REPUBLIC OF MOLDOVA

APA CANAL CHISINAU

CHISINAU WATER SUPPLY & SEWAGE TREATMENT - FEASIBILITY STUDY

Contract No: C21156/ECWC-2010-01-01

Non-Revenue Water Assessment - FINAL

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seureca A Subsidiary of VEOLIA ENVIRONNEMENT

In association with and Business Consulting Institute

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LIST OF ABBREVIATIONS AND ACRONYMS

ACC	Apa Canal Chisinau
NRW	Non-Revenue Water
ToR	Terms of Reference
WS	Water Supply
PZ	Pressure Zone
LLI	Linear Losses Index
PRV	Pressure Regulating Valve

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1. GENERAL

The high values of losses (39% of the total input in 2010) in the overall water supply network (potable water and technological water) as well as the high amount of repaired leaks (14 066 interventions in 2010) justify the need of permanent leak detection, location and repair activities.

Water losses in the distribution system cause additional costs (besides the production/pumping costs and the financial losses due to unbilled and under-metered billed volumes), by damaging other utilities' networks (telephone, heating, natural gas and hot water) and as well as roads and other transportation infrastructures.

Among the mains goals of this Feasibility Study are the reduction of Non-Revenue Water. The reduction of NRW constitutes one of the two pillars of demand management (in parallel with wastage reduction) and is crucial for a utility such as ACC.

The reduction of leakage is achieved via pro-active and systematic leak detection, location and repair. At present, ACC crews are swamped with record number of visible leaks (7.5 repairs per km per year in 2010, 38 times the French average) and the utility is implementing a passive leakage reduction policy geared towards the localization and repair of reported visible leaks.

The Terms of Reference of this study contemplated the implementation of pro-active and systematic leak detection, location and repair activities over a total length of 300km within the current transfer and distribution system.

1.2. LEAK DETECTION AND LOCATION CAMPAIGN OBJECTIVES

The objectives of such intense campaign are the following:

- Long term training of ACC staff on pro-active leak detection and location activities for mitigation of underground/invisible leaks;
- Theoretical and on-site interaction of ACC staff with VEOLIA technical staff from France and Romania to address best practises and share experience feedbacks between two similar working environments such as Chisinau and Bucharest;
- Appraisal by ACC staff of acoustic leak detection and location techniques, well adapted to the local context in Chisinau (majority of metallic water mains, high operating pressures, regular access points to the network), by using acoustic correlation and acoustic ground listening;
- Analysis of located and repaired leaks' characteristics (frequency and distribution by material and length), estimate of losses' volumes depending on the type of leak, assessment of repair costs and techniques as well as the organizational aspects of leak detection and location activities within the ACC utility structure;

- Determine the necessary unit within ACC for pro-active and systematic leak detection and location activities, based on efficient organizational structure and operational costs (nucleus for a future NRW reduction and control unit);

Originally, 7 areas were chosen to carry out the activities:

- Buiucani (Pressure Zone # 4)
- Buiucani (Pressure Zone # 3)
- Schinoasa (Pressure Zone # 4a)
- Independenta-Botanica (Pressure Zone # 3)
- Riscani (Pressure Zone # 3)
- Ciocana (Pressure Zone # 3)
- Ciocana (Pressure Zone # 4)

Such areas were selected based on the following parameters:

- Isolated area supplied by a single pumping station and not interconnected with other sectors;
- Discharge flows and pressures have to be monitored and values recorded with dataloggers;
- The area's assets' characteristics are well-known and available in short-scale maps to ease-up on-site operations;
- Valves can be easily operated to isolate portions of the network, if needed by the leak detection, location and repair activities;
- Majority of the WS network with metallic water mains, high operating pressures, and regular access points to the network, very important parameters for successful acoustic leak detection;

1.3. FACTORS AFFECTING LEAKAGE

There are several factors which affect leakage in a water distribution system.

Pressure:

- For a system with a number of leaking or broken pipes and leaking or faulty fittings, a change in pressure will change the rate of loss of water through those leaks;
- Increase of the pressure within a system, in some cases only by a few meters, can result in a fairly large number of bursts occurring within a relatively short period of time, depending upon the rate of corrosion for metallic pipes or weakening for non-metallic pipes;
- Pressure surges, sometimes greater than the design strength of the pipe, can be caused when a pump set or booster is switched on or off, or when a valve is opened or closed too quickly. The effects of surges can cause the main or

service connection to fracture, thrust blocks to move or joint sealant to be blown away from the joint cavity. Surges or other fluctuant pressures cause pipes to flex and move against rocks or other firm obstacles, resulting in local stress concentrations and sometimes failure of the pipe;

- Pipe fatigue can be caused by pressure cycling between high and low value within the design pressure, such as occurs when a pump set or booster is switching on and off, or by badly maintained or faulty pressure reducing valves;

Soil movement:

- Among the causes of soil movement are changes in moisture content (particularly for clays), changes in temperature, frost heave and subsidence. Movement of the soil may cause a pipe to break, joints to move, or result in local stress concentrations within the pipe or fittings which eventually lead to its failure;

Deteriorations of water mains and pipes:

- Internal corrosion is generally more severe in soft waters from upland sources. As corrosion of iron and steel pipes proceeds, the residual thickness of metal is reduced and hence the ability of the pipe to withstand internal pressure diminishes. Ultimately this process leads to complete penetration of the pipe wall and failure of the pipe with resultant leakage. The common forms of failure are hole formation and transverse or longitudinal fracture of the pipe;

- External corrosion can arise from a variety of causes including differential aeration, bimetallic corrosion, variations in concentrations of dissolved salts and microbiological action. The effects of external corrosion are similar to those of internal corrosion;

- Corrosion of concrete or asbestos cement pipes can be caused by soils or waters containing high levels of sulphates;

Poor quality of fittings, materials and workmanship:

- Leakage under this heading can occur in the apparatus of both the water undertakings and the consumers. Careful design and specifications of installations and components coupled with a high standard of supervision of construction are required in order to keep faults to the minimum;

Soil characteristics:

- An important factor which affects the running time of individual leaks is the permeability of the soil in which the pipes are laid. In some soils, water from underground leaks may show on the surface fairly quickly whereas similar leaks in soils such as chalk can run indefinitely without showing;

Traffic loading:

- The effects of vibration and high roadway loading caused by heavy trucks and other traffic is thought by many engineers to be a major factor affecting the failure of buried pipelines;

Age:

- Many of the factors listed above are time-dependent i.e. their effect will be greater as time goes on. Consequently age of a pipeline can appear to be the most significant factor affecting the likelihood of leakage;

To summarize, with the exception of pressure, none of the factors listed above can be easily altered once a pipeline has been laid. It is, therefore, extremely important that due consideration of these factors is taken during the design and construction stages and that adequate supervision is given to ensure that the desired standards are obtained.

2. EQUIPMENT & LOGISTICS - TECHNICAL STAFF

2.1. ACOUSTIC LEAK DETECTION AND LOCATION EQUIPMENT

2.1.1. RATIONALE BEHIND THE CHOICE OF THE EQUIPMENT

Acoustic techniques can be used by ACC for leak detection and location activities, as the following criteria are generally met within the current water transfer and supply system:

- Majority of metallic water mains (steel and iron);
- High operating pressures;
- Regular access points to the network through chambers and manholes (boundary and circulation valves, connection points between the distribution water mains and the service mains);

Leaks appear on:

- Transfer and distribution pipes;
- Service connections;
- Boundary, circulation and regulation valves;
- Accessories: fire hydrants, fountains, washouts, air valves, etc.;

Invisible leaks can be detected based on the noise they create, which is defined by:

- Its duration (continuously or intermittent if scheduled supply);
- Its position (the noise originates at the leakage point and propagates symmetrically along the pipe);
- Its invariability (the noise has the same level and frequency spectrum);

The noise originated by the leak is due to:

- The vibration of the pipe wall caused by the friction of the water through the holes, cracks and breaks;
- The turbulent movement of water close to the leakage point which creates shock waves (compression/expansion);
- The outbreak of water into the neighbouring soils which also creates shock waves (compression/expansion);

The energy of the noise generated by the leak depends on:

- The pipe material (ductile iron, steel, PVC, HDPE, etc.);
- The operating pressure (2 bars, 4 bars, etc.);
- The type of leak (cracks, breaks, holes, etc.);

- The speed of water through the leakage point, which depends on its size/dimensions;
- The type of soil on which the pipe was laid (sand, clays, etc.);
- The presence of a water pocket (high water table levels for example);

The noise's frequency is variable and is included within the range 20 Hz – 5 000 Hz in the human audible domain. There is no relationship between the noise intensity, the emitted frequencies and the leak's water flow.

