

S13.3-7 無収水削減に係る訓練（漏水探知）

The Project for Improvement of Non-Revenue Water Reduction Capacity for SW in Solomon Islands

Training for the NRW reduction

August, 2013

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JICA Expert Team

Contents

1. Presentation
 - How NRW reduction activities are conducted?
 - How do we detect leakage?
 - How have we got achievement?
2. Demonstration on the test pipe at leaf hat
 - Acoustic (Listening stick)
 - Pinpointing (Water leak detector)
 - Correlation (Leak noise correlator)

IWA's Terminology for NRW

System Input Volume	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption	Revenue Water
	Water Losses	Unbilled Authorized Consumption	Billed Non-metered Consumption	
		Apparent Losses	Unbilled Metered Consumption (water used for fire fighting, etc)	
		Real Losses	Unbilled Un-metered Consumption	
		Unauthorized Consumption (Illegal connection)	Non-Revenue Water	
		Metering Inaccuracies, Meter reading error		
		Leakage on Transmission and/or Distribution Mains		
		Leakage and Overflows at Utility's		
		Leakage on Service Connecting up to Customers' Meter		

Note: Source - The categories of the International Water Association (IWA).

Flow chart of NRW reduction activities

The flow chart details the process from 'Detection of pipe leak' through 'Leakage detection' to 'Leakage repair' and 'Verification'. It lists key personnel involved at each stage, such as Mr. Benjamin Billy for leakage detection and Mr. Mathias Bera for repair.

Action ① Selection of pilot areas

Pilot Area	Distribution length (km)	Number of customer
1 Namaka	1.2	75
2 Independence Valley	1.5	65
3 Lamakilo	1.0	89
4 Mbokani Vana-1	1.0	78
5 Honabu-1	0.8	30
6 Honabu-2	0.9	50
7 Vavua Ridge	1.2	70
8 Mhararambu	1.0	60
9 Mhararambu	1.2	27
10	*	*
11	*	*
12	*	*

Image of Pilot area

- Area size: 1-2km, 50 to 100 house holds.
- Distribution area: 24 hours distribution
- Water pressure: 0.1MPa or more at the end of area
- Location: End of distribution network or branching area.
- Measurement point: One point and one direction.

Action ②-1 Preparation of survey map

➢ Action team prepares a survey map including pipe route, pipe diameter, pipe material and location of valve.

Action ②-2 Valve locating and Pipe locating at the pilot area

Valve locating

Pipe locating

Take action Using Equipment

- Buried valve locating ⇒ Metal Locator
- Unclear pipe locating ⇒ Metal Pipe Locator
- Updating on the GIS ⇒ GPS

Valve condition survey Sample sheet

No.	Valve No.	Valve Type	Valve Size	Valve Material	Valve Status	Valve Location	Valve Condition	Remarks
1								
2								
3								
4								
5								
6								
7								
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9								
10								
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12								
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Isolation check is confirmed to make sure the pilot area gets completely isolated from the neighboring area when boundary valves is closed.

Action ④ Customer survey


Customer meter check list						Name of Pilot area		
Sl. No.	Customer name	Customer ID	Registered Meter No.	Problem description (if any)	Meter condition (OK, N, U, I, M, F)	Remarks	Sl. No.	Name of Pilot area

Billing data **Customer survey**

Customer list is made and identified. Visit customers and check the current situation of water use

Customer Survey

- **Check meter condition**
Action team checks meter status by door to door survey



- Meter status is categorized into **Working, Unmetered, Defective, Unreadable, Direct connection, Disconnect, and Illegal use.**
- **Visible leakage** around customer meter and service pipe is found.

- **Collect other information**
Action team collects more information such as capacity of storage tank, number of family, number of tap etc.,

- **Find illegal use**
Some of inhabitants get water without customer registration or illegally reconnect lines after having.


- **Unregistered.**
- **Registered customers once but got disconnected**
- **House hold who parasitize to registered customer without meter**



A case of detected illegal use

Action team found out a illegal line that is connected to a swimming pool and taps by customer survey in Lengakiki, and disconnected it.

- **Conduct meter accuracy test**
Action team checks accuracy of working meter by **connecting digital test meter** to water tap, and calculate inaccuracy rate of existing meter.




