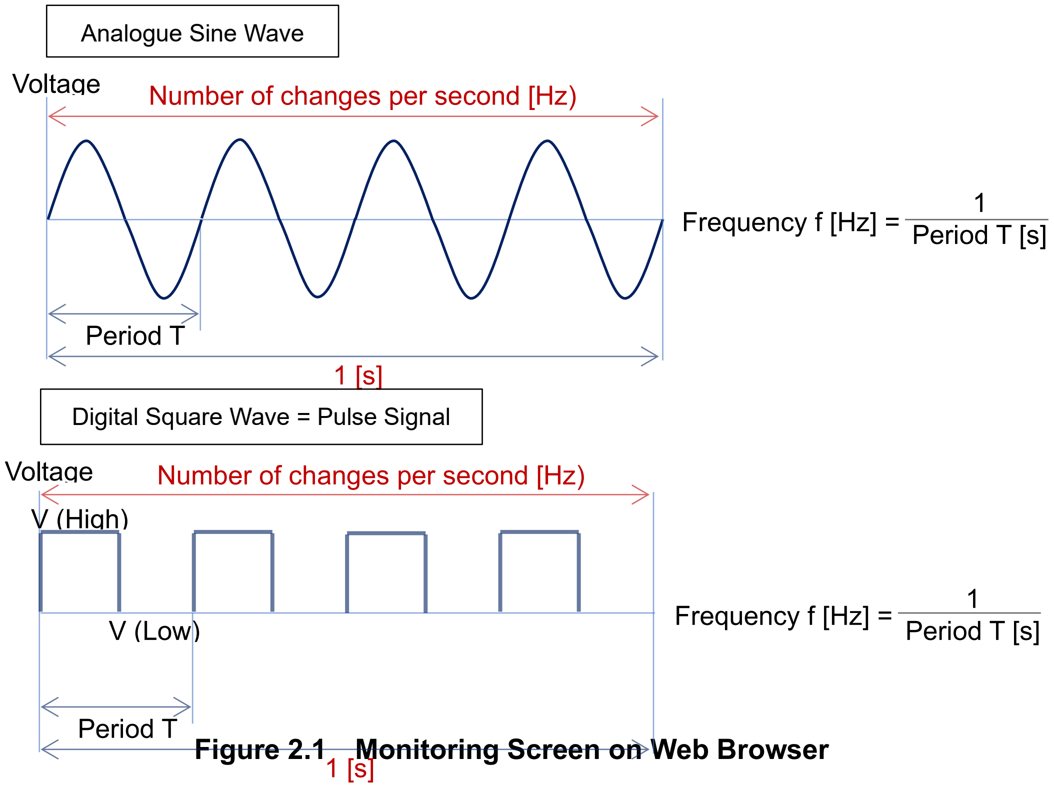


Figure 2.1　Monitoring Screen on Web Browser

(2) Example of electronic water meter

When measuring with a flow meter that emits one pulse when 10 L of water passes, if the data logger counts 10 pulses per minute, the passing flow rate can be calculated as 10 L x 10 pulses = 100 L/min.

There are several pulse signal output methods. The following explanation is an example of mechanism using the simplest open drain method.

An NPN transistor is built inside the flowmeter.

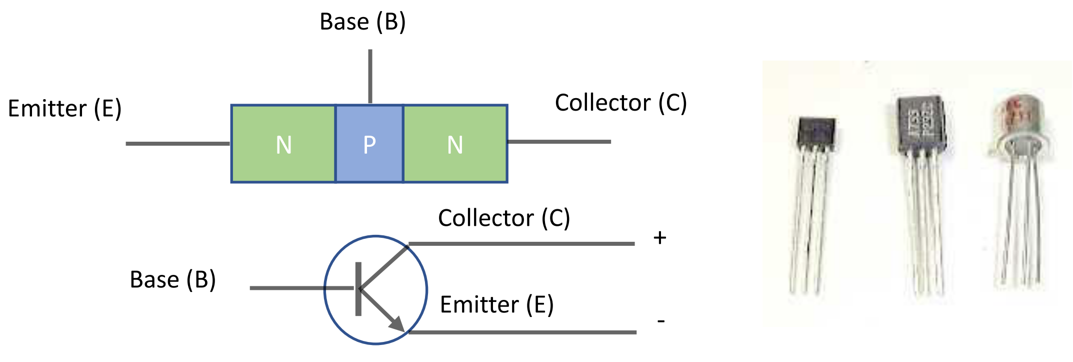


Figure 2.2　Mechanism of Transistor

A collector voltage (C), a base voltage (B), and an emitter voltage (E) are generated in the three electrodes of the transistor and play the role of a switch.

VB < VE	No current flows from B to E. The resistance between C and E is ∞Ω. → This means “Switch off state”.
VB > VE	Current flows from B to E. The resistance between C and E is 0 (zero) Ω. → This means “Switch on state”.

For example, design so that the base voltage (VB) is momentarily loaded when the flow meter counts 10 L, and a state of VB> VE is created. Then, every time the passing flow rate reaches 10 L, the resistance between C and E becomes 0 Ω, and a state in which current flows is created.

In this state, a current flow between C and E for a very short time, and the voltage becomes 0 V (LOW).

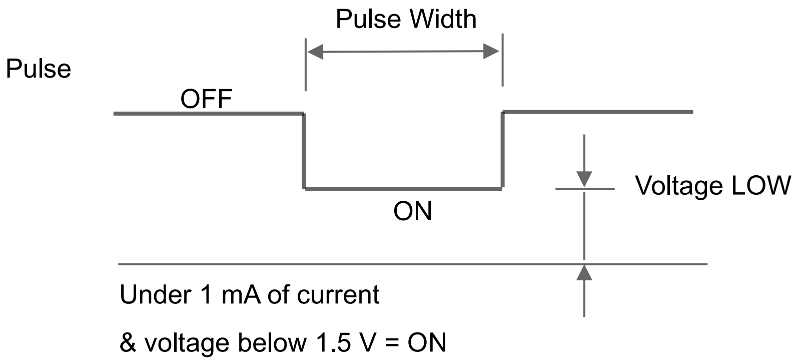


Figure 2.3 Relation between Pulse and Electrical Voltage

When receiving a pulse signal from the flow meter at the counter, the signal is counted at the moment when the voltage changes from HIGH to LOW.

When one pulse signal is generated, the resistance between C and E returns to the state of ∞Ω until the next 10L is reached.

Until then, no current flows, so the voltage between C and E reaches the maximum value (HIGH). As long as this OFF state continues, no pulse signal is generated.

(3) Sampling Rate

The sampling cycle at which the pulse is measured is called the "sampling rate", and the unit is [S/sec] (Sample per second). As the sampling rate becomes faster, the sampling cycle becomes narrower, so the faster the sampling cycle, the more accurate the waveform can be reproduced.

On the other hand, when the sampling rate is low, there arises a problem that a pulse having a short cycle cannot be detected and the pulse width cannot be measured.

That is, the measurement accuracy of the pulse width depends on the sampling rate, and it is important to set the sampling rate suitable for the frequency and characteristics of the original pulse signal.

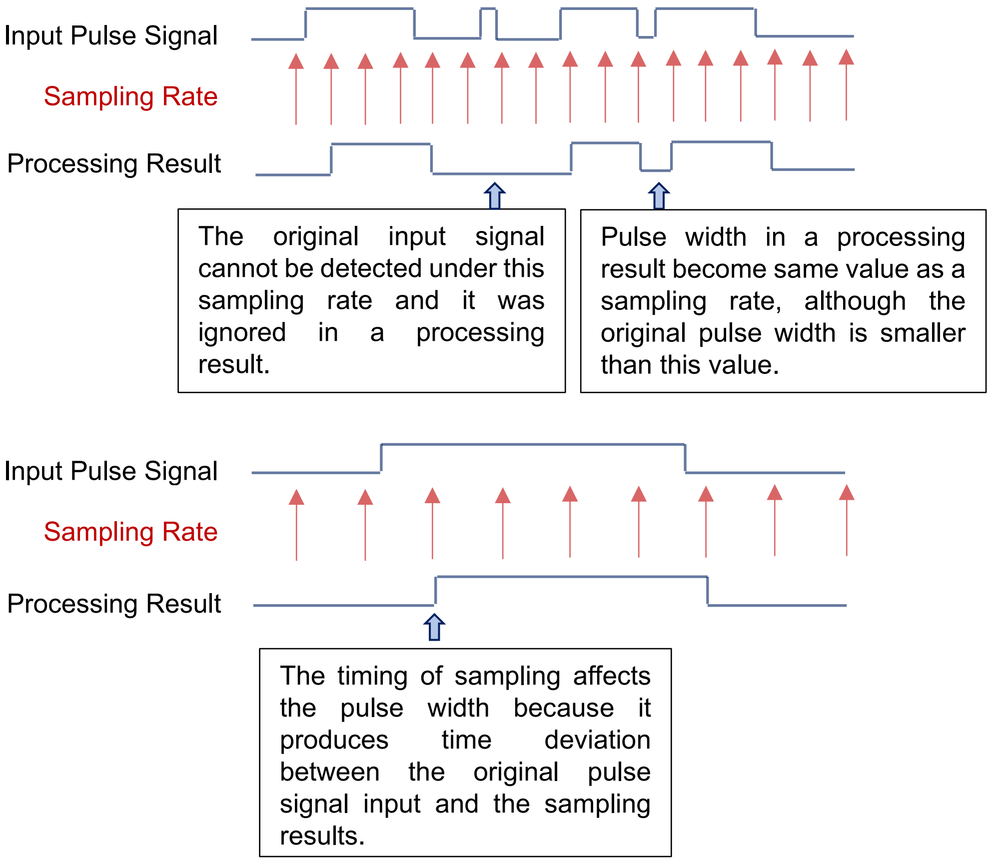


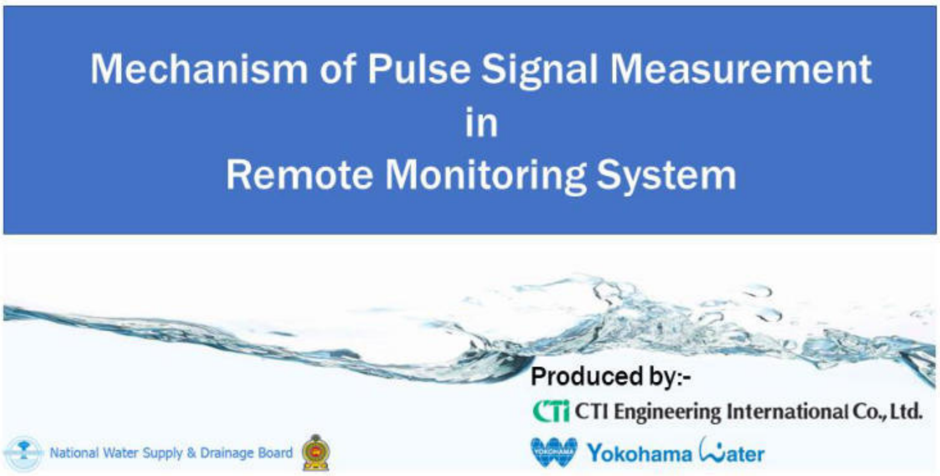
Figure 2.4 Importance of Selection of Appropriate Sampling Rate

2.2 Test Kit for Pulse Measurement Practice

The process of recording the pulse output from the flow meter with a data logger will be explained using the following system so that you can understand it in the indoor training.

Project for Enhancement of Operational Efficiency and Asset Management Capacity of Regional Support Center – Western South of NWSDB in Sri Lanka

Video Lecture



(1) Contents of the test kit

A. Electronic turbine flow meter

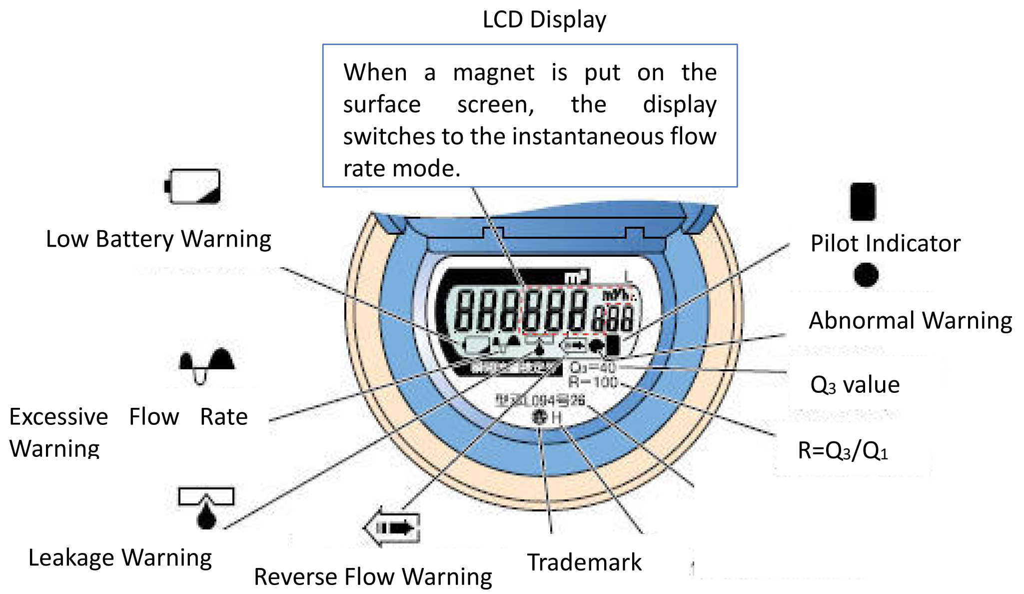
Nominal Diameter: 13mm   Type: Single jet turbine flow meter

Manufacturer: Aichitokei Denki EDS13Q

Specifications:

Q_1:	0.025 m^3/h (0.42 L/min)
Q_2:	0.040 m^3/h (0.67 L/min)
Q_3:	2.5 m^3/h (41.67 L/min)
R (Q_3/Q_1)	100
Pulse rate:	1 L/P (Open Drain Pulse)

Using the electric air pump of this test kit the impeller rotates at a speed equivalent to a flow rate of about 1.5 m^3/h.



B. Electric Air Pump

This pump is used supply air power to rotate the impeller of a water meter.

The internal battery (4000mAh) Can be charged with a USB cable.

Since the air volume is too large in the default state, it is desirable to cover half of the outlet with tape.

C. Wireless Pulse Logger

The pulse signal output from the water meter can be recorded and displayed as a graph on a tablet or PC using a dedicated application.

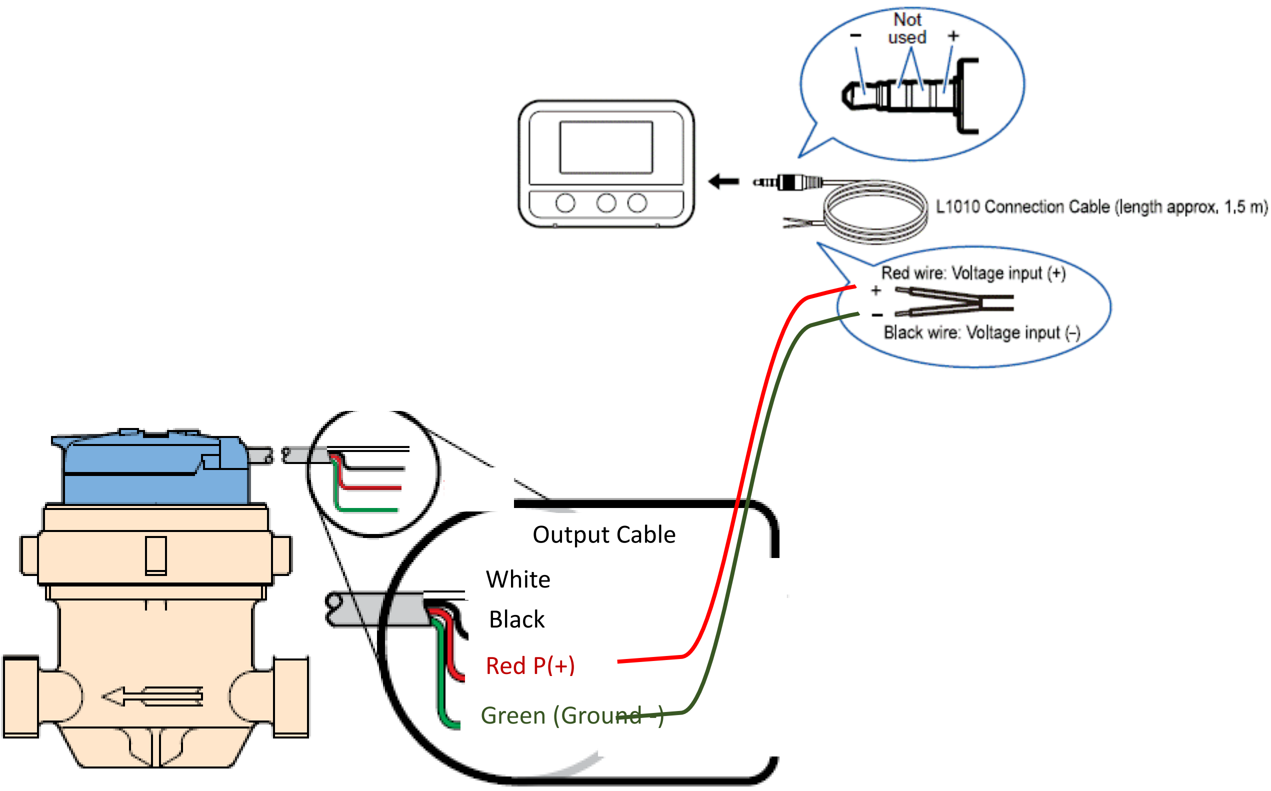
The battery life varies depending on the recording interval. In case of the free run function, the battery life is the same as for 1 second regardless of the ¥ recording interval setting. (when recording interval setting is more than 2 seconds.)

Mode	Recording interval			
	0.1 sec.	1 sec.	10 sec.	1 min.
Real-time measurement Bluetooth ON	Approx. 5 days	Approx. 7 days	Approx. 10 days	Approx. 10 days
Manual data collection Bluetooth ON	Approx. 14 days	Approx. 14 days	Approx. 14 days	Approx. 14 days
Manual data collection Bluetooth OFF	Approx. 1.5 months	Approx. 2 months	Approx. 2 months	Approx. 2 months

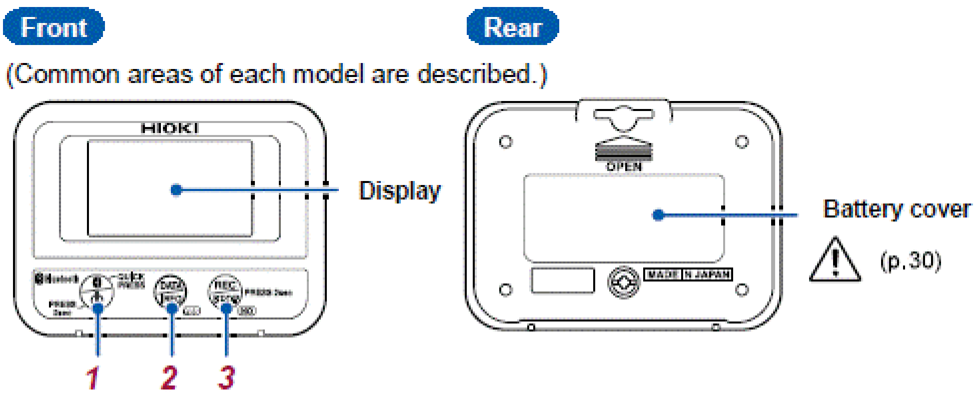
(2) Pulse measurement using a test kit

❶ Connect the pulse logger and electronic water meter

Connect the connection cable to the LR8512 connection terminal.



❷ Configure the pulse logger LR8512



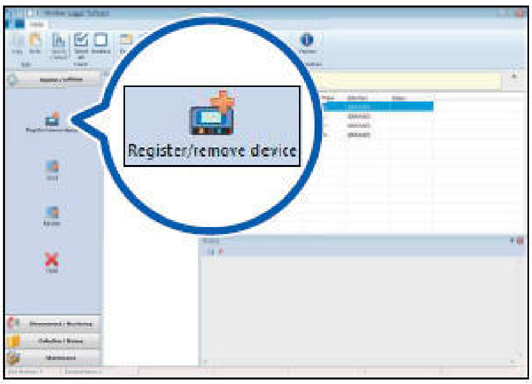
Operation keys	Press briefly	Hold down (for at least 2 seconds)
1 Power	Bluetooth ON/OFF	Power ON/OFF
2 Display	Display change YES (During operation verification)	-
3 Measurement	NO (During operation verification)	Measurement start/stop as manual mode

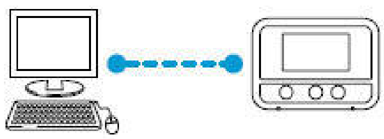
Note: To save the battery life, select OFF in Bluetooth mode if you do not need frequent communication.

Measurement Workflow

1 Install the software on the Windows® PC.

2 Register the instrument in Wireless Logger Collector.

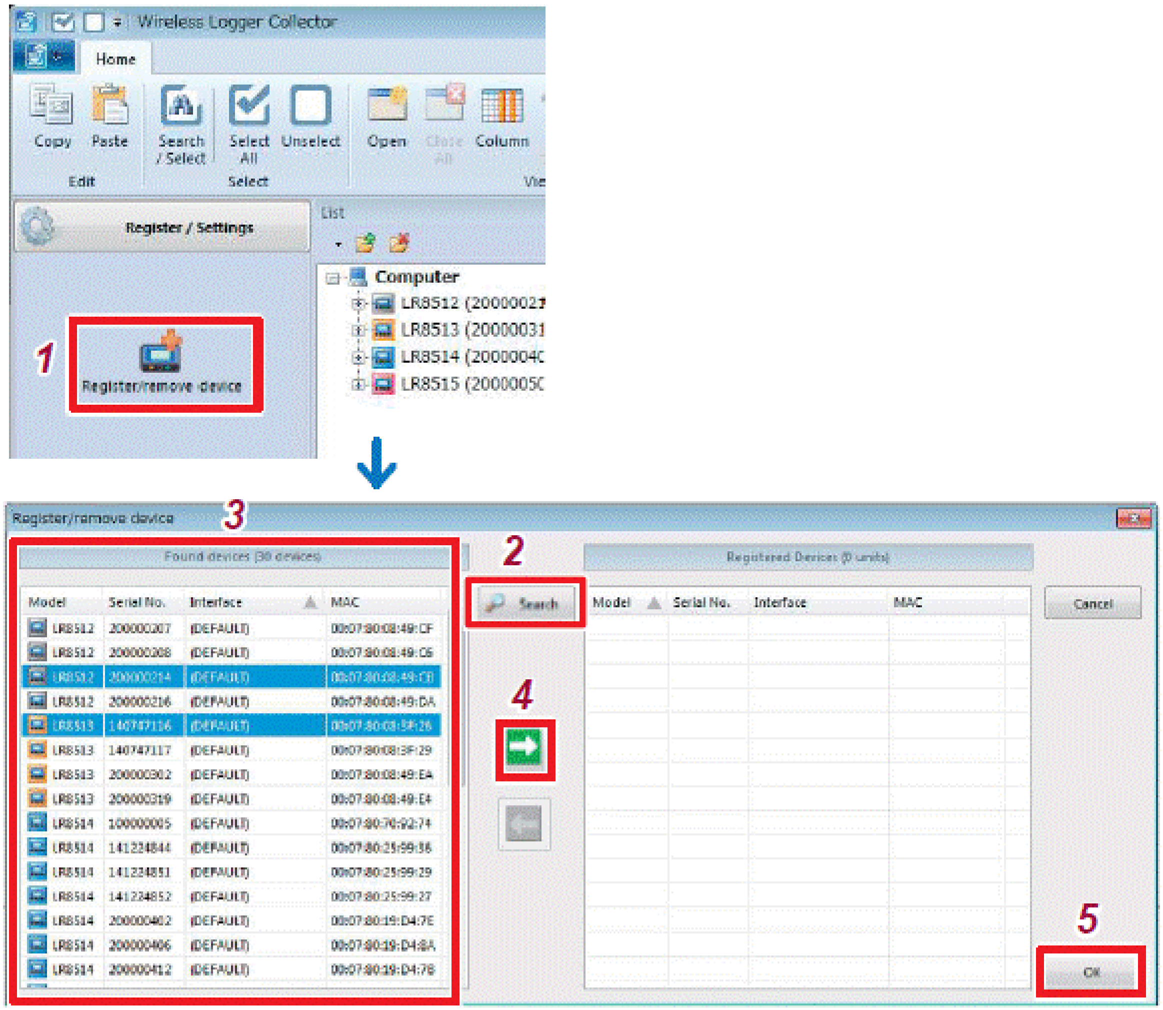




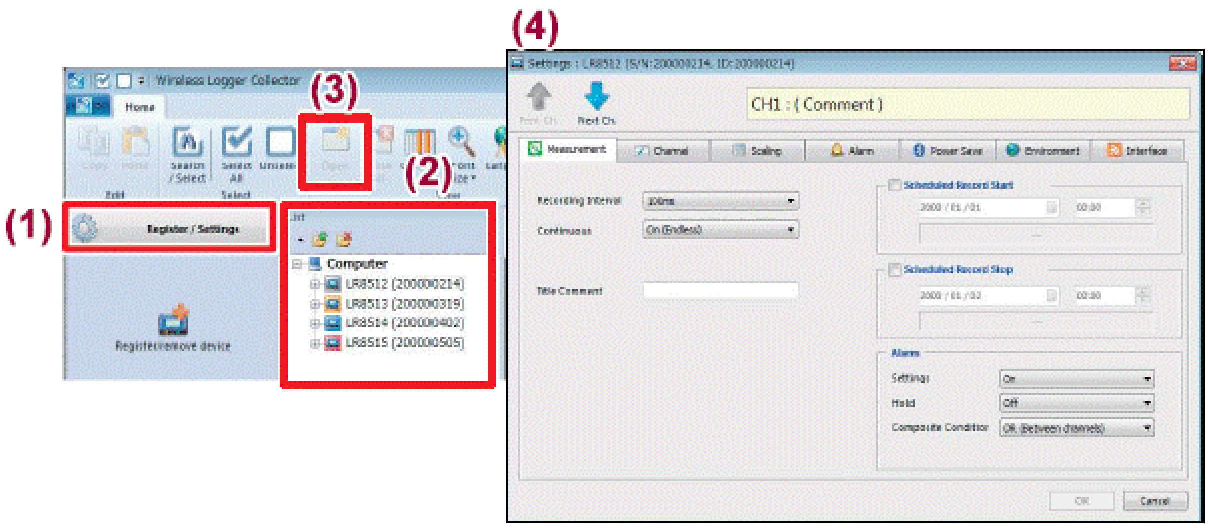
When no wireless logger is found

- When the symbol in the screen is off, press the power key to turn ON the Bluetooth function.
- When the symbol in the screen is off, a wireless connection is not established. Place the instrument closer to the PC or remove any obstacle and then search for the logger again.

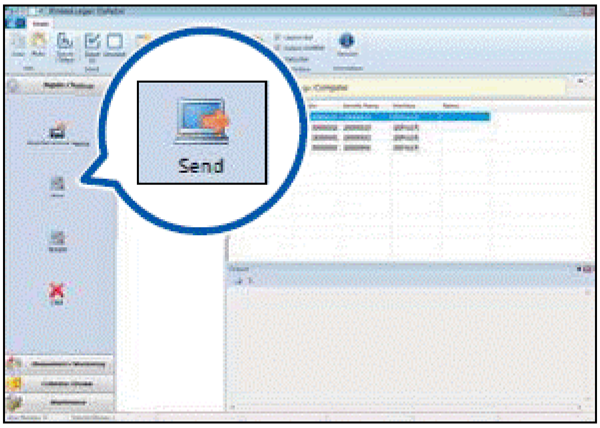
Registration



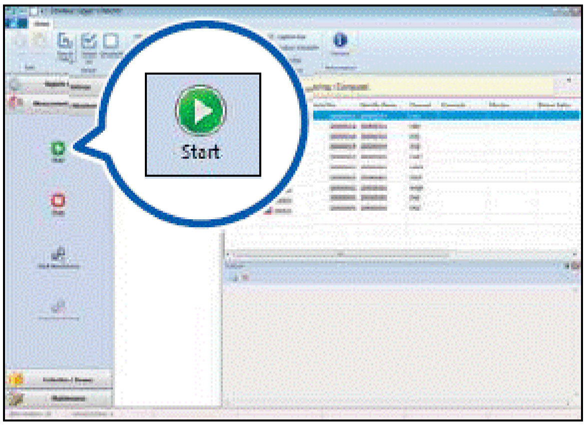
3 Set the measurement conditions in Wireless Logger Collector.

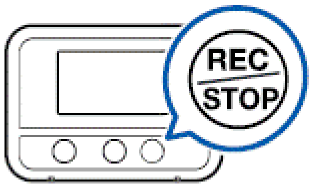


4 Send the measurement conditions to the instrument.



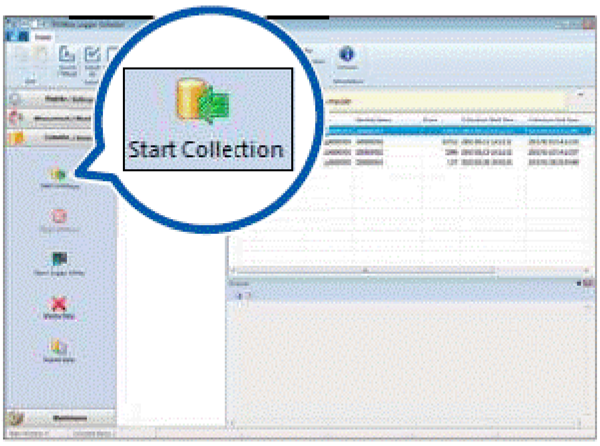
5 Start measurement.





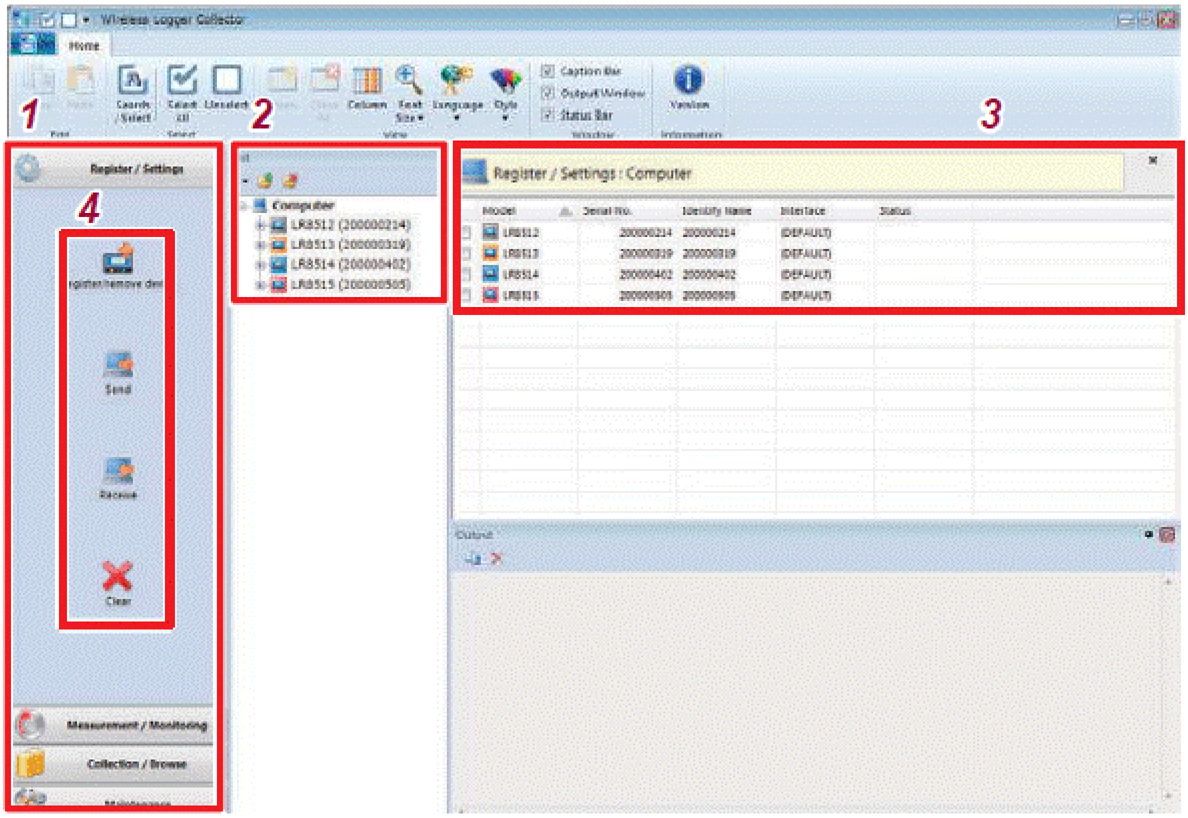
You can also start measurement by holding down this button.

6 Collect measurement data using Wireless Logger Collector



Basic Operation Procedure

[Operation flow]



1 Select one of the following categories from the Navigation bar.

[Register/Settings]

[Measurement/Monitoring]

[Collection/Browse]

[Maintenance]

2 Select a group and wireless logger from the wireless logger list.

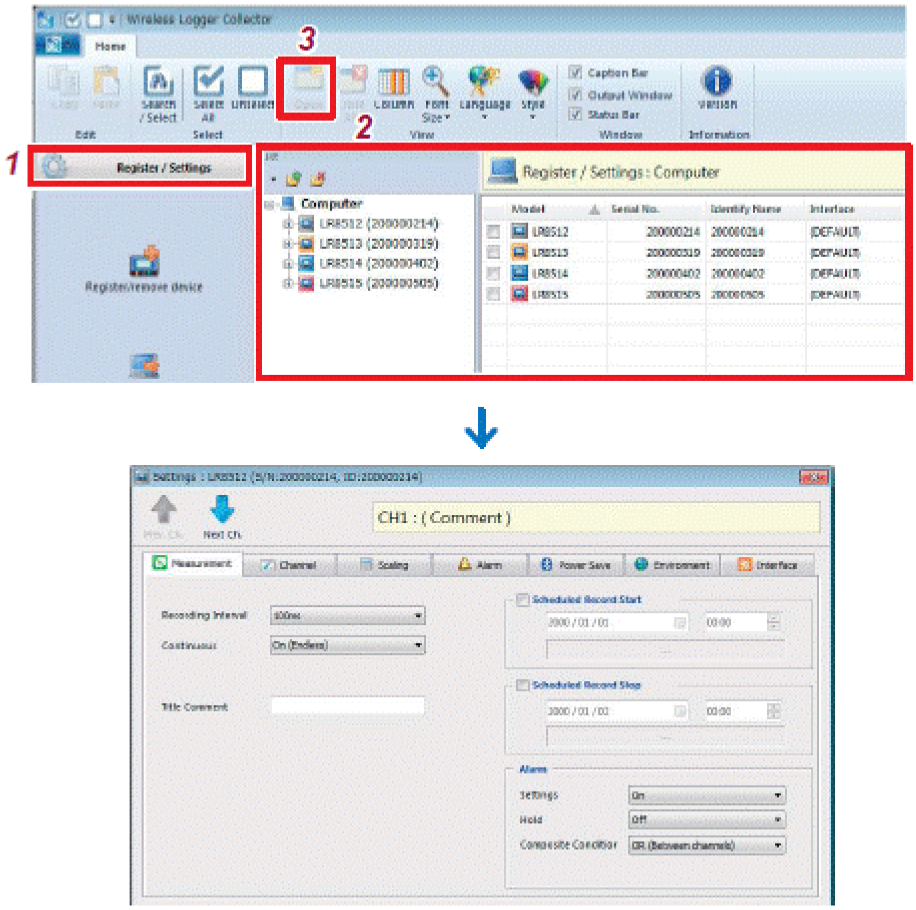
3 Select the item to be displayed from the wireless logger/channel/file list.