<u>The propagation of the noise created by the leak depends on:</u>

- The pipe's nominal diameter;
- The energy of the noise;
- The pipe's material (metallic or non-metallic);
- The network's accessories (tees, elbows, cones, service connections, etc.);

2.1.2. EQUIPMENT PROVIDED FOR THE LEAK DETECTION & LOCATION CAMPAIGN

2.1.2.1. Descriptive list of the equipment

The activities allowed the deployment of acoustic leak detection and location equipment, listed in the below table:

Table 1: List of provided equipment for the leak detection and location activities

<table>
<tr><th>Equipment Type</th><th>Quantity</th><th>Manufacturer</th><th>Model</th></tr>
<tr><td>a- Portable Acoustic Correlator</td><td>1</td><td rowspan="5">SEWERIN</td><td>SECORR 08</td></tr>
<tr><td>b- Portable Acoustic Ground Microphone</td><td>2</td><td>AQUAPHON A100</td></tr>
<tr><td>c- Metallic Pipes Detector and Locator</td><td>1</td><td>FERROPHON ELH02</td></tr>
<tr><td>d- Metallic Accessories Detector and Locator</td><td>1</td><td>FERROTEC 300</td></tr>
<tr><td>e- Big Wheel Odometer</td><td>1</td><td>NESTLER</td></tr>
</table>

Figure 1: Pictures of provided equipment for the leak detection and location activities

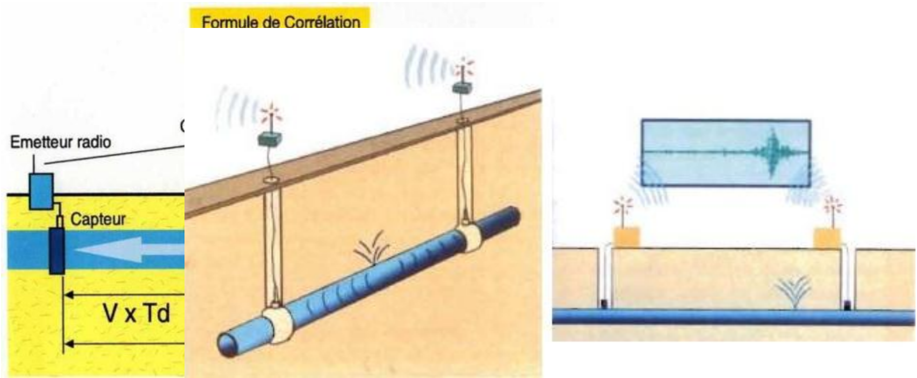
d-

a- b- c- e-

2.1.2.2. Working principle

Portable Acoustic Correlator:

Figure 2: Working principle of the portable acoustic correlator



Correlation is computer-assisted leak detection in underground pressure line systems. Leak sites emit a noise which is carried along the pipe material. This noise reaches two fittings (valves, hydrants, home shut-off valves etc.) at different times. The time lag depends on the distance of the leak from the two contact points.

Highly sensitive microphones record the incoming noises on the fittings and a radio transmitter transmits these noises to the receiver where the run time difference of the signals is determined.

The exact position of the leak is then calculated from the information about the material, the diameter and the length of the measuring section.

The velocity of sound within the pipe is dependent on the pipe material and diameter. Therefore, it is important that the material type of the pipe under correlation is known. Also, if the pipe has had a repair made to it which consisted of inserting a pipe which is of a different material, this too will affect the overall velocity in the main. Most modern correlators incorporate a facility whereby pipes of more than one material can be entered into the correlator and correlated successfully. As a result of this though, it is important that accurate records relating to the main materials and lengths are kept to minimise errors arising from unknown pipe materials.

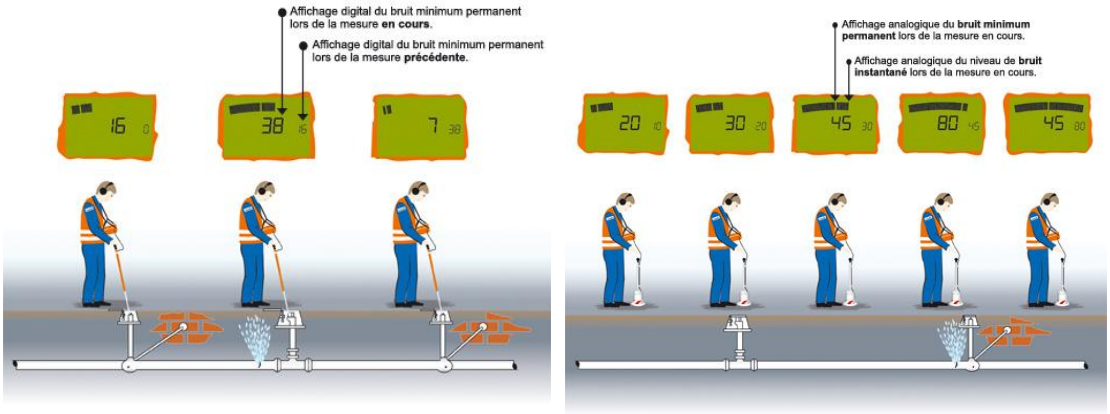
The other significant piece of information required is the distance between the two sensors or accelerometers. The accuracy of the correlation process and the leak location is dependent on the accuracy with which the length of pipe work between the two sensors can be measured. Thus, the route of the pipe should be established either from plans or by tracing the path of the mains to ensure that the distance can be measured as accurately as possible. This gives another reason for accurate records and plans to be maintained.

The general process for correlating is as follows;

- Locate two suitable points (e.g. valves, hydrant, air valves etc) for locating the accelerometers. Ensure the fittings are clean and that the sensors locate securely;
- Enter the correct velocity for the pipe;
- If the pipe is made up of more than one material enter the details for each section;
- For the first correlation, estimate the distance between the two sensors;
- Perform the correlation;
- If the correlation does not indicate a leak, move one of the sensors to the next fitting past the other sensor and repeat the process;
- If the correlator indicates the presence of a possible leak then the distance must be measured accurately and entered into the correlator;
- Repeat the correlation;
- Once the location of the suspected leak has been identified, use sounding to confirm the exact location is correct and whether the leak is on the main or the supply to a property;
- The possibility that the leak noise is being generated by water use must also be eliminated. This can also be achieved through sounding. If necessary, isolate the suspected supply and repeat the correlation;
- Once the reason for the indication of a leak has been established, move one sensor to the next fitting past the other sensor and repeat the process;

<u>Portable Acoustic Ground Microphone used for sounding:</u>

Figure 3: Working principle of the portable acoustic ground microphone



Water escaping from a pressurised pipe emits a sound over a range of frequencies and produces a hissing noise similar to the sound that can be heard when a sea shell is held up to the ear. The sound produced by a leak will be specific to that leak and will depend on such factors as the nature of the leak, the size of the hole through which the water is escaping, the pressure in the pipe, the pipe material, the nature of the ground in which the pipe is laid, and whether the ground is waterlogged or not.