Meter accuracy test will be checked twice

Meter ID	Time (min)	Tested Meter	TR-01	Tested Meter	TR-01 Meter	Tested Meter	TR-01	Difference	Error (%)
122005003	0	895	0.5	895	103.6	98	103.2	-5.2	-5.0
122005014	0	971	22.9	1072	328.4	101	100.5	-0.5	-0.5
122005140	5	289	100.0	298	116.9	98	100.9	-0.9	-0.8
122008722	4	110	854.9	108	955.4	99	100.6	-1.5	-1.5
122008726	4	289	102.5	105	413	101	100.5	-0.5	-0.5

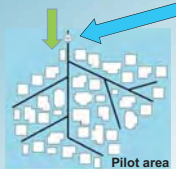

Action ⑤ Meter reading

- **Customer consumption** in the pilot area will be checked for 24 hours as a flow measurement survey.
- Meter readers **need to avoid miss-reading.**
- Flow measurement and meter reading **are conducted before and after countermeasures.**

Cross-check meter number and customer list



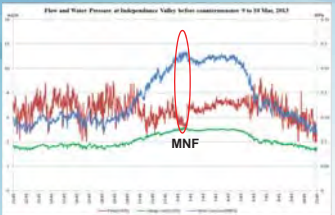
⑥ Flow meter installation and flow measurement

Flow measurement

Ultrasonic flow meter and water pressure logger

Flow and water pressure measurement





- Total inflow and water pressure
- Minimum Night Flow (Leakage volume + Night usage)

Action ⑦ Leakage detection survey

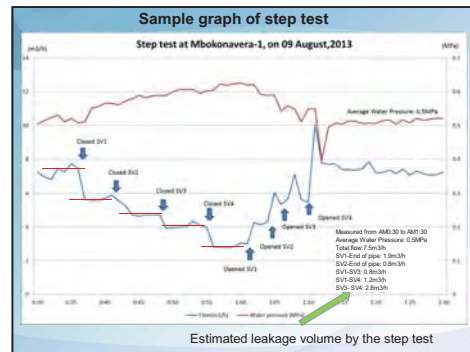
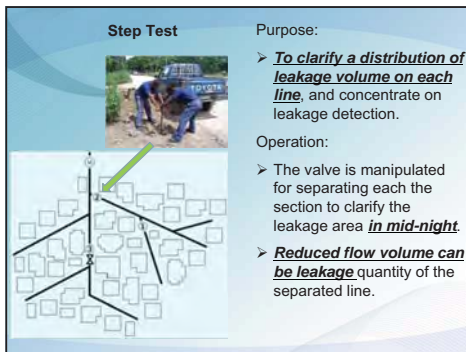
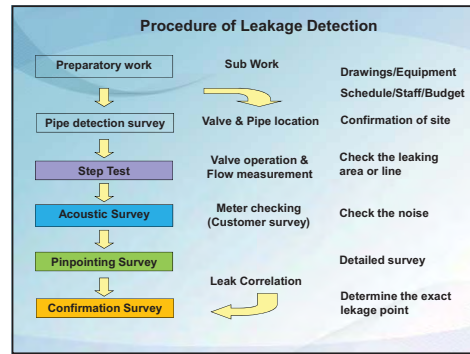
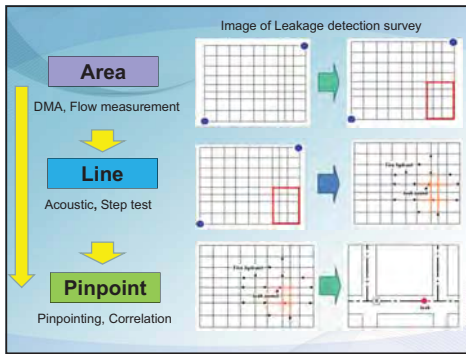
1. Visible leakage survey

- Patrol by SW staff, and report from customer
- Wet on ground (Even sunny days)
- Unknown water flows into ditch

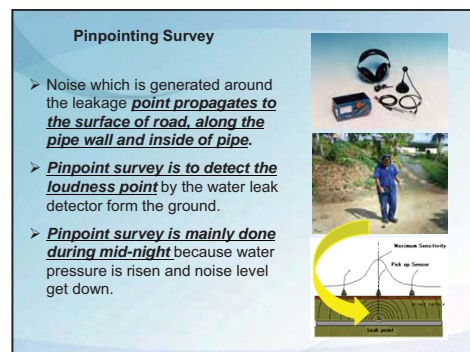
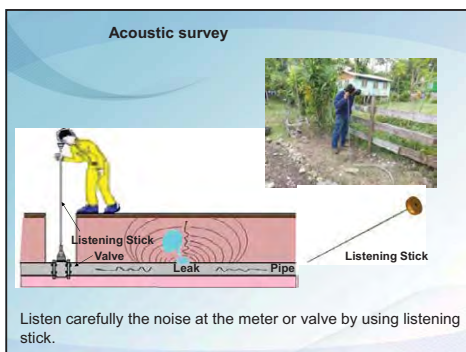
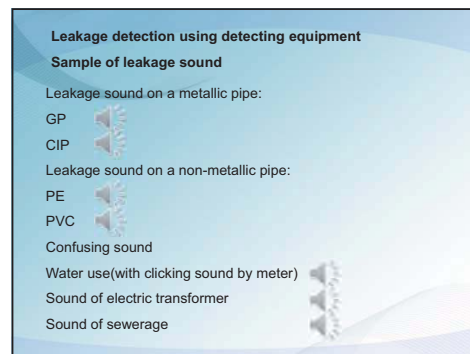
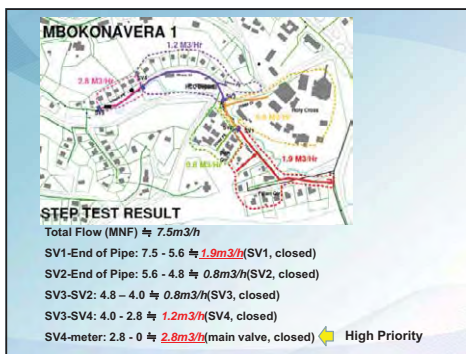