4 Press the operation button of the Navigation bar.

Or right-click the item in the list and select the operation from the displayed menu.

Setting Measurement Conditions

Set the measurement conditions for wireless loggers.



1 Select [Register/Settings] from the Navigation bar.

2 Select the target wireless logger.

3 Click [Open] on the Ribbon bar. → The settings dialog box is displayed.

Setting measurement

[Recording Interval]

Allows you to set the interval to import data.

Setting options:

0.1 sec., 0.2 sec., 0.5 sec., 1 sec., 2 sec., 5 sec., 10 sec., 20 sec., 30 sec., 1 min., 2 min., 5 min., 10 min., 20 min., 30 min., 1 hour

In this trial system with EDS13Q, the air pump blows between 1 and 2 m^3/h of air into the meter, so the meter will emit about 20 pulses per minute.

Therefore, in this trial work with HIOKI LR8512, select “1 min”.

[Continuous Recording]

Allows you to set a processing method when the memory is full.

Setting options:

Off (One-time):	Stops recording when the memory is full.
On (Endless):	Overwrites old data when the memory is full.

In this trial work with HIOKI LR8512, select “On (Endless)”.

[Title Comment]

Allows you to set the title comment. (Up to 40 single-byte characters)

The characters entered are converted to the following symbols.

^2	^{2} (Superscript)
^3	^{3} (Superscript)
~u	μ
~c	°
~e	ε

In this trial work with HIOKI LR8512, input “Trial” as a title comment.

[Scheduled Record Start]

Measurement can be started at the specified time.

If the current time has passed the preset time, measurement is not started.

Setting options:

☑	OFF (The preset start function is disabled.)
□	Starts recording at the preset time.

The instrument enters the recording start standby state at the same time as the Scheduled Record Start ON setting is sent. Measurement start by signal communications cannot be accepted in this state.

In this trial work with HIOKI LR8512, select “OFF”, because we use manual operation mode.

[Scheduled Record Stop]

Measurement can be stopped at the specified time.

If the current time has passed the preset time, measurement is not stopped.

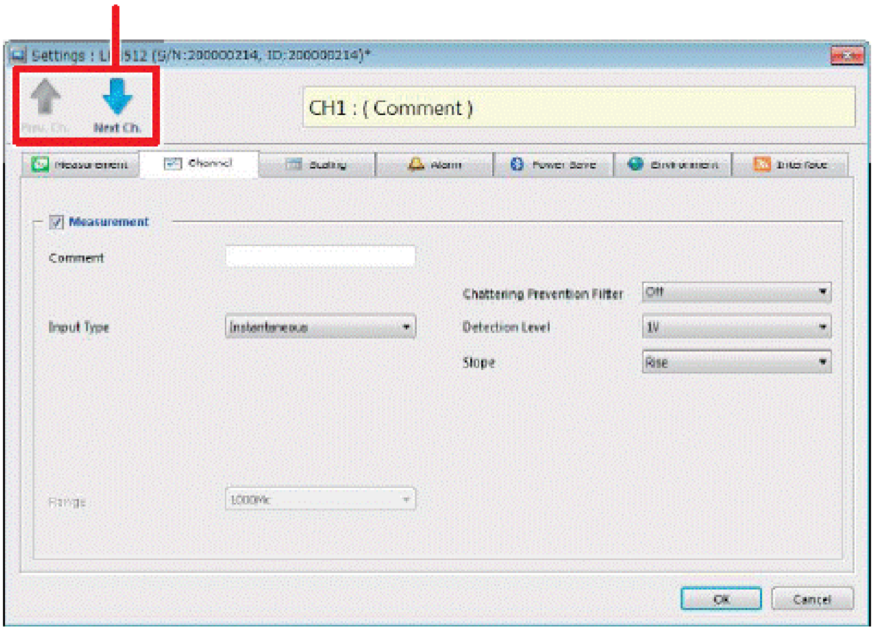
Setting options:

☑	OFF (The preset start function is disabled.)
□	Stops recording at the preset time.

In this trial work with HIOKI LR8512, select “OFF”, because we use manual operation mode.

Setting the channel

The channel to be set is switched.



In this trial work with HIOKI LR8512, no need setting for CH2 and delete the check from CH2 measurement.

[Measurement]

Allows you to set measurement to ON/OFF.

Setting options:

□	Does not perform measurement
☑	Performs measurement

After updating the firmware of Wireless Logger Collector, this selection mode will not appear.

[Comment]

Allows you to set the channel comment. (Up to 40 single-byte characters)

The characters entered are converted to the following symbols.

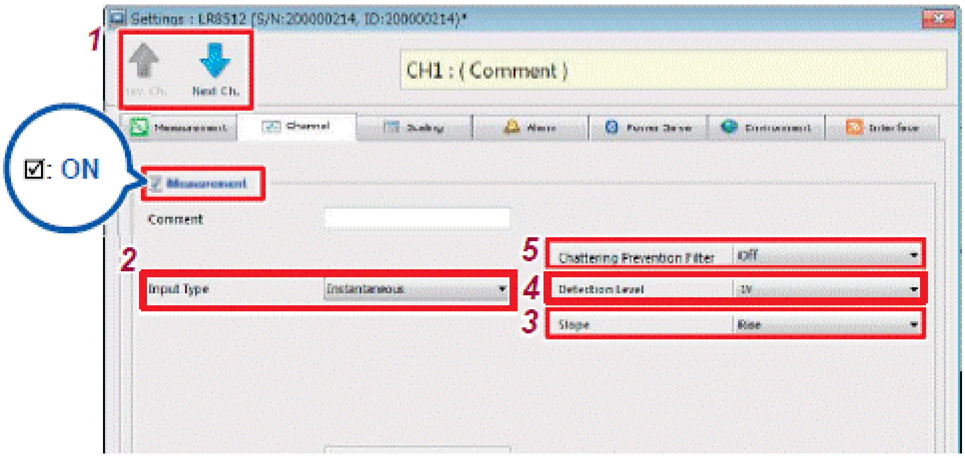
^2	^{2} (Superscript)
^3	^{3} (Superscript)
~u	μ
~c	°
~e	ε

In this trial work with HIOKI LR8512, remain this part blank

LR8512 Wireless Pulse Logger

Making setting for integrated measurement

The number of integrated pulse output from the integrated power meter or flow meter is measured.

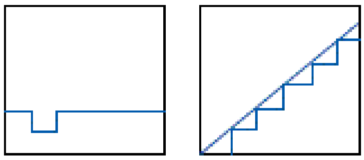


1 Select the channel to be set and check the Measurement checkbox [☑] (ON).

2 Select the input type.

Setting options:

Instantaneous	Measures the number of pulses input to the instrument within the recording interval. The number of pulses is reset for each recording interval.
Add	Measures the number of integrated pulses after measurement starts.



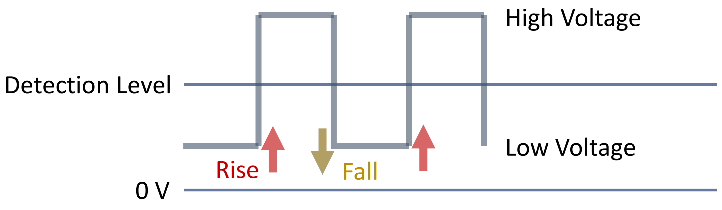
In this trial work with HIOKI LR8512, select “Instantaneous” mode.

3 Select the measurement reference (slope).

Setting options:

Rise	Integrates the number of times the pulse changes from LOW to HIGH.
Fall	Integrates the number of times the pulse changes from HIGH to LOW.

In this trial work with HIOKI LR8512, select “Fall” mode.



4 Select the HIGH/LOW reference value (detection level)

Setting options:

1 V	Determines 1.0 V or higher to be HIGH, 0 V to 0.5 V to be LOW.
4 V	Determines 4.0 V or higher to be HIGH, 0 V to 1.5 V to be LOW.

In this trial work with HIOKI LR8512, select “4V” mode.

5 Select the chattering prevention filter setting.

Setting options:

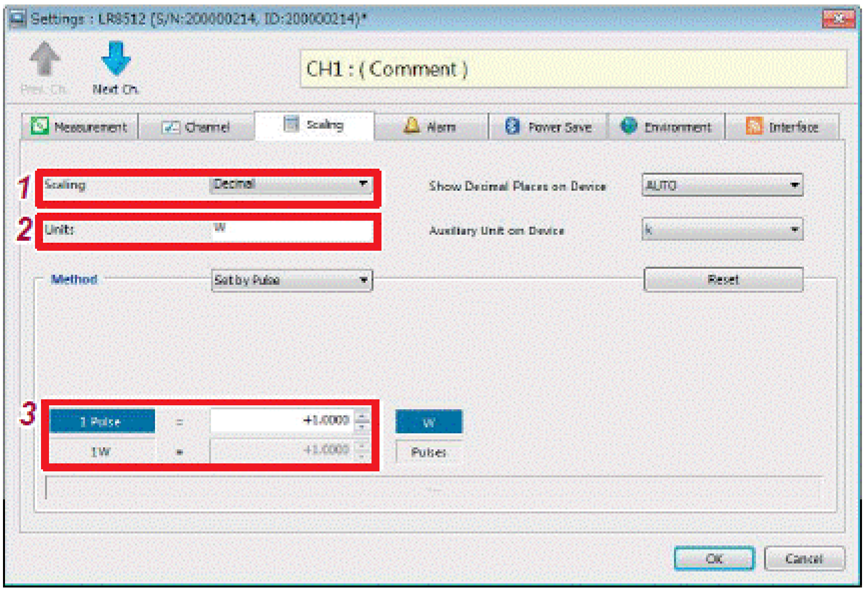
OFF	Turns OFF the chattering prevention filter.
ON	Turns ON the chattering prevention filter. For mechanical contact (relay) output signals, a count error due to chattering can be prevented.

In this trial work with HIOKI LR8512, select “OFF” mode.

Setting scaling for integrated measurement

The number of integrated pulses can be converted to a physical quantity for the object to be measured.

For a pulse output instrument, the physical quantity per pulse or the number of pulses per basic unit (example: 1 kWh, 1 L, 1 m^3) is defined.



1 Select the display format of the scaling value.

Setting options:

OFF	No scaling
Decimal	Displays the converted value as a decimal number
Exponential	Displays the converted value as an index number. Wireless logger display is in a decimal number only.

In this trial work, select “Decimal” mode.

2 Set the unit to be converted (up to 7 single-byte characters)

The characters entered are converted to the following symbols.

^2	^{2} (Superscript)
^3	^{3} (Superscript)
~u	μ
~c	°
~e	ε

3 Set the physical quantity per pulse or the number of pulses per basic unit

The electronic flow meter (EDS13Q) emits pulse signal per 1 L of water flow, so in this trial work the scale setting shall be the followings:

Scaling: Select "Decimal" option.

Unit: Input "L" from keyboard.

1 pulse = +1.000 L

Setting the displayed digit under decimal point

The measurement value is displayed with the decimal point fixed to the specified digit.

Setting options:

AUTO	Displays a 4-digit value (0,000 to ±9,999). The decimal point position is changes as needed.
0 Digit / 1 Digit 2 Digit / 3 Digit	The decimal point is fixed to the specified digit.

In this trial work, select "AUTO" mode.

Setting the auxiliary unit

The value obtained when the measurement value is multiplied by the constant shown in the following table is displayed in the wireless logger screen. (The measurement value is not affected.)

Setting options:

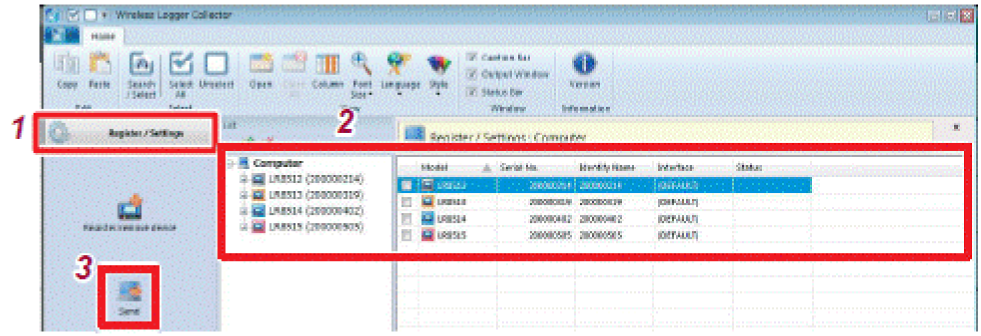
μ (micro)	$\times 10^{6}$
m (milli)	$\times 10^{3}$
-	×1
k (kilo)	$\times 10^{-3}$
M (mega)	$\times 10^{-6}$

Reset

The conversion parameter (conversion ratio, offset, input, output) is restored to the default setting.

Sending the settings

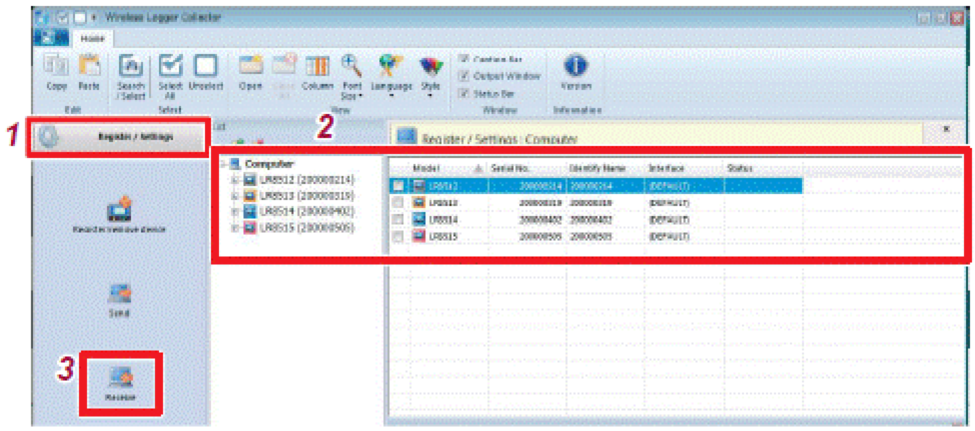
The setting conditions edited in Wireless Logger Collector are sent to and set for wireless loggers using wireless communications.



1 Select [Register/Settings] from the Navigation bar.
2 Select the target wireless logger.
3 Press [Send].

Receiving the settings

To confirm the current setting of logger, you can proceed to the following steps using wireless communications.

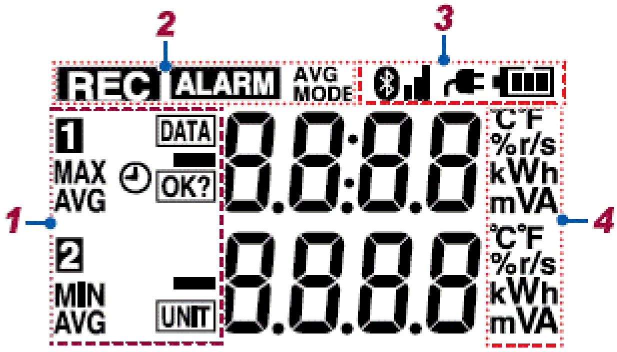


1 Select [Register/Settings] from the Navigation bar.
2 Select the target wireless logger.
3 Press [Receive].

> When the settings are received, the settings of the corresponding unit are all overwritten. The settings cannot be restored once they are overwritten.

Detail of Display

Display



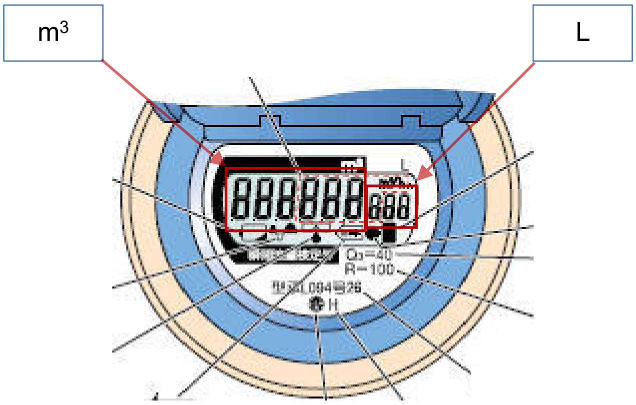
	Display	Description
1	1 2	Channel (CH) Blinking: During monitoring
	MAX MIN AVG	Maximum value Minimum value Average value
	DATA	Data number
	UNIT	Unit number
	(clock icon)	Date and time
	OK?	Operation verification
2	REC	Measurement Lit: Performing measurement Blinking: Waiting for a measurement start to be preset
	ALARM	Alarm Lit: The current measurement value is outside the range. Blinking: There was a value that was outside the range but the current value is in the range. (Alarm hold)

	Display	Description
2	AVG MODE	Lit: Average recording mode Blinking: Maximum recording mode (LR8513 Wireless Clamp Logger only)
3	(Bluetooth icon)	Lit: Bluetooth ON Blinking: Bluetooth OFF (The power saving function is enabled.) Off: Bluetooth OFF
	(antenna icon)	Bluetooth connection status (3 levels) (Signal strength 1: Weak to 3: Strong) Blinking: Security lock Off: Bluetooth not connected
	(AC adapter icon)	Operating with the AC adapter
	(battery icon)	Battery indicator display (p. 31)
4		Displays the unit of measurement values.

- While the Bluetooth is being connected (the antenna symbol (ıl) is lit), it cannot be turned off.
- The power cannot be turned off during measurement.
- During real-time measurement using the LR8410 Wireless Logging Station, the measurement cannot be stopped with key operation on the instrument.

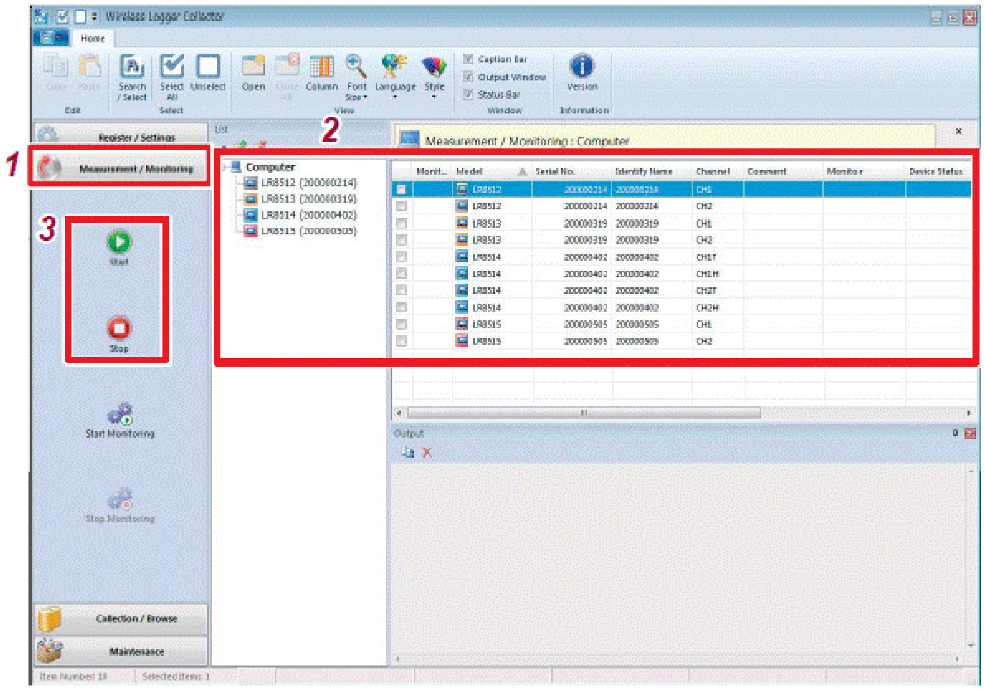
❸ Check the displayed value of the electronic turbine flow meter

Before starting the test, check and record the readings on the electronic turbine flow meter.



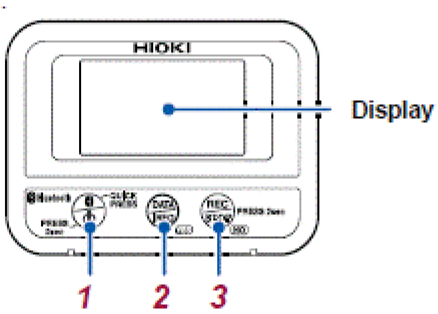
❹ Start recording of pulse logger

In this trial work, you start measurement by manual mode.



1 Select [Measurement/Monitoring] from the Navigation bar.
2 Select the target wireless logger.
3 Press [Start].

This start/step can also be controlled by manual mode as follows:



Hold down the button 1 for 2 seconds to start up the pulse logger.
Next, hold down the button 3 “REC/STOP” at least 2 seconds, and REC sign will appear on the display. Then Wireless logger measurement is started.

❺ Start the electric air pump and wait for 3 minutes.

Press the ON / OFF button of the electric air pump to send air into the flow meter.

Wait for about 3 minutes while checking that the value displayed on the meter is increasing.

❻ Stop the electric air pump

After about 3 minutes, press the ON / OFF button of the electric pump to stop.

❼ Stop recording of pulse logger

Select Stop in the same way as you started.
or
Hold down the button 3 “REC/STOP” at least 2 seconds, and REC sign will disappear on the display. Then Wireless logger measurement is stopped.

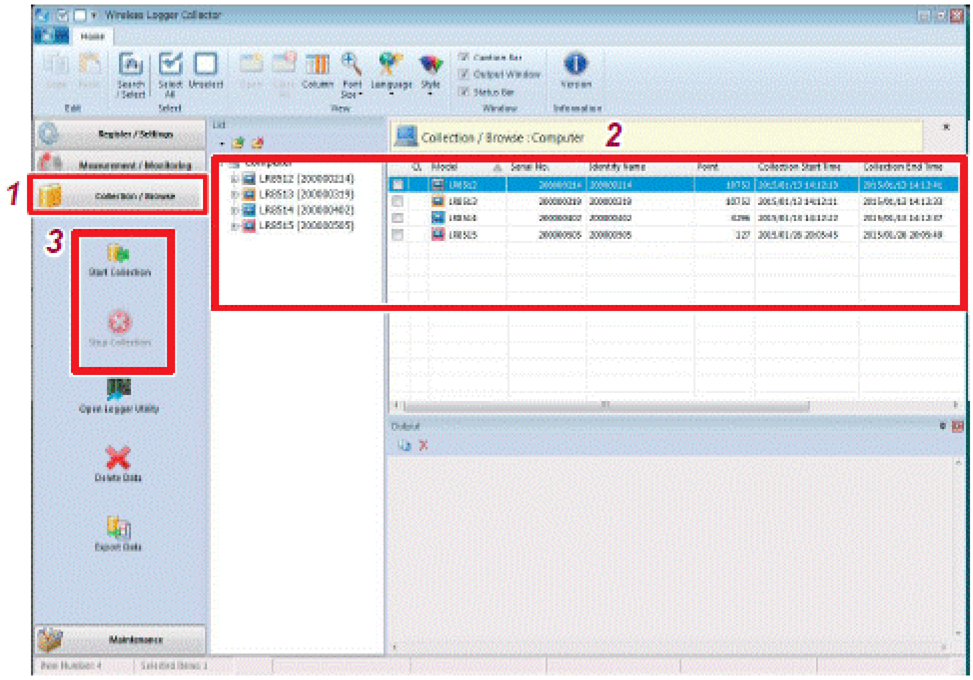
❽ Check the displayed value of the electronic water meter and calculate the passing flow rate

Before starting pump :	A (L)
After stopping pump :	B (L)
Passing flow :	B - A (L)

❾ Download recorded data of the pulse logger

Collecting Measurement Data

Measurement data is collected from wireless loggers. Measurement data can be collected even while wireless loggers are being measured. Measurement data is periodically collected until the data collection is stopped once the collection interval is set.



1 Select [Collection/Browse] from the Navigation bar.
2 Select the target wireless logger.
3 Press [Start Collection].

Browsing/Analyzing Measurement Data

You can select the one of the following two ways to check the downloaded pulse data:

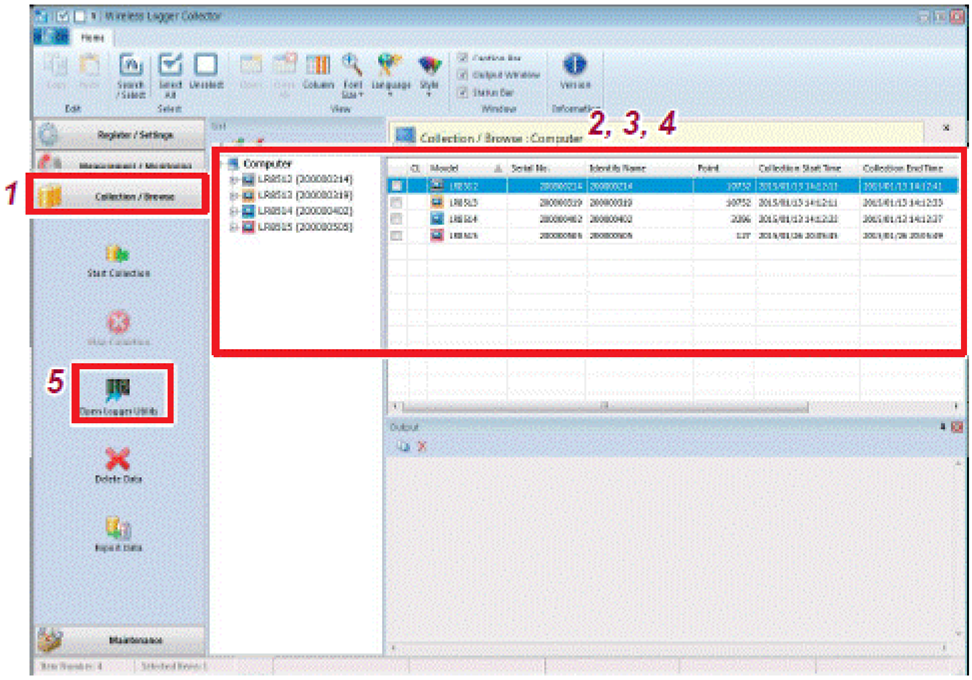
- Display with Logger Utility software
- Export data in csv format → Confirm it with MS Excel

[Logger Utility Software]

Logger Utility Software is for analyzing signal waveforms such as current, voltage, and temperature, and is not normally used for pulse loggers.

However, with this software, it is possible to check the data without downloading the data recorded in the pulse logger.

Collected measurement data can be displayed in a waveform using the Logger Utility.



1 Select [Collection/Browse] from the Navigation bar.
2 Select the target wireless logger.
3 Double-click the target wireless logger in the list using the mouse.
4 Select the measurement data to be browsed from the list.
5 Press [Open Logger Utility].

⑩ Calculate the flow rate from the recorded value of the pulse logger and compare it with the actual passing flow rate.

When the Logger Utility starts, the following screen is displayed.

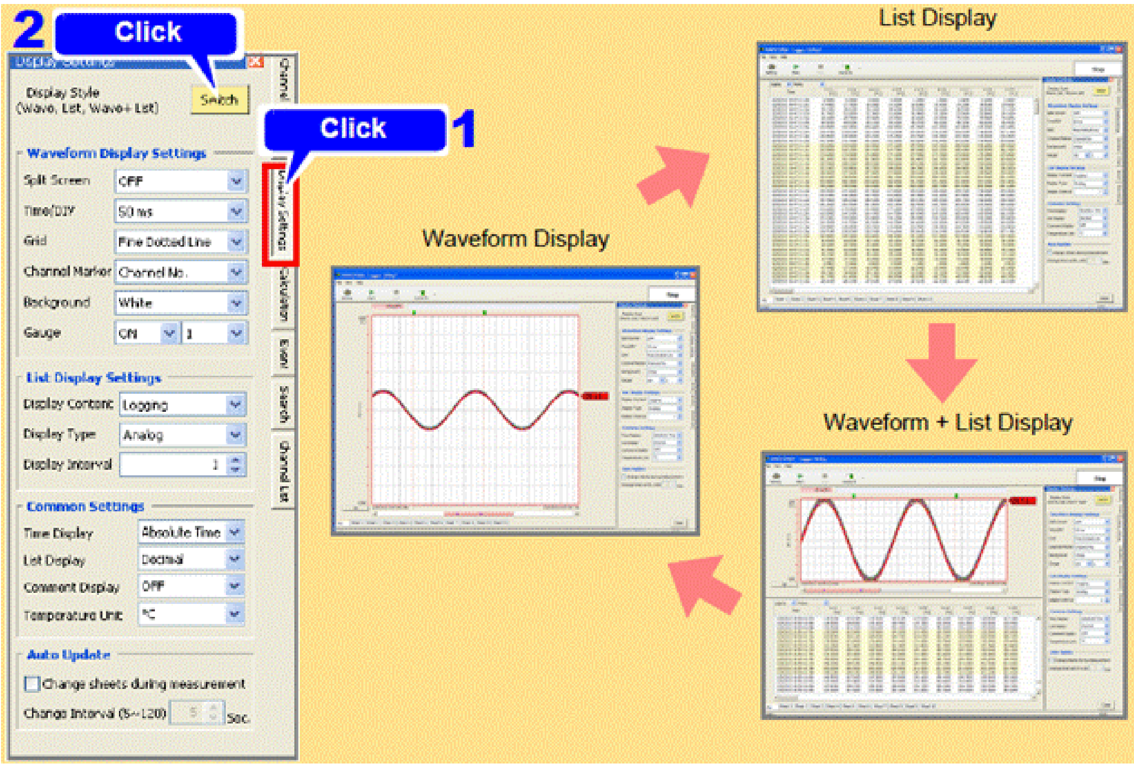
You can switch the measurement data display method of the main screen among waveform display, list display and waveform plus list display.

1 Click the [Display Setting] tab on the right side of the main screen to open the setting window.

2 Each click of the [Switch] button switches the display of the main screen.

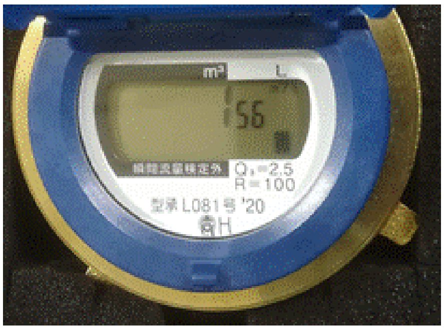
Selectable items:

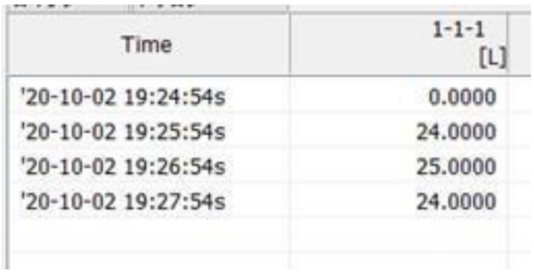
List Display	Displays waveforms data as numerical values. It is also possible to display calculation results.
Wave Display	Displays measured waveforms.
Wave + List display	display both the waveform display and list display in one screen.



In this trial test, the waveform is not displayed because it only counts the pulses generated every minute.

⓫ Example of trial test

No	Action and record	Photos
1	Meter reading before starting the test Meter reading: 0000 m^3 566.5 L	
2	Start recording of data logger → Start the electric air pump → Stop the electric air pump, after 3 minutes → Wait until the meter counter stops → Stop recording of data logger	
3	Meter reading after stopping the test 0000 m^3 644.5 L	
4	If you attach a magnet to the top of the meter during the test, the instantaneous flow rate will be displayed. Instantaneous flow : 1.56 m^3/h	
5	Passed flow: 644.5 - 566.5 = 78.0 L	

No	Action and record	Photos
6	Recorded data in the pulse logger: Initial 1 minute = 24 L Next 1 minute = 25 L last 1 minute = 24 L Total = 73 L Error = (78-73)/78*100 = 6.4 % (Note 1)	 | Time | 1-1-1 [L] | |---|---| | '20-10-02 19:24:54s | 0.0000 | | '20-10-02 19:25:54s | 24.0000 | | '20-10-02 19:26:54s | 25.0000 | | '20-10-02 19:27:54s | 24.0000 |
7	Calculate the instantaneous flow rate from the value of the pulse logger: 25 L/min → 1.5 m^3/h It matches the recorded value of the water meter.	

Note 1: The longer you record the data, the smaller the data error is.

Appendix-4

Mechanism of Ultrasonic Flow Meter

This Appendix explain the principal of ultrasonic flowmeter and mentions how to measure accurately.

Appendix-4
Mechanism of Ultrasonic Flow Meter

(1) Characteristics of Ultrasonic Waves

An UFM is a flowmeter that obtains an output proportional to the flow rate of a pipe by utilizing the phenomenon that the speed at which ultrasonic waves propagate in a liquid changes according to the flow velocity of the fluid.

The characteristics of ultrasonic waves are that they have a slower propagation speed and a shorter wavelength than radio waves.

Propagation velocity of Radio Waves:	approx. 300,000 km/second in air
Propagation velocity of Ultrasonic Waves:	approx. 340 m/second in air

When the distance of an object is extremely large, such as a broadcasting tower with a distance of several tens of kilometers or the distance of a celestial body, the propagation speed of radio waves becomes practical and is used for radar and communication.

However, at a short distance in the pipe, the arrival time of radio waves is extremely short, and it is extremely difficult to detect the difference in propagation time.

For this reason, ultrasonic waves with a slow propagation time are practical for flowmeters.

The "sound heard by the human ear" is said to be in the range of about 20Hz (bass) to 20,000Hz (treble). Sounds outside that range, that is, low sounds below about 20 Hz and high sounds above about 20,000 Hz, are called "ultrasonic waves".

"Sound" including ultrasonic waves propagates in a gas, liquid, solid, etc. as a medium, and does not propagate in a vacuum.

In addition, the ease of transmission differs depending on the object. For example, the propagation efficiency tends to increase in the order of gas < liquid < solid, and the speed tends to increase in this order. The speed of sound in the air is about 340 m / second, but in water it is about 1,500 m / second.

(2) Advantages and disadvantages of ultrasonic flowmeter

【Advantage】

- Not affected by liquid temperature, pressure and viscosity.
- As long as it is a liquid through which ultrasonic waves pass, it does not matter whether it is conductive or not.
- Low pressure head loss

- One flow meter can measure a wide range of flow rates.
- In the case of the clamp-on type that can be set on the outside of the pipe, pipe cutting work is not required.
- Since the structure is symmetrical upstream and downstream, it is possible to measure the flow in the opposite direction.
- The response speed is fast and it can follow the pulsatile flow.

【Disadvantage】

- If air bubbles, foreign substances, etc. are mixed in the liquid, an error will occur.
- Rust and deterioration of the inner surface of the pipe affect the measurement accuracy.
- Straight sections are required in the upstream and downstream parts.
- Clamp-on type measurement accuracy is about 2 to 3% of full scale.