The further away from a leak you are the quieter the sound will be due to attenuation of the noise within the pipe. Plastic pipes attenuate the noise faster than metallic pipes. It should be noted that not all leaks produce a detectable noise and that the detection level will depend on the quality of the hearing of the operator.

Sounding can be categorised into two types: Direct and Indirect. Direct soundings are made on the main or fittings on the main (hydrants, valves, etc.) and this type of sounding will generate a louder sound than indirect sounding methods where soundings are made on the ground surface above the pipeline.

Direct Sounding

This is the most common method of locating the position of a leak. Soundings are made on either the main or fittings on the main, such as fire hydrants, sluice valves, air valves, and stop-taps. The “sounder” has to use skill and experience to identify sounds that are generated by leaks and those generated by other sources (such as pumps and water meters for example).

Sounding can encompass either selected fittings or all fittings and will depend on the makeup of the network. Where the network is entirely metallic, and the operating pressure is sufficient to generate noise from leaks, not all fittings may need to be sounded. Where there are a high proportion of plastic pipes, every fitting may need to be sounded. In general sounding all fittings is more successful as small leaks may be missed during selective sounding.

If a sound is identified on a fitting, its presence should be confirmed at a different time during the day. If the sound is still present it may be that there is a leak or that there is water usage at that point. The presence of any property house service pipes should be identified, and where any exist, the stop-tap should be closed after having notified the property owner/occupier. This eliminates the possibility that the noise is being produced by usage by the customer.

If the noise stops it means either that there is a leak between the stop tap and the property or there was usage in the property.

If the noise does not stop there is a leak. If the noise can be heard on other mains fittings it is likely that there is a leak on the main. Otherwise, it is likely that there is a leak on the service pipe between the main and the stop-tap.

Indirect Sounding

This is also known as surface sounding as it consists of making soundings on the surface above the line of the pipeline to determine the point of maximum sound intensity. This method is most successful in urban areas where there is a hard surface above the main, although background noise caused by traffic can reduce its effectiveness, and is a supplemental tool to direct sounding for pinpointing the source of a leak noise identified through direct sounding.

2.1.2.3. Limits of use

The following parameters drastically reduce the efficiency of acoustic leak detection and location activities:

- Pipeline materials: non-metallic pipes (PVC/HDPE). These mains do not transmit leak noises very well thus hampering acoustic correlation and ground listening;
- Low operating pressures: prevailing network pressures that are below 3 bars thus reducing the energy emitted by the leak noises which negatively bears upon their detection rate with the correlator and the ground microphone;
- Limited contact points to the water network: the absence of direct contact points to the network (via domestic meters, valves and hydrants) limits the implementation of acoustic correlation and ground listening;
- Lack of knowledge on precise pipeline alignment and geometry;
- Inaccessibility of certain mains which run under private property;
- Presence of soft underlying soils (clays, water logged soils) which attenuate leak noises which are then undetectable from the surface;

2.2. STAFF INVOLVED IN THE CAMPAIGN

From the Consultants:

- 1 Leak Detection and Location Expert from VEOLIA FRANCE for the initial theoretical and practical training period (establishment of best practices);
- 1 Leak Detection and Location Expert from VEOLIA ROMANIA for the initial theoretical and practical training period and regular visits for practical training updates (establishment of best practices and sharing of experience feedbacks between two similar working environments such as Chisinau and Bucharest);
- 1 Leak Detection and Location Team Supervisor for daily on-site activities organization, supervision and reporting through sheets and maps;

From ACC:

- 2 Leak Detection and Location Technicians for the daily inspection of the 300km over the selected areas;
- 1 turncock / network operator from the sector where the area being inspected is located (to ensure proper knowledge of the pipes and chambers locations);

Figure 4: Staff working on ACC water supply network with the provided equipment

2.3. LOGISTICS – ORGANIZATION OF THE DAILY ACTIVITIES

Table 2: Brief summary of tasks and responsibilities during the campaign

Actions	Tasks / Comments	Performed by	Checked by	Recorded by
Detection and location of hidden losses	Acoustic correlation and direct listening on each section, branch by branch, fitting by fitting; Access to fittings, manholes and chambers; Submission of the leak position to ACC to ensure the launch of repair activities	Leak Detection and Location Team / ACC	Leak Detection and Location Team	ACC
Repairs of detected and located leaks	Excavation / Repair and replacement of damaged assets / Refurbishment of roads and chambers	ACC	Leak Detection and Location Team	ACC
Analysis of effects after repairs	ACC will immediately notify each repair	The Leak Detection and Location Team will register and mark the leak position on a map. Sporadic checks will be carried out to ensure that repairs have been done correctly and that no new leaks have appeared after the repairs.		

3. RESULTS FROM THE LEAK DETECTION AND LOCATION CAMPAIGN

3.1. GENERAL – PRIMARY RESULTS

This report summarizes the results gained during five months of activities (July; September to December), during which the contractual 300km of network were inspected. The activities are still ongoing and new leaks are detected and located every day, in the selected areas, but also in other parts of the network where emergencies arise needing the intervention of the team.

Table 3 - Figure 5 : Number of detected and located leaks per month

Month	Number of detected and located leaks
07	87
09	117
10	48
11	44
12	43
Total	**339**

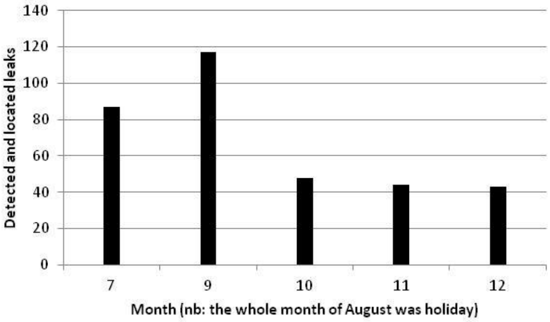
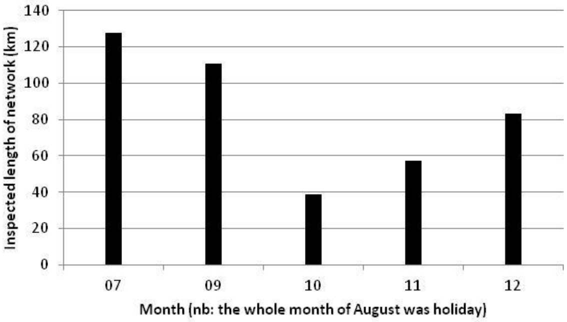


Table 4 - Figure 6 : Inspected length of network per month

Month	Inspected length of network (km)
07	128
09	111
10	39
11	57
12	83
Total	**418**



The team has found 339 hidden leaks over 5 months of activities and 418km of inspected network. The ratios that can be deducted from these primary results are:

- 0.8 hidden leaks per kilometre per day were detected and located by the team;
- 5.2 kilometres of network per day were inspected by the team;

Therefore, an average of 4 leaks per day was found by the team during the first 5 months of the campaign.

When considering 2 teams working full-time on pro-active leak detection and location activities, with the aforementioned ratios and an average of 21 labour days per month and 11 man-months per year:

- 5.2 x 11 x 21 = 1 200 inspected kilometres per year per team;
- 2 x 1 200 = 2 400 inspected kilometres per year for the 2 teams;

This means that by adding a new crew to the existing one ACC will be able to:

- Fully inspect the whole network once a year;
- Exceptionally deploy one team for emergency situations;

3.2. RESULTS PER SECTOR

Small changes were brought to the original list of areas mentioned in Chapter 1.2.