If residual chlorine contains, it must be SW's water

Unknown water is checked by residual chlorine tester



5



6

Distinguishing of leakage sound is affected by below factors.


- > **Size of leak** (Longer or Larger)
- > **Figure of leak** (Hole or Crack are better than Loose joint)
- > **Water pressure** (Higher, at least 0.15MPa or more)
- > **Material** (Metallic pipe is better than non-metallic)
- > **Diameter** (Smaller is higher)
- > **Pipe Depth** (Shallower is higher)
- > **Surface Condition** (Harder is higher)

<Difficult, Unclear> Surface condition <Easy, Clear>
 Sand ⇒ Grass ⇒ Soil ⇒ Concrete ⇒ Asphalt

- > Other condition
- **Groundwater** (water table is lower than pipe level)
- **Wind or Rain**
- **Noises** (Factory, passing car in the daytime)

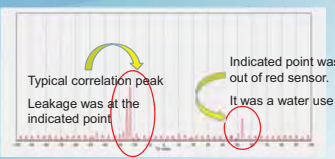
PROGRAM: METHODOLOGY OF WATER LEAKAGE DETECTION

Leak Noise Correlator can detect the leakage point



- > It is not affected by the external noises such as traffic and factory, therefore **survey is available during daytime**.
- > It is possible to detect the pinpointing even though leak sound does not reach surface due to **depth**.
- > Leakage point can be detected by inputting only three items, **pipe material, diameter and distance between two sensors**.

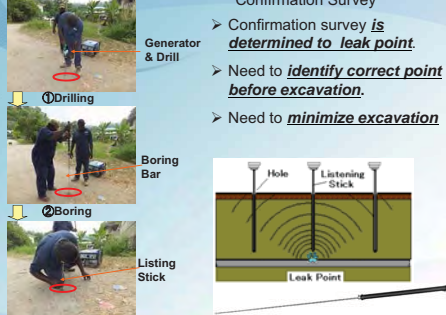
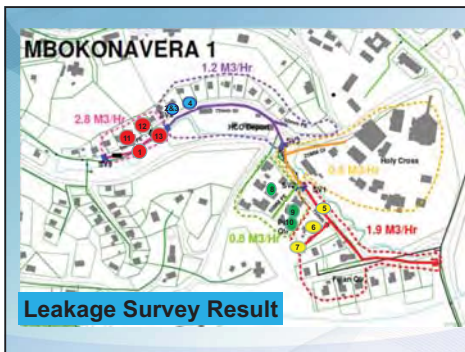
Correlation graph in Mbokonavera-1



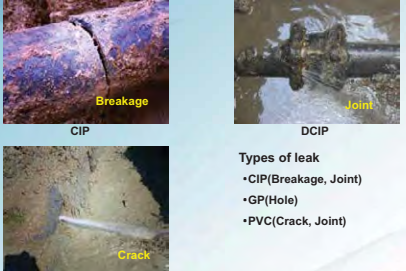
Date: 2012/08/14 Time: 15:36	Leak Position (From Blue)	16.34 m
Low Pass Filter 5000Hz	Leak Position (From Red)	46.36 m
High Pass Filter 180Hz	Delay Time	-22.90 mSec
Td Range 100 ms	Y zoom	1
Td Max 47.8 ms	Grade	A
Total 62.70 m	Pipe Diameter(mm)	Distance(m)
	A/Blue	GALV 75.0 62.70

Confirmation Survey

- > Confirmation survey **is determined to leak point**.
- > Need to **identify correct point before excavation**.
- > Need to **minimize excavation**.

Leakage repair work




Types of leak

- CIP(Breakage, Joint)
- GP(Hole)
- PVC(Crack, Joint)


Estimation of leakage quantity

It is useful to measure of leakage volume for estimation of cost benefit.