(3) Measurement principle of ultrasonic flowmeter

The type of ultrasonic flowmeter currently on the market is mainly the " Transit Time" type.

【Transit Time Method】

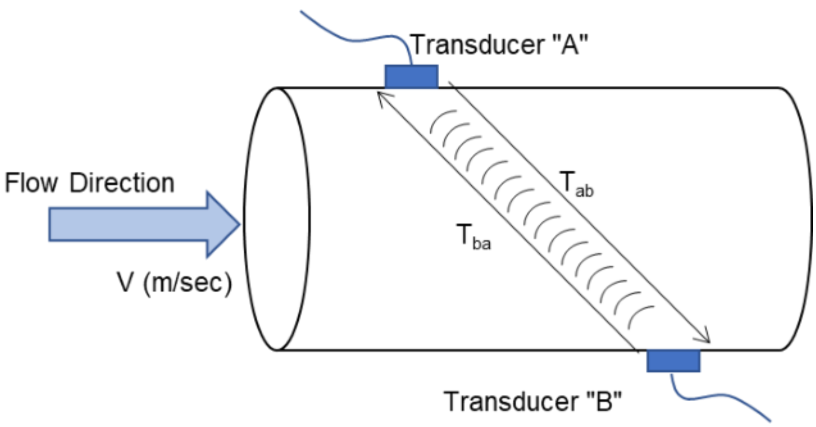


Figure 0.1 Principle of UFM

Several transducers (ultrasonic sensors) are placed in a pipe at a predetermined position to alternately transmit and receive ultrasonic waves.

When there is no flow, the time for ultrasonic waves to propagate from upstream A to downstream B (T_{ab}) is equal to the time for ultrasonic waves to propagate from B to A (T_{ba}).

When there is a flow in the tube, the ultrasonic waves transmitted from A to B are in the forward direction of the flow, so they propagate faster than when there is no flow. On the contrary, when it travels from B to A, it opposes the flow, so the propagation time is slower than when there is no flow.

The ultrasonic flowmeter detects such a difference in propagation time and calculates the flow velocity of the fluid by the principle formula. The calculated value is the average flow velocity, and the flow rate is calculated by multiplying this by the cross-sectional area in the pipe.

【Calculation Formla】

- V: Flow velocity of liquid
- T_{ab}: Transit time of ultrasonic waves from upstream to downstream
- T_{ba}: Transit time of ultrasonic waves from downstream to upstream
- L: Transit Distance
- C: Velocity of sound in liquid
- θ: Angle between the flow direction and the propagation direction of ultrasonic waves

With above-mentioned factors, we can get the following formula:

$$T_{ab} = L/(C + V\cdot\cos\theta) \text{ and } T_{ba} = L/(C - V\cdot\cos\theta)$$

From these two formula, we can get “V” value as follows:

$$V = (L / 2\cdot\cos\theta)\cdot(1/T_{ab} - 1/T_{ba})$$

When we set Q as flow volume, and D as diameter, we can get a following formula:

$$Q = (\pi\cdot D^2/4)\cdot V$$

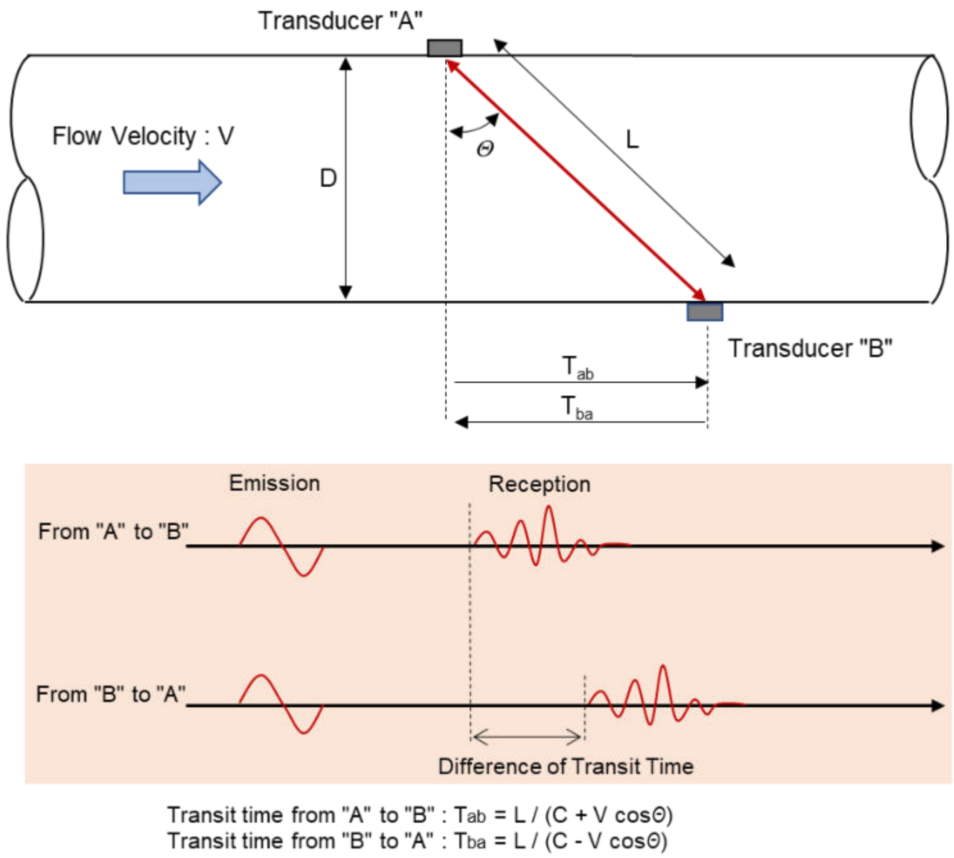


Figure 0.2 Calculation of velocity with difference of transit times (ΔT)

It should be noted that the above-mentioned calculation formula is a simplification and is not strictly correct.

The flow velocity V for converting to the flow rate must be the average flow velocity of the entire pipe cross section.

However, the flow velocity measured by the ultrasonic flowmeter is the average flow velocity on the path through which the ultrasonic waves propagate (called the line average flow velocity), not the average flow velocity of the surface.

Therefore there is an error between “Line Average Flow Velocity” and “Surface Average Flow Velocity”.

In an actual flow meter, the detected flow velocity value is corrected to the surface average flow velocity by the "flow rate correction coefficient", and then the flow velocity is calculated by multiplying the cross-sectional area.

(4) How to install the transducers

【V Method】

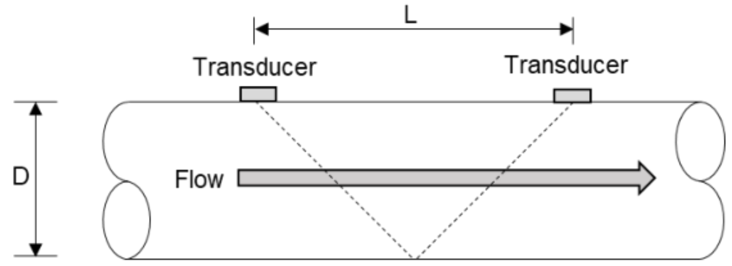


Figure 0.3 Setting of transducers in V method

This is the most basic and simple installation method, and is called the reflect mode.

Since the transducer (sensor) can be fixed to one guide rail and attached to the pipe, it is easy to set the distance between the sensors accurately.

If the resin pipe (PVC or PE), large-diameter pipe, or inner surface is treated with mortar lining, the V method may not be able to receive the signal well.

Normally, the V method is selected, but in the following cases, the Z method, etc. is applied.

- When the installation space is small
- When the turbidity of the liquid is high
- When the received wave signal is weak
- When the scale is thickly attached to the inner surface of the pipe

【Z Method】

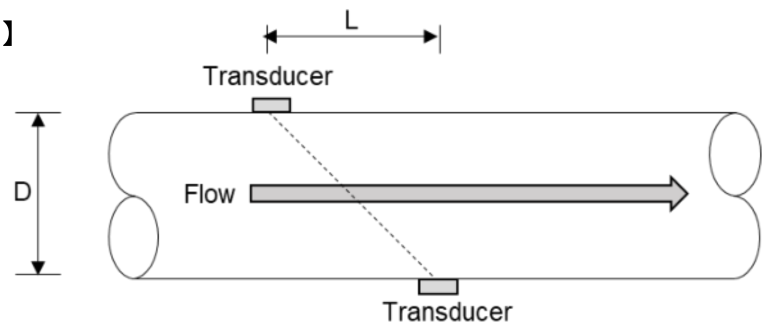


Figure 0.4 Setting of transducers in Z method

The Z method is known as direct mode.

Since the propagation path of ultrasonic waves can be shortened, it can be applied to flow rate measurement under fluid or pipe conditions where ultrasonic wave propagation conditions are not good.

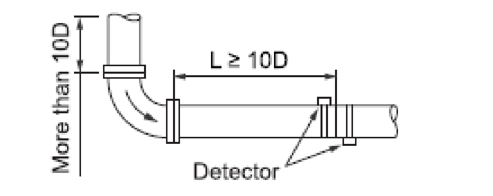
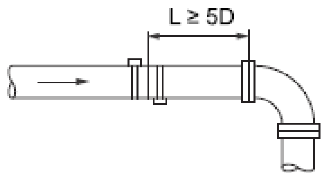
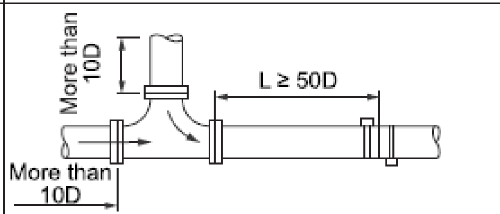
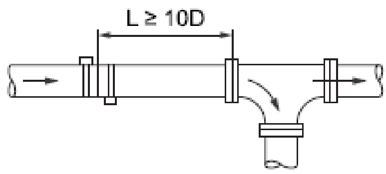
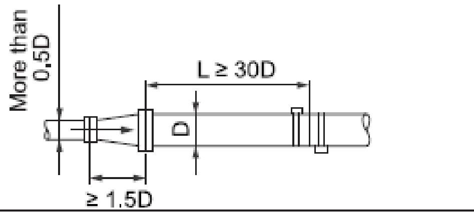
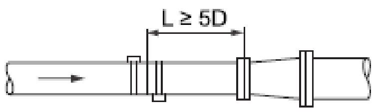
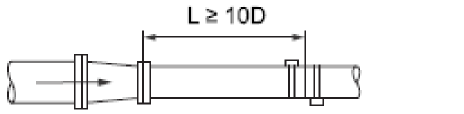
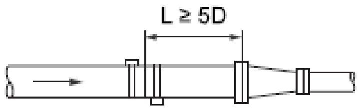
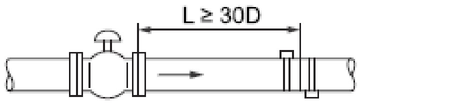
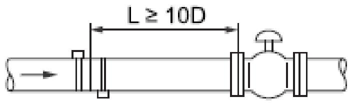
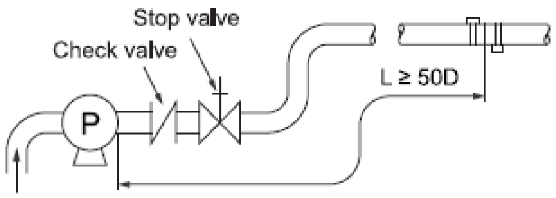
Since synthetic resins such as PVC or PE are less likely to propagate ultrasonic waves than metal pipes, it is recommended to use the Z method if the material of the tube to be measured is synthetic resin.

In addition, since the required straight section of the Z method is half that of the V method, the Z method is used even when there is no installation space.

(5) Recommended Condition of Transducer Setting

The transducers of the ultrasonic flowmeter cannot measure accurately unless it is fixed in an appropriate position.

Table 0.1 Recommended Distance for Detector Setting

Classification	For upstream side	For downstream side
90° bend		
Tee		
Diffuser		
Reducer		
Valves	 Flow control valve exists on upstream side.	 Flow control valve exists on downstream side.
Pump		

The piping must completely be filled with fluid when it flows.

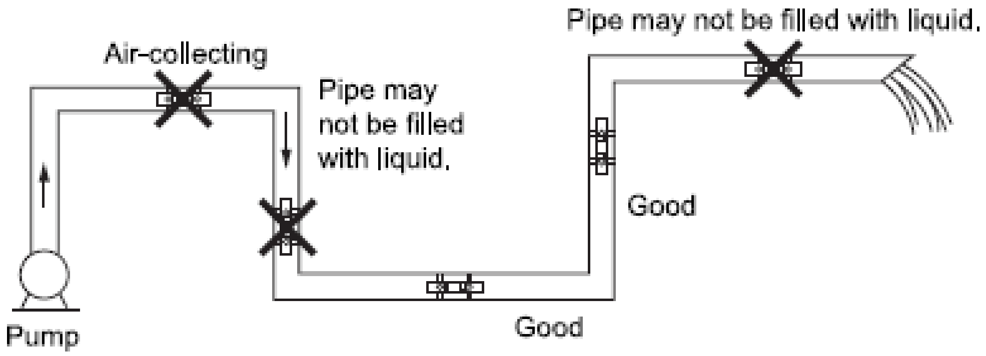


Figure 0.5 Ideal Location of Transducer (1)

For a horizontal pipe, mount the detector within ±45° of the horizontal plane.

For a vertical pipe, the detector can be mounted at any position on the outer circumference.

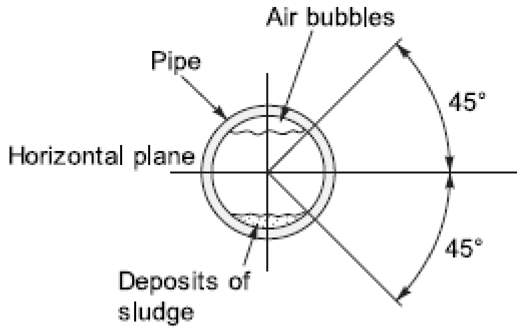


Figure 0.6 Ideal Location of Transducer (2)

Avoid mounting the detector near a deformation, flange or welded part on the pipe.

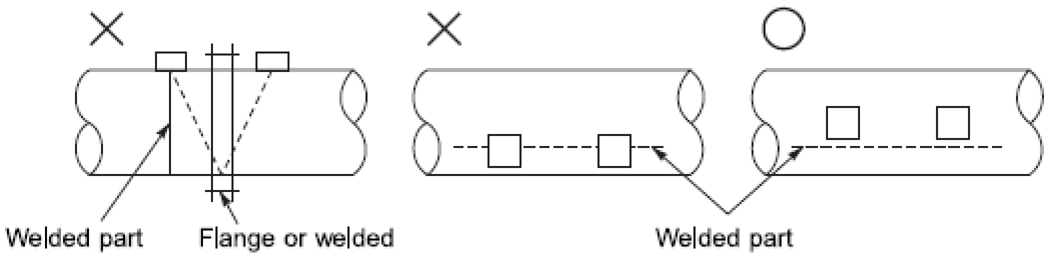


Figure 0.7 Ideal Location of Transducer (23

(6) Understanding Accuracy of UFM

All flow meters have an error in the equipment itself and it also applies to the ultrasonic flowmeter. Since the transducer is installed by a human, the position and accuracy of its installation greatly affect the error.

1) Influence of flow velocity

Since the ultrasonic flowmeter measures the flow velocity in principle, the guaranteed accuracy differs depending on the flow velocity of the flowing water.

Normally, if the flow velocity is 2 m / second or more, the measurement accuracy is very stable, but it should be noted that the slower the flow velocity, the larger the error.

Table 0.2 Guaranteed accuracy of ultrasonic flowmeter

Diameter	Range of velocity	Accuracy
13mm ～ 90mm	1 m/sec or more	+/-2.5% of reading value
	Less than 1 m/sec	+/-0.02 m/sec (*1)
100mm ～ 250mm	1 m/sec or more	+/-1.5% of reading value
	Less than 1 m/sec	+/-0.015 m/sec
300mm ～ 5000mm	1 m/sec or more	+/-1.0% of reading value
	Less than 1 m/sec	+/-0.01 m/sec

Source: Instruction Manual of UFP 20, Tokyo Keiki

【Example of accuracy calculation(*1)】

In case of Pipe of DN 50mm

Accuracy is ±0.02 m/sec under 0.9 m/sec of velocity

$$\pm 0.02 = 0.9 \text{ m/sec} \times E/100$$

$$E = \pm 0.02 \times 100/0.9 = \pm 2.2\ (\%)$$

Accuracy is ±0.02 m/sec under 0.5 m/sec of velocity

$$\pm 0.02 = 0.5 \text{ m/sec} \times E/100$$

$$E = \pm 0.02 \times 100/0.5 = \pm 4.0\ (\%)$$

2) Influence of error of diameter

It the diameter of the pipe to be input is not correct. It affects the measuring result. As a rough calculation, if the difference of diameter is 1%, the reading flow rate will have about 3% of error after conversion of flow rate.

Table 0.3 Comparison of area value under difference diameter

	Inner Diameter		
	99mm (Area: 0.007694m²)	100mm (Area: 0.007850m²)	101mm Area: 0.008008m²)
V=0.5m/sec	0.003847 m³/sec	0.003925 m³/sec	0.004004 m³/sec

The following example shows the flow rate error when the inner diameter values differ by 1 mm.

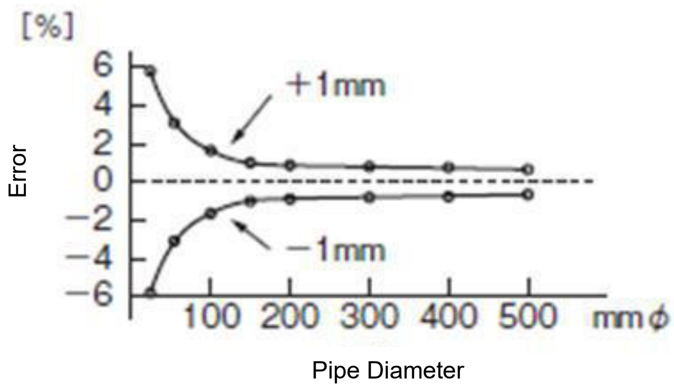


Figure 0.8 Influence of 1 mm of difference of inner diameter on flow rate error

3) Influence of transducer mounting interval

As a rough calculation, an error of +/- 1mm of distance between two transducers will result in a flow rate error of less than 1%.

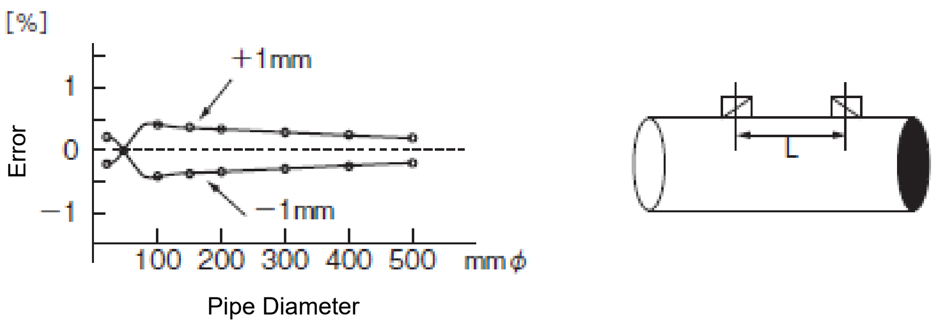


Figure 0.9 Influence of 1 mm of difference of transducer spacing on flow rate error

(7) Comparison with the measured value of the bulk meter

Thermometers and pressure gauges are easy to calibrate on-site, but flowmeters are difficult to calibrate. When using an ultrasonic flowmeter to check the accuracy of other flowmeters, the following points must be carefully considered.

- Consider each other's errors in the flowmeters.

Estimate the calibration error by paying attention to the accuracy notation (FS%, RS%) of each flow meter.

- Collect and consider systematic data if there are differences

Instead of comparing with the flow rate of only one point, write the measurement data in multiple flow rate ranges on a graph and evaluate it.

- Check the piping system thoroughly.

Even if you think that the piping system is the same, the evaluation may be wrong if it flows in or out from a branch pipe in the middle.

- It is difficult to compare two flow meters

Normally, if there is a difference between the measured values of the two flow meters, it is difficult to determine which is correct on site. It is necessary to confirm the standard criteria such as the water flow capacity of the pump and the change in the tank water level for which the capacity is known.

Appendix-5

Data Collection and Management

1 Purpose of collection of data related to the pipe soundness

Water pipe is usually buried and invisible. Therefore, the history of the pipe repair, leakage, accident, construction, customer complaint, etc. are very useful to evaluate the soundness.

NWSDB is developing comprehensive GIS system, and it must be helpful for the managing assets. However, the full use of its advantage depends on the accumulation and updating of the data from daily work at the site.

Water leakage from the pipe is a main factor to evaluate pipe deterioration. Accumulated leakage data is inevitable for asset management that suggest us the timing of pipe replace. Information that should be kept on the leakage repair record sheet is as shown below. A model leakage repair record sheet is shown in next page.

- Address of leak point and actual point
- Date of repair work and
- Date when water leakage was first confirmed
- Pipe material, diameter, part of leaking point on the pipe (strait, bend, joint, saddle, etc.)
- Rode surface form (asphalt, concrete gravel, etc.)
- Leak volume
- Required material for repairing
- Required time, number of staff, type of equipment and machine

Table Leakage Repair Record Sheet

The Project for Enhancement of Operational Efficiency and Asset Management Capacity of Regional Support Center-Westem South of NWSDB in Sri Lanka				
Leak Repair Detail Sheet	National Water Supply & Drainage Board			
	Office			
	Officer			
Work day	Day		Time	
Attendance day	Day			
Work reason	Complain	Meter reader	Leak detection	Other
Compainer's name & add				
Leakage location	Adress			
	Meter No.			
	Consumer No.			
	Coordinate			
Type of Leak	Meter	Connection pipe(Joint , pipe)	Ferrule	Distribution pipe
Cause of Leak				
Nature of repair	Diameter & Material			
Leake repair	Yes		No	
		Leak volume		M3/h
Material of use				

Machinery Used		Location(Sketch)
(1)	Power Light (1.5.1)Hrs	
(2)	Night work (1.5.2)Hrs	
(3)	Water Pump(Dewatering)Hrs	
(4)	Others	

Measurment						
BOQ Item No.	Description	Unit	L(m)	B(m)	D(m)	Qty

Comment

Contractor Officer

NWSDB Officer

2 Use of Geotagged Photograph

Currently, the smartphone is used commonly, and this device generally has the GPS (Global Positioning System). Therefore, smartphones have function of recording geographic data.

For instance, the photograph taken by the smartphone has geographical identification metadata, such as latitude and longitude coordinates, altitude, time, etc. It is called that such a function is geotagging.

The geotagged photograph has the coordinates data as itself, so that we can easily input the location data of the place where the photograph is taken with the image into the GIS.

To save the workload, it is highly recommended to request your staff member /contractor to take the photograph at the site and send it immediately to the OIC. Then, OIC is able to know where the leakage occurs and what type of repair/other measure is taken at the site, and input the all information on the GIS smoothly.

The following Figure shows an example which the Valve location indicated on the GIS with the image.

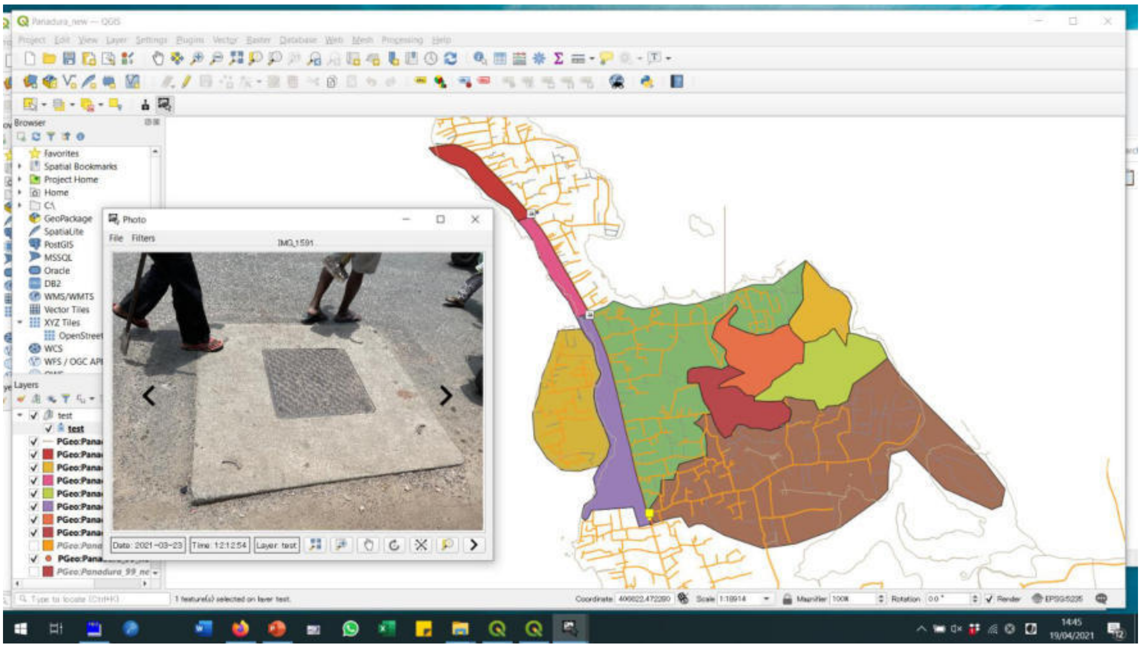


Figure 2.1 Example of the geotagged photograph appeared on GIS

The following points should be taken care of.

- Check the smartphone setting of Camera application and activate the Save Location Mode, or Location Services, etc.
- GPS is a system using satellite information, therefore, the location data cannot be collected precisely under following conditions,

- Inside the building, tunnel,
- Between tall buildings
- In forest
- Thick cloud

The open space is good for the more accurate positioning.

3 Data Pass

Collected should be sent to the GIS of HO through the proper manner.

GCWWMIIP is about to establish the Comprehensive GIS in NWSDB, and concrete data pass will be finalized. The all concerning officers are expected to properly register all data collected at the site because it is the essential and precious information.

4 Asset management

Leakage repair works data are required for Asset Management System (AMS). Since the occurrence of water leakage is an indicator of deterioration of pipelines, it is possible to know which pipeline has a large number of issues by collecting leakage records. Even if the water authority tries to keep the pipeline soundly, the cost of keeping it will increase due to frequent leaks. These pipelines must be given a higher priority of renewal, and renewing can maintain stable water supply.

Appendix-6

Manuals of Instruments introduced by the Project

6-1. Ultrasonic Flow Meter
6-2. Water Pressure Logger
6-3. Tapping Machine
6-4. Electronic Test Meter

Appendix 6.1　Ultra-Sonic Flowmeter

Brand: TOKYO KEIKI

Model: UFP-20

Country: JAPAN

Contents of this manual

1. Battery Charge
2. Unit Setting
3. Transducer Setting
4. Start and Stop Logging
5. Downloading Logs

1. Battery Change

Open side cover, then connect AC adaptor. Please be noted that battery charging will not start during the main unit runs

Fig. 1.2.3-4 Battery charge

The GREEN LED will light up when DC power is supplied, also RED LED when charging has started. Charging will be completed when RED LED turns off.

Please be noted following points

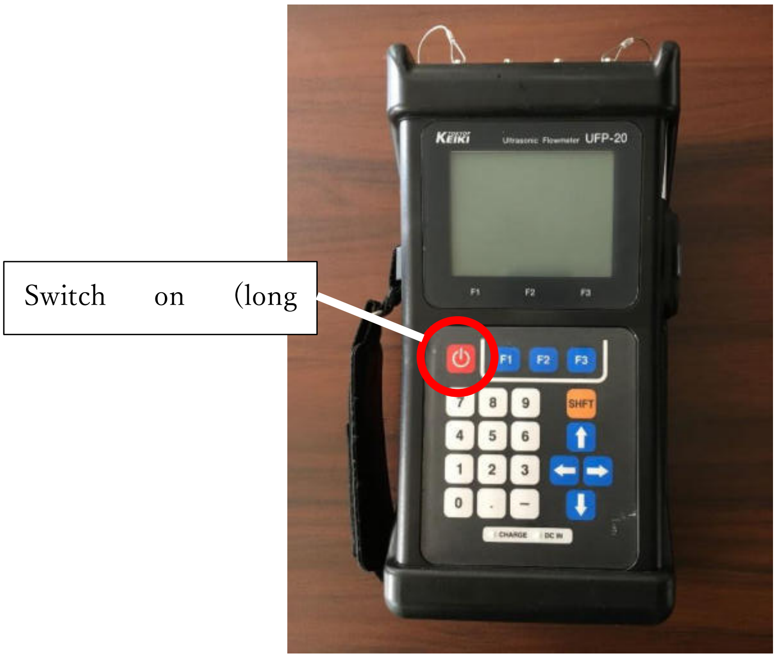
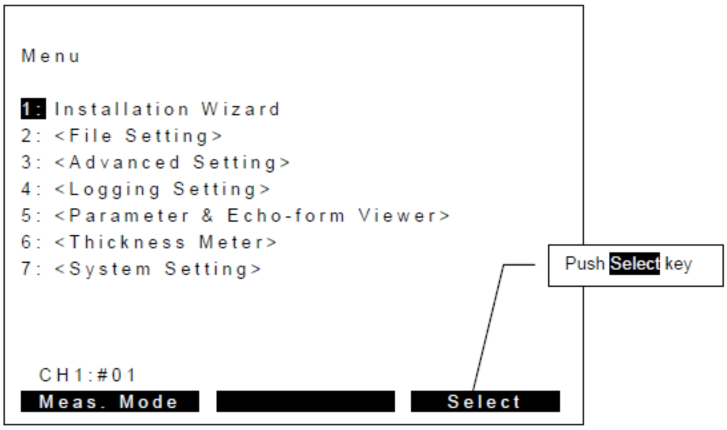
-Main unit cannot be charged during power on. Please turn off the power for battery charging.

-Proper battery icon with remaining levels will be indicated on the display after a few minutes.

-In case it is NOT used for more than 1 mount, battery must be disconnected from main unit and kept in a cool location.

-To comply with CE certification, do not operate the unit with the charger @legged in.

2. Unit Setting

Turn switch on. Then automatically Self Check will be carried out. After the Self Check, select “OK” <F3>

Select “Installation Wizard” on the basic menu Select “1: Installation Wizard” by direction or numeric button. Then push “Select” key (F3 button).
 Fig. 1.2.6-2 Basic menu

Select file position as “#No.”

Please select Not-Used area by direction button, then push “Enter“ key (F3 button).

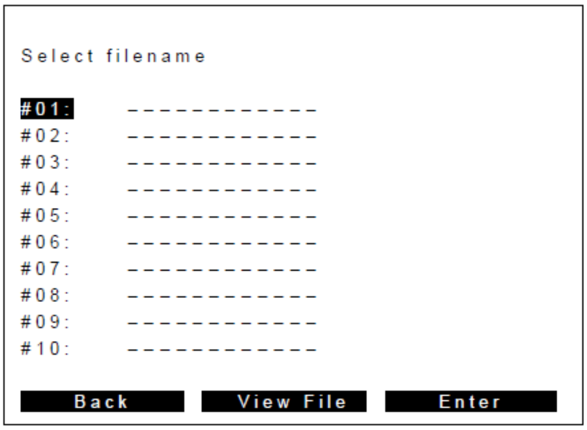


Fig. 1.2.6-3 File selection menu

Not-used area indicated as “--------” and you cannot select this position. To remove site setting file, please refer to Chapter 2. When you select used area, you can see the following indication.

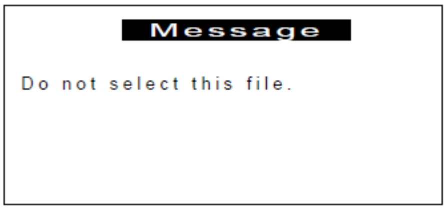


Fig.1.2.6-4 Message of selection not used area

File name input

Please input file name by direction button. Here for example, let’s input as “100/Steel/1M”.

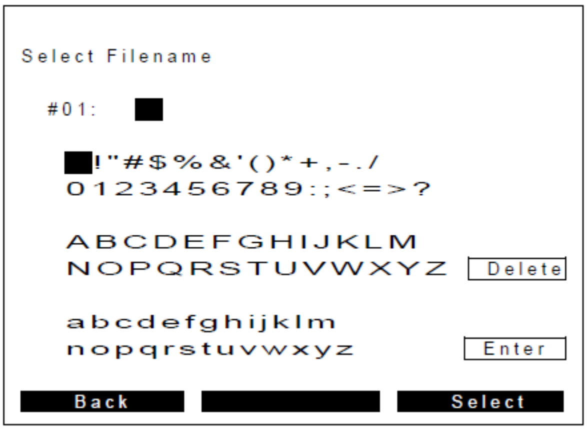


Fig. 1.2.6-5 File name input menu

Move cursor to “1” (for example) by direction button. and push “Select” key (F3 button) to select character. You can see that “1” would set first position as below.

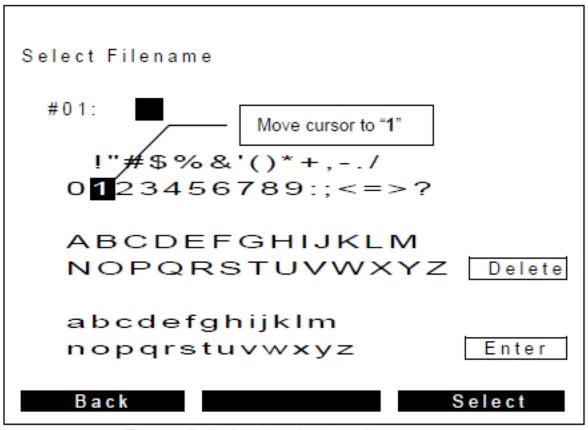


Fig. 1.2.6-6 Word selection menu

Finalizing file name

By repeating procedure of 1-4, you can input "100/Carbon Steel/1M" as follows. After finalizing the file name, proceed next menu by moving the cursor to "Enter" and push "Select" key (F3 button), otherwise [SHIFT] + F3 button makes the same step taken.