During the first five months of the campaign, the following sectors were under inspection:

- SCHINOASA (PZ # 4a);
- RISCANI (PZ # 3 & PZ # 2);
- CIOCANA (PZ # 4 & PZ # 3 & PZ # 2);
- INDEPENDENTA-BOTANICA (PZ # 3);
- CENTRU (PZ # 2);
- BUIUCANI (PZ # 4);
- VADUL-LUI-VODA;

Table 5 - Figure 7 : Number of detected and located leaks per sector

Sector	Number of detected and located leaks
BOTANICA	72
BUIUCANI	28
CENTRU	12
CIOCANA	127
RISCANI	65
SCHINOASA	4
VADUL LUI VODA	31
Total	**339**

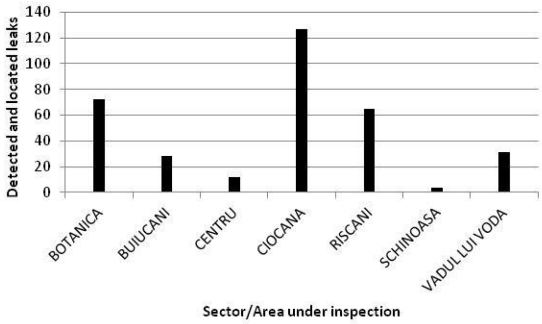
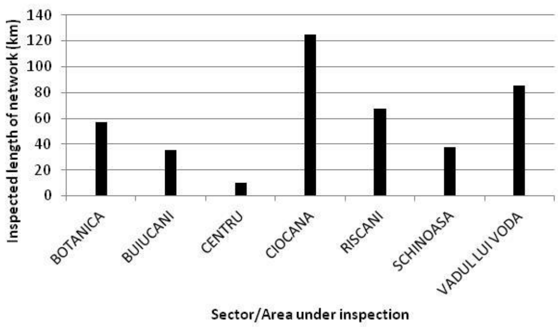


Table 6 - Figure 8 : Inspected length of network per sector

Sector	Inspected length of network (km)
BOTANICA	57
BUIUCANI	35
CENTRU	10
CIOCANA	125
RISCANI	68
SCHINOASA	37
VADUL LUI VODA	85
Total	**418**



The two areas with the highest ratio of leaks per kilometre are:

- **CIOCANA (PZ # 3) with 1.7 hidden leaks detected and located per kilometre** (76 leaks over a total inspected length of 46km). The measurement campaign on the water supply network led to a water balance that defined the LLI of this sector to **203 m^3/km/day**;

- **INDEPENDENTA-BOTANICA (PZ # 3) with 1.3 hidden leaks detected and located per kilometre** (72 leaks over a total inspected length of 57km)**.** The measurement campaign on the water supply network led to a water balance that defined the LLI of this sector to **76 m^3/km/day**;

These two areas with high levels of losses (7 255 m^3/day for CIOCANA PZ # 3 and 4 675 m^3/day for INDEPENDENTA-BOTANICA PZ # 3) can therefore be subject of periodical and intense leak detection and location activities, as they are prone to high operating pressures (6 bars to 8 bars), which added to the structural weakness of the current network, explains the high levels of hidden leaks in these two areas.

Figure 9 : Leaks in CIOCANA PZ # 3 & INDEPENDENTA-BOTANICA PZ # 3

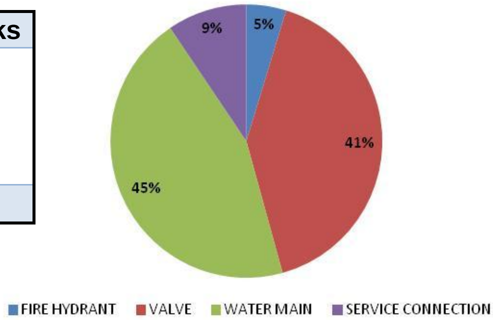
3.3. RESULTS PER LEAK TYPE

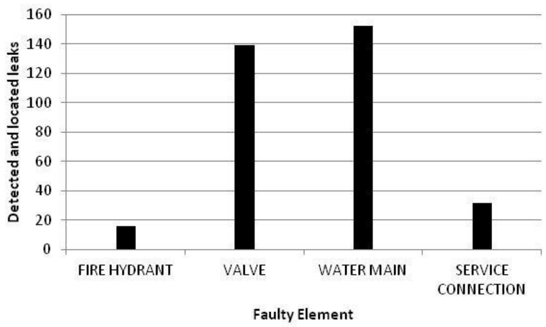
The hidden leaks found by the team were classified into 4 categories:

- Leaks on valves;
- Leaks on fire hydrants;
- Leaks on service connections;
- Leaks on water mains;

Table 7 - Figure 10 : Number of detected and located leaks per faulty element

Faulty Element	Number of detected and located leaks
FIRE HYDRANT	16
VALVE	139
WATER MAIN	152
SERVICE CONNECTION	32
Total	**339**

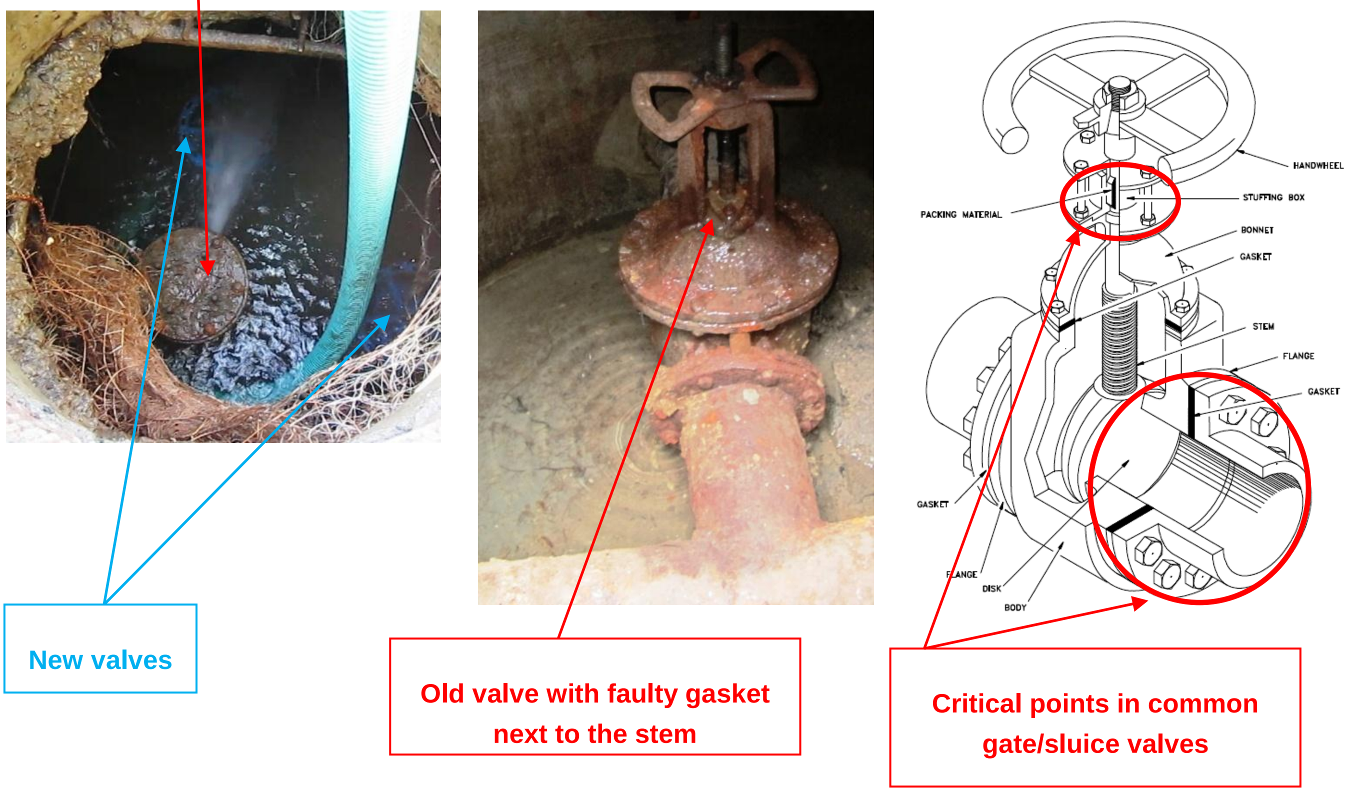




The majority of the hidden leaks were found on water mains (45% of the total) and valves (41% of the total), which raises the following conclusions:

- The percentage of detected and located leaks on valves is very high, even higher when joining the contribution of fire hydrants. Many hydraulic accessories on the water supply network in Chisinau are in bad conditions, timeworn and with high levels of corrosion, which means that a lot of them cannot be operated. Leaks are found on faulty gaskets located next to the flanges or to the stem, but also on empty valves bodies that were sealed with a steel plate.