- > **Measuring cup**
- > **Weir**
- > **Measure the hole size and calculate** volume from water pressure



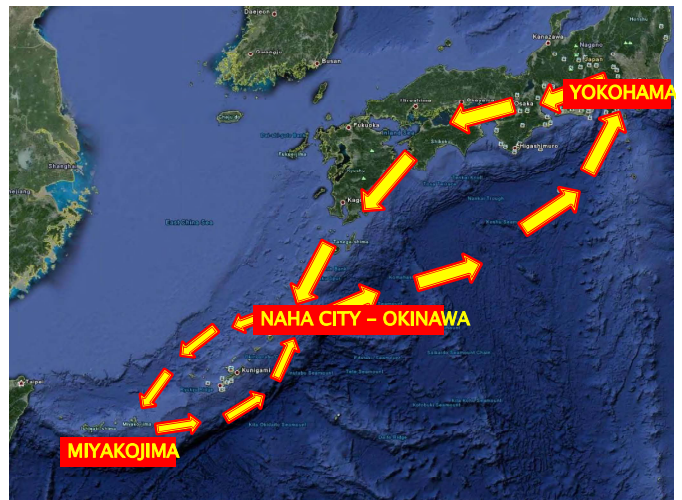
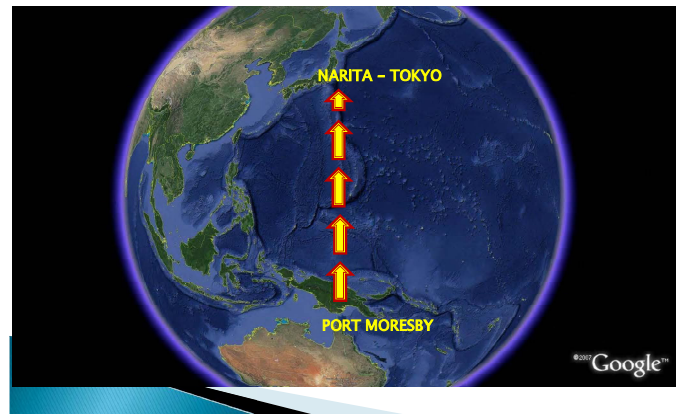
Leak repair sheet



- ← Leak information (Pipe, Location, Condition, Cause)
- ← Leak location & photo (Location, Figure)
- ← Information of leak repair

S13.3-8 第 2 次本邦研修の報告会

Action Plan for NRW Action Training October 2013



Introduction

- Training from 6th – 26th October 2013.
- Visited ~ 5 different Water Companies.
 - Yokohama Water Company
 - Yokohama Water Works Bureau
 - Okinawa Prefecture Enterprise Bureau
 - Miyakojima City Water Authority
 - Naha City Water Works

2.0 Connection Services

- Standardized Connections
- Constructions details
- Connection manual book



3.0 Leakage

- Skills in leakage detection
- Fixing of leakages
- Availability of materials in stock 24
- Proper tools for maintenance



Lesson Learnt

1.0 Network Operations

- Monitoring of water demand for each block & household per day, week, month and year.
- Consistency in installation of network fixtures.
- Documentation of data for future evaluations & improvements.

4.0 Meter Maintenance

- Keep records of meter installations
- Repair of meters
- Standard form for meter inaccuracy test



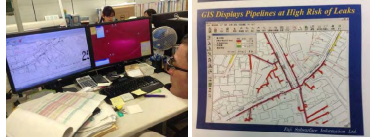
5.0 Water Quality

- Hardness of water
- Turbidity Test
- General Bacteria
- Ecoli Test



6.0 Mapping System

- Handling of Data (Construction Details)
- Data channel between onsite job and GIS



7.0 Life in Japan

- Good Food
- Reliable Transportation
- Friendly and Clean Environment



YOKOHAMA LANDMARK TOWER

Acknowledgement

Thank you Japan International Cooperation Agency(JICA) for providing and facilitating a very valuable training opportunity.

Thank you Solomon Water for having confidence in us to represent Solomon water abroad.

Japan Experience In Pictures



NISHIYA TRAINING YARD

Japan Experience In Pictures..



VISITING STORE FACILITY

Japan Experience In Pictures..



A LITTLE FEEL OF WATER QUALITY

Japan Experience In Pictures..



MANY YEARS OF CONSTRUCTION MAPS ARCHIVED

Japan Experience In Pictures..



VISITATION TO WATER SOURCE

Japan Experience In Pictures..



ONE OF FEW GIFTS PRESENTED ON SOLOMON WATER'S BEHALF

Japan Experience In Pictures..



GETTING FRIENDLY WITH LOCALS

Japan Experience In Pictures..



KURIMA ISLAND

Japan Experience In Pictures..



A WEEKEND VISIT TO SHURI CASTLE, NAHA

Japan Experience In Pictures..



WATER MUSEUM VISIT

-Arigatou gozaimashita~

**S13.3-9 無収水削減活動(夜間最小流量およびス
テップテスト)に係る集中講義**

Revised procedure on the leakage detection survey at pilot area

Revised points

(1) Procedure of step test

If MNF volume is less than $3.0\text{m}^3/\text{h}/\text{km}$ (unit flow rate), step test could be skipped.

(2) Secondary activity

Secondary activity on leakage detection should be conducted when NRW reduction point is less than 30 points and leakage ratio is more than 30% after countermeasure.