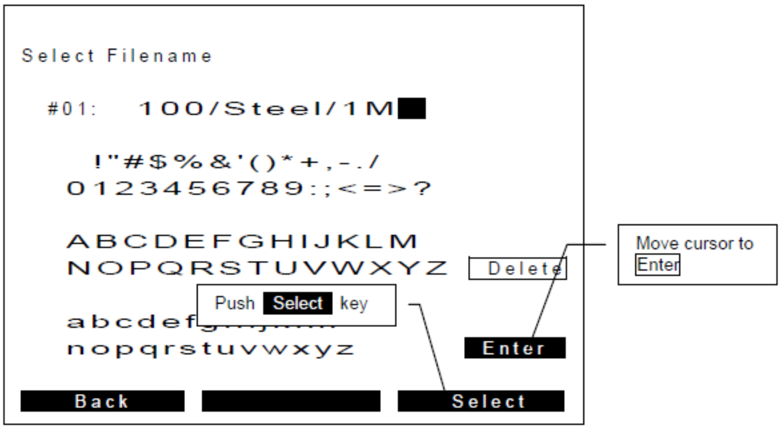


Fig. 1.2.6-9 File name finalize

Pipe size setting

Input pipe diameter-by-diameter itself or circumference of pipe. You can select which way you want by direction or numeric button. Here for example, select "1: Diameter" by push "Select" key (F3 button). Note: diameter should be OUTER diameter. Please refer to

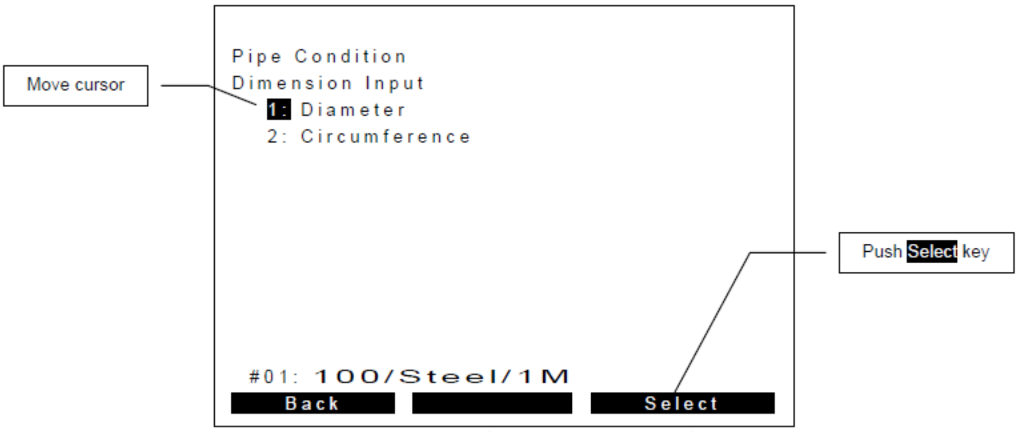


Fig. 1.2.6-10 Selection menu by diameter

Input diameter by numeric button directly. Here for example, input 114.30mm as right. Then push "Enter" key (F3 button) to proceed to next step.

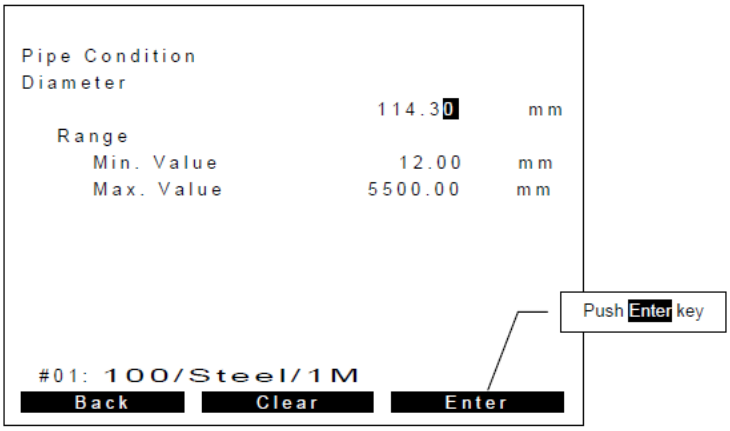


Fig. 1.2.6-11 Input menu

Pipe material

Select material of the pipe from default choices or User Defined by direction or numeric button. Here for example, select “1: Carbon Steel”, then push “Select” key (F3 button) to proceed next step.

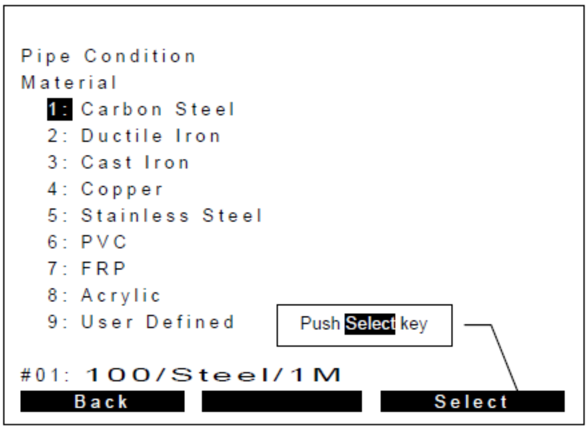


Fig. 1.2.6-12 Pipe material selection menu

Following sound speed is defined as default listed material.

Table 1.2.6-2 Selectable items of pipe material

Material	Sound speed [m/s]
Carbon Steel	3200
Ductile Iron	3000
Cast-Iron	2500
Copper	2270
Stainless Steel	3100
PVC (Poly Vinyl Chloride)	2280
FRP	2560
Acrylic	2720

After you select material, you will see predefined sound speed, normally just proceed to next. If you would like to select any un-listed materials, please select “User Defined” then enter actual sound speed of the material at the next extra menu.

Thickness of pipe

Input pipe thickness by numeric button directly. Here for example, input “4.50mm”, then push “Enter” key (F3 button) to proceed to next step.

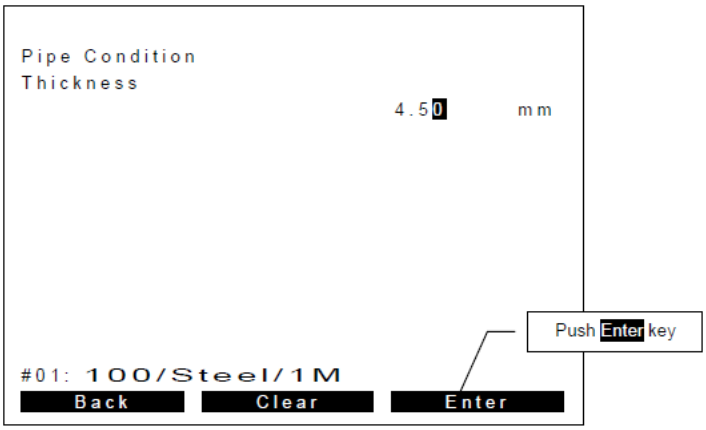


Fig. 1.2.6-13 Pipe thickness input menu

Note: Over ½ of pipe diameter is invalid value. (Max range: up to 100mm)

Lining material

Select material of the lining from default choices or User Defined by direction or numeric button. Here for example, select “2: Epoxy”, then push “Select” key (F3 button) to proceed next step.

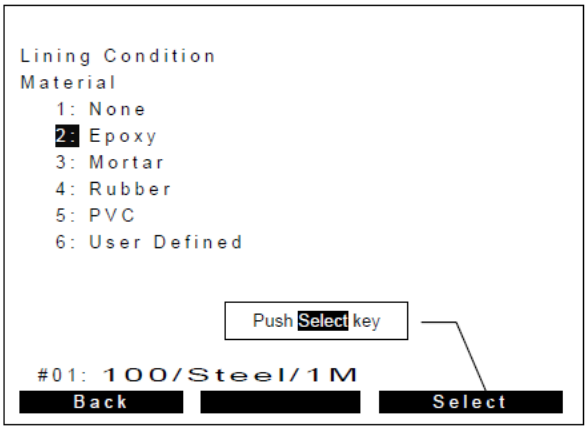


Fig. 1.2.6-14 Lining material selection menu

Following sound speed is defined as default listed material.

Table 1.2.6-3 Selectable items of lining material

Material	Sound speed [m/s]
Epoxy	2000
Mortar	2500
Rubber	1900
PVC (Poly Vinyl Chloride)	2280

After you select material, you will see predefined sound speed, normally just proceed to next. If you would like to select any un-listed materials, please select “User Defined” then enter actual sound speed of the material later at the next extra menu.

Thickness of lining

Input lining thickness by numeric button directly. Here for example, input “1.00mm”, then push “Enter” key (F3 button) to proceed to next step.

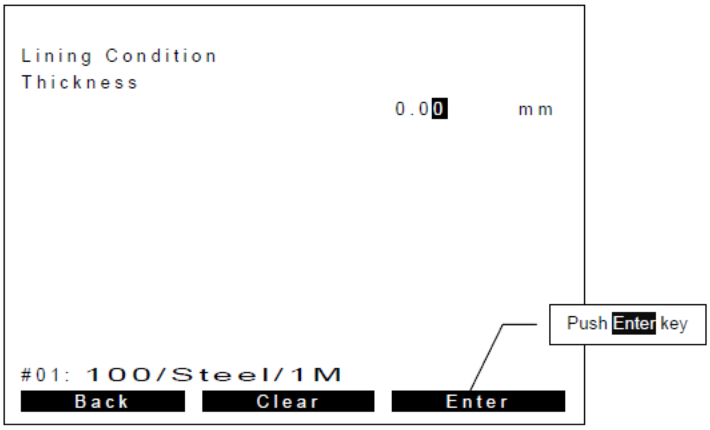


Fig. 1.2.6-15 Lining thickness input menu

Note: Over ½ of pipe diameter is invalid value. (Max range: up to 100mm)

Fluid Selection

Select fluid from default choices or User Defined by direction or numeric button. Here for example, select “1: Water”, then push “Select” key (F3 button) to proceed next step.

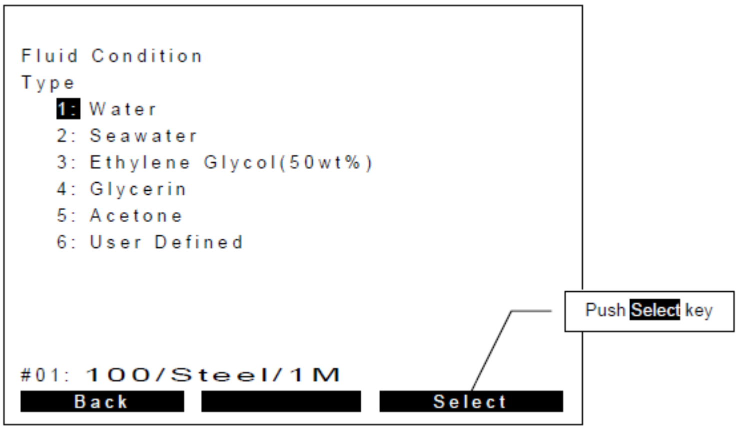


Fig. 1.2.6-16 Fluid type selection

After you select material, you will see predefined sound speed and viscosity, normally just proceed to next. If you would like to select any un-listed fluid, please select “User Defined” then enter actual sound speed of the fluid later at the next extra menu.

Table 1.2.6-4 Selectable items of fluid type

Fluid	Sound speed [m/s]	Viscosity [$x10^{-6}$ m^2/s]
Water	1460	1.20
Sea Water	1510	1.00
Ethylene Glycol (50wt%)	1691	4.13
Glycerin	1923	1188.50
Acetone	1190	0.41

12. Transducer type

Select transducer type from default choices by direction or numeric button. Here for example, select “2: UP10AST”, then push “Select” key (F3 button) to proceed to the next step.

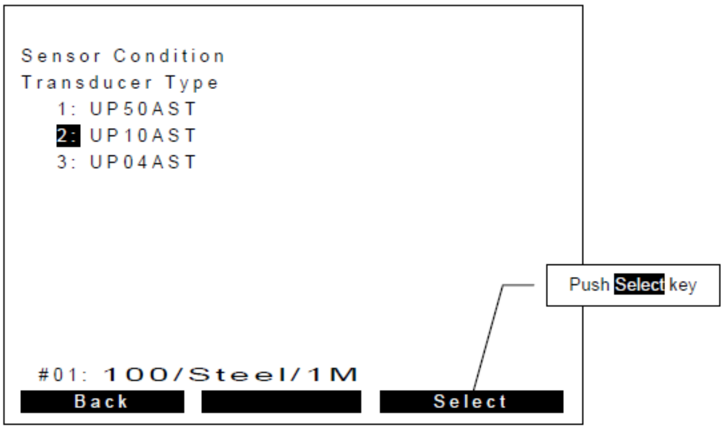


Fig. 1.2.6-17 Transducer type selection menu

Sound-path selection

Select sound-path method from default choices by direction or numeric button. Here for example, select “2: V-Path method”, then push “Select” key (F3 button) to proceed to the next step.

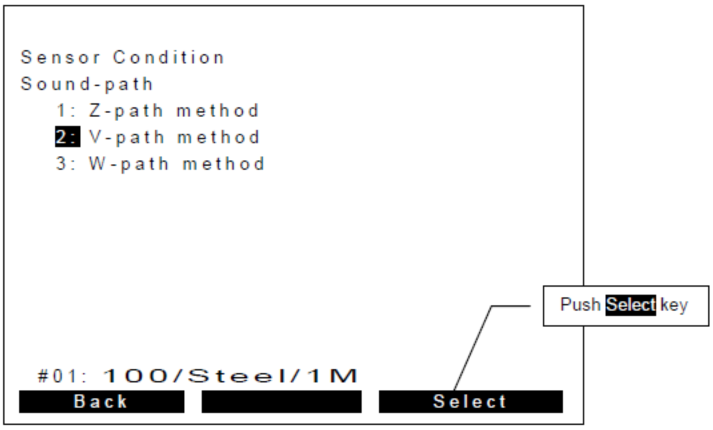


Fig.1.2.6-18 Sound-path selection menu

Flow rate unit setting

Select flow rate unit from default choices by direction or numeric button. Here for example, select “3: m3/h”, then push “Select” key (F3 button) to proceed to the next step.

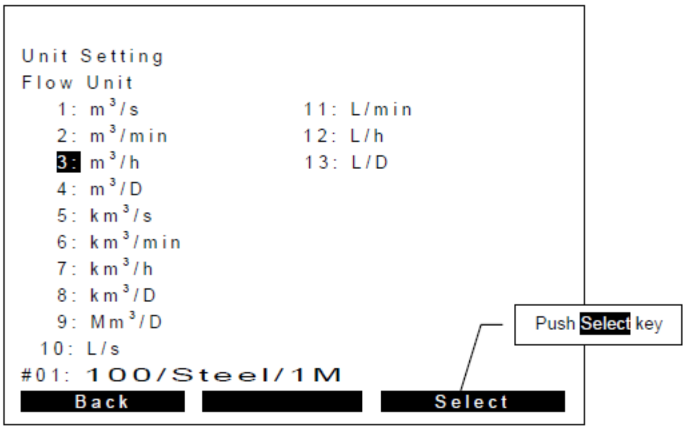


Fig. 1.2.6-22 Flow rate unit setting menu

Decimal point position

Select decimal point position from default choices by direction or numeric button. Here for example, select "***.***", then push "Select" key (F3 button) to proceed to the next step.

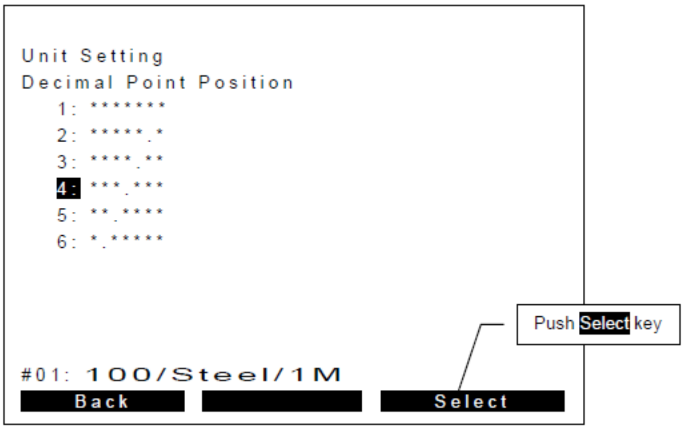


Fig. 1.2.6-23 Decimal point position setting menu

Totalizing unit setting

Select totalizing unit from default choices by direction or numeric button.

Here for example, select "1: ×1m3", then push "Select" key (F3 button) to proceed to the next step.

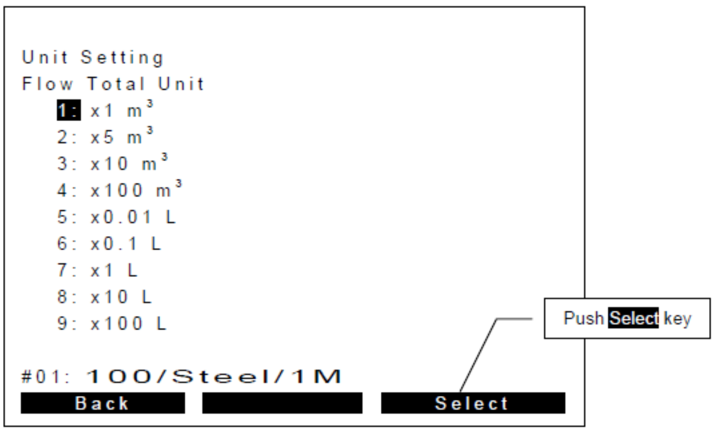


Fig.1.2.6-24 Totalizing unit setting menu

Store site data

Finalize wizard by store all data on this menu. Select “2: Yes” by direction or numeric button. Then push “Select” key (F3 button) to proceed to the next step.

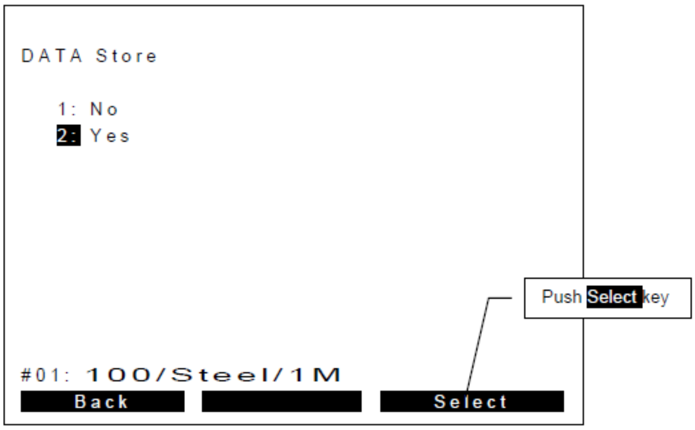


Fig. 1.2.6-25 Data storing menu

When select “2: Yes”, following message will be shown.

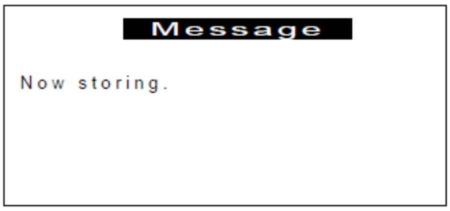


Fig. 1.2.6-26 Data storing

After storing site-setting data, following confirmation message will show up. Then push “Yes” (F3 button) to proceed to the next step. Otherwise when you select “No” (F1 button), return to initial basic menu.

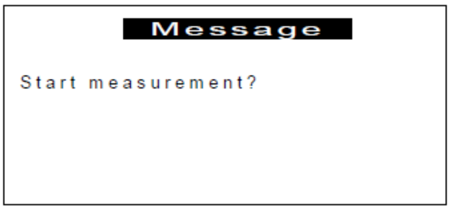


Fig. 1.2.6-28 Confirmation message to start measurement

Mounting transducers

The main unit calculates proper distance between transducers as according to the message appearing below. Then push “OK” (F3 button) to start measurement. Please set transducer mounting with indicated transducer distance in accordance with instruction on Chapter 1.2.9. On this example, distance of transducers is 63.8 mm.

Then proceed with Transducer setting.

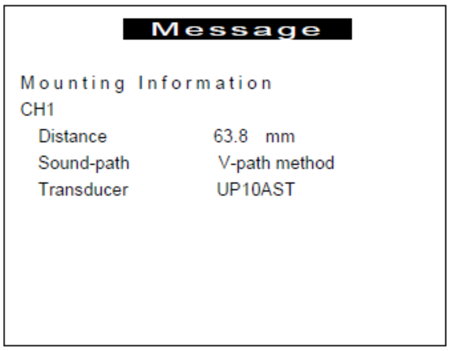


Fig. 1.2.6-29 Message of mounting information

3. Transducer Setting

Transducer distance setting

Set distance between transducers on mounting fixture in accordance with the main unit calculation.

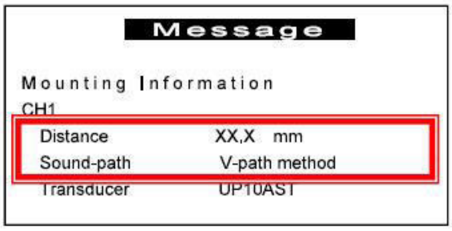


Fig. 1.2.9-9 Message of mounting information

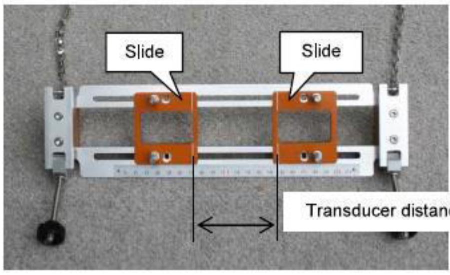


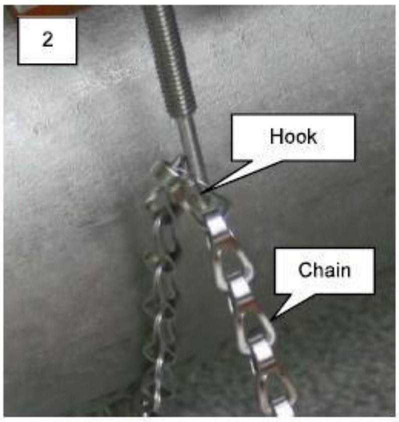
Fig. 1.2.9-10 Set transducer distance on fixture

Set mounting fixture onto the pipe

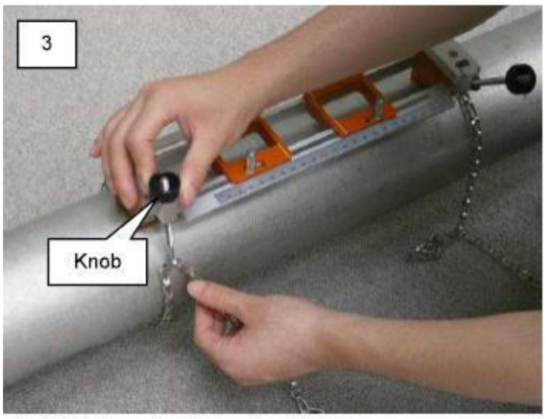
Wrap the mounting chain around the pipe and hook an endo link with the hook knob arrangement.

Tighten the chain at the other end of the fixture.

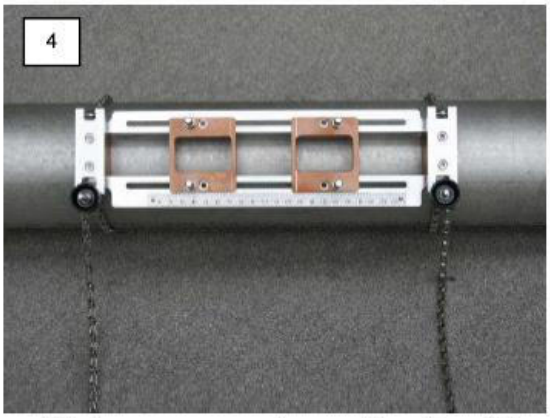
1. Roll chain around the pipe.



2.Hook the chain at appropriate length.



3. Tighten chain by knob.



4.Take same procedure on the other side, then complete.

Fig. 1.2.9-11 Set mounting fixture

Add coupslant and set transducers to mounting fixture

Add silicone grease as acoustic couplant onto surface of tranceducers.

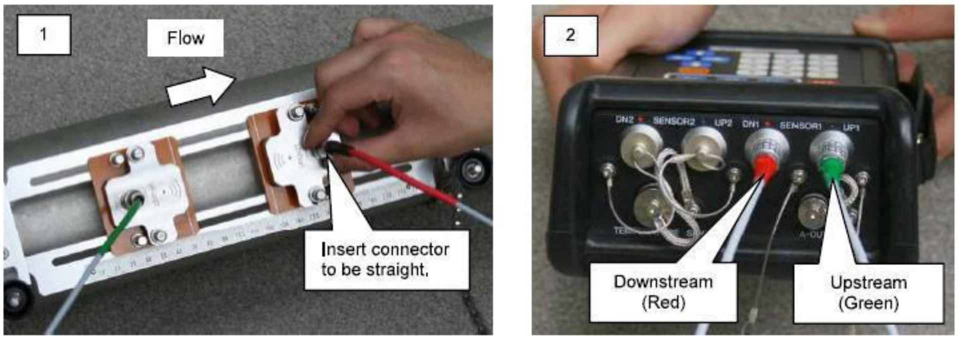
Then set them into mounting fixture.

1. Add couplant onto surface of transducer as photo.
2. Set transducer to fixture.
3. Fix transducers by screw.

Fig. 1.2.9-12 Set the transducers into mounting fixture

Set cables with the transducers and the main unit

Connect cables with the transducers to the main unit



1. Connect with the transducers.
2. Connect with the main unit.

Fig. 1.2.9-13 Connect with the transducer cables

Let's start measurement

Complete prepartion for measurement. Push OK key as Fig. 1.2.9-9 to start measurement (mounting information menu)

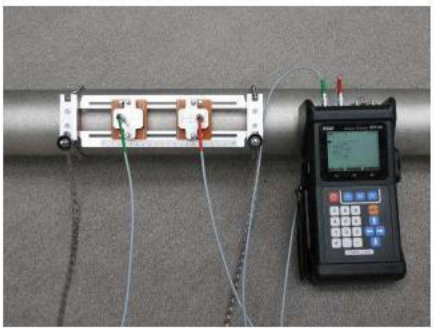


Fig. 1.2.9-14 Finished medium size transducer setting

Measurement for over DN200mm pipe

In case of measurement for over DN200mm, you need to use mounting fixture 1 and 2 for extension together as below. The distance between fixtures is 100mm.

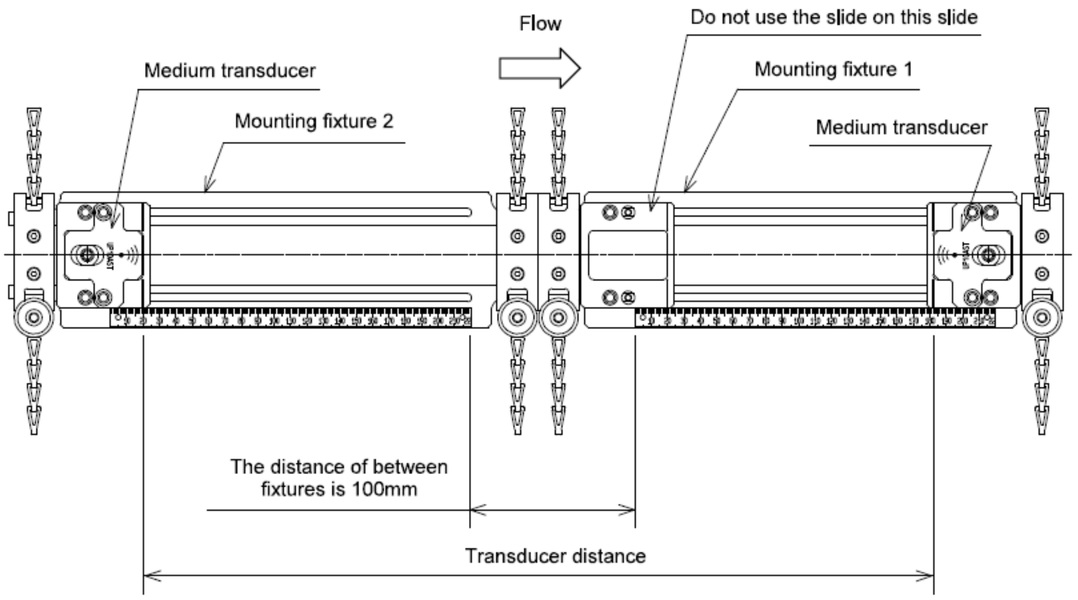


Fig. 1.2.9-15 Combine mounting fixture (over DN200mm)

When the transducer distance is 245mm(DN300mm), if Up side slide sets t 200mm point, Down side slide must be set at 125mm point. The point of scale is just a sample. Whenever transducer distance can be kept, scale point does not matter.

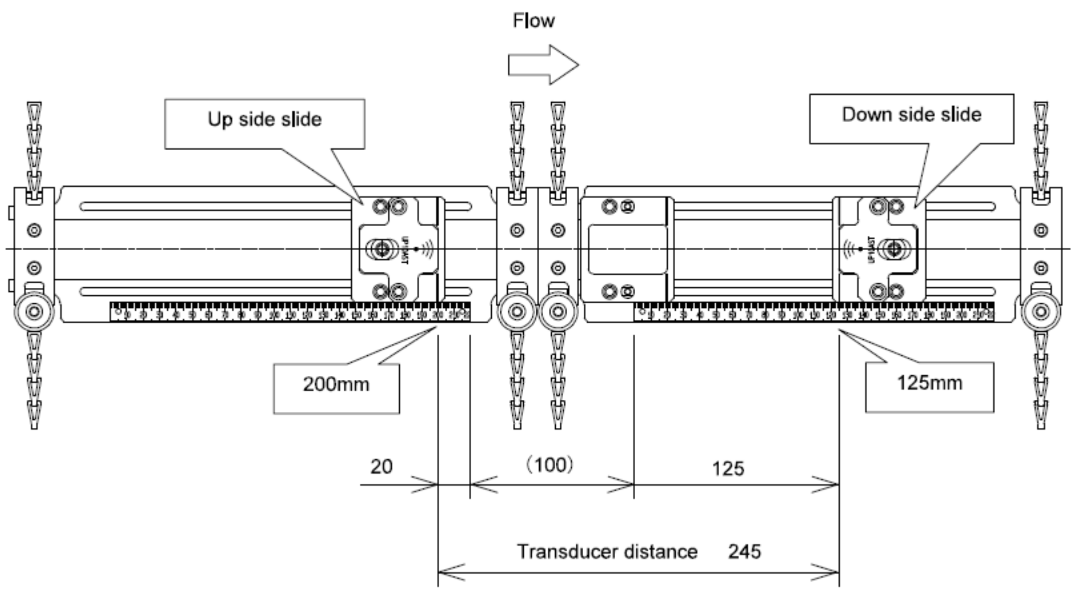
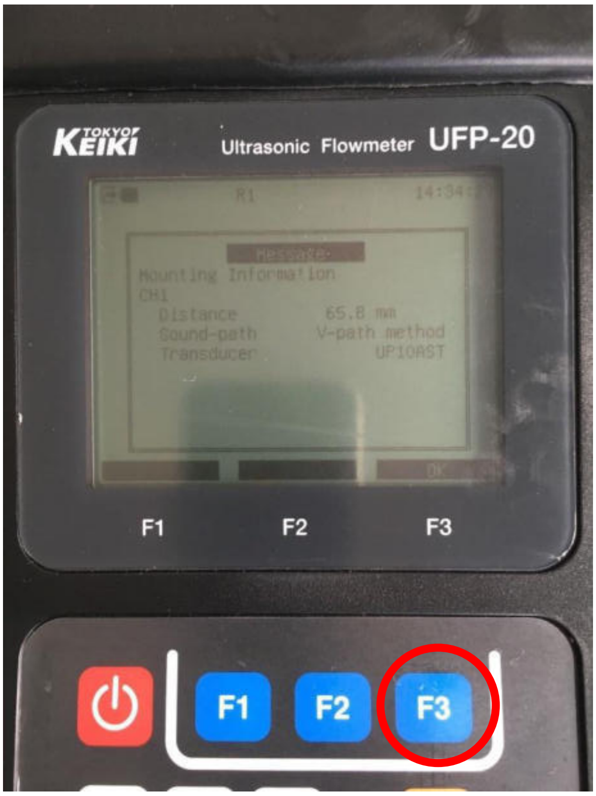
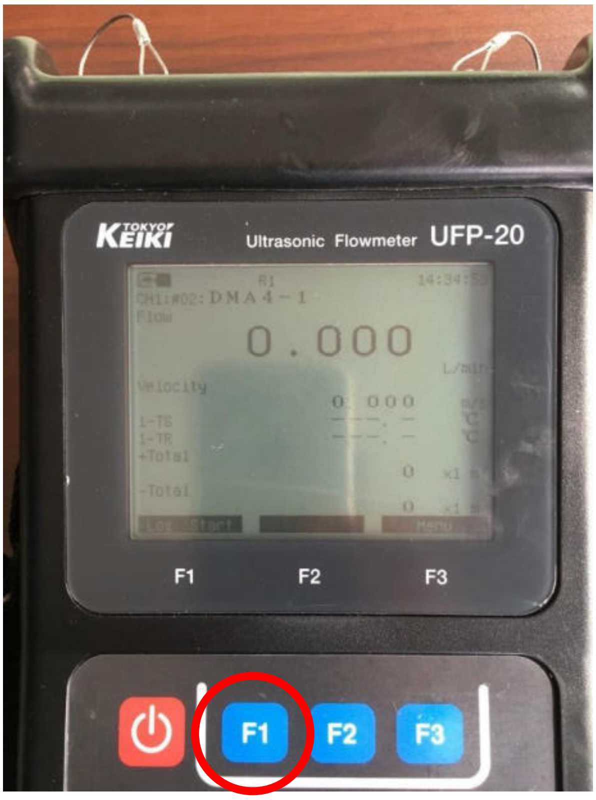
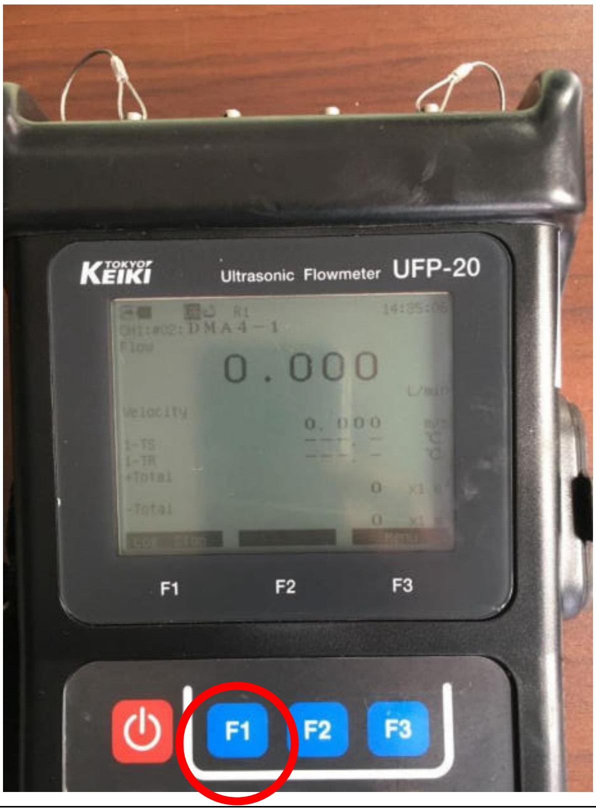


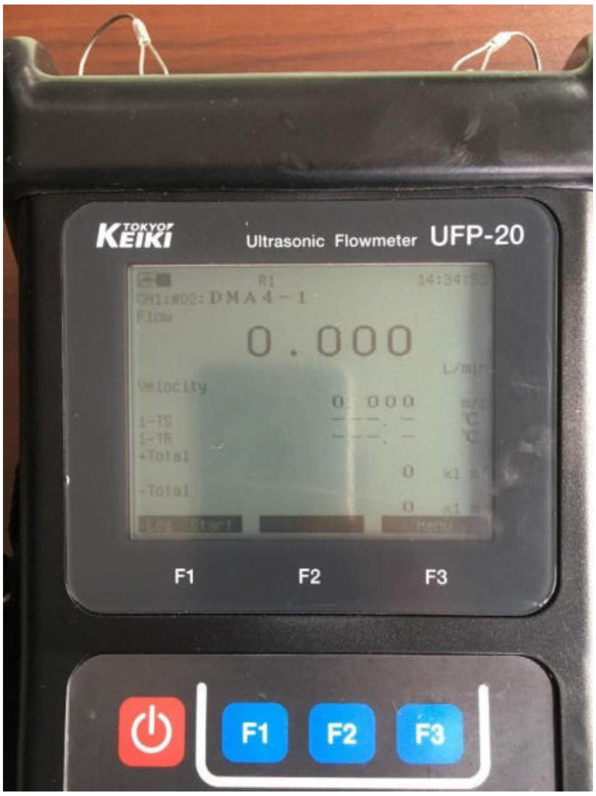
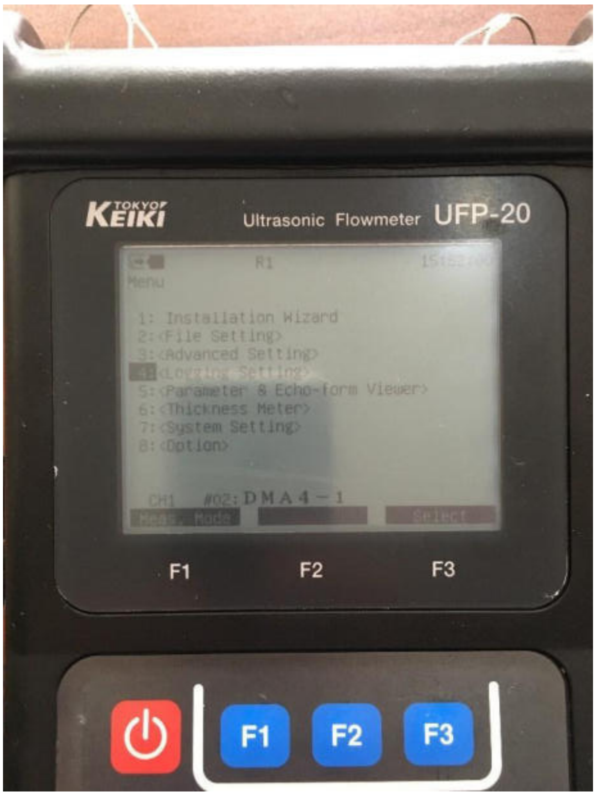
Fig. 1.2.9-16 Sample of combine mounting fixture (Transducer distance : 245mm)

4. Start and Stop Logging

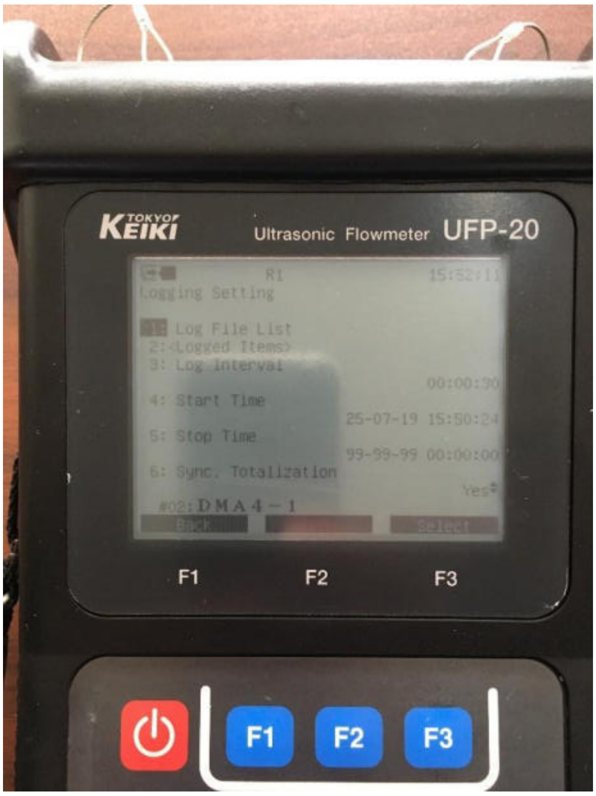
Continue from the last step of [2. Unit setting] Select “OK”<F3>

Select “Log Start”<F1>, and then start logging.