Figure 11 : Typical leaks found on valves in Chisinau WS network

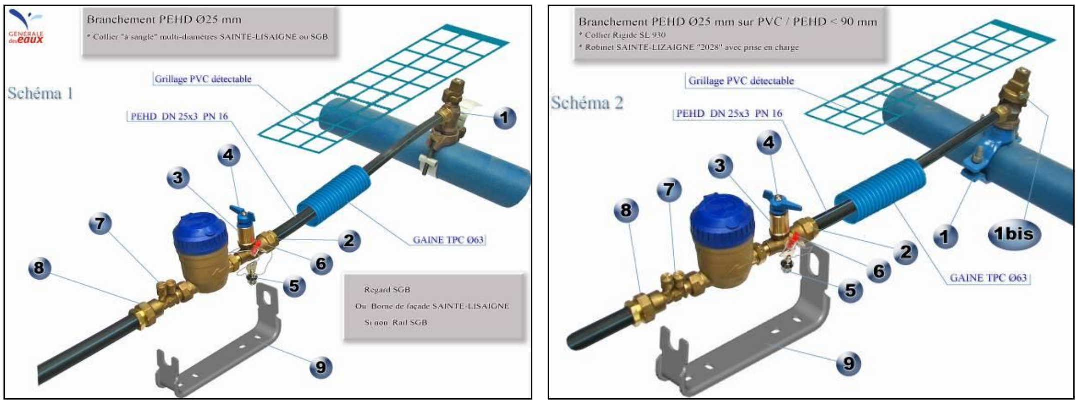


- The percentage of detected and located leaks on service connections is very low (9% of the total – 17% when excluding hydraulic accessories) when compared to international ratios which generally show that 80% of leaks are repaired on service connections and 20% on water mains. In Chisinau's context, it could be explained by the fact that the leak detection and location team allocated its efforts into highly dense areas, with predominant vertical habitat and a low rate of service connections per kilometre inspected when compared to areas with predominant horizontal habitat.

Figure 12 : Typical leaks found on mains & service connections in Chisinau WS network

During the leak detection and location campaign, the team has observed that no standard design and installation procedures are followed during the implementation of service connections within ACC service area. A large number of different pipe materials, nominal diameters, fittings, water meters and connections to the water mains can be observed on site, many of which contribute to the appearance of leaks due to the poor quality of materials and workmanship. The typical design of a DN 25 mm HDPE service connection in France is shown hereafter:

Figure 13 : Typical design of a DN 25 mm PN 16 service connection in France



1 & 1bis: Variable or fixed tapping-collar with incorporated ferrule and stop-cock

2&8: HDPE adaptor; 3: Stop-cock located upstream of the water meter;

4: Stop-cock manoeuvre key; 5: Stop-cock locking mechanism; 6: Sealing thread with ID number;

7: Check-valve with drainage outlet; 9: Support rail for the whole installation

3.4. LEAKS ON WATER MAINS & SERVICE CONNECTIONS: PER DN & PER MATERIAL

Table 8: Number of detected and located leaks per DN & material

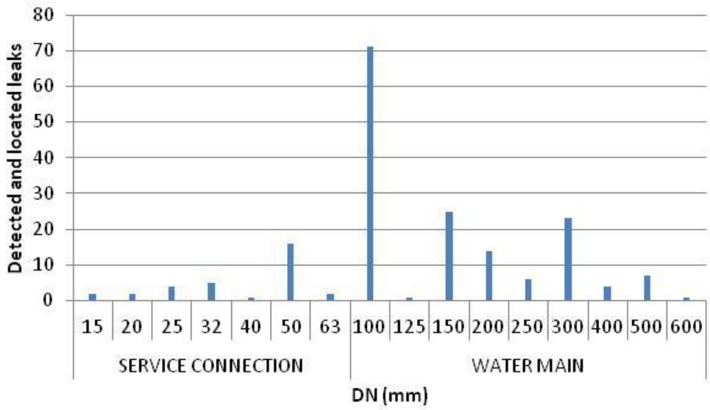
DN (mm)	Number of detected and located leaks
SERVICE CONNECTION	**32**
15	**2**
HDPE	1
STEEL	**1**
20	**2**
HDPE	1
STEEL	**1**
25	**4**
HDPE	1
STEEL	**3**
32	**5**
HDPE	2
STEEL	**3**
40	**1**
STEEL	**1**
50	**16**
HDPE	1
STEEL	**15**
63	**2**
HDPE	2
WATER MAIN	**152**
100	**71**
CAST IRON	4
HDPE	1
STEEL	**66**
125	**1**
HDPE	1
150	**25**
CAST IRON	6
STEEL	**19**
200	**14**
CAST IRON	2
STEEL	**12**
250	**6**
CAST IRON	1
STEEL	**5**
300	**23**
CAST IRON	3
STEEL	**20**
400	**4**
STEEL	**4**
500	**7**
CAST IRON	1
STEEL	**6**
600	**1**
CAST IRON	1
Total	**184**

The above table shows that:

- **75% of leaks detected and located on service connections concern pipes made of steel**, from DN 15 mm to DN 50 mm;
- **87% of leaks found on water mains concern pipes made of steel**, from DN 100 mm to DN 500 mm;

These high rates of hidden leaks on steel pipes therefore confirm the proposals made under the investment program for the water supply network operated by ACC. Such program clearly highlights the need of the rehabilitation/replacement of steel pipes with DN ranging from 100 mm to 400 mm and the associated service connections.

Figure 14 : Number of detected and located leaks per DN



3.5. HYDRAULIC DIAGNOSIS LEADING TO PROACTIVE LEAK DETECTION AND LOCATION ACTIVITIES

The Consultants carried out a full measurement campaign on the water supply network which led to the establishment of the hydraulic balance and the set-up of performance parameters for 33 hydraulic entities (network efficiency and LLI).

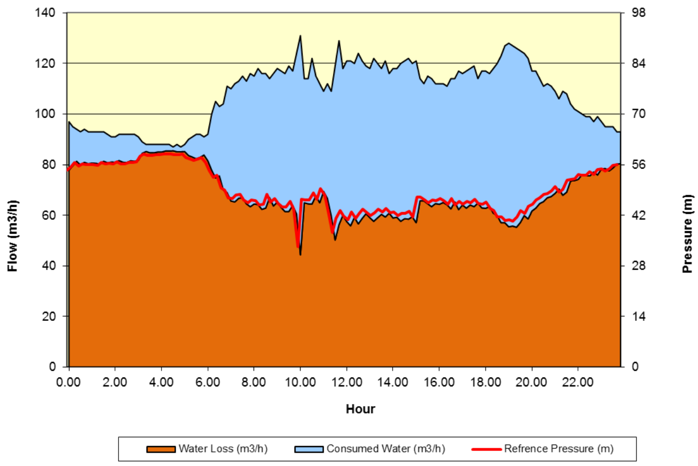
ACC asked to allocate the team efforts on the hydraulic entity covering Vadul-lui-Voda area, as the measurement campaign results determined that such network had an efficiency of 24% and a LLI of 17.3 m^3/km/day (for a total network length of 91 km).