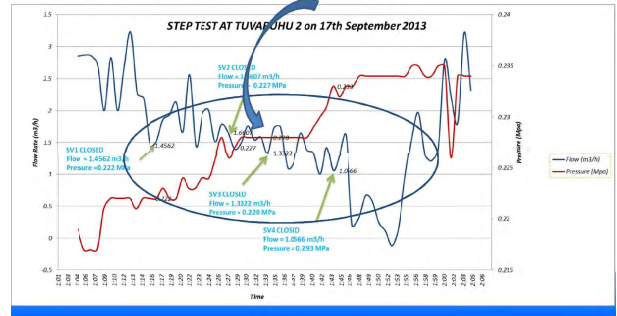
<Actions in secondary activity>

- Select the target lines that is more than $3.0\text{m}^3/\text{h}/\text{km}$ based on the previous step test.
- Install additional sluice valves on the suspected lines and conduct the step test.
- Identify leakage points on long service lines by tracing.
- Identify leakage points on main or branching points by correlator.

1. Skipping step test based on MNF unit flow

Leakage volume in each section may not be able to be identified clearly, if change of volume is small and *MNF is less than $3.0\text{m}^3/\text{h}/\text{km}$* .

For example, $1.47\text{m}^3/\text{h}/\text{km}$ in MNF rate at Tuvuru-2 as below graph, it is difficult to identify leakage volume by the change of flow in each section.



Criteria of step test is compared with unit flow of MNF

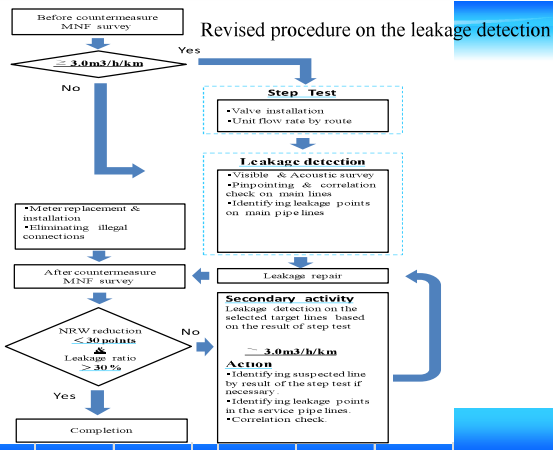
Pilot area	Distance of distribution line (m)	Number of household	MNF on Before countermeasure (m³/h)	Unit flow of rate (m³/h/km)	Necessity of step test
1	1,028	83	15.54	15.12	○
2	2,468	91	4.38	1.77	×
3	2,344	161	18.18	7.76	○
4	1,196	76	5.81	4.86	○
5	997	47	1.97	1.98	×
6	1,325	62	1.90	1.43	×

Three of six pilot areas were less than $3.0\text{m}^3/\text{h}/\text{km}$ in MNF unit flow.

(2) Advantage of skipping step test

- Activity schedule will be shorter.
- Materials for step test is saved.
- Action team is aware of MNF volume well and leakage detection procedure.

Revised procedure on the leakage detection

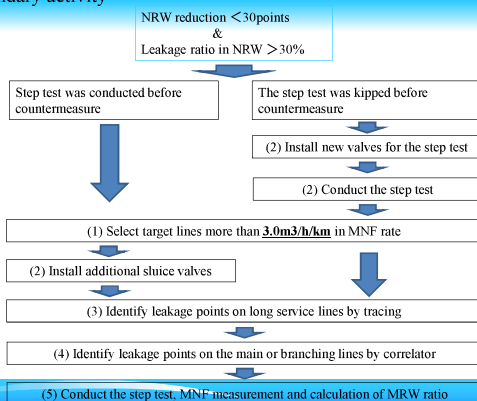


2. The Secondary Leakage Detection

Leakage detection will be conducted as the secondary activity to the pilot areas where could not reduce 30 points on NRW reduction indicator and still have over leakage ratio of 30% after countermeasure.

- (1) Select the target lines at a pilot area where step test has been conducted, and install some new sluice valves at suitable location to identify leakage points.
- (2) Conduct step test at the pilot area where step test was skipped before countermeasure.
- (3) Identify leakage points on the long service lines with high leakage volume (over $3.0\text{m}^3/\text{h}/\text{km}$) by tracing the routes that are unknown or passing through in the properties.
- (4) Identify leakage points on the main or branching points by correlator.
- (5) Conduct step test and MNF measurement of the secondary activity after leakage repair.