Select “Log Stop”<F1> when you want to stop logging.


5. Downloading Logs

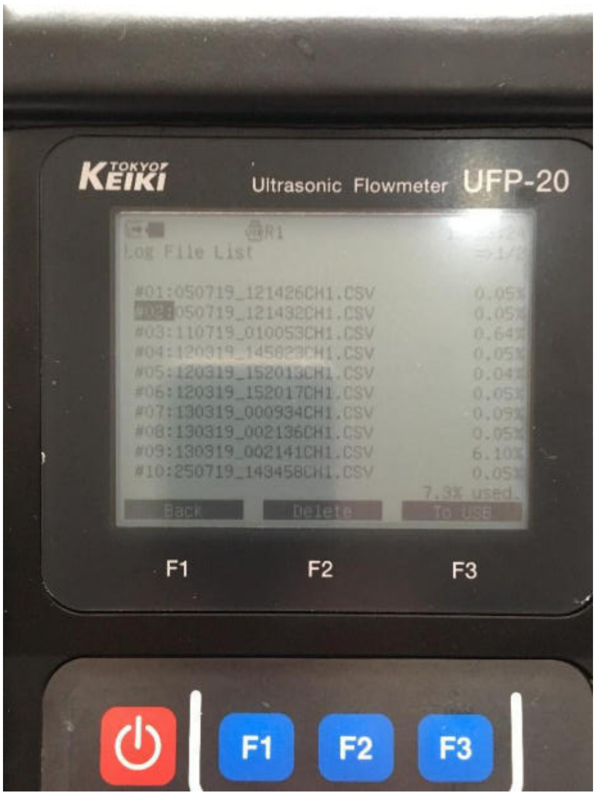
When you have stopped logging, select “MENU”<F3>.

Select “Logging Setting” from the menu list<F3>.


Select “1 : Log File List”



The logging filename is defined automatically. [DDMMYY.csv]

Connect a pen drive to the unit.

Choose a certain file, and then select “To USB”<F3>.


End

Appendix 6.2 Water Pressure Logger

Brand : HWM-Water Ltd

Model : LoLog LL/Vista

Country : UK

Contents of this manual

1. Software Installation
2. Pre-Setting
3. Installing to an Actual Site
4. Downloading Logs

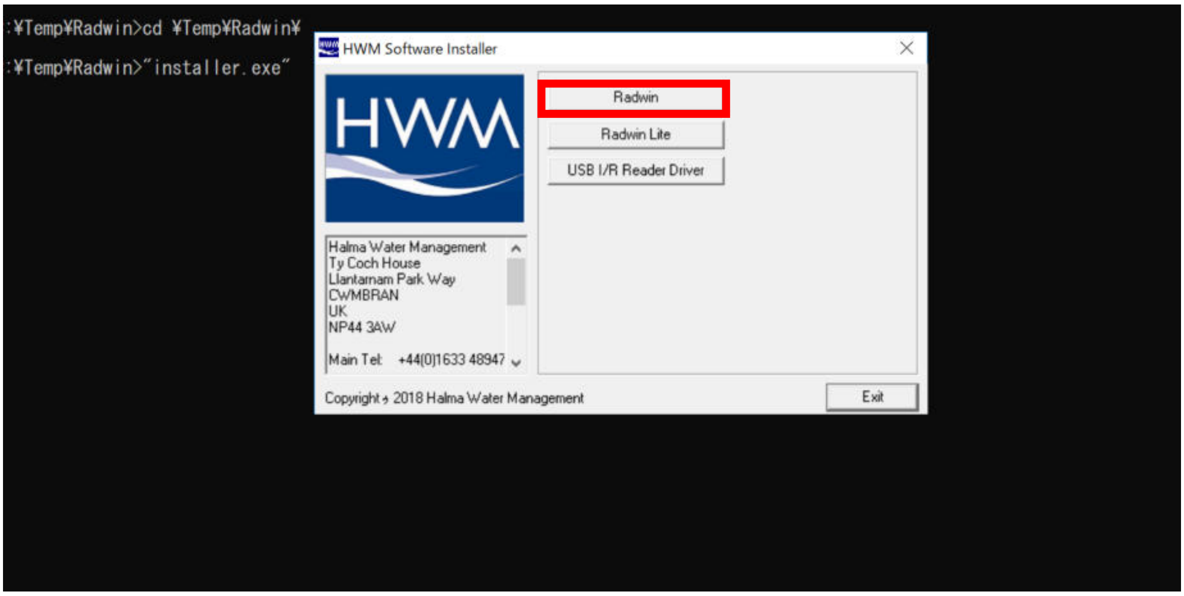
Note : Up to 5 years battery life. It does not need to be charged.

1. Software Installation

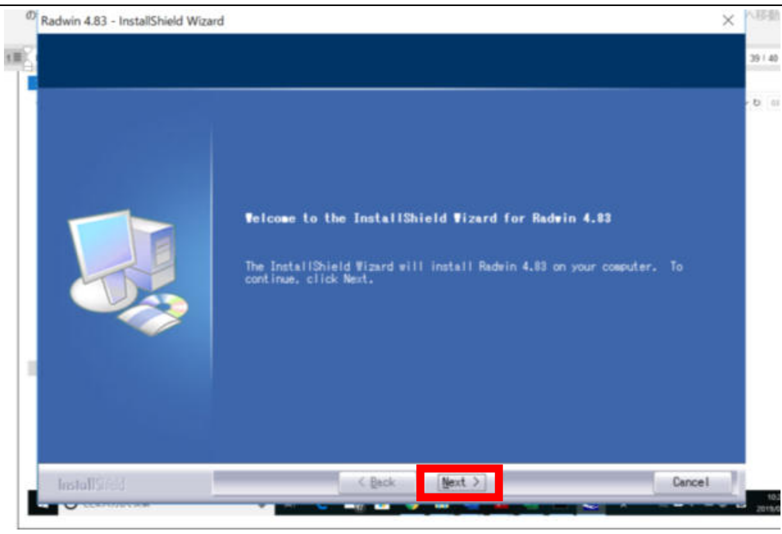
Copy the Radwin installation file from the CD-ROM or link below onto your PC, and run the file.

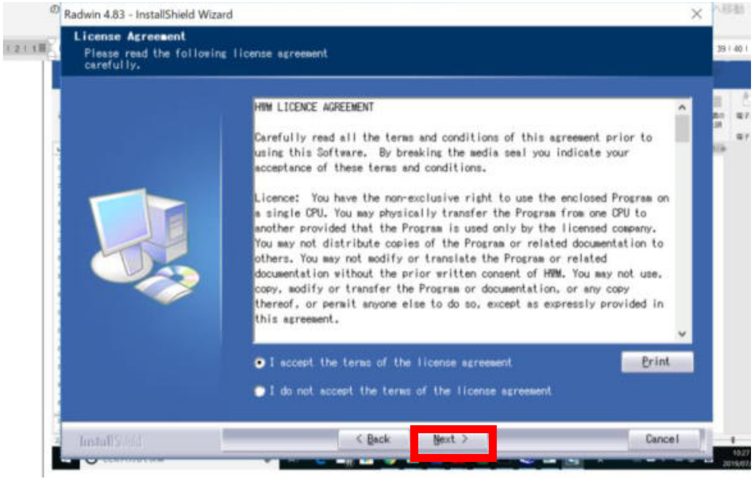
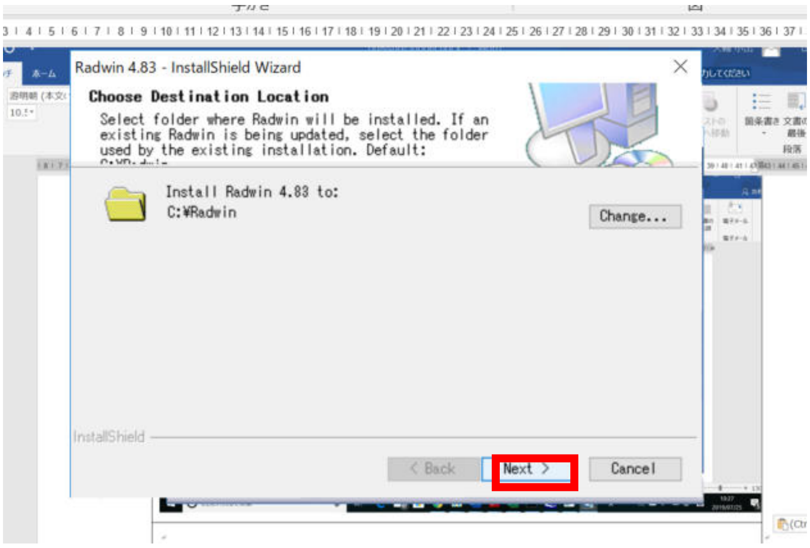
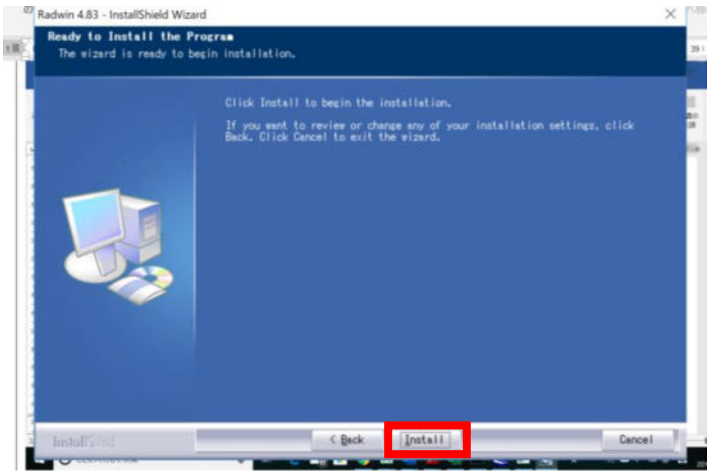
Link: http://www.hwmglobal.com (Registration is needed before downloading)

Select "Radwin"

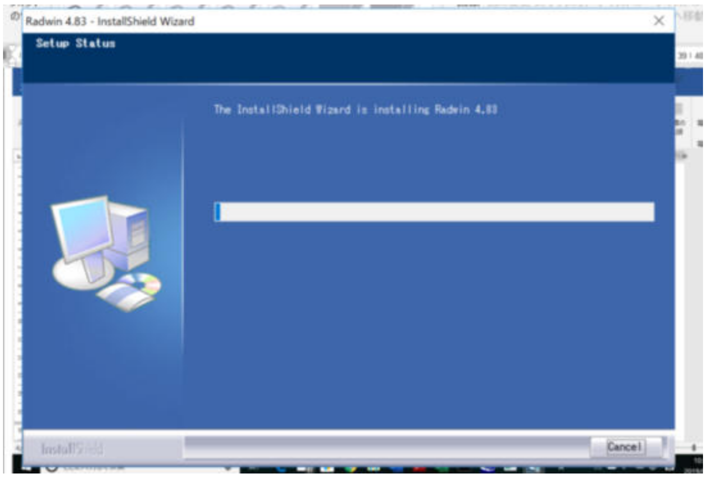


Install wizard will appear . Then select "Next".

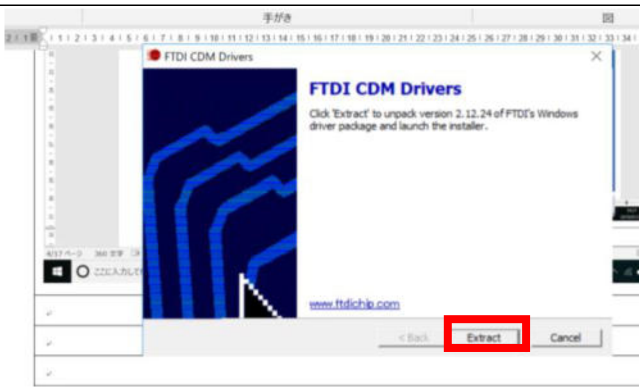


License agreement appear. Then select “I accept”, and “Next”.

Select “Next”.

Select “install”.


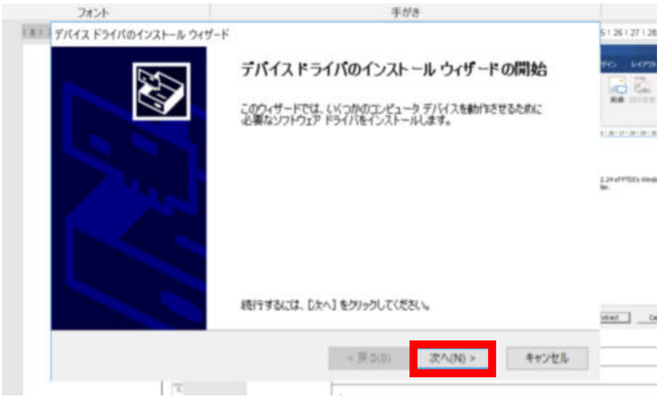
Install process will start.



Select “Extract”.

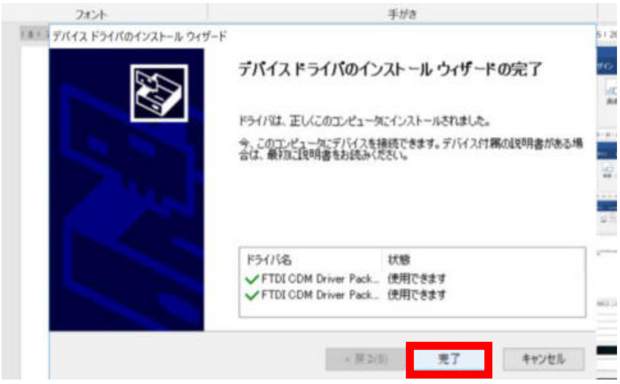


Select “Next”.

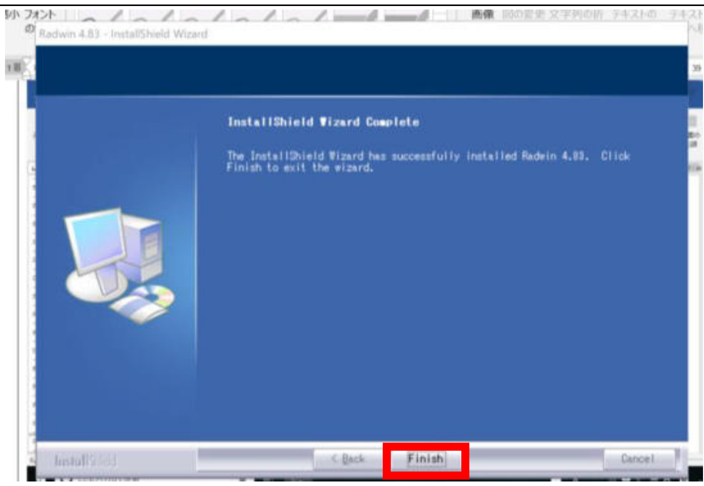


Select “I accept”, then select “Next”.

Select “Finish”.



Select “Finish”, then software installatin is complete.



2. Pre-Setting of the logger

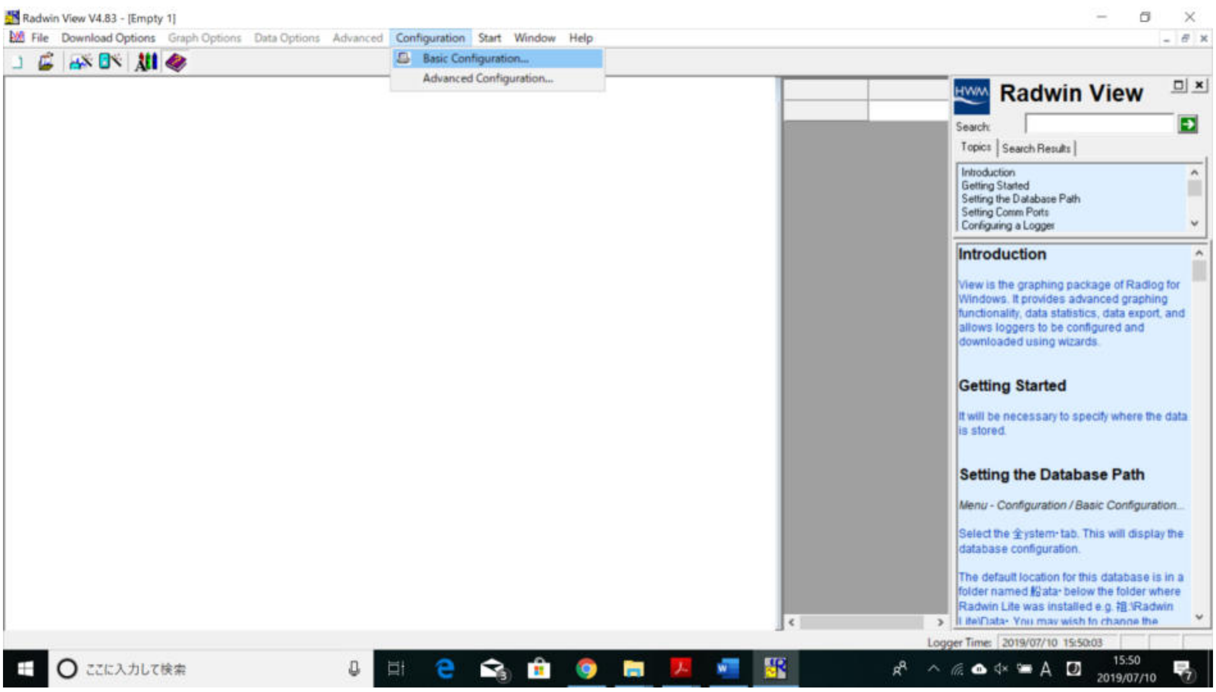
Connect the logger to PC by connector cable.　Then run “Radwin View” on your PC.

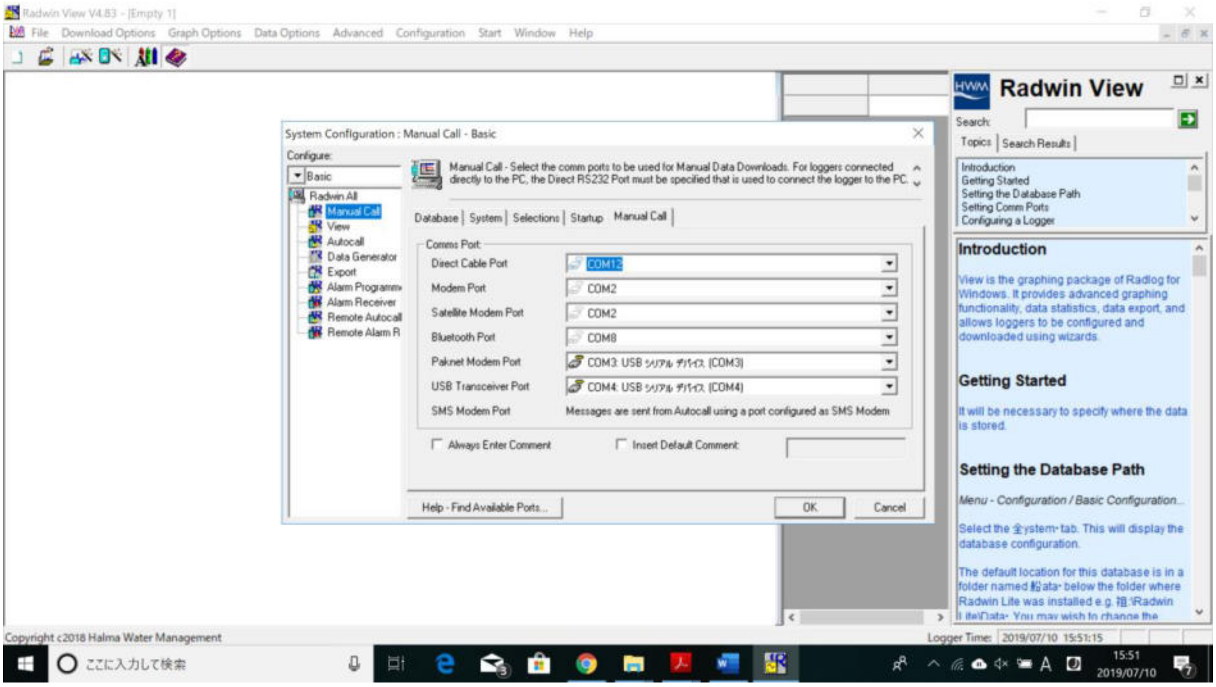
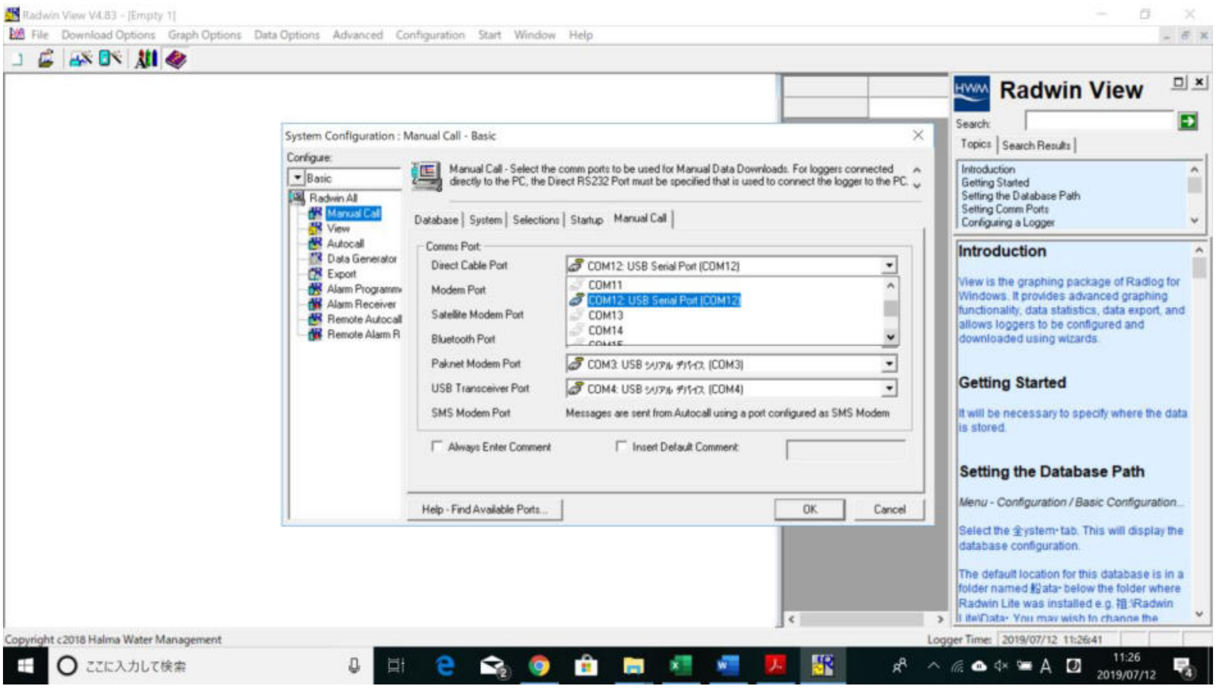
1. Connect the USB plug to a spare USB port on your computer or the Serial plug to a spare Serial port on your computer.

2. Position the reader head on the logger as shown below

Port Setting

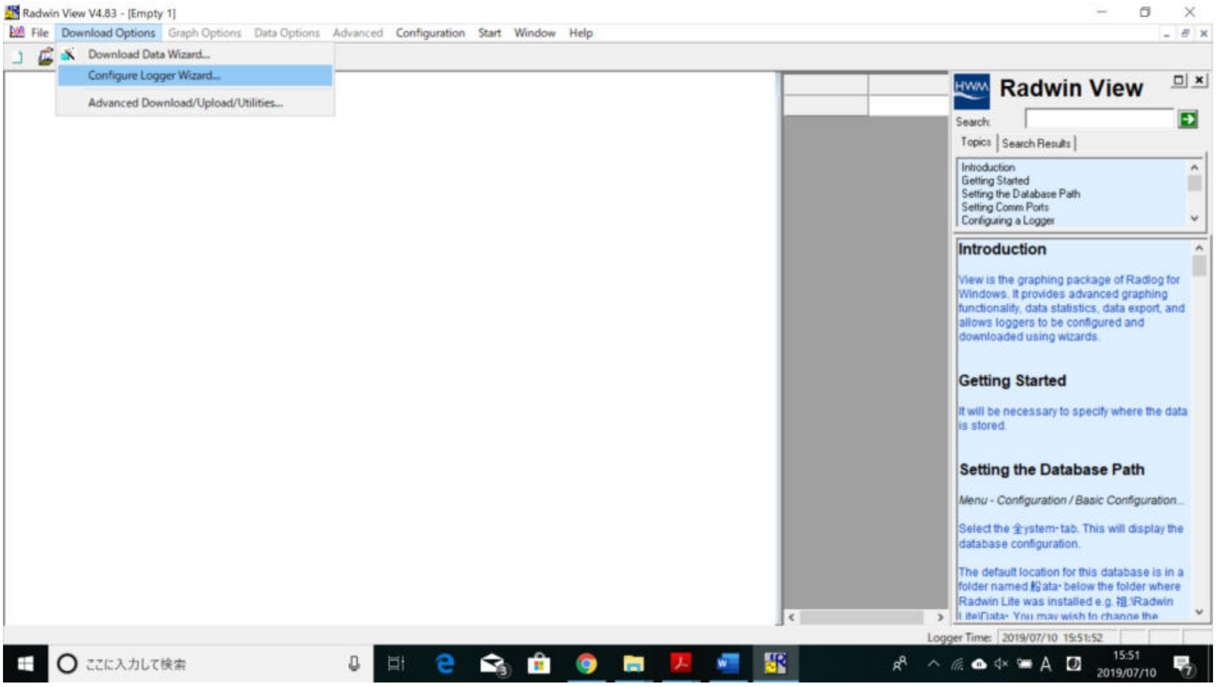
Select “Configuration” from command bar, and choose “Basic configuration” as below.



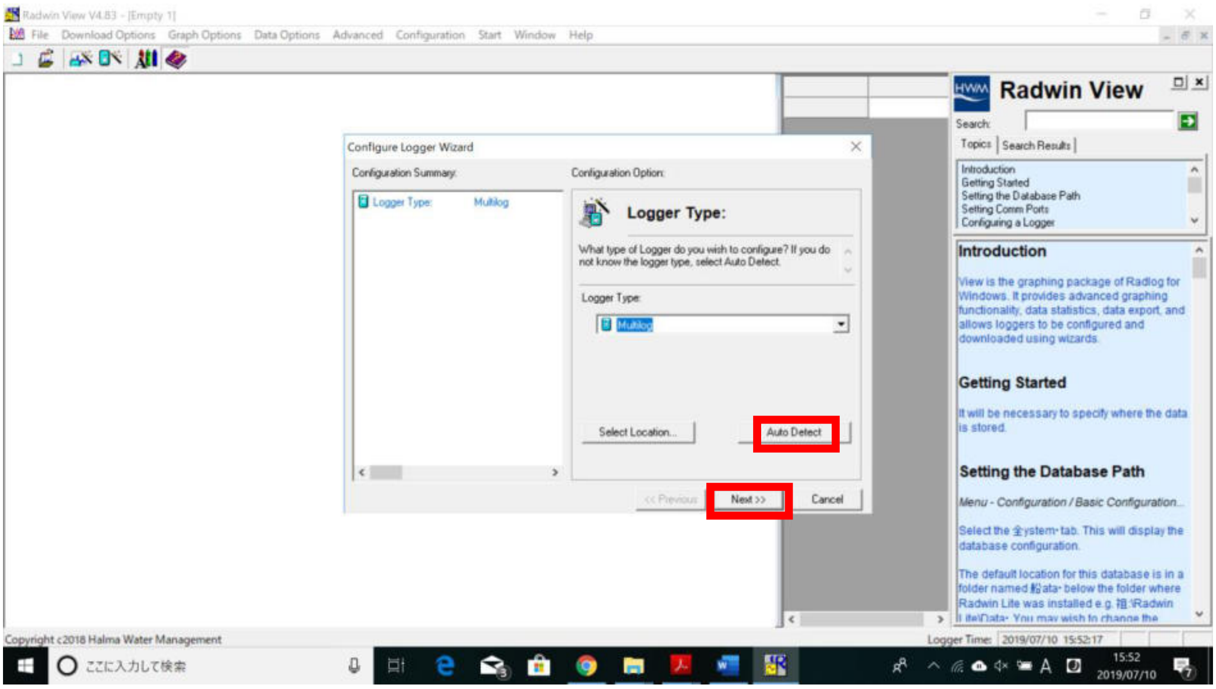
Select “Manual Call” from side bar, and then select the tab of “manual Call”.

Select “USB Serial Port” from the dropdown list of “Direct Cable Port” then press “OK” Port setting is done. *Note: If you have any problems about this setting, please refer to Page12 of original manual.*


Pressure Logger Configurating

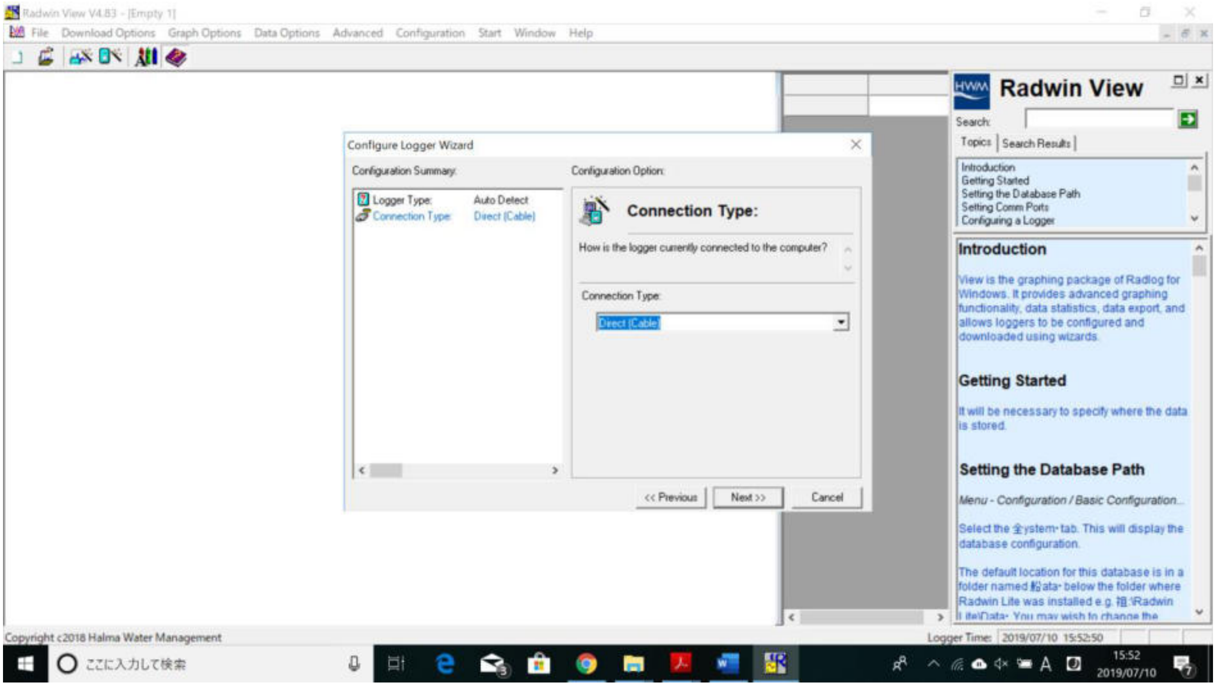
Select "Download Options" from command bar, and choose "Configure Logger Wizard" as below.