This is a clear example of how a permanent hydraulic diagnosis of the water supply network can be used to plan leak detection and location activities in areas with continuously bad performance indicators or with sudden increases in LLI values (or drops in efficiency values).

Diminishing or maintaining the losses' levels on a water supply network implies a precise and regular follow-up of volumes delivered into the system. Therefore, the network needs to be cut into hydraulic entities or sectors where a hydraulic balance can be performed on a regular basis, thus helping to limit the leaks' running time and the water losses.

As soon as an anomaly is detected, leak detection and location teams can be sent on site to find the causes of the performance degradation raised by the hydraulic balance.

Table 9 - Figure 15 : Measurement campaign results in Vadul-lui-Voda

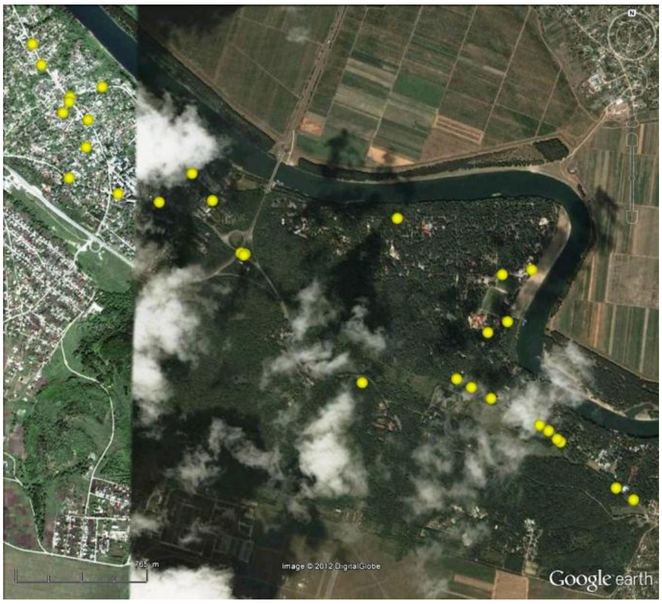


Average day	Network efficiency	**24%**
	Length of the network (km)	91
	Linear leakage Index (m^3/d/km)	17.3
Reference day	Date	25/08/2011
	Consumption (m^3/d)	1 025
	Water losses (m^3/d)	1 569
	Delivered flow coefficient	1.26
	Consumption coefficient	2.09
Average consumption (m^3/d)		490

The team inspected 85 km on the water supply network, finding 31 leaks, from which:

- 12 were on DN 300 mm pipes (steel and cast iron);
- 3 were on DN 150 mm pipes (steel);
- 4 were on DN 100 mm pipes (steel);

Figure 16 : Leaks in VADUL-LUI-VODA hydraulic entity



The leaks found in Vadul-lui-Voda urban centre and the forests alongside the Nistru River towards Balabanesti were in their majority large breaks on the transfer and distribution pipes that had created small lagoons in streets and neighbouring fields, without being properly reported to ACC by local customers and network operators. Furthermore, breaks were observed on wastewater collectors, close to the recreational and vocational areas. This means that proper attention should be brought to peripheral communities within the service area, whose customers might not be aware of the communication channels put in place by ACC for operational claims such as visible leaks, and with an intermittent presence of ACC network operators.

Within Vadul-lui-Voda context, another issue should be highlighted that might explain the current low value of network efficiency. The leak detection and location team has observed that no standard service connection scheme can be seen on-site:

- There are only a few chambers / surface boxes for service connections: some houses are connected to the water main but there is no chamber for the connection. The legality of such branch pipes should be assessed;
- Some of the water meters are installed within the customers' premises, on yards or inside the houses. Such a disposition facilitates the implementation of illegal connections, which could be used to water gardens, wash cars, irrigate agricultural lands, etc.;

A comprehensive customer survey (customer census) could be done in Vadul-lui-Voda and other communities within the service area to determine the type and the number of final water consuming endpoints (all of which should be metered) in the entire service area leading to the suppression and legalization of illegal connections.

4. DRAWBACKS – FIELD OBSERVATIONS

The first five months of pro-active leak detection and location activities allowed observing some drawbacks in daily ACC operations or within the current network that limit the impact (NRW reduction) of the efforts carried out by the team. They are presented hereafter and some remedial solutions are proposed to decrease their effects.

4.1. LEAKS REPORTED TO ACC AND NOT REPAIRED

All leaks detected and located by the team were reported daily to ACC's central dispatch, responsible of informing the operational sectors in charge of the repairs. Once a week, the team was in charge of inspecting the points where leaks had been found and repaired to assess if:

- The repair was efficient, i.e. the leak had been stopped and no other one had appeared upstream or downstream of the location;
- The repair was "really" carried out by the operational sector, i.e. no misunderstandings happened between central dispatch and repair teams;

This control/supervision exercise was fruitful, as it allowed verifying the limits of current repair techniques and organization. Indeed, the team observed along the first five months of activities that certain leaks reported to ACC and announced as repaired were in fact intact. Such leaks had basically two profiles:

- Leaks that needed trench digging (mobilization of heavy-duty equipment) and road/sidewalk rehabilitation;
- Leaks on accessories (valve gaskets or hydrant flanges) that might have been considered as "too small" to be repaired;

Figure 17 : Unrepaired leaks reported as solved by operational sectors

Such situations argue in favour of the implementation of a control procedure that would weekly select a sample of reported repaired leaks for field inspection to determine whether the work was really carried out or not.

4.2. LEAKS STILL ACTIVE AFTER REPAIR

The control/supervision exercise allowed also finding leaks still active after repair. Indeed, current repair techniques used by ACC's crews are limited and very often cannot effectively restrain the leakage flow (the current leaks' recurrence rate is around 30%).

Figure 18 : Leaks still active after repair

Repair interventions on steel and cast iron pipes are made as follows (see specific report on Network Operation Recommendations):

- Leaks due to corrosion on steel pipes ("hole in pipe" type of failures) are being repaired with wooden cones inserted in the hole with a sealing paste;
- For leaks on large steel pipes, a piece of steel is welded on top of the wooden cones, and normally bitumen is applied on top on the welded plate to protect it from further corrosion;
- Circumferential breaks: this type of failure occurs on cast iron pipes when differential pressure applies on the pipe. The cast iron pipe is very sensible to this phenomenon, and breaks mostly happen at thaw periods. For this type of failure, the repair is done by ACC using a piece of steel pipe cut lengthways in 2 pieces. 2 twisted wires are welded 5 cm from the extremity of each side. The 2 pieces are then welded together around the circumferential break on the cast iron pipe. The tightness is done with some rope mixed with bitumen, and then beating

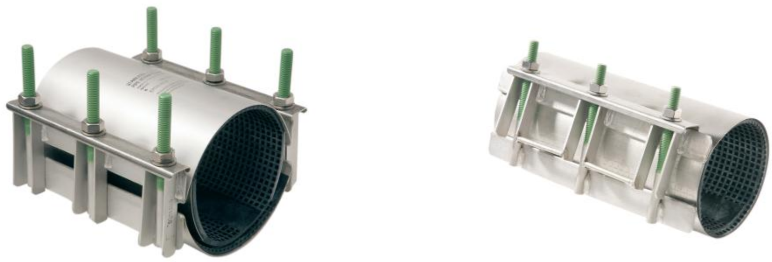
some lead to finish. The risk or problem of this technique is that the welding will corrode quickly and a new leak will happen. Problems happen also with the tightness of the lead;