Secondary activity



S13.3-10 第二回検針業務に係るロール・プレイ

Team Meter Reading Role Play

Friday 29th November, SW Conference Room

Customer	Expected Response	General Attributes
<p>1. Sure Customer</p> <ul style="list-style-type: none"> • Why one month bill gets too high? • Why Sometimes no water? 	<ul style="list-style-type: none"> ➤ Possibility of in-house plumbing leakage ➤ Additional household members ➤ Save water tips (Use bucket while shower) ➤ Water Rationing ➤ Major bursts on service lines (repair in progress) 	<ul style="list-style-type: none"> ± Voice Tone ± Listening Ability ± Confidence ± Clear Explanation
<p>2. Customer with lots of Complain</p> <ul style="list-style-type: none"> • Meter Reading low and SW's high...why? • Where to you get your reading if the meter is not working? • Why other charges? • Request a new meter 	<ul style="list-style-type: none"> ➤ Meter stopped working, faulty. ➤ Average Charge ➤ Observe/verify reading and advise customer accordingly ➤ Waste Water Charge ➤ Advice customer that meter will be replaced 	
<p>3. Talkative Customer</p> <ul style="list-style-type: none"> ➤ Why Charge when no water? ➤ 	<ul style="list-style-type: none"> ➤ Explain Meter Movement(indicating water usage, if any) ➤ Explain water charges, standing charge ➤ Average Charge 	

S13.3-11 無収水削減活動に係る補習

Summary of Action Team Lecturer & Practical exercise.

Refresher Training on NRW Reduction Activities and Method


On the 24th of January the NRW Technical team, did refresher training in all NRW activities for field staff in the Solomon Water conference room.

The objective of this training:

- 1 All staff to understand and familiarise with each activity.
- 2 How to carry out these activities and what we all expected out of come each activity.
- 3 The time line of this activities & reporting and filling of Forms.

Members Present.

- 1 Mathias Bera – NRW action Team
- 2 Frank Daukalia-NRW action Team
- 3 Eric Unga – Leakage Team
- 4 Marista Kapini – NRW Consultant
- 5 Gavin Bare - GIS
- 6 Benjamin Billy – NRW Action Team
- 7 Andrew Kopeinao - Supervisor filed team
- 8 Liston Tora - Plumber
- 9 Derrick Hoa - Plumber
- 10 Mathias Dykes – Plumber
- 11 Mathew Mafe – Plumber (Leakage)
- 12 John Teno – Plumber
- 13 John Chede- Supervisor
- 14 Ishmael Aquila
- 15 Francis Hlri
- 16 Selina Fai



No.	Activities	Leading team	Supporting team	Tasks	Forms /Examples	Comments /Forms
1	Preparation of Network Drawings	GIS	TL & NM	<ul style="list-style-type: none"> • Identify pilot site network • Draw imaginary boundary around pilot sites • Print out Map for field confirmation 	a) Network Drawing	
2	Field Survey	NM & CCo & LD		<ul style="list-style-type: none"> • Identification of Valves/conditions- and Recorded in Valve condition sheet • Check for Visible leaks & Recorded in Leakage sheet • Checking connection Services 	a) Valve condition forms. b) Leakage Form. c) Customer list	

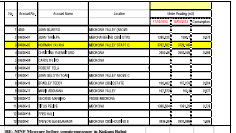
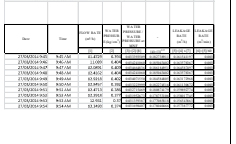
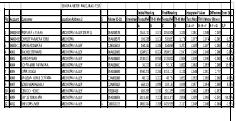
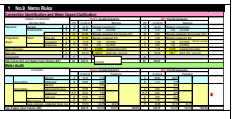
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Mode of presentation:

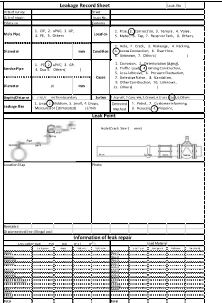

- a. Hand outs
- b. Lecture
- c. Discussion/demonstration
- d. Question and answer session.
- e. Field practical – at sites

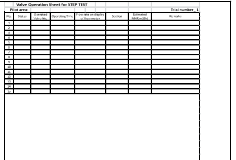
3	Preparation of Isolation and Step test	NM & Pro	LD	<ul style="list-style-type: none"> • Confirm all boundary valves & step valves • Installation of step valves • Procurement of valves and storage & delivery. 		
4	Preparation of Customer List	BL	TL & MR	<ul style="list-style-type: none"> • Identify Cycles covered by pilot sites • Billing to print out cycles confirmed by MR • Print out to be used in the field for connection Identification & Verifications 	a) Customer list	
5	On Site Awareness	PR	CCa	<ul style="list-style-type: none"> • Highlight NRW Activities & Benefits to water service in Honiara • Inform of Supporting agency who assist this program • Emphasize how we all can help address the issues of NRW. 		
6	Distribution Of Pamphlets	PR	CCa	<ul style="list-style-type: none"> • Preparation and printing of Pamphlets • Distribution to all houses at Pilot sites • Record all distribution 	a) Pamphlet	

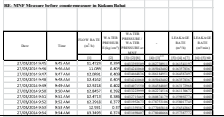
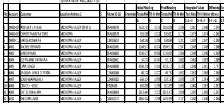
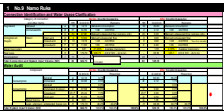
7	Connection Identification & Verification	CCo &	NM & CCo & MR & LT	<ul style="list-style-type: none"> Identify all connection for all users in the pilot sites Verified this field data with billing status Check for parasite customers. 	
8	Customer Meter functioning checks	CCo.	MR & NM & LD	<ul style="list-style-type: none"> Check all function meters Check meter buried & stop Report on meter status in the field and billing. 	