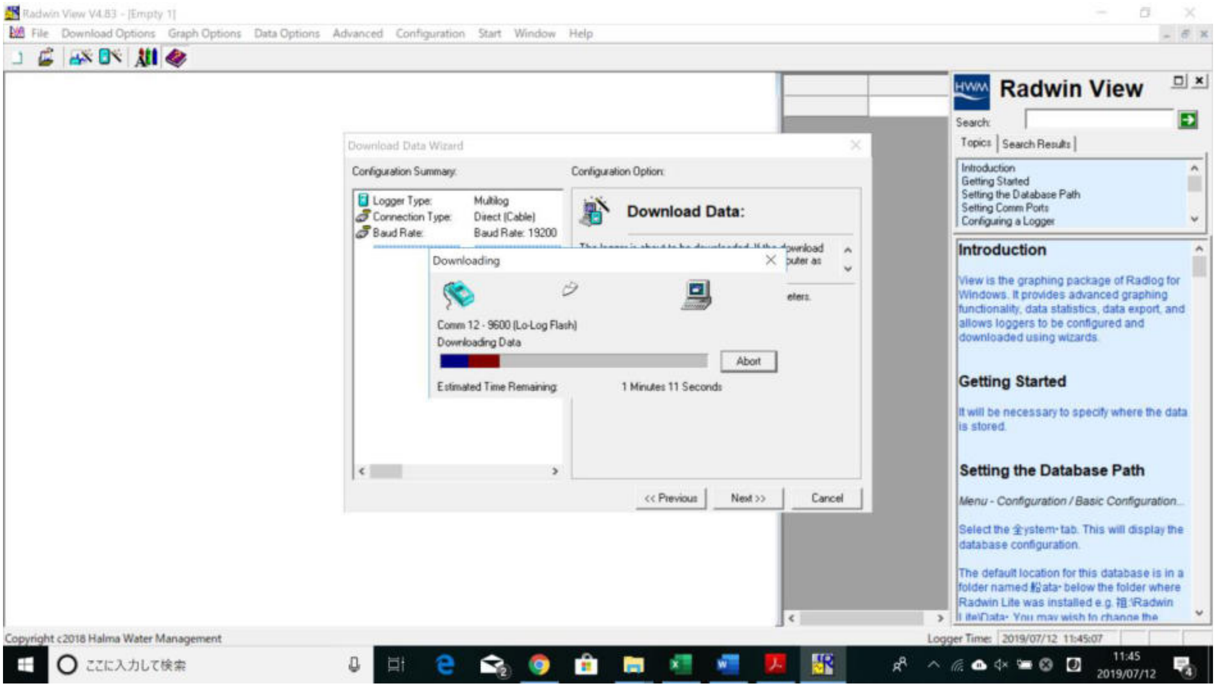
Logger Type Select Menu is opened. Press "Auto Detect", then "Next".



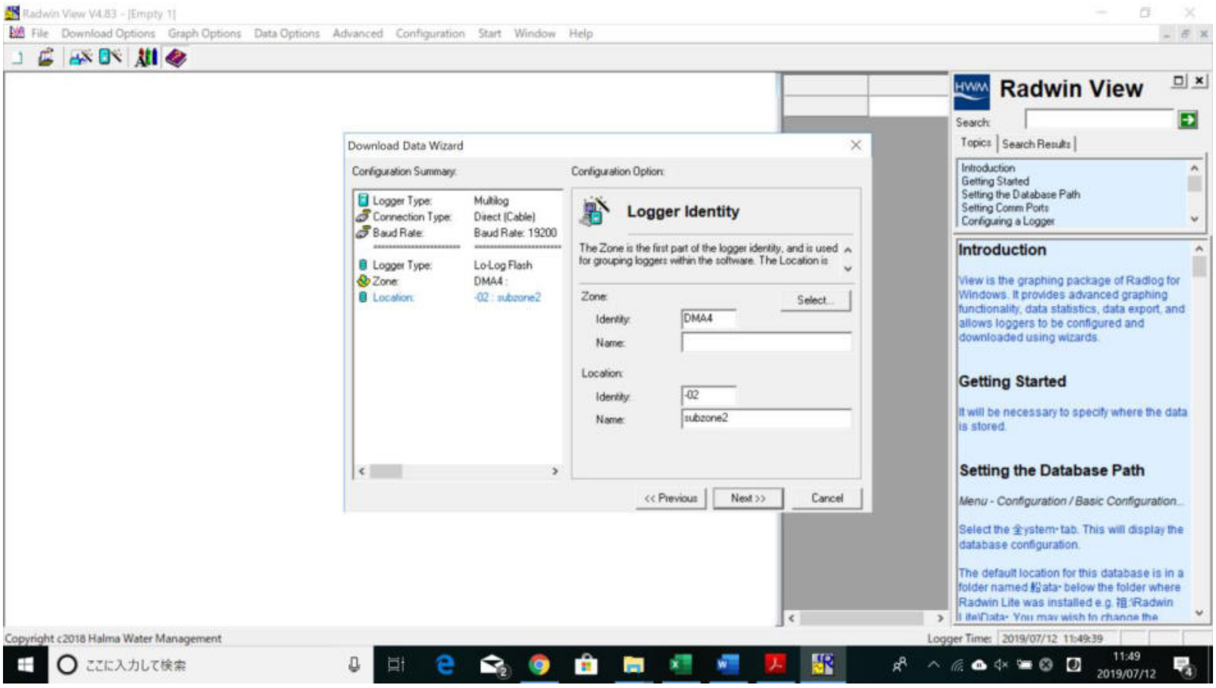
Connection Select Menu is opened. Select “Direct[Cable]” from dropdown list, then “Next”.



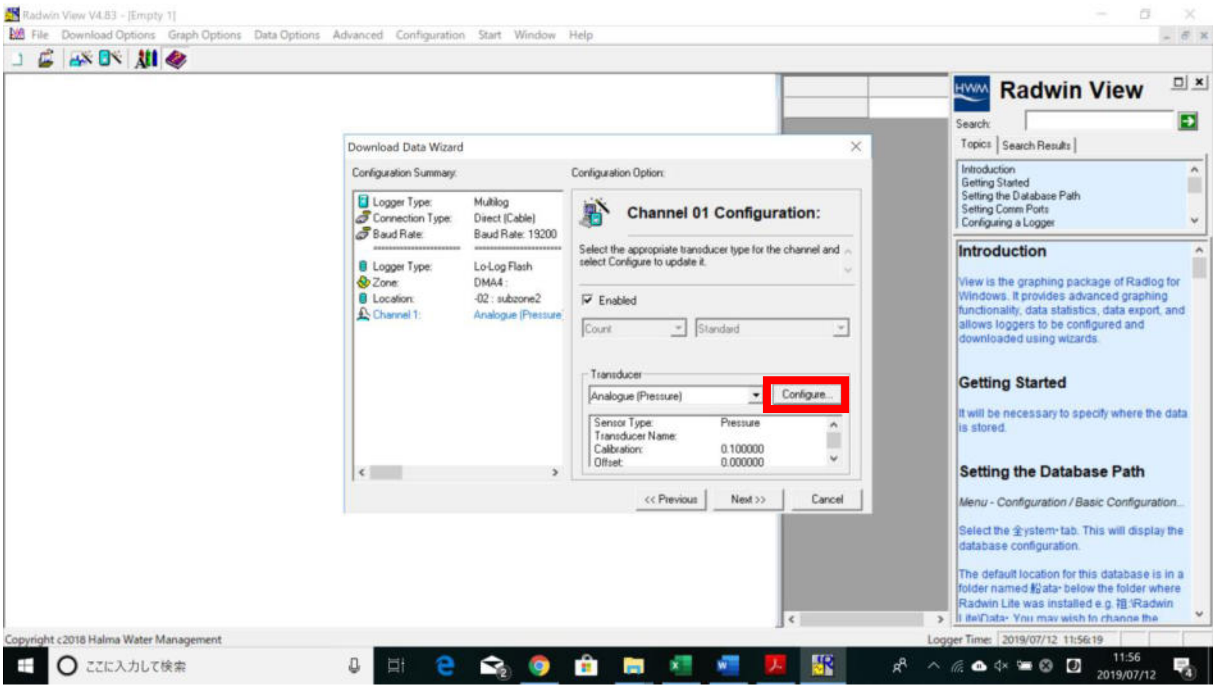
Download Process is carried out.



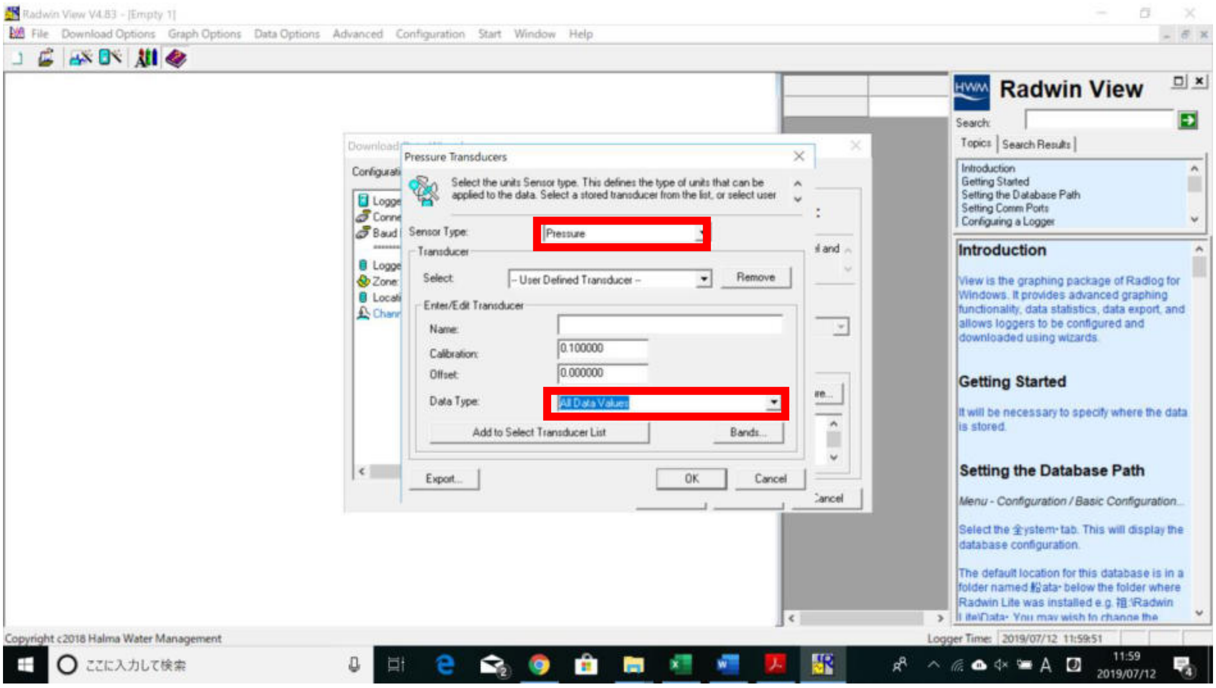
Logger Identify Menu is opened.　Put the logger name what you want, then “Next”.



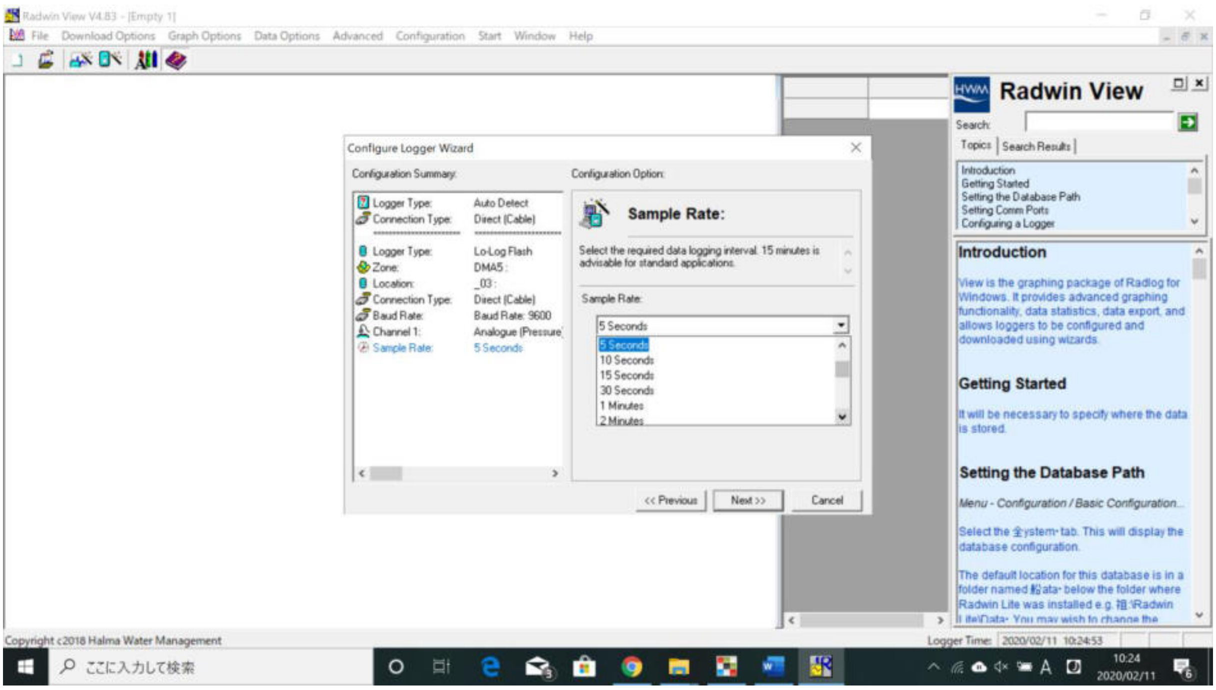
Configuration Menu is opened. Check the “Enabled”, select “Analogue [Pressure]” from the dropdown list of Transducer, then “Configure”.



Sensor type should be “Pressure”, Data type should be “All Data Value”, then “OK“, “Next” 3 times and “Finish”. Then pressure logger configurating is done.



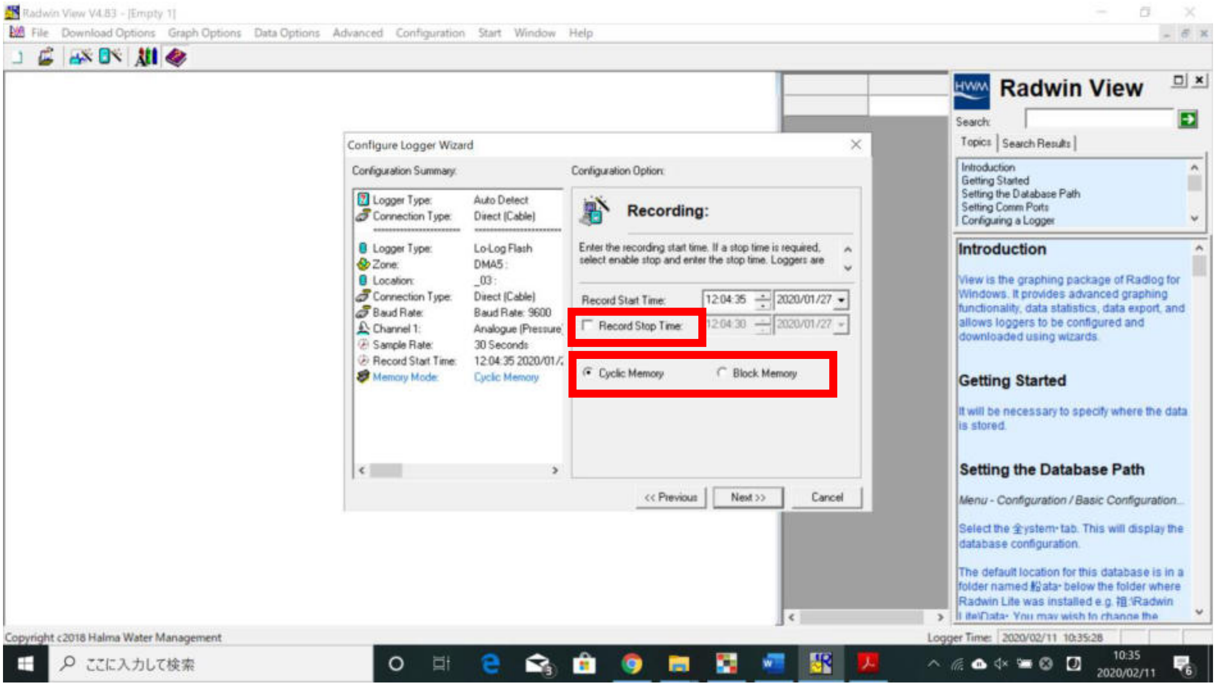
Sample rate can be selected available from “1 second” to “24 hour”. 30 seconds are recommendable. Note that the storable number of logged data is 16,000.



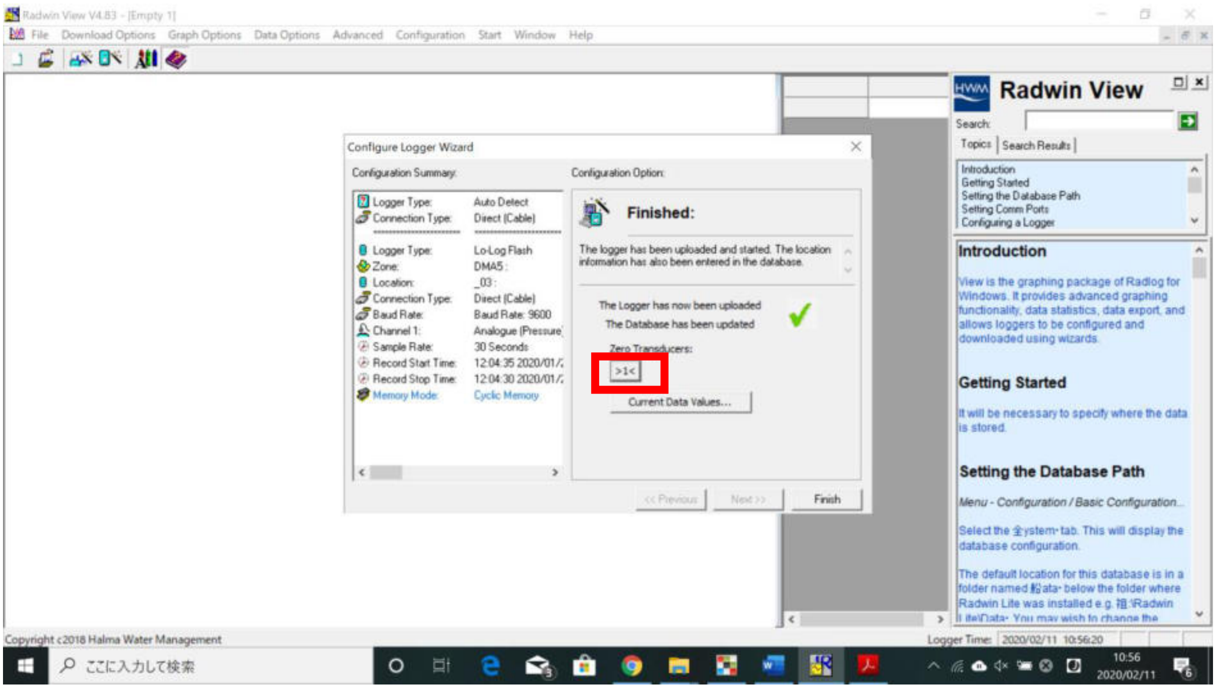
"Record stop time" can be set. If it is set, the logger will not log after time set.

Also select "Cyclic Memory" or "Block Memory". In case of "Cyclic Memory", the logger overwrites the recorded data if it exceeds tha capacity. In case of "Block Memory", the logger stops recording if it reaches to the capacity. <u>Note that the capasity is 16,000 readings.</u>

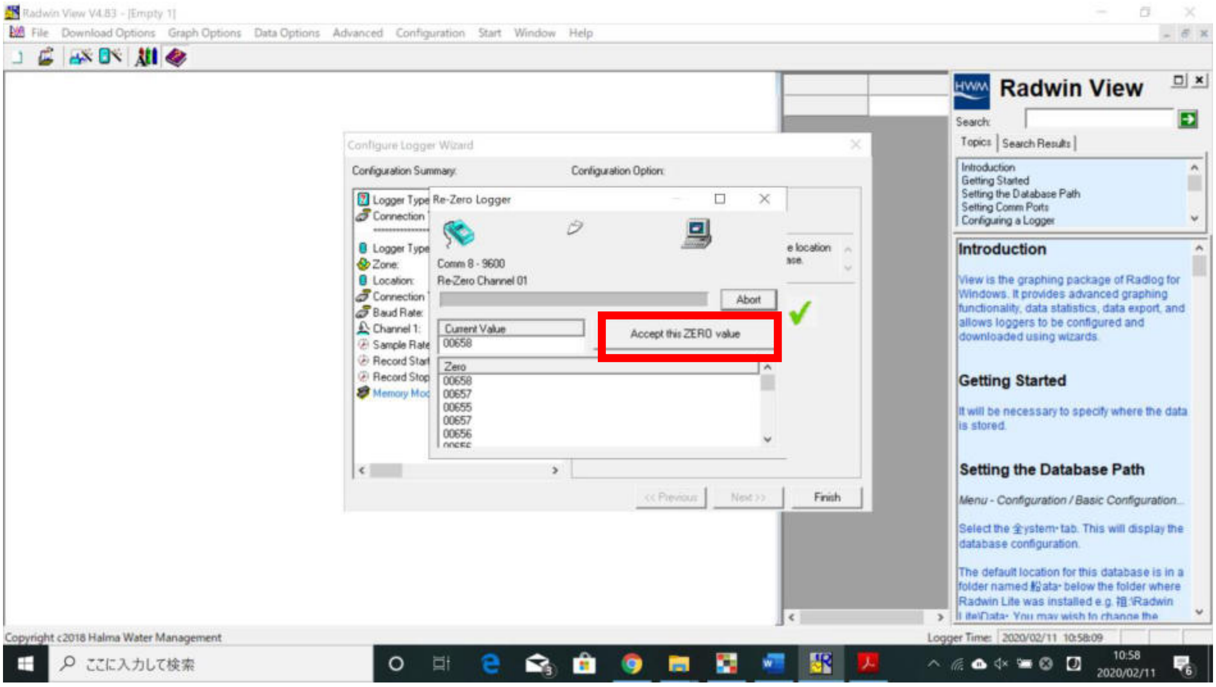
After setting, press "Next" 2times.



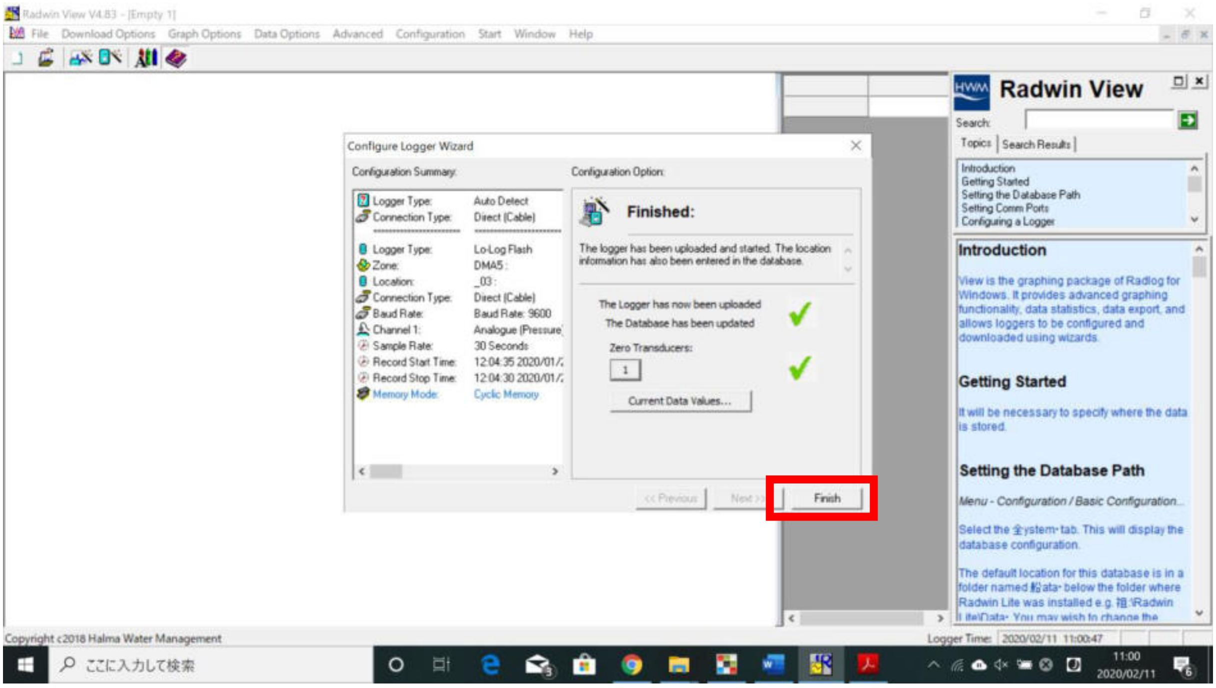
Move on to Zero Trancducer setting.



Accept and store current atmospheric pressure as new zero value.



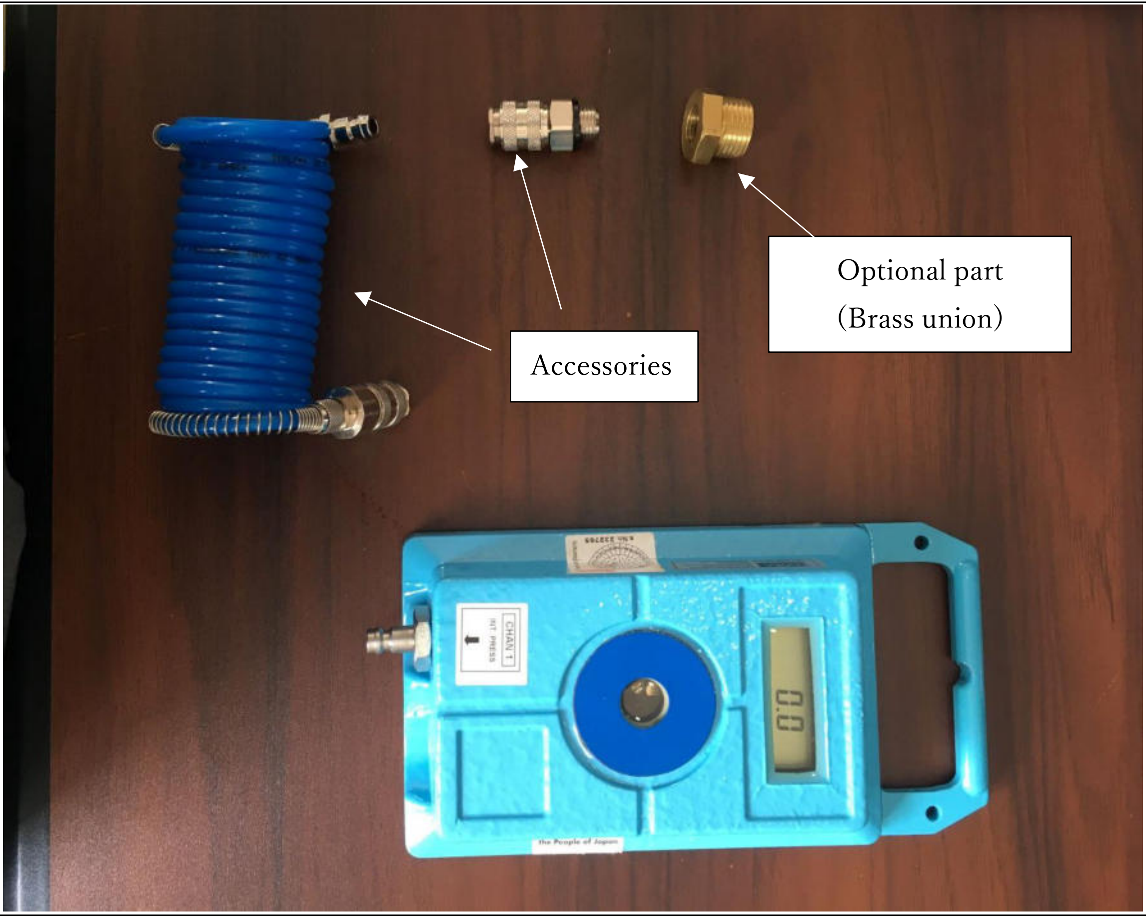
Press “finish”. Now pre-setting is done. Remove the logger from the PC.



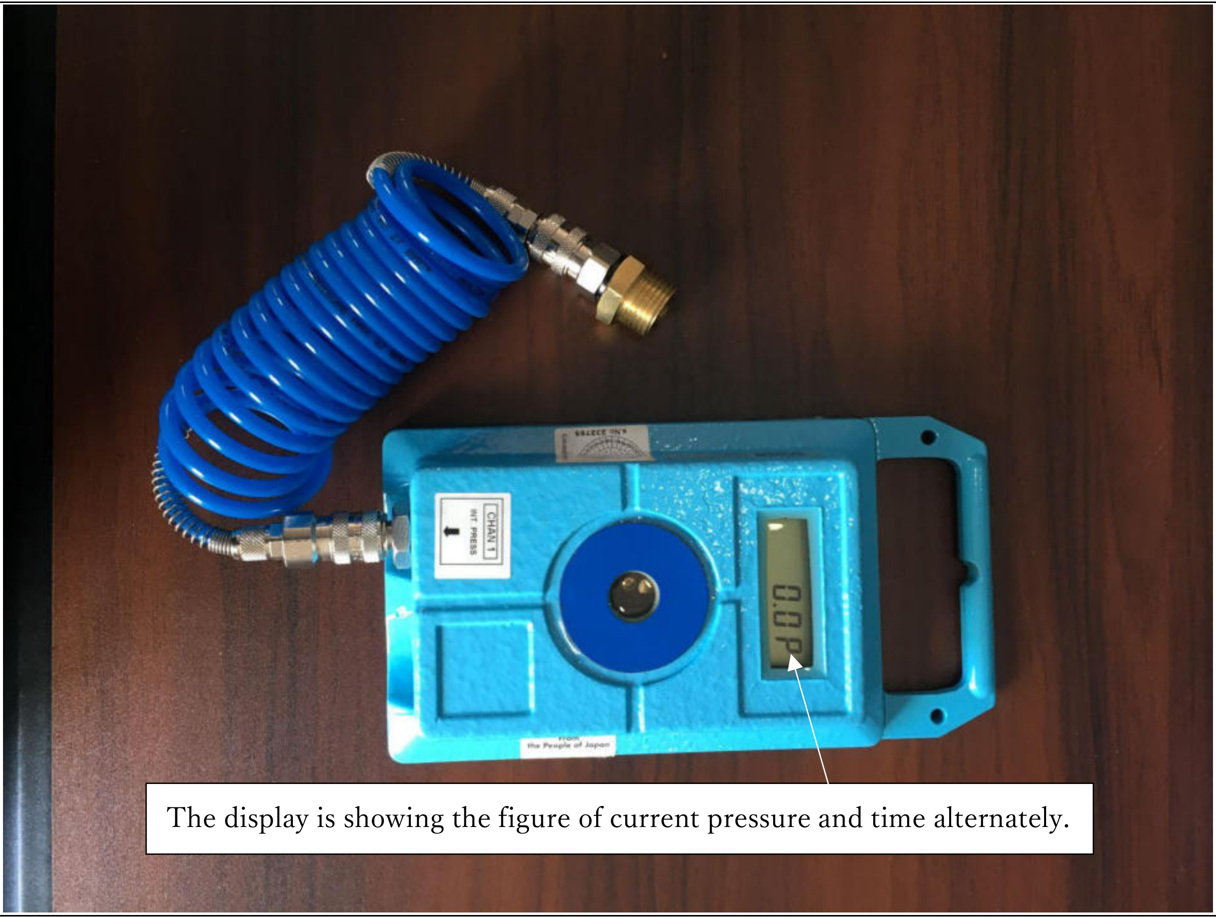
3. Installing to an Actual Site

All accessories and an optional part should be assembled.

The optional part appearing phot below is Brass Union, which is necessary for connecting to the parts of ordinary domestic taps.

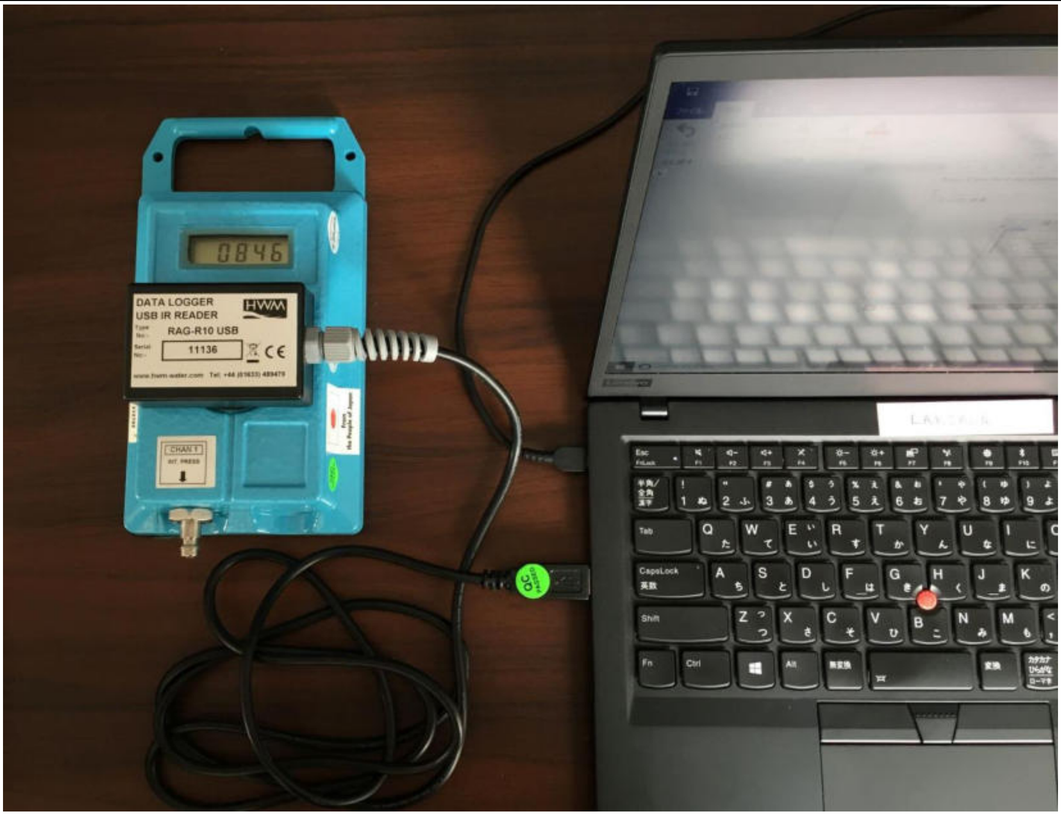


Screw the Brass Union on to the connector.