- Longitudinal splits: this type of failure occurs on both cast iron pipes and steel pipes in case of high pressure. For this failure, and any other type which requires the replacement of a portion of the pipe, the repair is done by ACC by using a piece of steel pipe with 2 couplings made as described above (with a piece of steel pipe cut lengthways in 2 pieces and then welded together around the pipe to link). Again, this type of repair, with the corrosion of welded parts, will lead to further failures;

As developed in the Network Operations Recommendations report, such leaks should be repaired following current best practices which are:

- For circumferential breaks and corrosion pin-holes in steel pipes: the repair will use of a stainless steel repair clamp;

Figure 19 : Stainless steel repair clamps



- For longitudinal splits or any repair where a piece of pipe needs to be replaced (excessively corroded pipe, joint leaks, or an outburst): the repair will require a piece of pipe of the same material (cast iron on a cast iron failure), and 2 couplings large tolerance;

Figure 20 : Couplings large tolerance

- Most leaks on valves (many examples found by the leak detection and location team) are due to a defective stuffing box assembly. The best practice to repair a leak on a stuffing box assembly is to use a permatight seal. The valve stem must be dismantled, and a specific permatight diameter seal put in place.

Figure 21 : Permatight seals

4.3. NETWORK MANHOLES FULL OF WATER

Current manholes used to access the water supply network are often full of water (leakage water or surface/ground water), which prevents the leak detection and location team of using contact points for acoustic correlation or direct listening. The team always had to carry a dewatering pump that turned out to be essential for the works.

Figure 22 : Network manholes full of water

ACC should therefore continue with the regular inspection of manholes/chambers on the water supply network, which could be done by a dedicated person in each operation sector in parallel of the proactive leak detection and location activities. Such waterlogged chambers and manholes accelerate the process of corrosion as pipes and hydraulic accessories are permanently immersed in water.

5. RECOMMENDATIONS

5.1. HUMAN RESOURCES & EQUIPMENT

ACC technicians currently working on the leak detection and location team already have a confirmed experience in the use of the equipment and the work methodology. Excellent results have been obtained over the first five months of works. ACC can therefore capitalize on this nucleus to expand its NRW unit towards a second team.

As proposed on the Network Operation Recommendations Report and validated by the results of the campaign carried out under this Feasibility Study, both teams should be equipped with the following items:

Transportation Unit:

- Light Commercial Vehicle;

Electromechanical Equipment:

- Generator;
- Drill;
- Dewatering Pump;

Leak Detection and Location – Measurement Equipment:

- Portable Acoustic Correlator;
- Portable Acoustic Ground Microphone;
- Portable Ultrasonic Flowmeter;
- Metallic and Non-Metallic Pipes Detector and Locator;
- Metallic Accessories Detector and Locator;
- Pressure Gauge with Datalogger;

IT equipment:

- Portable PC with GIS software and the water supply system database;
- Precision GPS for georeferencing leaks and anomalies found during fieldworks;

Tools: brushes, hammers, screwdrivers, spanners, tape measure, manhole cover lifters (for metallic and concrete covers), flashlights, etc.

Safety equipment: identification badges, gloves, shoes, fluorescent jackets, roadwork signs (traffic cones), etc.

Both teams could be organized as follows:

- Team #1 for the operational sectors located on the right side of the Bîc river (Buiucani, Centru and Botanica), including the attached communities to these sectors;

- Team #2 for the operational sectors located on the left hand side of the Bîc river (Ciocana and Riscani), including the attached communities to these sectors;

During a normal working week, both teams' responsibilities could be as follows:

- One team would carry out its normal work, i.e. fully inspect the networks under its responsibility under previously planned activities;
- The other team would do the same but additionally would be under emergency duty calls for night and weekends interventions;
- In the situation where many emergency duty calls arise, which can happen after thaw at the beginning of spring, both teams resources could be allocated to such interventions;

5.2. Reporting & data analysis

Currently, reporting on leak detection and location activities as well as leak repairs is done by ACC Central Dispatch, which liaises with all operational sectors. As it was shown in section 4.1. of this report, there are some mistakes/errors in the liaising between such entities. With the implementation of a GIS system in ACC central office, procedures will need to be strengthened in terms of data collection and updates concerning operational interventions such as leak detection, location and repairs activities.

All reporting documentation will be held at the central office both in hard copy but also, and more importantly, on a computerised database that should be able to interact with the implemented GIS.

Leakage Detection and Rectification Procedure

It is essential that information about the identification and rectification of losses is collected and analysed to identify the performance of assets and the effectiveness of the different detection techniques.

The information will initially be recorded in a paper format. This will then be transferred to the central office for entry into a computerised database.

Collection of information in this way makes all data available in a single format which is appropriate for detailed analysis and compilation of activity reports.

A further repository for the location of leaks is in the GIS. In this other form of database the number of leaks on each section of pipe can be recorded and the information used to prioritise rehabilitation and renewal programmes.

The information to be collected in each case is:

- Leak detection and location programme:
  - Date of test;
  - Streets included in test;
  - Length of mains tested;
  - Number of connections in test;

- Number of properties included and the population supplied;
- Names of leak detection team technicians;
- Time taken for the test;
- Number of leaks detected;
- Detection techniques employed;

- Leak repair programme:
    - Date of repair;
    - Pipe material, size, internal and external condition;
    - Type of leak – hole, joint, fracture (circumferential or longitudinal);
    - Whether renewal of the main is recommended and if so what length;
    - Details of the connections renewed including the fittings used;
    - Number of leaks repaired;
    - GPS coordinates of leaks;
    - Information relating to the repairs carried out to the main;
    - Flushing and disinfection records;
    - The position of the main in relation to a fixed position (either the curb line or a property boundary);
    - The depth of the main;
    - The location of the stop-cock in relation to a fixed position (for example the main entrance to the property);
    - The road category;

The benefits of using this information recording system are:

- The records are easier for the operatives to complete;
- Records are maintained in an electronic format that would enable the information to be used to generate reports on burst occurrence, condition assessment etc.;
- The GIS information will be kept up-to-date;
- The data can be used by management for reporting and operational staff for prioritising their work;

Active Leakage Control Procedure:

The strategy for the reduction of losses centres on the development of a dedicated leakage detection and location unit to undertake active leakage control. This will ultimately result in more leakage repairs being undertaken than is currently the case as leaks will be actively sought out. It is therefore important to be able to track both the identification of leaks and the repairs that result. In order to achieve this two types of information are collected:

- Leakage Information

The following data will be collected by the team upon detecting and locating a confirmed leak, and entered onto a reporting form:

  - Date of detection and location;
  - Operational area;
  - Location address;
  - Description of repair assumed to be required;
  - Information relating to the pipe to be repaired as known at the time;
  - Any other information of use (for example a sketch of the pipe layout and position of leak);

This information will assist the repair teams with the repair process by directing them to the position of the required repair and by indicating what type and size of repair fittings may be required.

The information will be returned to the central office in order that the details relating to the leak can be entered into the computerised database to allow for analysis at a future date.

Once input, a unique reference number will be assigned to the leak. This number allows the repair of the leak to be tracked and the repair details referenced to the correct leak location entry. The reference number will be printed on a second form which is given to the repair team.

- Repair Information

The information regarding the actual repair carried out falls into two categories:

  - Repairs to mains (including hydrants, valves etc.);
  - Repairs to service connections;

The information to be collected at this stage relates to the assets that have been exposed during the repair process along with the actual date of the repair. Blank forms (with the exception of the unique reference number) are printed following the input of the leak location data into the database. A copy of the leak detection and location information is given to the repair team along with the repair information form to enable them to locate the leak position.

On completion of the leak repair, the forms should be returned to the central office so that the data relating to the leakage repair can be input into the database and the record completed. A copy should be retained by the operational sector office for its own records.