11	Customer meter reading 24 hours consumption	MR	NM & CCo & LD	<ul style="list-style-type: none"> Reading of all function meters consumption for 24 hours Using finalised meter reading list @ pilot sites 	a) Customer list	
12	MNF & Pressure Measurement	LD	NM	<ul style="list-style-type: none"> Mounting of Pressure gauge device. Measurement of MNF by setting up Bulk logging parameters 	a) Using Ultrasonic Bulk meter set up Manual procedure for mounting the meter.	
13	Customer Meter inaccuracy test(all meters)	CCo	NM, MR & LD	<ul style="list-style-type: none"> Conduct meter inaccuracy test Taken initial and final readings after 5 minutes from Meter & the test machine 	a) Meter inaccuracy form	
14	Calculation of NRW Ratio	TL		<ul style="list-style-type: none"> Documentation of all NRW components in the A3 Audit table. 	a) A3 Audit Table	
Counter measures						

S133-11-2

9	Measurements of Visible leakages	LD	NM & GIS	<ul style="list-style-type: none"> Measure (estimates) all visible leakage Correctly fill the leakage form Photo taken and recorded using white board 	a) Leakage form b) White board	
10.	Notification letter to illegal user	PR	MR	<ul style="list-style-type: none"> Preparation of Notification of letter & distribution to illegal users 	a) Illegal notification letter	

15	Step test	LD	NM	<ul style="list-style-type: none"> Set up Pressure Gauge & ultrasonic flow meter Test at mid night Begin from end of the network back to test point 	a) Step test valve turning	
16	Leakage Detection	LD	NM	<ul style="list-style-type: none"> Using acoustic listening devices, Leakage detector, Correlator Investigate invisible leakage. Check lines with flow more than 3m3/h/km 	a) Listen stick b) Leakage detector c) Correlator	
17	Pipe repairs	NM	LD	<ul style="list-style-type: none"> Fixing of visible & Invisible leakages 	a) Using the leakage sheets as reference to complete filling	
18	Legalise illegal customers	CCa	CCo	<ul style="list-style-type: none"> Customer who came after grace period to validate their accounts 	a) Customer service illegal form	
	Disconnect illegal customers	CCo	CCa	<ul style="list-style-type: none"> Customers validate legalised accounts 	a) Illegal form disconnected	
19	Customer installations(New/Replacement)	CCo & Pro	NM & LD & BL & MR	<ul style="list-style-type: none"> Installation of new meters for direct lines Replacement of faulty meters 	a) Meter inaccuracy form	

				<ul style="list-style-type: none"> Properly mount old meters which their accuracy is $\pm 5\%$ and below. 		
After Counter measures						
20	Customer meter 24 hour reading	MR	NM & CCo & LD	<ul style="list-style-type: none"> Reading of all meters after counter measure -24 hour consumption 	a) 24 reading form customer list	
21	MNF & Pressure Measurement	LD	NM	<ul style="list-style-type: none"> MNF & Pressure measures for 24 hour 	a) Using Ultrasonic Bulk meter set up Manual procedure for mounting the meter.	
22	Customer Meter inaccuracy test(random)	CCo	NM, MR & LD	<ul style="list-style-type: none"> Conduct meter inaccuracy test Taken initial and final readings after 5 minutes from Meter & the test machine 	a) Meter inaccuracy form	
23	Calculation of NRW Ratio	TL		<ul style="list-style-type: none"> Documentation of all NRW components in the A3 Audit table. 	b) A3 Audit Table	
Monitoring activities						
24	Illegal checks	CCo. & MR	LD & CCo	<ul style="list-style-type: none"> Check for illegal customer 		

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25	Leakages	LD	NM	<ul style="list-style-type: none"> Check for visible leakages & invisible if possible. Document and report to the action team for counter measures. 		

Note:

This lecture is followed by two weeks of field activity at Mbua valley and Bahai Kukum Pilot sites for practical sessions for how to carry out the activities and documentation of the data on the forms provided.

**S13.3-12 無収水削減活動（夜間最小流量および
ステップテスト）に係る集中講義**

Revised Technical Procedures of NRW Reduction

Revised Points

(1) Proposed Criteria to carry out Step Test

If the per-km flow volume of all pipelines, which is calculated through results of MNF survey, is less than 3.0m³/hr/km, step test can be skipped.

(2) Leakage Re-Detection

When the NRW reduction point is less than 30 before and after countermeasures and also leakage ratio in NRW is 30% or more after countermeasures, Leakage Re-Detection should be conducted.

Activities in Leakage Re-Detection

- Leakage re-detection along the pipeline sections targeted by step test, particularly, of which per-km flow volume is 3.0m³/hr/km or more in MNF survey.
- Leakage detection along the suspected pipeline sections by correlator.
- Leakage detection along long service pipelines and meters.

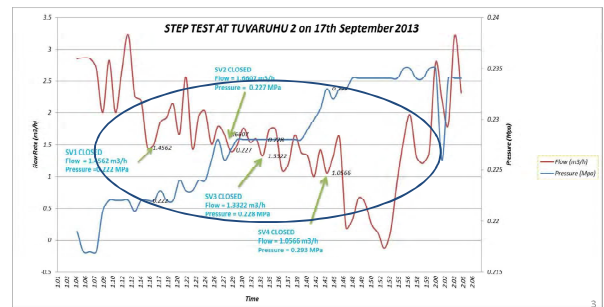
Besides, re-survey on unseen illegal connections should be conducted.

1

Skip of Step Test by Result of Per-km Flow Volume in MNF Survey

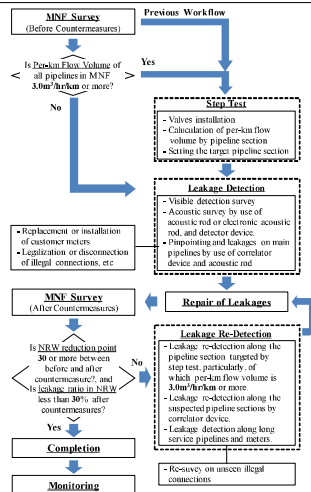
In MNF survey, if per-km flow volume of all pipelines is less than 3.0m³/hr/km, flow volume of each pipeline section may not be identified clearly due to little change of the volume.

For example, 1.47m³/hr/km was calculated in Tuvuru-2 as shown in the graph below, but it is difficult to identify changes in flow volume of pipeline sections.



3

Flow Chart of Revised Technical Procedures of NRW Reduction



2

Skip Criteria of Step Test by the Result of Per-km Flow Volume in MNF Survey

Pilot Area	Pipeline Length (m)	No. of Household	Flow Volume in MNF (m ³ /hr)	Per-km Flow Volume (m ³ /hr/km)	Necessity of Step Test
1	1,028	83	15.54	15.12	Yes
2	2,468	91	4.38	1.77	No
3	2,344	161	18.18	7.76	Yes
4	1,196	76	5.81	4.86	Yes
5	997	47	1.97	1.98	No
6	1,325	62	1.90	1.43	No

⇒ Per-km flow volumes are more than 3.0m³/hr/km in three out of six pilot areas. Therefore, step test should be conducted in these three areas.

Advantages of Skip of Step Test

- Activity can be made more efficient, that is, its period can be shortened.
- Materials such as valves and couplings can be economized.
- NRW Action Team pay attentions to flow volume in MNF survey and procedures of leakage detection.

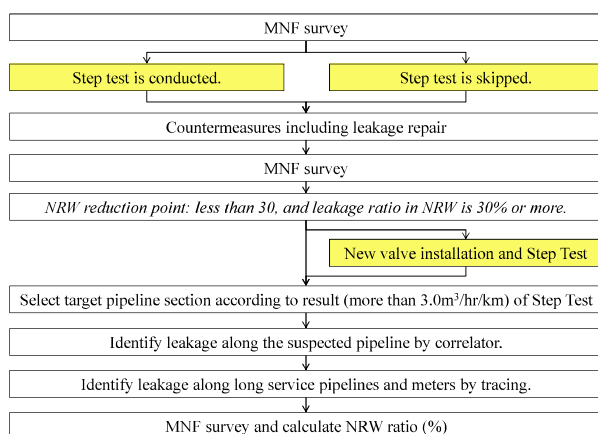
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Leakage Re-Detection

Leakage re-detection should be conducted if NRW reduction points is less than 30% and also leakage ratio in NRW is 30% or more after countermeasures.

- (1) For the pilot area in which step test was conducted, select the target pipeline section(s) according to result (more than 3.0m³/hr/km) of the step test, and install some valves at appropriate locations to identify leakage points.
- (2) For the pilot area in which step test was skipped, conduct step test, and select the target section(s) according to result (more than 3.0m³/hr/km) of the step test, and then install some valves at appropriate locations to identify leakage points.
- (3) Identify leakage along the suspected pipeline section by correlator.
- (4) Identify leakage along long service pipelines and meters which are connected to the pipeline section having higher per-km flow volume (more than 3.0m³/hr/km), by tracing the pipeline route that is unknown or passing through under the properties.
- (5) Conduct MNF survey again after countermeasures such as leakage repair.

5



6