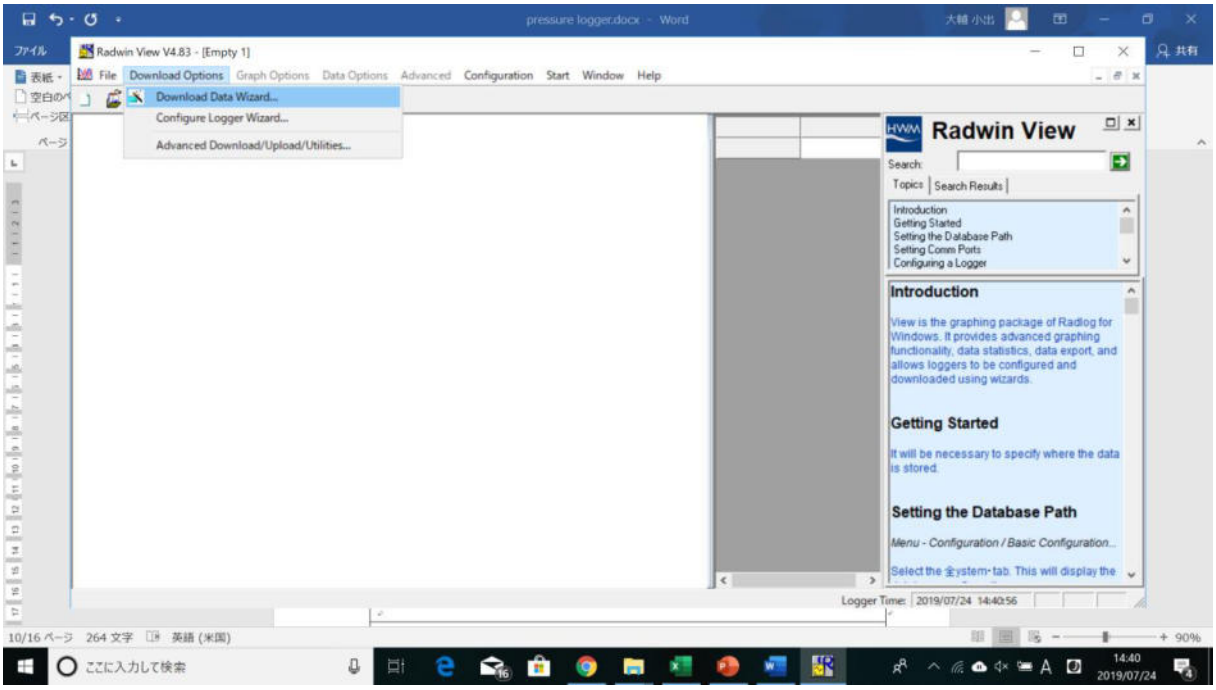
Connect all parts.

Remove a domestic tap. (It should be a direct line, not from a tank,)
Screw the brass part on to the pipe, then start logging.

4. Downloading Logs

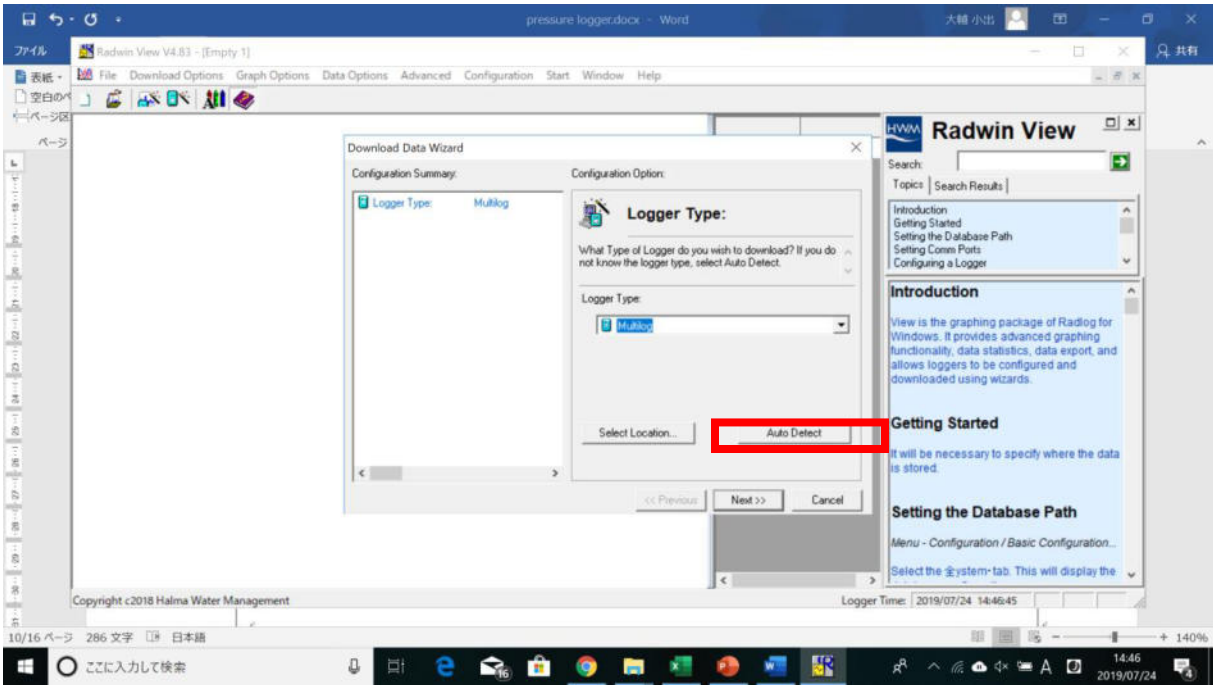
Connect the pressure logger to PC



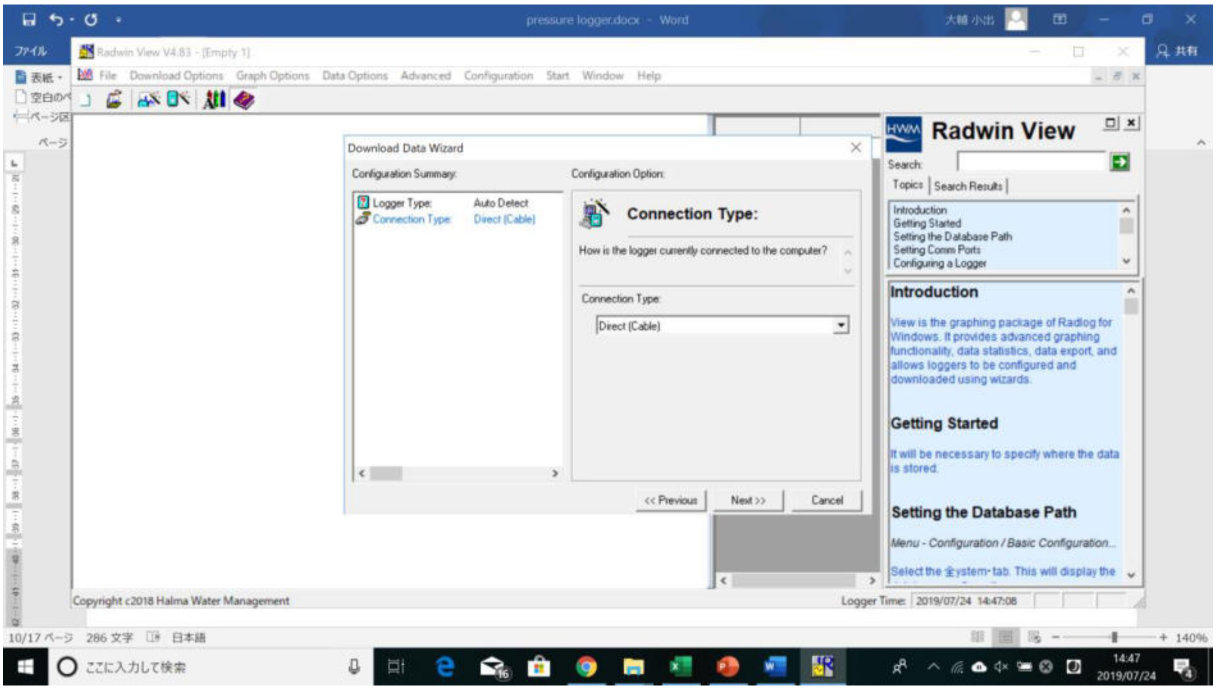
Select "Download Options" from command bar, and choose "Download Data Wizard" as below.



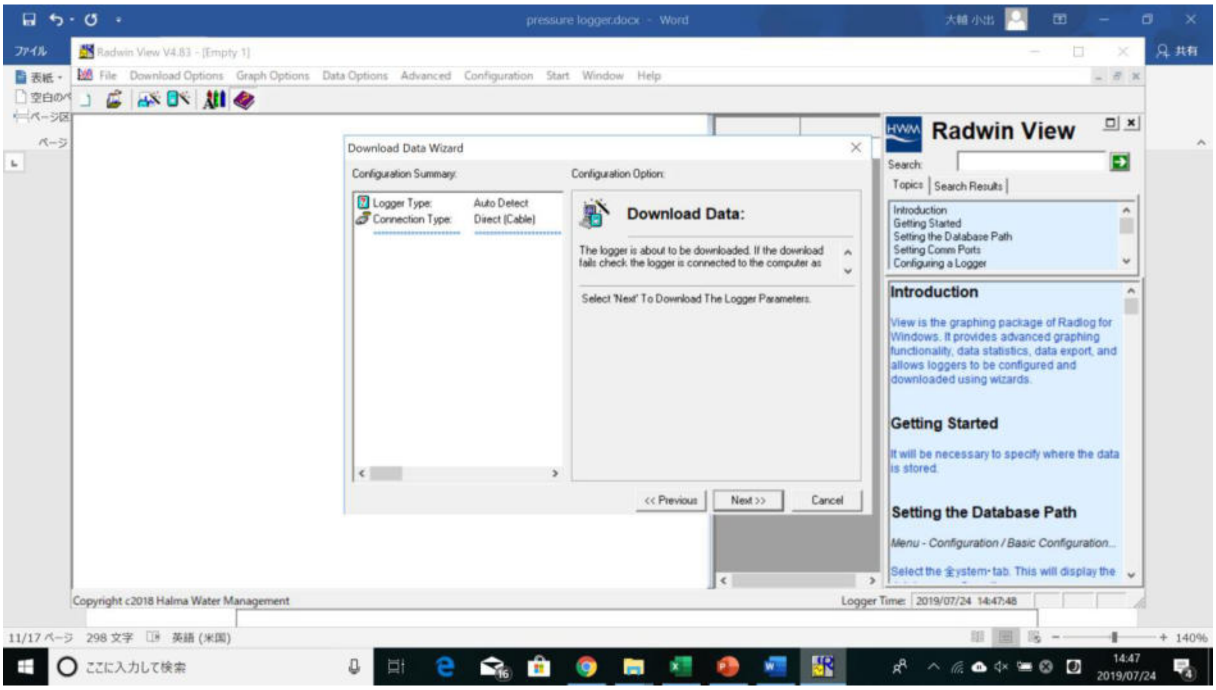
Logger Type Select Menu will open. Press “Auto Detect”, then “Next”.



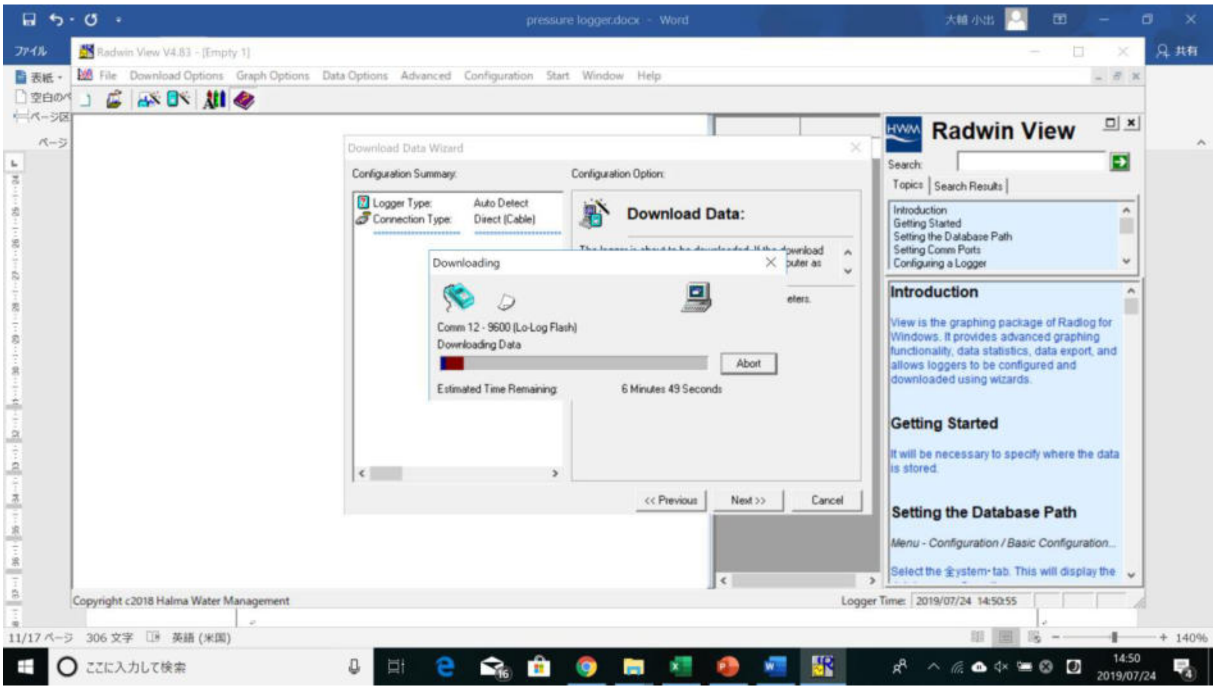
Connection Select Menu will open. Select “Direct [Cable]” from dropdown list, then “Next”.



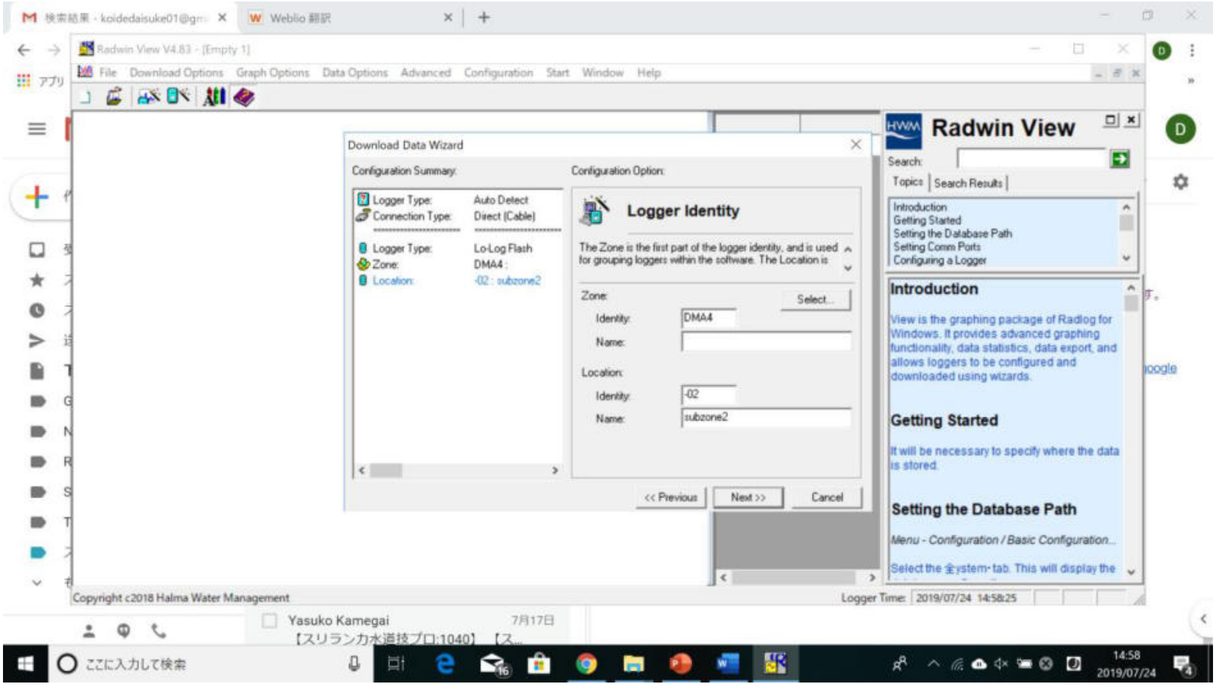
Download Data menu will open. Then select “Next”.



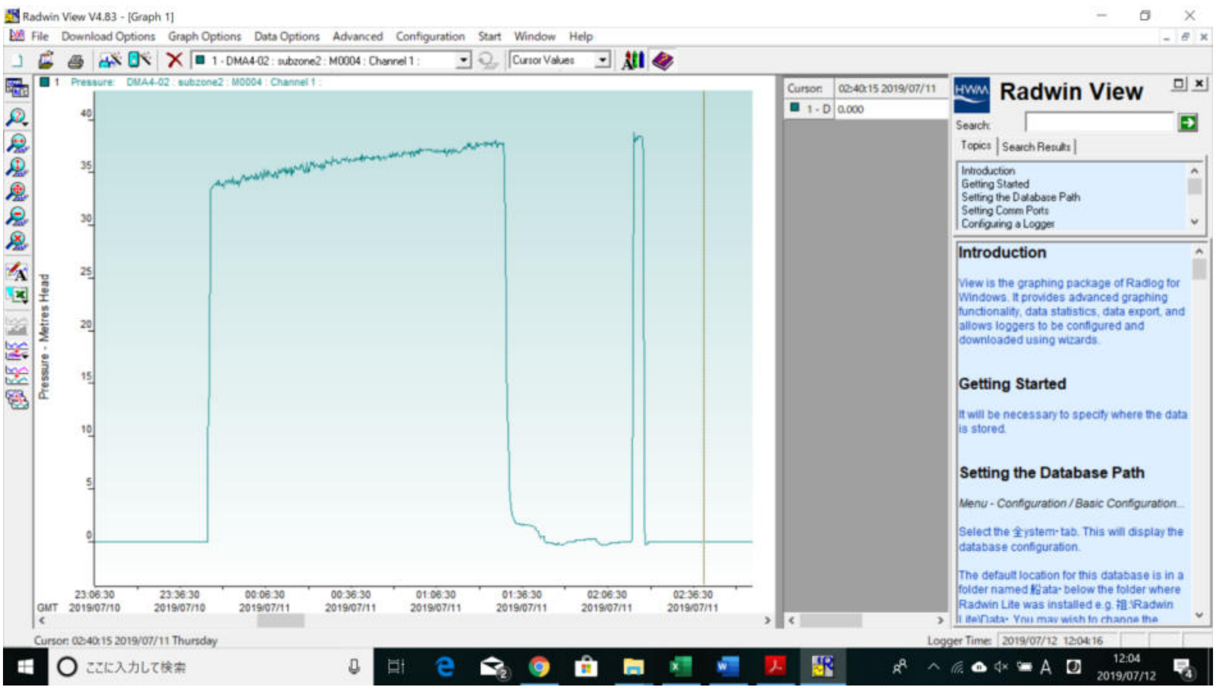
Download Process is carried out.

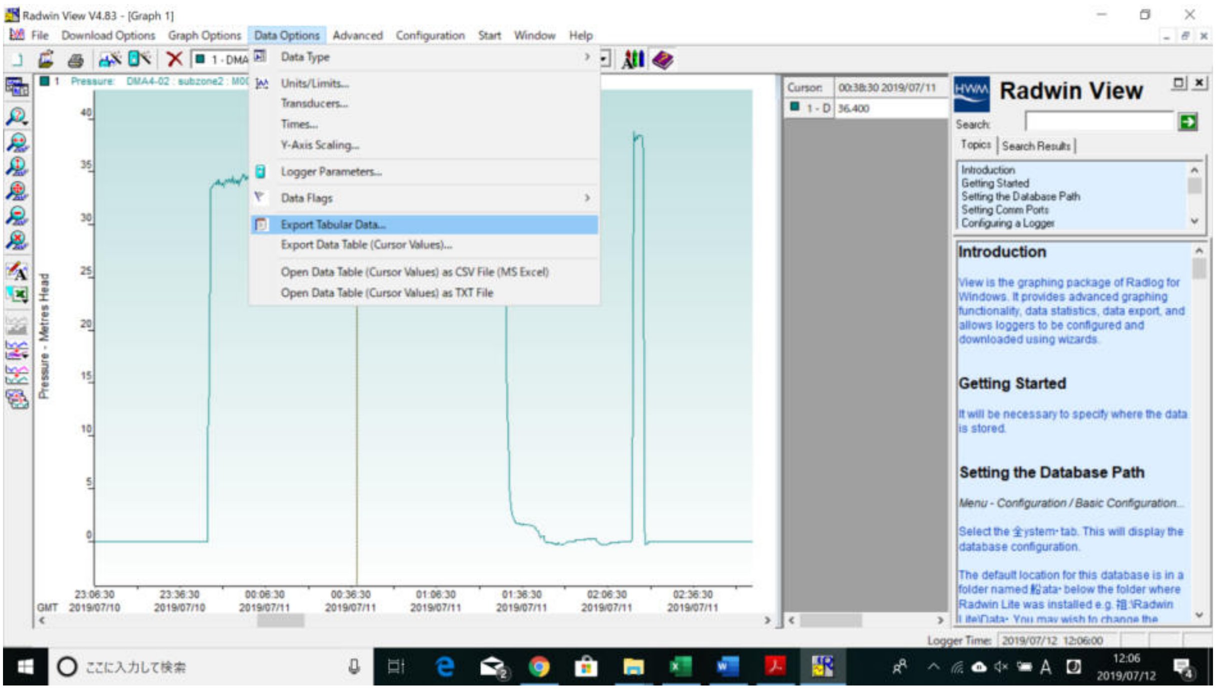
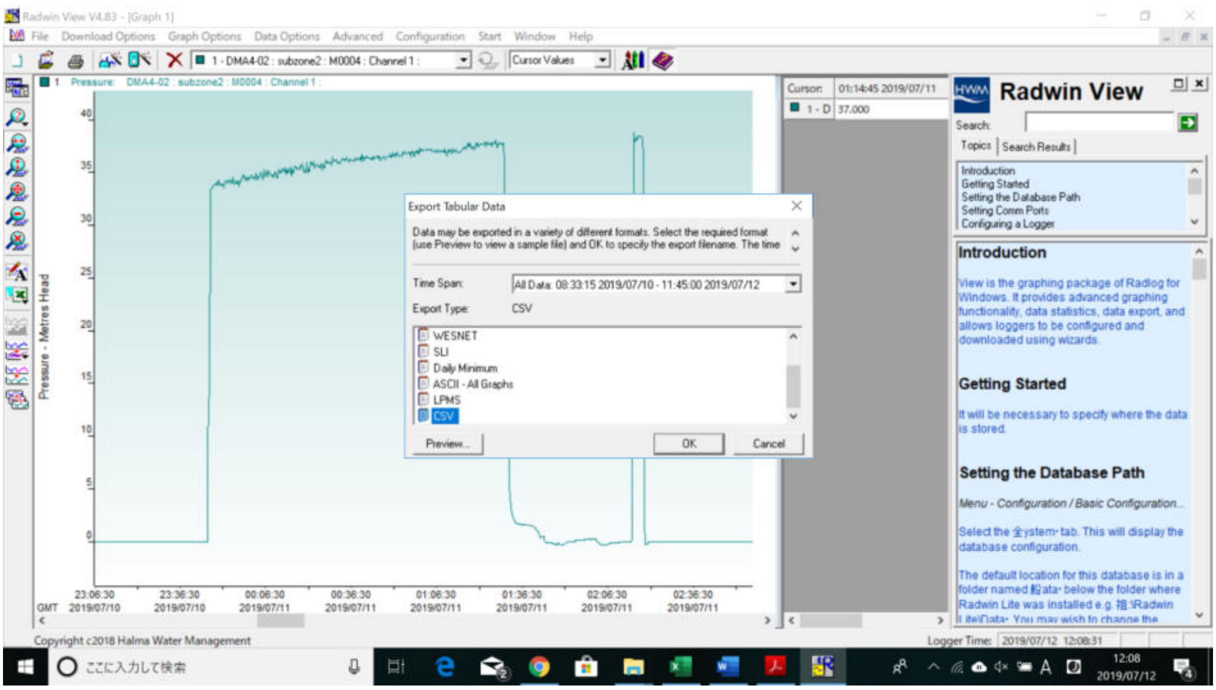


Logger Identify menu will open. Select “Next”. After this, select “Next” several times.



Then logged data will appear.



Select “Data Options” from Command bar, and choose “Export Tabular Data”.

Time Span should be “All Data”, “CSV” may be fine in Export Type. Then you can get CSV file so that you can make and edit a graph by Excel for your report.


End

Appendix 6.3 Tapping Machine

Brand : PIPELINE TECHNOLOGY Ltd

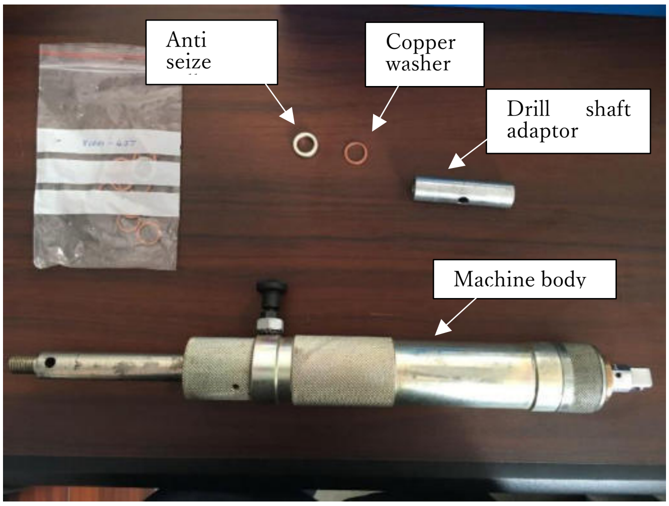
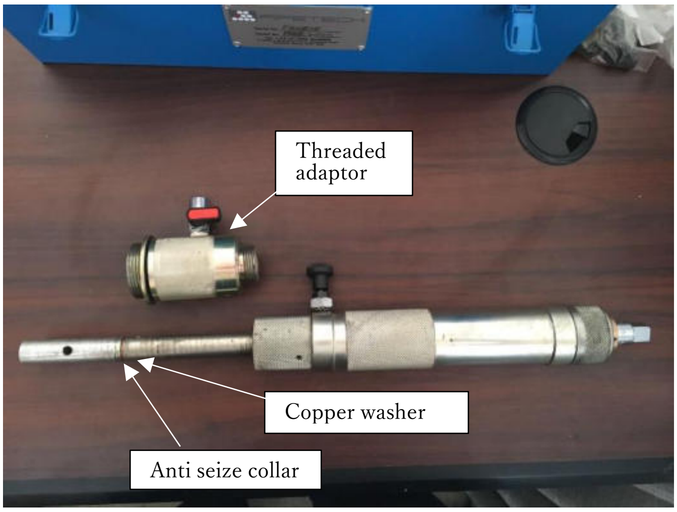
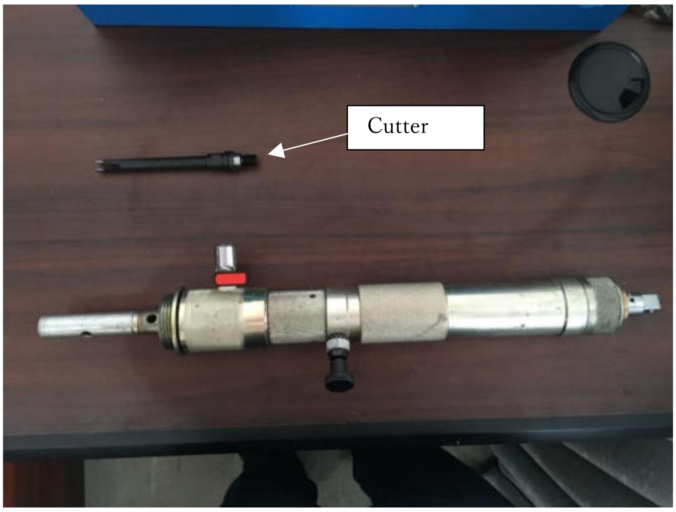
Model : PQR4000

Country : UK

Contents of this manual

1. Drilling
2. Plug insertion

Note: PQR4000 is applicable to uPVC, PE, DI for drilling.

	1. Remove the Drilling Machine Body from the Box.
	2 Screw the special Drill Shaft Adaptor onto the Main Drill Spindle, ensuring the anti-seize collar and a copper washer are located on the male thread.
	3 Attach a suitable Threaded Adaptor to the machine body thread, and tighten using the appropriate C spanners making sure the O Ring creates a good clean seal.

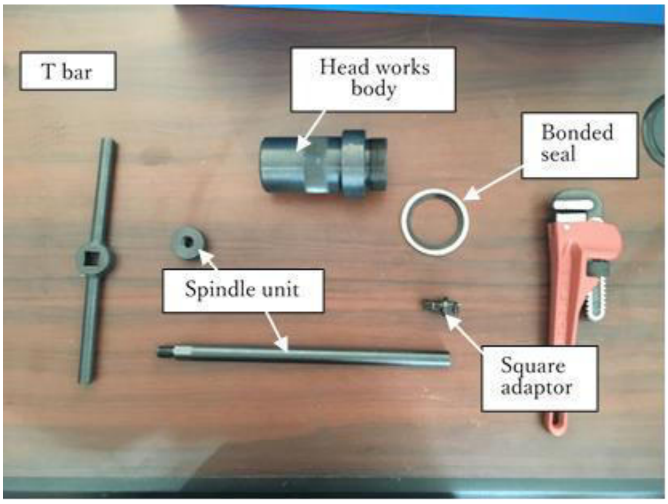
	4 Attach the required Cutter.
	5 Turn the Feed nut, in an anti-clockwise direction to retract the drill spindle and the appropriate cutter into the chamber of the threaded adaptor.
	6. Screw the drilling machine and threaded adaptor containing the desired cutter to the valve and fully tighten using the correct C Spanner.

7 Turn the handwheel on the valve in an anti-clockwise direction to ensure the valve is fully open.

	8. Feed the machine down carefully until the drill touches the main, this can be seen when a gap appears between the Stop Plate item 1 and the Spring Retaining Cap.
	9. As soon as this touches, the drill spindle needs to be rotated clockwise with the Ratchet Brace.

10. Continue rotating the drill spindle ensuring a minimum gap of 4 to 6 mm is maintained between the two faces of Stop Plate item 1, and Spring Retaining Cap Item 2. When the cutter starts to break through the pipeline the gap should be reduced to a minimum to avoid snatching.

When drilling PVC pipe the gap should be reduced to a maximum of 1 mm.

11. The gap between the two faces ensures the drill is under a constant load, which will improve the drilling operation and life expectancy of the cutters. **However care should be taken not to increase the gap beyond 20 mm.** In the event of the cutter becoming difficult to rotate, release the feed mechanism and restart the feed process as stated in section 8 above. *DO NOT TURN THE SPINDLE IN AN ANTI CLOCKWISE DIRECTION.*	
12. When drilling is complete retract the drill spindle fully, until the cutter is completely withdrawn into the threaded adaptor. It is impossible to withdraw the drill spindle beyond the safety limit without the Locking Pin item 7 being activated. Should this occur the pin should be pulled out and simultaneously rotate the Spindle in a Clockwise direction.	
	1. Remove the Headworks Body assembly from the box. -Head works body -Tee bar -Spindle unit -Appropriate square or plug adaptor -Bonded seal
	2. Attach the square adaptor to the spindle.

	3. Put the spindle through the head works body from the top of the spindle.

	4. Fit the T bar and bonded seal to the spindle.

	5. Fit the ferrule plug to the corresponding square adaptor. Fit the complete headworks assembly to the closed gate valve.
	6. Fully open the gate valve and push the headworks spindle down until it makes contact with the ferrule, once contact has been made, turn the Headworks Tee Bar in a Clockwise direction to insert the plug into the ferrule, continue until the unit is fully tightened.
7. Plug insertion is now complete and the unit can be withdrawn back into the headworks chamber, close valve fully before dismantling.	
8. Remove headworks assembly from valve unit, gradually open valve to ensure the unit is not pressurised. Remove Valve and ferrule adaptors.	
9. Refit ferrule banjo housing and seals. The operation is now complete.	

Appendix 6.4 Electronic Test Meter

Brand : Aichi Tokei Denki Co., Ltd.

Model : TR-IV

Country : Japan

[1] General

Electronic Test Meter TR- IV is a portable test meter which uses a electronic water meter (EDS 20) for measurement, and is equipped with a counter which can selectively display the momentary flow rate and trip accumulated amount (with reset) based on the pulse output from the water meter.

This test meter is designed to check instrumental errors of installed water meters on site.

[2] How to install the test meter

Refer to the "Installation Diagram TR-IV-APP" (on Page 6).

(1) Check the flow direction of the body.

(2) Connect each of the supplied hoses with one-touch joint (connector) (i.e., a transparent hose with connectors on the both ends for the upstream side and one with a connector on one end for the downstream side) to each joint (nipple) of the body. (Pull each hose gently to check if it is firmly connected.)

(3) Choose one of the joints (nipples) below according to the type of the tap where the test meter is to be installed and attach it to the tap:

1) Tap nipple with band (pipe-type flexible faucet 1/2 caliper (13) for tap)
2) Nipple for foam tap (e.g., single-lever type)

(4) Connect the one-touch joint (connector) on the other end of the hose connected to the upstream side of the body (i.e., the hose with connectors on both ends) to the joint (nipple) connected to the tap.

[3] Test method

3-1. Preparation (Refer to "[4] Operation procedure" for the details of how to operate the test meter to display measured data.)

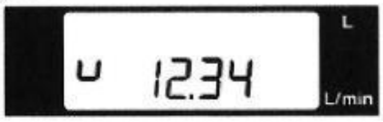
(1) Remove air from the test meter to ensure that it is full of water.

(2) Arrange the downstream hose so that it is partially higher than the test meter to prevent air from entering the meter when the water flow stops. Also be sure to place the meter horizontally.

(3) Close the valve of the body and confirm that there is no leak from the pipe.

(4) Set the counter display to the momentary flow rate.

"U" is shown to the left of the figures while the momentary flow rate is displayed, and up to four digits are displayed.



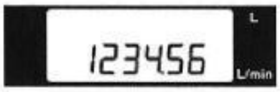
(5) Fully open the valve of the body and adjust the flow rate for inspection by adjusting the valve aperture. Use the flow rates for inspection as listed in the instrumental error achievement table (see the table below).
Note that the unit for the momentary flow rate is "L/min." Use the following formula to convert it to "L/h."

Converted flow rate (L/h) = Actual flow rate (L/min) × 60 (min/h)

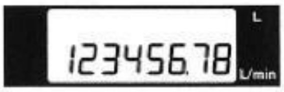
Flow rate listed in the instrumental error achievement table	Flow rate	
	L/h	L/min
High	1000	16.67
Middle	200	3.33
Low	100	1.67

(6) Close the valve of the body after adjusting the flow rate.