Where a discrepancy is identified between the recorded asset information and the actual asset information, the relevant departments, such as GIS, will be informed and all records updated.

Where necessary, staff should be assisted to accurately complete the reports to ensure all repair information is captured.

Following this process will ensure that all the relevant data required for tracking leakage repairs is captured and that sufficient data is available to enable production of detailed reports relating to leakage repairs and asset condition.

Complaint Data Procedure:

Detailed records of a similar type to those completed for the leakage detection and rectification works will be completed for complaint data.

In a similar manner to the process outlined in the leakage detection and rectification section above, the complaint records will be sent to the central office (a copy will also be kept locally at the operational sector office), and the information entered onto a customer complaint database and directly onto the GIS. The comprehensive collection of data in this way makes it available for the preparation of reports, future planning of leakage detection activities and prioritisation of network improvement programmes.

This information will also be accessible by head office and operational sector staff.

The benefits of this process are:

- Detailed records will be maintained;
- Records will be maintained in an electronic format that enable the information to be used to generate reports on complaint types, asset condition, ranking of areas by complaint frequency and type etc;
- The GIS information will be kept up-to-date;
- The data can be used by management for reporting and operational staff for prioritising their work;

Management Reports Procedure:

The main advantage of holding the data in a database format is that a report can be generated using as many or as few of the data fields as required. Incorporation of the data into the GIS provides a geographical link that enables identification of 'clusters' of problems that require a broader approach to identifying a remedy than is the case with more isolated problems. This dual approach means that a number of reports can be readily built by engineers to present information in a clear and meaningful manner.

Examples of the content of reports that will provide useful information for the planning of both current and future actions are:

- A report containing a list of all the streets (pipes when there is more than one pipe in a street) where more than a fixed number of leakage repairs (for example 5) have been carried out during a certain period (for example the last 12 months). The benefits of this type of report are that:
    - It enables deterioration of the assets condition over time to be tracked;
    - An asset renewal schedule can be determined based on known failures;

- Valuable financial resources can be targeted more effectively resulting in greater capital efficiency;
- The reliability of the distribution network will be improved through the identification and replacement of “trouble spots”;
- It facilitates budgeting for future expenditure;

- A report which monitors the number of leakage repairs or service connection pipe renewals that are carried out within a predefined time scale (i.e. weekly or monthly) and for a specified reason (e.g. leak repair). This has a number of benefits, namely:
  - It allows the monitoring of the performance of staff;
  - It enables the efficient management of all related costs;
  - It facilitates budgeting for future costs;
- The number of repairs, and the time taken to carry out a repair from the date that the leak was located, can be analysed. This information will become increasingly more important as more leak detection work is undertaken since the number of leakage repairs required will increase. The benefits of this data are:
  - It enables the staffing levels of the repair teams to be monitored. If the time taken to repair leaks escalates it may indicate that more teams are required;
  - It facilitates budgeting for repair costs;
  - Over a period of time trends can be identified. For instance during certain periods during the year leaks may be more prevalent than at other times. Identifying these periods enables them to be managed more effectively;

6. CONCLUSION

The successful results obtained during the first five months of the leak detection and location activities show that there is a scope within ACC service area for proactive leakage search with acoustic techniques.

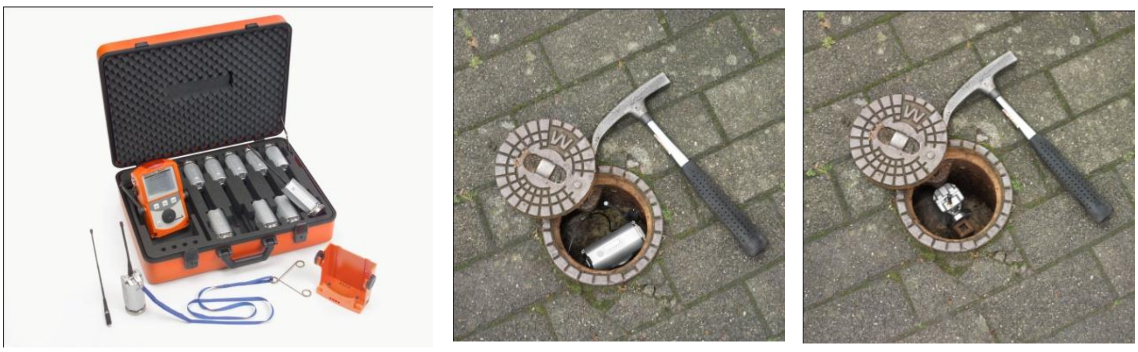
The nearby future should see ACC implement two teams working hand to hand in daily activities and emergency situations. The volume of hidden leaks found by both teams should continue during the first years to be equal to the ratios obtained during the pilot study (4 leaks per day per team) as the network rehabilitation process and the improvement of repair techniques will have a strong impact towards leakage reduction in mid-term and long-term futures.

The implementation of HDPE/PVC pipes in rehabilitation works and the control of pressure with PRVs will make more complex leak detection and location activities. This advocates for a future planning of leakage search activities based on a permanent hydraulic diagnosis of the water supply network that will track areas with constant or sudden degraded performance indicators (as shown in Vadul-lui-Voda example).

This last approach could be coupled to the use of stationary noise loggers that offer a practical alternative for permanently monitoring areas which have already been declared leak-free. Loggers are positioned into valves inside the measuring area. They can, of course, also be fitted to fire hydrants. The instruments record sounds in a defined measurement cycle and emit signals at a certain radio time. These are then transmitted out of the valve box by radio. The signals are received by a master receiver operated by a technician who collects the data when driving past.

The loggers do not have to be removed from their measuring positions, nor do the covers have to be opened. These data packets contain the main information from the previous measurement cycle. The minimum noise level plays a crucial role here. If the noise loggers at the measuring points are systematically patrolled in rotation, the minimum noise level readings for the respective measurement location can be compared. Provided there are no leaks, these values will not change. However, if a leak does occur, the minimum noise level will rise and remain at this increased level. Depending on the patrol schedule (e.g. weekly), the duration of the leak will be limited to this short period and the leak will be detected well before the next systematic network inspection, which may only take place in several months' time.

Figure 23 : Permanent leak noise loggers



Advantages:

- The loggers continuously monitor the background noise levels;
- The loggers can be deployed during the day and left for long periods enabling several surveys to be completed;
- The time taken to survey an area is reduced. With enough loggers, a hydraulic sector could be surveyed in a few hours (dependant on size, traffic etc);
- The process of leak detecting is de-skilled and automated;
- The productivity of the survey team is increased;

Disadvantages:

- Correlation or additional leak detection and location work within the areas of interest is still required;
- The units can generate false leak signals;
- It is expensive to cover a whole area with loggers;
- The method is dependent on the availability of suitable fittings;

The first results of the leak detection and location campaign show that within the inspected part of the network, the most critical areas in terms of hidden leaks are:

- **CIOCANA (PZ # 3) with 1.7 hidden leaks detected and located per kilometre** (76 leaks over a total inspected length of 46km). The measurement campaign on the water supply network led to a water balance that defined the LLI of this sector to **203 m^3/km/day**;
- **INDEPENDENTA-BOTANICA (PZ # 3) with 1.3 hidden leaks detected and located per kilometre** (72 leaks over a total inspected length of 57km)**.** The measurement campaign on the water supply network led to a water balance that defined the LLI of this sector to **76 m^3/km/day**;

In the next months, the leak detection and location team should be affected to the other areas where the measurement campaign on the water supply network found high values for the LLI parameter.

Future NRW reduction activities will need strong and well-organized interactions between the two leak detection and location teams, ACC central dispatch, operational sectors, GIS department and Commercial department to ensure its permanent success in improving performance parameters within the whole service area.