(7) Switch the counter display to the trip accumulated amount display in up to six digits or accumulated flow amount display in up to eight digits by pressing  and holding for approximately 3 seconds. (Display returns to the state immediately before switching to the momentary flow rate display.)
If the display has switched to the trip accumulated amount display (in up to six digits), retain it. If it has switched to the accumulated flow amount display (in up to eight digits), press  to switch to the trip accumulated amount display.



Trip accumulated amount display (in up to six digits)



Accumulated flow amount display (in up to eight digits)

(8) Press  to reset the displayed value to zero.

3-2. Inspection

(1) Read the value indicated on the inspection target meter.

(2) Fully open the valve of the body to flow 100 L of water (recommended).

(3) Close the valve of the body and read the value indicated on the inspection target meter.

(4) The instrumental error ca be calculated with the following formula:

$$\text{Instrumental error (\%)} = \frac{\text{Accumulated amount value of the inspection target meter} - \text{Accumulated amount value of the test meter}}{\text{Accumulated amount value of the test meter}} \times 100 + \text{Instrumental error compensation value}$$

Instrumental error compensation value: Add the instrumental error value for the corresponding flow rate as listed on the attached instrumental error achievement table.

(Subtract the instrumental error if it is negative.)

[4] Operation procedure

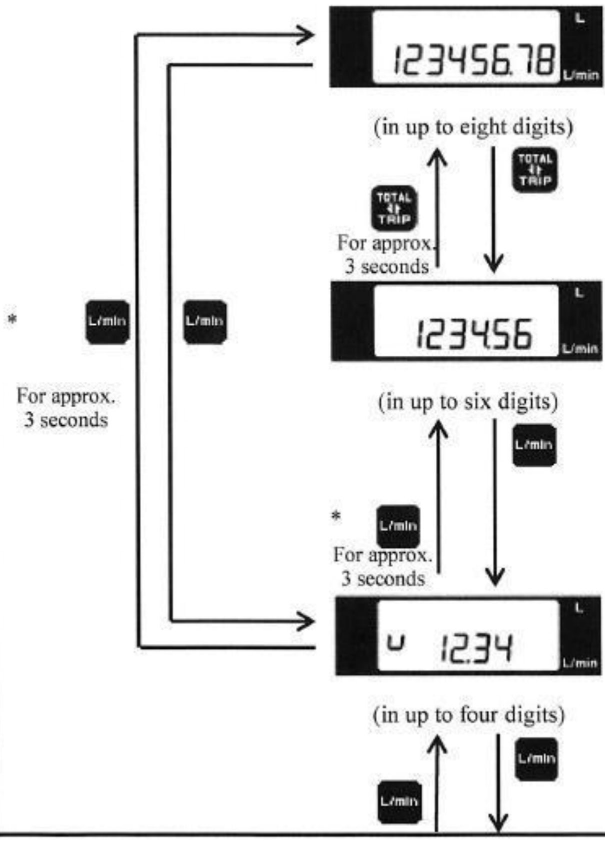
⚠ Do not hold TOTAL TRIP and L/min depressed for a long time simultaneously.

This operation transfers to the configuration mode (blinking display). If you change the configuration setting incorrectly, correct measurement will not be guaranteed.

Return to the measurement mode (solid display) by leaving the test meter for 10 seconds or longer without any operation or by pressing TOTAL TRIP.

⚠ Ensure that the display is not blinking.

Blinking display indicates that the test meter is in the configuration mode. If you change the configuration setting incorrectly, correct measurement will not be guaranteed. Return to the measurement mode (solid display) by leaving the test meter for 10 seconds or longer without any operation or by pressing TOTAL TRIP.



Accumulated flow amount display

Shows the accumulated flow amount.

Trip accumulated amount display

Shows the trip accumulated amount.

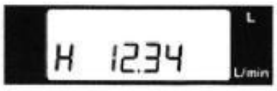
Pressing TOTAL TRIP resets the trip accumulated amount to zero.

Just transferring to the momentary flow rate display does not reset it to zero.

Momentary flow rate display

Shows the momentary flow rate.

* Pressing and holding L/min for approximately 3 seconds, the display returns to the state immediately before switching to the momentary flow rate display.



(in up to four digits)

Momentary flow rate hold display

Holds the momentary flow rate value.
Measurement of the momentary flow rate, accumulated amount, and trip accumulated amount continues during the hold display.

[5] Storage and maintenance

(1) Discharge water from the test meter completely.

(2) Attach the caps on the connection ports of the test meter to prevent dusts and foreign matters from entering the meter.

(3) Regular inspection (once in two years) is recommended in order to maintain precision of the instrumental errors.
(While the meter used in the measurement part is an officially approved device, regular inspection of the instrumental error precision is recommended since this test meter is designed to be portable.)

<table>
<tr><th colspan="3">Instrumental error achievement table</th></tr>
<tr><td>Product name</td><td colspan="2">TR-IV</td></tr>
<tr><td>Serial No.</td><td colspan="2"></td></tr>
<tr><td>Official approval term of validity</td><td colspan="2"></td></tr>
<tr><td colspan="3">This product contains a battery powered water meter which is a specified measuring instrument.</td></tr>
<tr><td>Test date</td><td colspan="2"></td></tr>
<tr><td>Test tank</td><td colspan="2">0.5m³ tank</td></tr>
<tr><td colspan="3">Instrumental error</td></tr>
<tr><td>High flow rate</td><td>Middle flow rate</td><td>Low flow rate</td></tr>
<tr><td>1000 L/h</td><td>200 L/h</td><td>100 L/h</td></tr>
<tr><td>16.7 L/min</td><td>3.3 L/min</td><td>1.7 L/min</td></tr>
<tr><td>%</td><td>%</td><td>%</td></tr>
<tr><td colspan="3">Aichi Tokei Denki Co., Ltd.
Inspection Division, Quality Assurance Headquarters
1-2-70 Chitose, Atsuta-ku, Nagoya</td></tr>
<tr><td rowspan="2">Regular inspection (once in two years) is recommended in order to maintain precision of the instrumental errors.</td><td>Approval</td><td>Creation</td></tr>
<tr><td></td><td></td></tr>
</table>

Instrumental Error Achievement Table (Standard Sample)

[6] Warranty and after-sales service

● Warranty period

If a defect which is subject to our liability should occur during the warranty period under normal use, we shall repair the product or replace it with a normal product for free.

● Repair request

When there is a failure with the meter, consult our local branch or sales office for repair with detailed description of the failure.

Note that for a repair after the warranty period, we shall repair it by your request for a charge only if the product ca be restored to the functional state by the repair.

● Warranty scope

We are making every effort to produce our products with high quality, however if a defect which is subject to our liability should occur during the warranty period under normal use, we shall repair the product or replace it with a normal product for free.

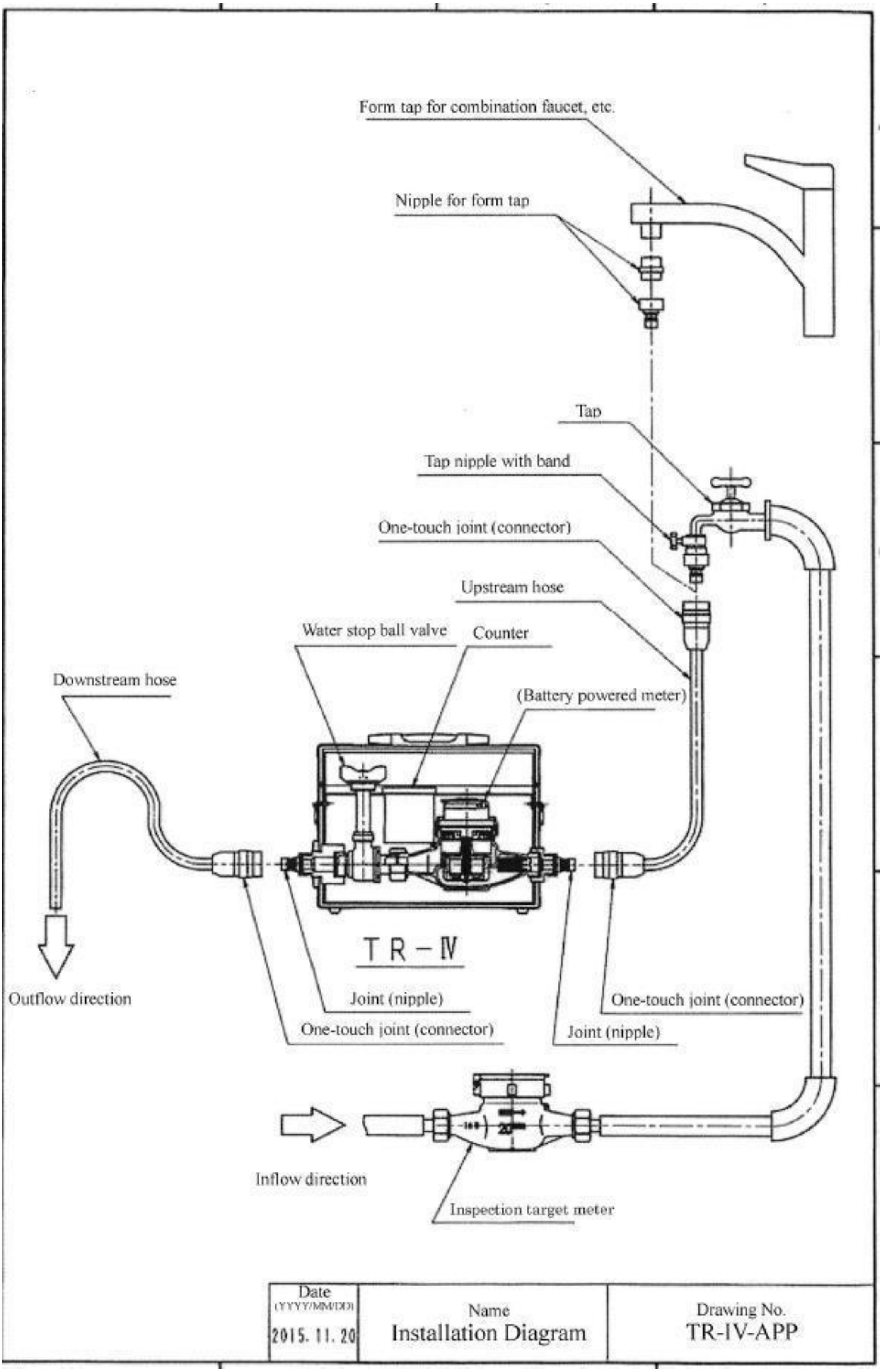
Please understand that we shall determine whether the free remedy shall apply to your situation after our investigation of the product.

Also please understand that the free remedy shall not be applied to a defect:

1) Caused by use which does not follow the instructions given in our catalog, product specifications, and/or operation manual,
2) Caused by disaster such as a fire, earthquake, storm, flood, or lightening, or a destructive act such as a crime,
3) Caused by corrosion due to use in a corrosive environment,
4) Caused by acts of animals such as a dog, cat, rat, or insect,
5) Caused by a factor other than our product,
6) Which could not be foreseen with the science and technology levels at the time of shipment,
7) Caused by a repair or alteration other than done by or specified by us, and/or
8) Caused by an inappropriate inspection and/or maintenance or replacement of a consumable.

Please note that "warranty" in this context means warranty for our product alone and we shall not reliable for any damage resulting from a defect of our product, including but not limited to a damage to equipment other than our product, loss of profit, loss of opportunity, transportation fee, and construction fee.

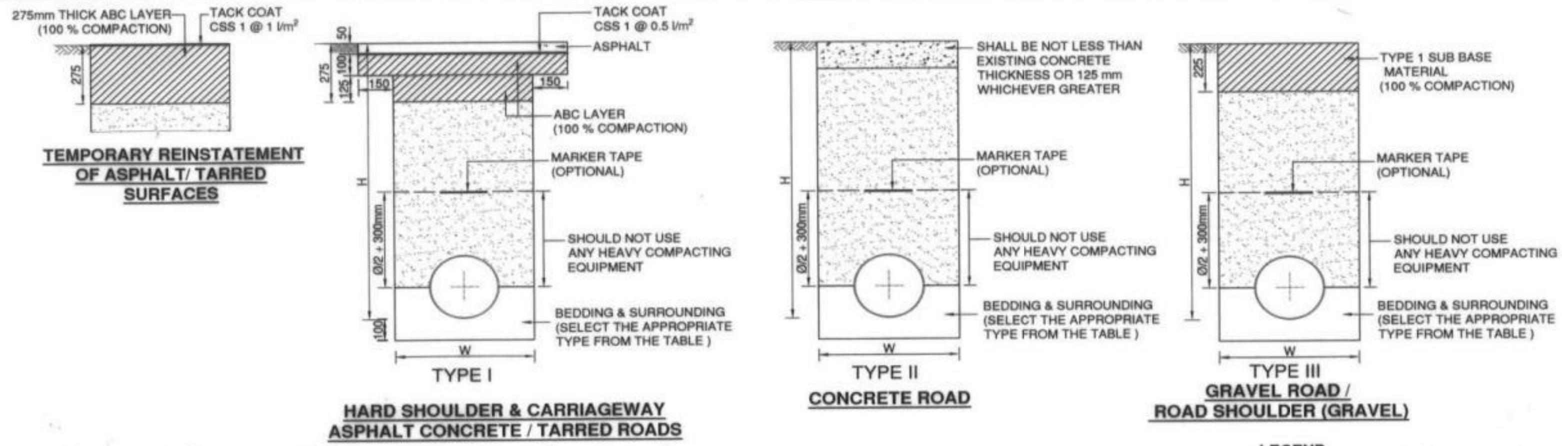
Concluded


Form tap for combination faucet, etc.
Nipple for form tap
Tap
Tap nipple with band
One-touch joint (connector)
Upstream hose
Water stop ball valve
Counter
Downstream hose
(Battery powered meter)
TR－Ⅳ
Outflow direction
Joint (nipple)
One-touch joint (connector)
Joint (nipple)
One-touch joint (connector)
Inflow direction
Inspection target meter
Date
(YYYY/MM/DD)
2015. 11. 20
Name
Installation Diagram
Drawing No.
TR-IV-APP

End

Appendix-7

Backfilling Instatement



DETAIL OF TRENCH FOR DI PIPES		
DIA(Ø) (mm)	WIDTH(W) (m)	DEPTH(H) (m)
80	0.60	0.95
100	0.60	0.95
150	0.60	1.00
200	0.60	1.20
250	0.60	1.25
300	0.60	1.30
350	0.75	1.35
400	0.90	1.40
450	0.90	1.45
500	0.90	1.50
600	1.10	1.60
700	1.20	1.70
800	1.30	1.90
900	1.50	2.00
1000	1.60	2.10
1100	1.70	2.25
1200	1.80	2.40
1400	2.00	2.60

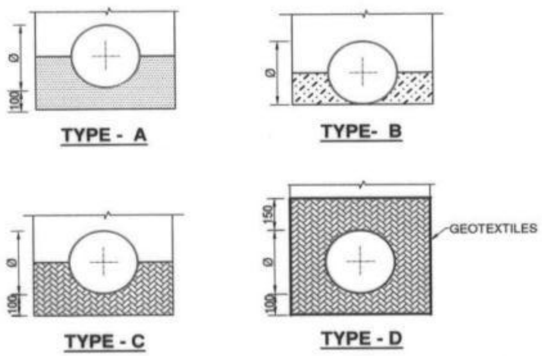
BACK FILLING AND PERMANENT REINSTATEMENT

LEGEND

- IMPORTED OR EXCAVATED SELECTED BACK FILL MATERIAL TO BE COMPACTED TO A DRY DENSITY NOT LESS THAN 98% OF MAXIMUM DRY DENSITY OF THE MATERIAL,HAVING MAX. PLASTIC LIMIT OF 15% AND LIQUID LIMIT OF 40 % AND FREE FROM STONES GREATER THAN 25mm
- QUARRY DUST / MINED SAND COMPACTED.
- EXCAVATED / IMPORTED SOIL FILL COMPACTED OF PARTICLE SIZES NOT GREATER THAN 25 mm WITH THE PROPERTIES PL<15, LL<40, CBR>20
- CRUSHED STONE (<6 mm) COMPACTED

TABLE TO SELECT APPROPRIATE BEDDING AND SURROUNDING TYPE

EXISTING SOIL CONDITION	APPROXIMATE BEARING CAPACITY KN/m²	TYPE
HARD SOIL/ROCK	>200	A
NORMAL SOIL	100-200	B
LOOSE SOIL	<200	C
CLAY	>75	C
	<75	D
PEAT/MASHY AREAS	<75	D



BEDDING AND SURROUNDING TYPES

NOTE:-

1. ALL DIMENSIONS ARE IN MILLIMETRES.
2. EXCAVATED SOIL CAN BE USED AS BACK FILLING MATERIAL IF THEY CONFORM TO THE REQUIRED SPECIFICATION.
3. IN CASE OF TYPE 'D' BEDDING AND SURROUNDING, CRUSHED STONE SHALL BE COMPLETELY SURROUNDED BY A GEOTEXTILE AS SHOWN AND AS DIRECTED BY THE ENGINEER.
   THE GEOTEXTILE FABRIC SHALL BE WOVEN POLYPROPYLINE THERMALLY BONDED HAVING FOLLOWING PROPERTIES;
   WEIGHT 150 G/M (MINIMUM) (ASTM D5261)
   TENSILE STRENGTH 9KN/m (MINIMUM) (ASTM D4595) @ 5% ELONGATION
   PERMEABILITY 30L/m²/S (MINIMUM) (BS 6906/3)(100mm WATER HEAD)
   PORE SIZE (O_{90}) <300 MICRONS (BS 6906/2).
4. AV UPPER LAYER OF 150 mm THICK ABC HAS TO BE REMOVED PRIOR TO PERMANENT REINSTATEMENT.

NOT TO SCALE

THIS DRAWING SUPERSEDES DRG. No. WT403/BT/01.

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தேசிய நீர் வழங்கல் வடிகாலமைப்புச் சபை
NATIONAL WATER SUPPLY AND DRAINAGE BOARD

TYPE DRAWING
BEDDING, SURROUNDING, BACK FILLING AND ROAD REINSTATEMENT
FOR DI PIPES

REV.	DESCRIPTION	DATE	SIGN.

K.A.V.S/ DRAWN | S.D.O.A.(D) | ENGINEER (D) | C.E. (D) | A.G.M. (P&D)/SPECIALIST | D.G.M. (P&D)
WT403/BT/01A Drg.No.
11. 07. 2018 DATE

Drawing No. WT 403/BT/01A

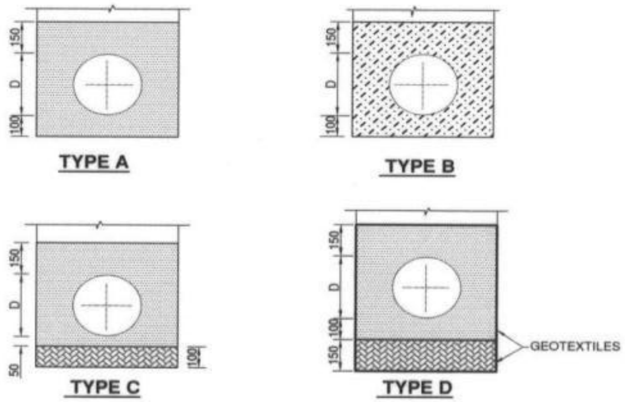
BACK FILLING & PERMANENT REINSTATEMENT

DETAIL OF TRENCH FOR PVC PIPE		
DIA(Ø) (mm)	WIDTH(W) (m)	DEPTH(H) (m)
63	0.40	0.90
90	0.45	1.10
110	0.45	1.20
160	0.60	1.20
225	0.60	1.30

DETAIL OF TRENCH FOR PE PIPES		
DIA(Ø) (mm)	WIDTH(W) (m)	DEPTH(H) (m)
90	0.40	1.00
110	0.40	1.12
125	0.40	1.14
140	0.40	1.15
160	0.45	1.17
180	0.45	1.19
200	0.45	1.21
225	0.50	1.24
250	0.50	1.26
280	0.60	1.29
315	0.60	1.33
355	0.70	1.37
400	0.70	1.41
450	0.70	1.46
500	0.75	1.51
560	0.90	1.64
630	0.90	1.64

TABLE TO SELECT APPROPRIATE BEDDING AND SURROUNDING TYPE

EXISTING SOIL CONDITION	APPROXIMATE BEARING CAPACITY KN/m²	TYPE
HARD SOIL/ROCK	>200	A
NORMAL SOIL	100-200	B
LOOSE SOIL	<100	C
CLAY	>75	C
	<75	D
PEAT/MASHY AREAS	<75	D



BEDDING AND SURROUNDING TYPES

LEGEND

- IMPORTED OR EXCAVATED SELECTED BACK FILL MATERIAL TO BE COMPACTED TO A DRY DENSITY NOT LESS THAN 98% OF MAXIMUM DRY DENSITY OF THE MATERIAL,HAVING MAX. PLASTIC LIMIT OF 15% AND LIQUID LIMIT OF 40 % AND FREE FROM STONES GREATER THAN 25mm
- QUARRY DUST / MINED SAND COMPACTED.
- EXCAVATED / IMPORTED SOIL FILL COMPACTED OF PARTICLE SIZES NOT GREATER THAN 25 mm WITH THE PROPERTIES PL<15, LL<40, CBR>20
- CRUSHED STONE (<6 mm) COMPACTED

NOTE:-

1. ALL DIMENSIONS ARE IN MILLIMETRES.
2. EXCAVATED SOIL CAN BE USED AS BACK FILLING MATERIAL IF THEY CONFORM TO THE REQUIRED SPECIFICATION.
3. IN CASE OF TYPE 'D' THE BEDDING AND SURROUNDING MATERIAL SHALL BE COMPLETELY SURROUNDED BY A GEOTEXTILE AS SHOWN AND AS DIRECTED BY THE ENGINEER.
   THE GEOTEXTILE FABRIC SHALL BE WOVEN POLYPROPYLINE THERMALLY BONDED HAVING FOLLOWING PROPERTIES;
   WEIGHT 150 G/M (MINIMUM) (ASTM D5261)
   TENSILE STRENGTH 9KN/m (MINIMUM) (ASTM D4595) @ 5% ELONGATION
   PERMEABILITY 30L/m²/S (MINIMUM) (BS 6906/3)(100mm WATER HEAD)
   PORE SIZE (0_{90}) <300 MICRONS (BS 6906/2).
4. AN UPPER LAYER OF 150 mm THICK ABC HAS TO BE REMOVED PRIOR TO PERMANENT REINSTATEMENT.

NOT TO SCALE

THIS DRAWING SUPERSEDES DRG. No. WT403/BT/02.

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தேசிய நீர் வழங்கல் வடிகாலமைப்புச் சபை
NATIONAL WATER SUPPLY AND DRAINAGE BOARD

TYPE DRAWING
BEDDING AND SURROUNDING, BACK FILLING AND ROAD REINSTATEMENT
FOR uPVC & PE PIPES

REV. | DESCRIPTION | DATE | SIGN.

K.A.V.S/Ramyamali — DRAWN; S.D.O.A.(D); ENGINEER (D); C.E. (D); A.G.M. (P&D)/SPECIALIST; D.G.M. (P&D)

WT403/BT/02A Drg.No.
11. 07. 2018 DATE

Drawing No. WT 403/BT/02A

Appendix-8

THEFT PREVENTION STRATEGY

CHAPTER 7

THEFT PREVENTION STRATEGY

7.1 Introduction

For the year 2010, NWSDB estimated that 17,000 m^3/day of water was being illegally extracted from the system. At the average supply cost of Rs. 30 per m^3, NWSDB is losing about Rs. 190 million each year. This is a huge number, which strongly suggests a serious effort be made to apprehend the persons who are guilty of this theft and to strengthen the current legislation to make it easier for NWSDB to sue illegal users and recover the cost of the stolen water.
NWSDB has already introduced Illegal Connection Detection Unit which carryout search on a predetermined programme and it has shown remarkable results.

7.2 Pertinent Tools and methods for managing unauthorized use of water

Unauthorized water use, or theft, occurs through certain deliberate actions of customers or other users who draw water from the system unlawfully without making any payment to NWSDB.

The ways in which the theft, or unauthorised consumption, is taking place in a water supply system include

- illegal connections,
- illegal-reconnections after disconnection
- meter by-passes by customers
- tampering of meters
- abuse of fire hydrants.

In general, the unauthorized water use is a sociocultural and technical problem that involves not only engineering solutions but also socio-cultural approaches.

These approaches should finally deliver:

a) changes in behavior and attitudes of the community towards water use
b) a strong policy against dishonest, deceitful and fraudulent practices of water users as well as any NWSDB staff who might be involved.

The socio-cultural based approaches should be planned and implemented with the active participation of local communities at the lowest administrative level together with street level consumers and NWSDB staff working in the same area. It is reported that these types of approaches to make everyone to participate in the endeavour has produced results and are being the major drivers in reducing NRW in some Asian cities experiencing similar problems to Colombo.

In the east zone of Metro Manila where NRW has been reduced from 63% to 11% in the past 14 years saving over 0.6 million m3 of water per day (Luczon and Ramos 2012- Water Loss Management 2012).

Hence some possible measures to minimise or eliminate illegal use of water shall include:

- **Socio Economic Aspect**:
  The reports show that high number of illegal use cases are reported in cities which are attributed to poverty and unplanned settlements (slums).

  Another form of unauthorized consumption is due to illegal reconnections by disconnected customers due to non-payment of bills.
  Some reports alleged that some field plumbers actually carry out the illegal connections and reconnections to earn extra income.

  This covers the customers as well as the employees of NWSDB. The illegal connections, meter by-passes and illegal reconnections of disconnected properties are carried out by the connivance of employees of NWSDB or by some field plumbers.

- **Cultural Aspects**:
  The cultural factors and attitude of the community also influence to illegal use of water by one the forms explained above.

  Hence, Illegal use of water is a complex social-technical problem that needs social-cultural approaches.

  Reports show that not only poor communities, but also some commercial and priority customers, attempt to use illegal consumption. There is no doubt that some people affected by psychological effect of kleptomania will also include stealing water by illegal means as one of their objectives.

- **Governance issues:**
  Poor Governance has also been regarded as the root of the NRW problems. Water theft in countries with high levels of corruption, low government effectiveness, political instability and ineffective accountability appears to be on the rise and water revenues can be significantly affected. The fines levied in courts of law are often too low, a fact that can act as a deterrent to the authorities to enforce law.

7.3 Possible Options to Reduce Theft of Water

The reduction of Apparent Losses, particularly theft prevention, results in increased revenues and enhanced financial viability of the utility. Most utility operators prefer to have quick results and quick boost in revenues. Whereas, the Apparent Losses reduction Strategies falls far beyond conventional engineering approaches to tactical managerial solutions that primarily encompass social and behavioural sciences. As reported it cannot totally be eradicated but the following interventions have proved to be promising and to have contributed effectively in minimizing theft and reduction in Apparent Loss:

a) Amnesty:

Providing Amnesty for illegal connections, have reported successful results. The period shall be one to three months. The media and special campaign shall be launched to get the public cooperation. Regularising the connection shall be a simple affordable to the community.
It is suggested that those found with illegal connections after the amnesty period should be convicted in courts of law and heavy penalties be levied.

The Amnesty system did not produce good results in Colombo City in the past and has not been considered further by NWSDB.

b) Incentives:

NWSDB shall provide employees and the public with incentives, such as cash rewards, for reporting illegal use of water. This is also found to be very effective. NWSDB employees need genuine incentives and rewards for their effort made for detecting illegal connections, meter bypasses, illegal re-connections and erroneous meter readings.
The IDU unit handles this aspect and discussion reveals that this need to further improved to motivate the staff involved.

c) Survey of Entire CMC area and Updating GIS database

A programme of sweep to cover the survey of the entire CMC area in a systematic way from North of the City to the South is essential.

With the impending ADB Colombo Water Supply Service Improvement Project, large sections of the distribution system will be rehabilitated and replaced. Before this work gets underway it is recommended that the IDU, temporarily reinforced by additional gangs, undertake a series of sweeps which would cover the entire CMC a systematic way from North of the City to the South. The objective would be to identify as many regular and illegal connections as possible on each sweep and record the locations on GIS maps. The system upgrade can then follow. Thereafter, the second stage survey on selected premises should be continued and any areas locations previously noted as suspicious can fall under surprised check,

d) Formation of Consumer Societies/ Street Committee

A street committee shall be formed comprising the representatives of the area and NWSDB officers to survey and investigate and report any illicit use of water in the area. Public cooperation is essential.

Periodical survey and consumption pattern survey and low consumption or sudden drop in consumption shall be investigated. Meter readers shall be trained and be motivated in this regard.

e) Periodical and Surprised Checks of Disconnected Premises

All disconnected premises shall be periodically inspected with extra interventions by surprised checks too.

7.4 Provide Seal on Customer Meters

General observations on Customer Meters

The following photograph shows a typical consumer meter recently installed, (just outside the project office) but not in accordance with NWSDB's protocol – the error.

There is no NWSDB wiring and lead seal on the meter unions and no lead seal on the meter.

Figure 7.1: Customer Meter

It was easy to unscrew the lock nuts by hand, no special tools were necessary. It would have been quite simple, therefore, to insert a short piece of pipe and keep it in place until nearby the time the next meter reading was due. At least, in this case the meter was wired (though not sealed). In other instances, where the meter is not sealed or where the seal is no longer intact, it would be possible to modify the meter and replace it to work in the reverse direction and reduce the meter reading. Done with a minimum amount of care, neither operation would leave any evidence of tampering.

The obvious solution is to ensure that the meter and its lock nuts are installed correctly with wiring and seals. Without this first level of protection, there will be a constant temptation for so-minded people to cheat the system. On the other hand, with this first level of protection in place, most property owners will accept the situation as normal, as they do for the electric meters, where there are fewer tendencies for tampering for obvious reasons.

Recommendation

An immediate action NWSDB could make would be to enforce its own regulations that require wiring and sealing of the meters and the lock nuts that attach the meter to the property connection pipe at its inlet and outlet ends

Subsections under Strategy Item 6: *Leakage Prevention Strategy* recommends that regular "sweeps" of property connections be carried out to detect those which are leaking. It is recommended that the "sweeps" also include an inspection of the installed meter and its lock nuts to ensure that all the required wires are in place and correctly sealed as required by NWSDB regulations.

Attachment 3: Leakage repair record sheet

The Project for Enhancement of Operational Efficiency and Asset Management Capacity of Regional Support Center-Western South of NWSDB in Sri Lanka

Serial number

Leak Repair Detail Sheet	National Water Supply & Drainage Board							
	Office							
	OIC				Zone			
	Officer							
Work day	Day				Time			
Attendance day	Day							
Work reason	Complain	Meter reader		Leak detection		Other		
Compainer's name & add								
Leakage location	Adress							
	Meter No.							
	Consumer No.							
	Coordinate							
Type of Leak	Meter	Connection pipe(Joint , pipe)			Ferrule		Distribution pipe	
Cause of Leak								
Nature of repair	Diameter & Material							
Leake repair	Yes		No		Leak volume			M3/h
Material of use								

Machinery Used		Location(Sketch)
(1)	Power Light (1.5.1)Hrs	
(2)	Night work (1.5.2)Hrs	
(3)	Water Pump(Dewatering)Hrs	
(4)	Others	

Measurment

BOQ Item No.	Description	Unit	L(m)	B(m)	D(m)	Oty

Comment

Contractor Officer   Zone Officer   NWSDB Officer

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අනුක්‍රමික අංකය					
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	වැඩභාර නිලධාරී		කලාපය		
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වැඩ කළ දිනය	දිනය		වේලාව		
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	මනු අංකය				
	පාරිභෝගිකගේ අංකය.				
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භාවිතාකළ ද්‍රව්‍ය					

භාවිතා කරන යන්ත්‍රෝපකරණ		ස්ථානය(සිතියම)
(1)	ආලෝක ශක්තිය (1.5.1) පැය	
(2)	රාත්‍රී වැඩ (1.5.2) පැය	
(3)	ජලය පොම්ප කිරීම (ජලය ඉවත් කිරීම)පැය	
(4)	වෙනත්	

මිනුම්

ප්‍රමාණ බිල්පත්(BOQ) අයිතමය අංකය	විස්තරය	ඒකකය	දිග (මීටර)	පළල (මීටර)	ගැඹුර (මීටර)	ප්‍රමාණය

අදහස්

කොන්ත්‍රාත් නිලධාරී ____________ කලාප භාර නිලධාරී ____________ NWSDB නිලධාරී ____________

Attachment 4: Output 2 Capacity assessment sheet

QUESTIONNAIRE SHEET 1

CAPACITY ASSESSMENT FOR OUTPUT2(Pilot Activity) of The Project for Enhancement of Operational Efficiency and Asset Management Capacity of RSCWS of NWSDB in Sri Lanka

Name:________________ Assignment of this Project:________________ Date:________

Organization:________________ Position and working place:________________

Personal records and General Questions	ANSWER	
Academic background		
Specialties		
How many years have you belonged to NWSDB or current organization ?	____ years	
What is your main roles and responsibility in NWSDB?		
Have you ever participated in NRW reduction project (especially leakage control) conducted by other parties ?		
If so, what is your main role on the project ?		
What kind of problem or difficulties do you have for doing leakage control activities?		
What do you expect for this project?		

How to Answer(Please select number 1 - 5)		
	1	Poor knowledge
	2	Have a fair knowledge.
	3	Have fair knowledge and practical experience.
	4	Have sufficient knowledge and practical experience
	5	Have sufficient knowledge and practical experience. And can teach other staff

CHECK ITEM	TIMING ON ANSWER			NOTE
	Jan,2019			
1.Basic Knowledge of NRW				
I understand what is IWA Water Balance Component				
I understand what is Billed water component				
I understand what is NRW component				
I understand why NRW is an important issue				
I understand what is Authorized Consumption Component				
I understand what is Water losses Component				
I can calculate NRW ratio				
2.Planning on NRW countermeasure				
I can plan NRW reduction activities for Real (Physical) losses				
I can plan NRW reduction activities for Apparent(Commrcial) losses				
I can plan DMA creation				
I can evaluate customer consumption data				
I have cost estimation knowledge for NRW reduction activities				
3.Leak detection(Real Losses)				
I understand cause of Leakage				
I have knowledge of leak detection survey method & Equipment shown as below	/	/	/	
1,Flow Measurement, Minimum Night Flow, Step test				
2,Leak detection				
3,Pressure Measurement				
4.Pipe locating method				
I can estimate leakage volume on the leaking pipe				
I understand the cause of revival of leakage				
4. Leakage repair work				
I understand proper leakage repair work and pipe replace work	/	/	/	
1, Meter				
2,Service pipe				
3,Ferrul(Branch connection)				
4,Distribution Pipe				
I understand the need for pipe washing after water suspension during construction work				
I understand safety management regarding construction work				
I can supervise repair work and pipe laying work (service pipe)				
I can supervise repair work and pipe laying work (distribution pipe)				
5.Commercial losses(Apparent losses)				
I understand commercial loss survey method	/	/	/	
1, Meter inaccuracy				
2, Illegal connection				
3, Water use amount by NWSDB themselves				
4, Unbilled metered consumption, discount for specific parties(Army, temple, Government office, etc.,,)				
6.Data collection				
I understand the necessary data for NRW reduction activities				
I understand how to collect the necessary data				
I understand the necessary data for Aseet Management				

Your Comments: