Sustainable water network management in Lempäälä municipality

Md. Mahabobur Rahaman Chowdhury

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Tampere University of Applied Sciences

ABSTRACT

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Md, Mahabobur Rahaman Chowdhury:
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The problem of NRW (Non-Revenue Water) in the water distribution network is a complex situation and causes trouble for water utilities worldwide. Leakage in the water system is one of the main sources of huge amount of water loss that involves poor service, complaint about quality standards and cost increase. The recovery of water loss due to the leakage in the distribution and transmission pipe can provide a solution. In LMWS (Lempäälä Municipality Water Service) the amount of lost water due to the leakage is a major problem. One fourth of the total water in the system is lost where most of the losses are caused by leaks.

The research concerns mainly the water management of LMWS, leak localisation and financial aspects. Literature survey was used to provide the clear picture of water loss and related topic. The common internationally used tools were also focused to reduce water losses. The main objective of the research was to locate leaks in the water distribution network and the survey was done only on the cast iron, asbestos cement and concrete pipe connection network. In this research financial loss caused by the water leakage was also assessed.

According to the key figure of 2011, the volume of NRW was estimated 266000 m^3, where 26600 m^3 of water was apparent loss and the rest 239400 m^3 was real loss and it was due to water leakage. The price of this water was calculated 139869,5 euro. Then, according to the leak report of the earlier years; the leak repair cost was figured out 13200 euro, where the financial loss due to the leakage was estimated 67503,8 euro.
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Key words: Water network, Non-revenue water, Water loss, Leakage, Lempäala municipality.

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ABBREVIATIONS AND NOTATIONS

AWWA	American Water Works Association
CAD	computer aided design
DMA	district metering areas
IWA	International Water Association
Jv-puhdistamo	Waste water treatment plant area
KA	key aqua
LMWS	Lempäälä municipality water services
NWR	non-revenue water
N/A	Lost water was not approximated
PE	Polyethylene
PRV	pressure reducing valve
PVC	Polyvinyl Chloride
VAT	Value Added Tax

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1 INTRODUCTION

Water is the most essential element of the world which is the best gift of nature. In everyday life it is one of the most widely used elements. It is the basic need for human life and human being cannot survive without water. Water is used for drinking, washing, heat exchanging, food processing, fire controlling and so on. It is also important for industrial use and agriculture. The natural water resources is limited so further availability of water is an important issue to sustain the human world. There are several factors that affect the water recourses. Population growth, weather changes, unusual use of water, lack of knowledge, waste of water, proper water management, Changes in the technologies and so on. The developing and the under developed countries are already suffering a lot for pure drinking water. In future the rate will increase more due to the increased demand of water. Due to rapid population growth, water withdrawal will increase 22 % by 2025 comparing to 1995 where in developing countries the level is 27 %. For domestic, industrial and livestock usage the increased level will be 62% where 71% will increase for domestic consumption and in developing countries the level will be 90%. (Rosegrant et al. 2002.)

Lempäälä municipality is a medium sized municipality of Finland. The economy of Lempäälä is based for instance on high-tech, automation and modern service industry. The population of the municipality is gradually increasing. New houses and industries are being built and therefore water demand is also increasing.

The water utility of Lempäälä is managed by LMWS, which one is also responsible for the waste water management. About 83 % of all residents are connected to LMWS. As Finland is a land of lakes, so the main sources of surface water are the natural lakes where ground water is also the source of water. The LMWS purchases treated water from Tampere water and City of Valkeakoski. The water network of Lempäälä is relatively old. The first water pipe was installed in 1960. The pipe material during that time was poor qualities cast iron and asbestos cement. The cast iron was the most problematic material in terms of failure. The plastic pipes were introduced on 1970 and currently 87 % of the whole network is made of plastic where still 8 % are cast iron (Löppönen, A. 2010). The NRW of LMWS is quite a lot which consist of apparent loss and real loss. The main problem in LMWS is the leakage. It causes a huge amount of water loss in the distribution network which does not have revenue value.

PICTURE1.1. Lempäälä municipality (Pärinäpojan 2012)

2 WATER BALANCE AND NON-REVENUE WATER

2.1 Definitions of water balance

The water balance means the detailed picture of the water produced, imported and exported, consumed and lost. It is like a guide which provides the information about the water lost. And the result comes in forms of consumers meter inaccuracy, data handling error, apparent loss and real loss. It also provides information about the lost water amount and reasons of water loss. (AWWA 2009, 8.)

<table>
<tr><td rowspan="10">System Input Volume (corrected for known errors)</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption (including water exported)</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="8">Non-Revenue Water (NRW)</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="6">Water Losses</td><td rowspan="3">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies</td></tr>
<tr><td>Systematic Data Handling Errors</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer metering</td></tr>
</table>

FIGURE 2.1. The IWA "best practice" water balance (Lambert & Mckenzie 2002).

According to the principle of water balance terms introduced by AWWA, Staff (2009, 10), the definitions are as follows:

- Annual volume of water input to the water supply is the system input volume.
- Annual volume of metered or unmetered water taken by registered customers on consume is authorised consumption.
- Difference between system input volume and authorised consumption is water losses.
- Unauthorised consumption, customer metering errors and data handling errors are apparent losses.
- Annual lost volume of water through leaks, breaks, overflows, service connection, up to the point of customer metering is real losses.
- System input volume that is billed and produce revenue is revenue water.
- The sum of unbilled authorised consumption, apparent losses and real losses is nonrevenue water which can be determined according to the difference between system input volume and billed authorised consumption.

2.2 Non-revenue water

NRW is the volume of water which can be defined as water that enters into the system input but cannot be determined from the system output. It means that it does not generate revenue. Basically NRW is the total loss of water which can be calculated from the difference of system input volume of water and billed authorised consumption. The NWR is combination of unbilled authorised consumption of water, apparent loss of water and real loss of water (Liemberger & Farley 2004).

The NWR is very important issue in the water distribution network and almost all distribution networks has a volume of NRW. According to the NRW rates in the urban area, the highest NRW rate is found in Guayaquil (city of Ecuador). The Rate is 73% where rate in Melbourne (city of Australia) is only 3%. In Helsinki (city of Finland) the rate is 17%. (SWAN 2011.)

2.2.1 Unbilled consumption

Unbilled consumption can be authorised or un-authorised. The unbilled consumption does not generate revenue. The consumption can be metered or un- metered. Example might be filling city street cleaning truck or swimming pool, water used by the fire department. (EPA 2009.)

The unbilled metered consumption is the quantity of water which is not lost from the system but no payment is received from the consumption. Water used in the treatment process can be the example. (EPA 2009.)

The unbilled un-metered consumption is the quantity of water which is authorised to use but no payment received for the consumption. Water main flushing and fire fighting are this type of consumption. (EPA 2009.)

The unauthorised consumption of water is the amount of water removed from the system without authorisation. It can be theft by illegal pipe connection or using un-metered fire hydrant for construction or other purposes. (EPA 2009.)

2.2.2 Apparent losses

Apparent loss of water consists of illegal water consumption, errors with the water meter and billing system. The apparent loss is the amount of consumed water for what no payment received. It is also nearly impossible to get the actual apparent loss. (Rizzo et al. 2007).

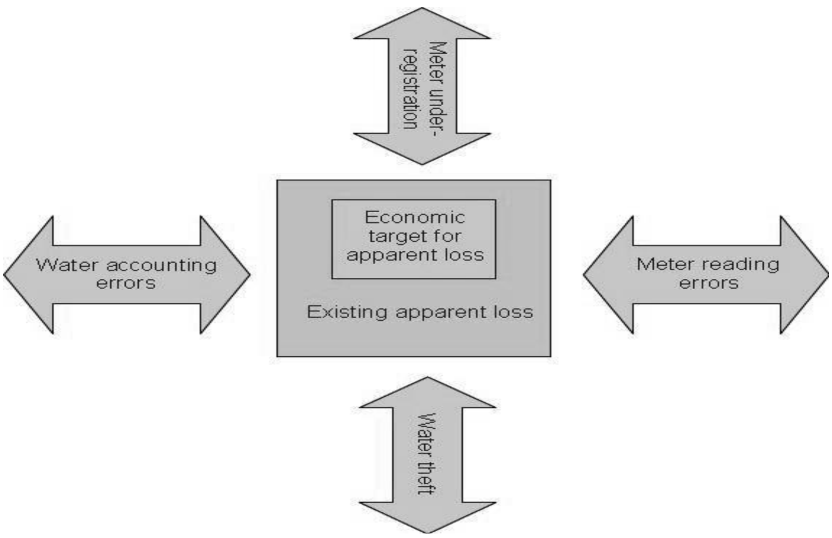

FIGURE 2.2. Sources of apparent losses (Rizzo et al. 2007).

According to the figure 2.2, it can be said that four factors are responsible for the apparent loss. The water theft can be possible from the fire hydrant or unbilled un-metered connection. The registered water meter can have error for which makes it impossible to measure accurate flows. Meter reading with mistaken can cause the meter reading error and computer based estimation which does not reflect the actual consumption can cause the accounting error. (Rizzo et al. 2007).

2.2.3 Real losses

The real losses of water are the physical or the actual loss of water from the system. Usually this water is not received by the customers to use. So it does not have revenue value but the cost of producing the water is available. The real losses are the physical leakage which is found in the water transmission and distribution system. Leakage and overflows from the storage tanks and leakage from the service connection is also included to the real losses. (EPA 2009.)

Distribution and transmission main leaks cause water loss from the system which receives no revenue can damage the system reliability and may cause the water quality problem. Storage leaks and overflows water is the quantity of lost water from the storage within the system. And lost water in the pipe connection from the main to the customer's point of use are the quantities of lost water from service connection piping leaks. (EPA 2009.)

2.3 Facts that affect the water losses

2.3.1 Effects from the water meter and pipes

Water Metering:

Water metering is an important part to reduce water loss. It causes a biggest part of the apparent losses. The first reason of water metering is to account the amount of water pumped to the system and accounting the charge for the use of water (Mays 2010). As water meter is a mechanical device, so the accuracy depends on proper use of meter. If the meter is under registered by small percentage for large volume of customers, it can result in sufficient loss of revenue. It is because of high volume of water passing through the inaccurate meter. On the other hand, if meter is over registered by small parentage, then the consumers will be overcharged. So, the meter should have accurately registered and should be tested. At the same time, if the device reaches its life time, it should be removed from the system to ensure the accurate metering. (Billings & Bruce 2009, 50.)

According to Kenneth & James (2009), the customer meter inaccuracies can have major impact on the Non-revenue water. The audit report, generated based on the city of Austin, Texas for 2005 represents that the water loss rate is 15.2 percent. And the under-recording customer meter were responsible for 25 percent of this loss, which is 3.8 percent.

Pipes:

Water pipes are important material in the water distribution system. Water reaches from treatment plant to customer through the pipe connection. But pipe breaks or burst results in real water loss. Pipe burst or breaks can happen for different reasons. If the material handled in laying pipe is not done correctly then pipe can have leakage. Also if the length of the pipe is not appropriate and stones are in contact of pipe then leakage can happen. Usage of nonadherence to join gaps, poor backfilling of tranches or excessive joint deflection also can be the reasons of pipe breaks. Excessive pressure, closing valves rapidly also cases pipe breaks. If the pipe material is metal then corrosion is also another cause of pipe leaking. (AWWA 2009, 93-95.)

2.3.2 Effects of pressure

Water pressure is the force of water needed to move water into the pipes. Water pressure management is the appropriate pressure level maintaining in the system to provide the service level for the customers. High pressure can cause the burst of water mains, leak and water waste. Computerised pressure control valves or retrofitting of electrics on the pressure reducing valves can be used to reduce un-necessary pressure in the night time which can minimise the breaking of pipe due to the high pressure of water (Pank

Mistry 2005). Water pressure management is the use pressure regulation valves and monitoring point to achieve consistent and lower water pressure level across the supply system. Reduced water pressure does not cause less water but a little bit more time needed to fill the washing machine or so on. (Sydney Water 2006.)

Pressure has a great effect in the leak rate. According to Van Zyl (2004), it has been determined that water pressure has much more effect than it is assumed. If the pressure is doubled then leakage rate in the pipeline increases by 40% but the rate is theoretical. The real rate of leakage is 100% and it increases as high as 570% which is identified using measurement in the water distribution system in UK and South Africa. (Van Zyl 2004.) It is also found that the pressure management does not only save the water volume from losses but also reduces the pipe burst (Meyer et al. 2009).

2.4 Methods of controlling the water loss

Water loss can be successfully controlled if the water in the system can be managed in right way. The First important approach can be indentifying the major reason of water loss and finding out the appropriate way to minimise that loss. Water loss means apparent loss, un-billed consumption and real loss (Liemberger & Farley 2004). According to the earlier presentation of this thesis, it can be figured out that water metering, pressure management and leaks in the networks are main reasons of water loss. Where water meter is responsible for the apparent loss, pressure in the water flow is responsible for the pipe burst and increasing of leaking water and leaks are responsible for real water losses.

According to Shammas & Ai-Dwohalia (1992), there are two ways of leakage control; active and passive. Active leakage control is to find out the leak in the system, locate it and repair the leak using appropriate methods. And passive control is to detect and repair the leak either due to the customer’s complaints or due to the appeared water on the surface area of the leaking places. (Shammas & Ai-Dwohalia 1992.)

2.4.1 Water metering

Water meter is an essential element in the water system. The main reason of the water meter is to help collecting revenue from the customers or helping in making the bill for the customers. On the other hand it also helps to locate the leaks, pressure problem in the water way, identifying the peak and non-peak hours. (EPD 2007.)

There is a saying "what you cannot measure you cannot manage". The water meter is a measuring device. So it can be said that it is a management tool. (Nsonde & Musumali 2009.) Water meters are not 100% accurate and can deteriorate its accuracy after the life time expired. As inaccurate meter provides inaccurate assessment; the accuracy of the water meter is very important. To provide the accurate data, bill and assure water accounted accurately; meter should be calibrated regularly and tested accordance to the recommendations. (EPD 2007.)

The DMA (District Metering Areas) is an efficient way to find out amount of NRW in the most problematic areas. Usually it is a defined area which has boundaries with water entering valve and closure valve. Bulk meter is installed in the entering and leaving points and it is use to record the quantities of water in the specific areas. Night flow measurement is another way to determine the NRW. Usually on the night time the water consumption goes down and so if any big pipe burst happens which is not appeared from the surface; can be identified easily by the night flow measurement within the DMA. When the renovation of big leakage is done then the water consumption in the DMA reduces which is visible in the night flow measurement but if the volume of the leakage water is very small amount then the repair may not meet the visibility threshold. (Morrison 2004.)

2.4.2 Pressure management

Reducing the real water losses in the water distribution system due to pressure management is nowadays' widely regarded. Pressure management influences the flow rate of existing leaks and burst. It also influences the frequency of the new leaks and burst. Economic frequency of active leakage control can also be influenced by proper pressure management. It can also extend the infrastructure life. In many cases, pressure management is considered as the first priority of the pipe burst frequencies and which reduces the repair cost. (Trow 2009.)

The main purpose of pressure management is to reduce water loss, minimise water leakage and maintain the required pressure at every node. The PRV (Pressure Reducing Valve) can be classified in three categories (Mckenzie 2002): fixed outlet, time modulated and flow modulated. The fixed outlet is very simple. It keeps the constant downstream flow through the PRV. The second one, time modulated categories is a time bounded device and that's why a timing device is connected with it. It reduces the downstream in a certain time of the day. And the certain time of the day is determined earlier as little demand. This category is effective if the demand of water always remain same which is not always possible. The flow modulated category works according to the demand. When the demand is high, the PRV works as deactivated and when the demand is low, the PRV reduces the downstream pressure to a fixed minimum level. The flow modulated controller can be updated with telephone or radio link to a critical point in order to maintain virtually no excess pressure at the critical point. (Nicolini & Zovatto 2009.)

Pressure management cannot stop the water loss from the existing leaks but proper pressure management can reduce the volume of lost water and further pipe burst. According to Liemberger & Farley (2004), a few tasks should be done before implementing a pressure management:

- Identifying the problematic zones
- Analysing the customers and limitation of control
- Field measurement of flow and pressure
- Potential output of the model
- Identify the correct control pressure valve
- Right control model to get the desired result
- Cost benefit analysis

2.4.3 Leak localigation

Leakage in the water distribution system causes the real loss of water. Water loss due to leakage can be in the transmission pipe, connection pipes, distribution pipes, joints, valves, fire hydrant, storage tank and reservoirs. The water loss in the system due to leakage is basically 20 to 30% (Cheong 1991). It can be more than that in some distribution systems and can be 50% (AWWA 1987).

There are some equipments which are commonly used for locating the leaks in the water pipe. The devices are noise logger, listening stick and noise correlators. The noise logger is good device to find out the leak in the pipe system easily but the effectiveness is questionable. The noise logger also cannot pinpoint the leak. (Hunaiodi et al. 2004.) The listening stick is a good device to make sure about the leaks. Basically it is used to listen the valve and the fire hydrant. Ground microphone is also a listening device which can pinpoint the leak. The effectiveness of both listening stick's and the ground microphone's depends on the experiences of the users. Noise correlator is the most effective device for pinpointing the leaks and for accurate result. It does not require experiences like the listening device requires. It also has some lacks. It is not reliable for silent leaks in cast iron pipes. It can be relied if the pipe material is plastic and diameter is large. Another important thing is that correlators are expensive. (Hunaiodi et al. 2004.)

Noise logger

Noise logger is a vibration sensor or hydrophone sensor which is a programmable data logger. It is a good device for investigating large area. The main outcome of this device is; it can detect the leak but cannot locate or pinpoint the exact leaking place. So it can help to easily find the leaking area. Basically the loggers are placed up on the valve or fire hydrant in the distribution area and left for whole night.

Usually the loggers are placed 200 to 500m apart from each other because each logger can cover that area. The distance can be differed for the pipe materials. The loggers are programmed to collect the pipe noise between 2 to 4 AM. So on the next day when the loggers are picked up, the data can be stored in the personal computer. The frequency of the noise level can detect the presence of the leaks. The new models of the noise logger are quite handy to use. It sends the results wirelessly to a roaming receiver. It also displays whether the pipe is leaking or not. (Hunaiodi et al. 2004.)

The effectiveness is questionable because the loggers are moved from one survey area to another survey area. According to Van der Klejj and Stephenson (2002), it was found that the noise logger failed to detect 40% of leaks which were detected by detailed listening surveys.

Listening stick

The listening device includes listening stick and ground microphone. The Listening stick is basically used to listen the valve and fire hydrant and analysing the noise; whether the noise is from the leaks or from the surrounding. If the valve or fire hydrant is totally silent then it can be confirmed that there is no leak but if there is any noise then detection of the right noise depends on the inspector's experiences. The same thing also happens to the ground microphones. The effectiveness depends on the experiences. The difference between listening stick and the ground microphone is that the listening stick cannot pinpoint the leak but the ground microphone can do it (Hunaiodi et al. 2004). In this case, noise logger can be the first step to find out the leaked area, valve and fire hydrant. Then listening stick can be used to confirm the leakage through the network and then ground microphone can be used to pinpoint the exact leaking point.

Noise correlator

Noise correlator is a microprocessor-based device which is portable, easy to use and very much effective method to pinpoint the exact leaking place. It measures the leak noise from two locations of a pipe section. Depending on the device, the leak noise can be either sound or vibration. The measured noise signal transmitted wirelessly to the correlator device. It pin points the leaking position based on time shift of two signals, propagation velocity of the leak noise and distance between the two sensors. (Hunaiodi et al. 2004.)

The accuracy depends on the pipe material, diameter and distance. The pipe material is important because noise velocity is different in different materials. If the diameter and distance is not measured accurately, the correlator will locate the leaking position far from its exact position. Then basically the correlator cannot help in pinpointing the leaks.

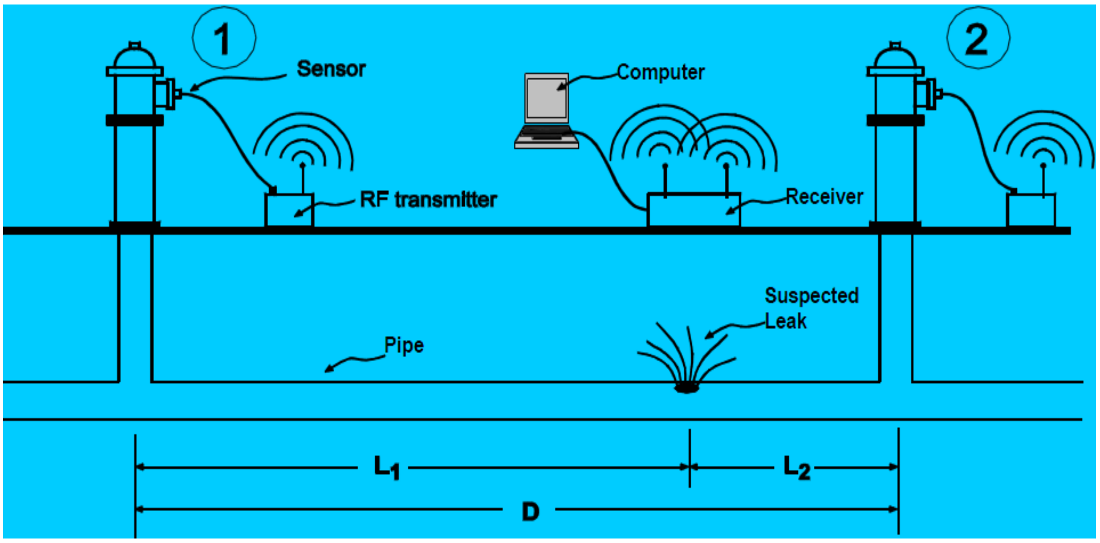

FIGURE 2.3. Principle of leak noise correlator. The leak emits a sound wave which is transmitted through the pipeline to the sensors 1 and 2 (Hunaiodi et al. 2004).

The new model of noise correlator is more effective and can be used for all types of pipe materials. If the distance of the two sensors is short then it gives best result. For plastic, 100 m can be the highest distance with the low frequency vibration sensors. For higher distance, use of hydrophones is recommended. For metal pipe the distance can be 500 m but 200 m is recommended. (Hunaiodi et al. 2004.)

3 ANALYSIS ON LEMPÄÄLÄ MUNICIPALITY

Lempäälä is a medium sized town of Finland and it is situated close to the industrialised town Tampere. Before talking about Lempäälä municipality, it is good have a little introduction about Finland. Finland is of the Nordic countries which is known as a land of thousands lakes. There are total 188,000 lakes and 180,000 islands. The 10% of the whole surface is covered with water and 69% by forest. The temperature in the winter can be -30 °C and summer +20 °C but it depend on the place of measurement. (Jänis 2012; Löppönen 2010.)

In Finland the municipalities are responsible for water and waste water services. The first piped water supply system was built about 100 years ago. On that time the surface water was the only source of water but during the last 30 years the ground water usage has been increased. (Pietilä 2006.)

In Finland, each municipality has its own water and waste water utility. The largest one is the Helsinki Metropolitan Area Water Company. (Pietilä 2006.)

TABLE 3.1. The largest water suppliers in Finland in 2004 (Pietilä 2006)

City	Population Served	Water Supplied Million (m3/year)
Helsinki	920000(1)	80
Espoo	220000(2)	20
Tampere	200000(2)	20
Vantaa	180000	16
Turku	175000	17
Oulu	125000	10

Notes:
(1) Includes residents of neighbouring municipalities
(2) Excludes water supplied to neighbouring municipalities

3.1 Lempäälä municipality

Lempäälä is situated in the Tampere region approximately 160 km north from the Finnish capital Helsinki. The municipality is about 20 km south of Tampere. The municipality area is 307.6 km^2 and the population is about 20589 (2010) which has increased 14% comparing to the population of 2003. The population density is 66.9 per km^2. The population is increasing and economy is based on automation and modern service industry. (Seppänen 2008; Löppönen 2010.)

3.2 Water management in Lempäala:

Lempäälä municipality is responsible for water and waste water services and management. Lempäälä water works supplies water for about 17800 residents. About 83% of the total resident is connected to the Lempäälä municipality water network. The LMWS sales water to Pirkkala, Viiala and to Vesilahti municipality. (Löppönen 2010.)

The LMWS has its own three ground water intake plants which are situated in Leukamaa, Sotavalta and Lempoinen. It comprises 37.5% of the total water demand. LMWS purchases treated water from Tampere water and city of Valkeakoski. The average amount of bought water is 2000 m^3 per day. The raw water is treated before it goes to the distribution network. Water quality is monitored and water sample is taken randomly during different times of the year from different distribution networks and delivered to the laboratories for analysing. The water quality of the water coming from the customers' water taps is also monitored. (Seppänen 2008; Löppönen 2010.)

Water connection is made according to the customer's application. Customer, connected to the distribution network, is responsible for providing the service pipe to the mains. There is a fixed fees for installing meter in the house and plumber works to make the connection. The LMWS provides the plumbers and whole connection works where the customer pays for it. Usually the meter size is 10 to 20 mm for single family houses but for multi-storey buildings or factories the meter size can be 20 to 100 mm. In Finland, checking the water meter by the utility staff is rare. In Lempäälä the customers make phone call or send the meter reading via internet. In multi-storied building there is usually one meter and that's why the bill is made according to the number of consumers and size of the apartment. (Seppänen 2008.)

3.3 Water network and distribution:

The total length of the water network of Lempäälä is 251 km where the first water pipe was built in 1960. Main pipe materials for the water network are cast-iron, asbestos cement, variation of PVC (Polyvinyl Chloride) and PE (polyethylene) (PE includes PEM & PEH). The plastic material was mostly introduced on 1970's and till now the plastic material is the main pipe material in Lempäälä water network. (Seppänen 2008.) In Lempäälä if the older pipe connection is repaired due to leakage or renovation work takes place in an area where the pipe material is not plastic, then the plastic pipe is used instead of using cast iron or asbestos cement pipe.

The TABLE 3.2. shows the different pipe materials and the length of those pipe materials. According to the table it can be identified that most of the water pipe material is plastic. There is also cast iron and asbestos cement and clay material but LMWS is trying to change all these material to plastic material and that's why every year they are renovating some specific area where the pipe connection is very old and has leakage problem. This renovation parameter depends on the fund and budget specified for each year.

TABLE 3.2. Different Type of pipe materials and length

Pipe material	Length (m)
Asbestos	16298,2
Concrete	293,7
Not specified	612,3
Clay	63,8
Cast iron	22791
Plastic	302875,4
PEH Plastic	24641,1
PEM plastic	964,2
PVC plastic	3673,6
Un known	41801,3

The FIGURE 3.1. shows the percentage of different pipe material and from the figure it can easily determined that most of the pipe material is plastic. There are also PEH, PEM, PVC; which are different types of plastic. There are also unknown and unspecified materials which are mentioned in the LMWS database.

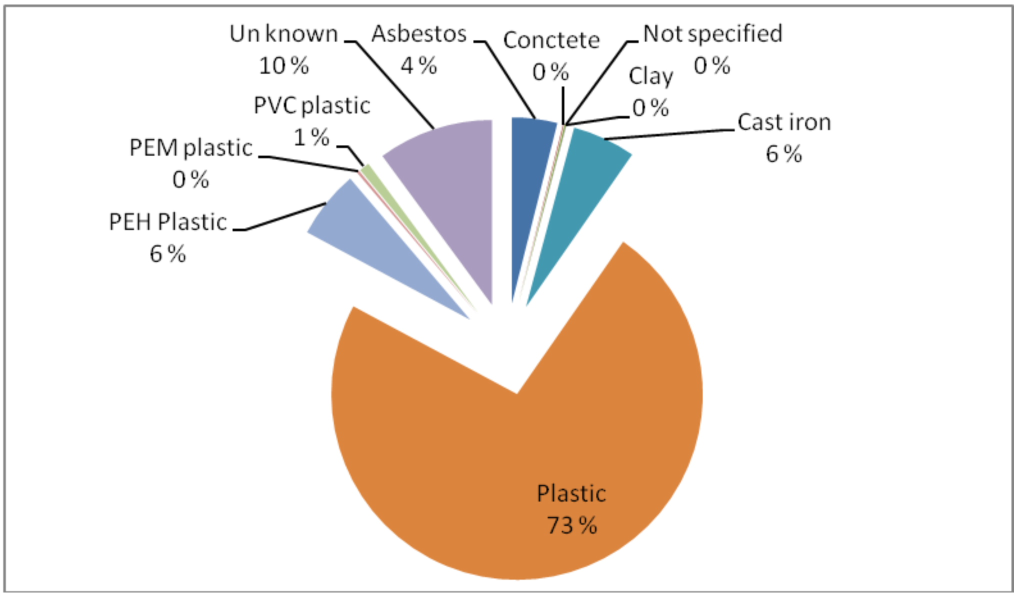

FIGURE 3.1. Different type of pipe material in percentage

The cast iron pipe is most problematic pipe material. The failure of the pipe connection is important and it depends on several cases. Freezing cold is also one case of failure. The most common causes are the installation work and excavation work. Internal corrosion is also another reason for failure what happens to the old cast iron pipe connection. (Löppönen 2010.)

LMWS has two water towers which are named as Sääksjärvi and Hakkari water towers. LMWS has four pressures Zone which is pressurized by four booster pump station. There are sufficient shut valve and fire hydrant in the municipality which are generally in good condition though they are not checked in a regular basis. All pump stations and the critical points are in the computer system and so critical information goes to the duty officers. (Seppänen 2008; Löppönen 2010.)

3.4 Water loss management

LMWS uses Sophisticated CAD based software which is known as KA (Key Aqua). All the data about the network is stored there. It has got the whole water network maps and is updated all the time. The software contains information about the pipe material, installation year, length and diameter. It also includes the information about the water meter. The software is used for both pure and waste water network. The manhole, shut valve and fire hydrant can be located according to the map. The software also keeps the information about the pipe burst information. If the pipe is renovated then the new pipe material length and diameter is updated to the software. On the same way if the valve or fire hydrant is moved or new valve and fire hydrant is installed then it is also updated to the software. When the leaks are identified and renovated, the total information about the leaks are stored in the software for further use. The leakage information contains the leaked position, repair date, isolation time, number of houses affected for isolation, repair cost, losses of water and so on. Basically this information is stored by the engineer responsible for that work.

As the district meters are connected to the monitoring system, the consumption of water can be observed from the database. The remarkable leakage can be indentified in that particular pressure zone from the monitoring database. In the water network there are several pressure sensors which indicates the fluctuation of pressure and which also indicates the suspection of burst or leakage. The database also saves the data and that's why the data from the earlier year can be found from the database. The water consumption can be observed on hourly basis, weekly basis, monthly basis or yearly basis depending on use, which helps to compare the data. It also helps to determine the night flow analysis. If the leakage water can manage to enter the waste water network then the amount of pumping waste water increases. So, when it can be approved that the leakage water enters into the waste water network then by analysing the pumping water of that specific pumping station, total leakage water can be identified. From when the leakage is active can be also identified from this data. Basically on the day of repair the water consumption goes down, which can be observed from the pure water monitoring database (if the volume of leakage water is high). It is also true to the waste water pumping station monitoring database (only if the leakage water enters to the waste water network).

LMWS repairs the pipe when the leakage or pipe burst is found in the network. Basically it is done according to their own suspection or customers complaints or phone.

PICTURE 3.1. Excavation happening to find out the leaking point (Chowdhury 2012)

LMWS has its own noise loggers, listening stick and ground microphone. These devices help to find out and locate the leaks. LMWS does not have its own correlator. So, in case of need; LMWS hires private company for the correlation. On 2011 and 2012 the water network was surveyed using all kinds of leak locating devices.

Pressure is controlled by the pumping station and the level of water tower. The pump is equipped with the frequency converters. The pump gets signal from the pressure sensors in the network. So, when the pressure goes down or high; the pump automatically adjusts the pressure according to the desired levels. Pressure control to reduce the water loss is favourable for LMWS. (Löppönen 2010.)

3.5 Leak report from last year

In the year 2011, total 12 leak suspects were found with noise logger. The suspects areas were Ahosti, Jv-puhdistamo, Karhunpelto, Majauslahti, vanattara and Välimäki. Among them eight leak suspects did not give leaking sound or the sound was coming from the nearby manhole when they were checked with the listening stick. Other four were proved to be actual leaks. Those places were correlated.

TABLE 3.3. Leak suspection found with noise logger in 2011

Place	lk	Area
Next to kehätie	L	Ahosti
Cross road of Tamperentie and ke-hätie	L	Ahosti
Kiertolahdentie	L	Jv-puhdistamo
Fire hydrant 94	L	Jv-puhdistamo
Riihirannantie	L	Jv-puhdistamo
Fire hydrant 220	L	Karhunpelto
Koskitie	L	Majauslahti
Fire hydrant 57	L	Majauslahti
Fire hydrant 78	L	Majauslahti
Valve near the pump in Vanattara	L	Vanattara
Kynäröntie	L	Välimäki
Next Välimäki pump sation	L	Välimäki

The first correlation was done for fire hydrant 78. Pipe lines near that places were correlated in three directions and all correlations showed that the leak was in the valve of a house connection. The valve was next to manhole 13319 in the cross roads but there was no water in the pipe around the valve and also no water entered into the manhole next to the valve. The fire hydrant was listened again and finally came up to the result was that there might be a leak also in the connection of the fire hydrant.

The second correlation place was in Rypyntie. The purpose of this correlation is to check the leak suspects found in fire hydrant 57. But there was no need to do correlation in that place because the house connection valve next to the fire hydrant was found leaking water. Pipe around the valve was covered with water. The valve was also verified with the listening stick.

The correlation place was in the cross road of Kivenkkääntie and Höytämöntie to check the leak suspects Kyynäröntie. The house connection valve near manhole 29215 was correlated in both directions and the correlation showed that the leak was in the house connection valve or close to it. Sound heard with the ground microphone was loudest in close to the valve. So, most likely the leak was in the house connection valve.

The leaking sound was heard from the main valve next to the pump station. Correlation in Ratatie and Välimäenranta showed that the leak was the valve. Surrounding of the valve was listened with the ground microphone but almost nothing was heared because the ground was recently moulded and the material was soft clay which transferred sound poorly.

4 SCOPE OF THE RESEARCH

The research basically focuses on the water distribution services of LMWS. Though LMWS is responsible for both water and waste water distribution services, the research is only carried out on the water distribution services. The scope of the research is to concentrate only the water loss management of LMWS which is due to the leakage in the distribution network. The total Infrastructure of the water management is focused (without detailed analyses) to help formulating the real problem.

4.1 Objectives

The aim of this task is to find out leaks in the water distribution network, figure out the amount of lost water due to the leakage and the economical effect of lost water caused by the leakage. The research goes on LMWS water network. As the most problematic pipe networks are cast iron and asbestos cement therefore, the research basically carried out on those specific pipe networks. The water management of Lämpäälä municipality is also focused in the Thesis. The older record of pipe burst and leakage is analysed and the economical effect is figured out.

The Thesis focuses on the following parts:

- Different facts related to water loss
- Different factors that generate water loss
- The way how water is being lost
- The way to control water loss
- Step before and after identifying the leakage
- Economical losses due to leakage

5 MATERIALS AND MATHODS USED IN THIS STUDY

Leakage identification is very important step to reduce water loss. The main purpose of the research was to identify leakage in the pure water network. The research focused on the data found during the survey. The first step of doing the investigation was to follow the map and determine the place where the investigation will be done. The investigation was basically carried on the asbestos-cement and cast iron pipe connection.

5.1 Noise logger investigation

The noise logger was used first to determine the leak. The LMWS has 10 loggers. So, it was possible to install 10 loggers in a day in 10 different places. After checking the map from KA, the 12 or 13 valve and fire hydrant were determined to install loggers. The more two or three valve or fire hydrant was determined because sometimes some valve or fire hydrant could not be found or it did not have enough space to install the logger. Then the maps were printed out to help finding the valve or fire hydrant during the installation work. Then the loggers were installed and the number of logger (printed in each logger) and place of installation was recorded in an excel sheet.

PICTURE 5.1. Noise logger installation inside the fire hydrant (Chowdhury 2012)

The loggers were left there for the whole night because it was programmed to collect the pipe noise between 2 to 4 AM. On the next day; the logger s were picked and at the same time the data from each logger was stored in the excel sheet.

5.2 Listening stick investigation

After doing the noise logger checking; the next step was to listen the valve or fire hydrant physically. Only those fire hydrants and valves were listened where the leak suspection was found from the noise logger investigation.

PICTURE 5.2. Listening valve with listening stick (Chowdhury 2012)

The listening stick investigation was done with accompany of Arto Löppönen (Engineer of LMWS). Some of the leak suspections were skipped because those were either in the renovation area or found leaking early. With the listing stick; the specific valves and fire hydrant was listened and made assumption of possible leakage.

5.3 Correlation investigation

The final step of the leakage identification was correlation. The correlation report gives the exact position of the leakage. But sometimes there are number of factors which disturb the correlation process. The pipe material, diameter and distance are the important factors of the correlation. Thus, not always the exact position is given by the correlator.

After checking the suspected valve and fire hydrant with the listening stick the survey team estimated three places to do correlation. The LMWS does not have its own correlation device. So, the correlation service was hired from a private company. Before the correlation, the pipe material, diameter of the pipe and the distance of the valve or fire hydrant were determined.

PICTURE 5.3. Noise correlator investigation (Chowdhury 2012)

On the correlation process, the both devices were installed in the valves and analysed the graph. In every case, the correlation was done between the suspicious valve/fire hydrant and the surrounded valve/fire hydrant.

6 RESULTS AND DISCISSION

6.1 Leakage identified with noise logger (DATA)

The data shows the result about the noise logger investigation. Here the (Place) shows the fire hydrant and valve where the logger had been installed. The fire hydrant has got its own number but the valve does not have any number. So the valve is identified according to a nearby manhole which has an identification number. In some cases if there was no manhole found nearby then the place had been identified according to the cross road name or any identical location. (LK) means whether the valve or fire hydrant gives leak suspection or not. (Area) gives the information about the area of Lempäälä where the logger had been installed and the time shows the day and time when the logger had been picked. The (L) mark shows the leakage. The investigation was on Ahosti, Höytämö, Jv-puhdistamo, Karhunpelto, Kulju, Majauslahti, Moisio 1, Myllyranata, Ryynikka, Vanattara and Välimäki areas. Basically these areas have cast iron and asbestos cement pipe network. The logger had been installed in 121 places. Among them 27 places are from Ahosti, 3 places from Höytämö, 24 places from Jv-puhdistamo, 11 places form Karhunpelto, 6 places from kulju, 10 places from Majauslahti, 2 places form Moisio 1, 2 places from Myllyranata, 9 places from Ryynikka, 1 place from Vanattara and 25 places from Välimäki area. The Installetion started on 19th of April and continued till 22th of May.

TABLE 6.1. Noise logger survey data

Place	Lk	Area	Time
Fire hydrant (197)	N	Ahosti	20.04.2012 (08.10)
close to manhole 01346	N	Ahosti	20.04.2012 (08.14)
Close to manhole 01317	N	Ahosti	20.04.2012 (08.21)
Fire hydrant (202)	L	Ahosti	20.04.2012 (08.28)
Fire hydrant (204)	N	Ahosti	20.04.2012 (08.28)
Close to manhole 01315	N	Ahosti	20.04.2012 (09.06)
Fire hydrant (199)	N	Ahosti	20.04.2012 (09.08)
On left side of 01130 and 01129	N	Ahosti	23.04.2012 (12.21)
Fire hydrant (194)	N	Ahosti	23.04.2012 (12.12)
Near manhole 01356	N	Ahosti	23.04.2012 (12.30)
Near manhole 01317	N	Ahosti	23.04.2012 (12.26)
Cross road of tamperentie and kehatie	N	Ahosti	23.04.2012 (12.16)
Fire hydrant 202	L	Ahosti	25.04.2012 (01.12)
Valve near the fire hydrant 202	N	Ahosti	26.04.2012 (11.40)

Close to manhole 01315	N	Ahosti	18.05.2012 (10.10)
Fire hydrant close to manhole 01346	N	Ahosti	18.05.2012 (10.10)
Fire hydrant 197	L	Ahosti	18.05.2012 (10.10)
Fire hydrant 198	N	Ahosti	18.05.2012 (10.20)
Valve after manhole 01130	N	Ahosti	18.05.2012 (10.30)
Fire hydrant 194	N	Ahosti	18.05.2012 (10.30)
Fire hydrant	N	Ahosti	18.05.2012 (10.20)
Close to manhole 01226	N	Ahosti	22.05.2012 (08.56)
Beside tamperentie on the same line to fire hydrant 197 and man-hole 01349	N	Ahosti	22.05.2012 (09.01)
Beside tamperentie on the same line to fire hydrant 197 and man-hole 01349	N	Ahosti	22.05.2012 (09.12)
Beside tamperentie on the same line to fire hydrant 197 and man-hole 01349	N	Ahosti	22.05.2012 (09.11)
Beside tamperentie on the same line to fire hydrant 197 and man-hole 01349	N	Ahosti	22.05.2012 (09.04)
Beside tamperentie on the same line to fire hydrant 197 and man-hole 01349	N	Ahosti	22.05.2012 (09.03)
The end of Höytämönkuja	L	Höytämö	25.04.2012 (12.12)
Höyämönpolku, near manhole 39219	N	Höytämö	26.04.2012 (11.50)
The end of Höytämönkuja, an-other valve	L	Höytämö	26.04.2012 (11.52)
Fire hydrant 94	L	Jv-puhdistamo	26.04.2012 (11.03)
Valve close to manhole 32119	N	Jv-puhdistamo	26.04.2012 (11.07)
Fire hydrant 110	N	Jv-puhdistamo	26.04.2012 (11.09)
Fire hydrant 111	N	Jv-puhdistamo	26.04.2012 (11.13)
Fire hydrant 112	N	Jv-puhdistamo	26.04.2012 (11.11)
Urheilukatu near manhole 32128	N	Jv-puhdistamo	27.04.2012 (10.32)
Fire hydrant 114	N	Jv-puhdistamo	27.04.2012 (10.30)
Rekolantanhua, near manhole 32108	N	Jv-puhdistamo	27.04.2012 (10.40)
Beside pirkkalantie and close manhole 32206	N	Jv-puhdistamo	27.04.2012 (10.38)
Fire hydrant 95	N	Jv-puhdistamo	30.04.2012 (11.03)
kiertolahdentie, near manhole 32403	L	Jv-puhdistamo	30.04.2011 (11.01)

Sammalpolku, near manhole 32216	N	Jv-puhdistamo	30.04.2012 (11.10)
Cross road of sienipolku and keskuskatu	N	Jv-puhdistamo	30.04.2012 (11.20)
Fire hydrant 106	N	Jv-puhdistamo	30.04.2012 (11.13)
Fire hydrant 96	N	Jv-puhdistamo	30.04.2012 (11.24)
Fire hydrant 97	N	Jv-puhdistamo	30.04.2012 (11.27)
Near manhole 32422	N	Jv-puhdistamo	30.04.2012 (11.32)
Fire hydrant 98, close to manhole 32428	N	Jv-puhdistamo	30.04.2012 (11.36)
Fire hydrant 104	N	Jv-puhdistamo	02.05.2012 (10.55)
Fire hydrant 102	N	Jv-puhdistamo	02.05.2012 (10.57)
Fire hydrant 101	N	Jv-puhdistamo	02.05.2012 (11.24)
Behind the treatment plant	N	Jv-puhdistamo	02.05.2012 (11.00)
Close to manhole 32403	N	Jv-puhdistamo	07.05.2012 (11.20)
Fire hydrant 115	N	Jv-puhdistamo	27.04.2012 (10.35)
Fire hydrant (206)	N	Karhunpelto	20.04.2012 (09.12)
Fire hydrant 278	N	Karhunpelto	25.04.2012 (12.55)
Fire hydrant 246	N	Karhunpelto	25.04.2012 (12.58)
Fire hydrant 248	N	Karhunpelto	25.04.2012 (01.01)
Valve near Fire hydrant 249	N	Karhunpelto	25.04.2012 (01.04)
Fire hydrant 220	N	Karhunpelto	25.04.2012 (01.08)
Fire hydrant 246	N	Karhunpelto	15.05.2012 (11.41)
Fire hydrant 248	N	Karhunpelto	15.05.2012 (11.43)
Close to fire hydrant 249	N	Karhunpelto	15.05.2012 (11.45)
Close to fire hydrant 278	N	Karhunpelto	15.05.2012 (11.39)
Fire hydrant 206	N	Karhunpelto	18.05.2012 (09.59)
Near manhole 11606	N	Kulju	23.04.2012 (12.05)
Near manhole 11103	N	Kulju	23.04.2012 (11.34)
Near manhole 11143	N	Kulju	23.04.2012 (11.37)
Near manhole 11314	L	Kulju	23.04.2012 (11.21)
On peräkorventie near the presserising pump and near manhole 11313	N	Kulju	24.04.2012 (08.38)
Close to manhole 11315	N	Kulju	27.04.2012 (09.12)
Fire hydrant 81	N	Majauslahti	02.05.2012 (11.10)
Majauslahdentie, near manhole 13308	N	Majauslahti	02.05.2012 (11.13)
Fire hydrant 75	N	Majauslahti	02.05.2012 (11.19)
Close to manhole 13104	L	Majauslahti	02.05.2012 (11.20)
Close to manhole13209, Fire hy-	N	Majauslahti	02.05.2012 (11.17)

drant			
Close to manhole 13205	N	Majauslahti	03.05.2012 (11.50)
Close to manhole 13107	N	Majauslahti	03.05.2012 (11.52)
Fire hydrant 58	N	Majauslahti	03.05.2012 (12.00)
Fire hydrant 57	L	Majauslahti	03.05.2012 (12.03)
Close to manhole 13226	N	Majauslahti	03.05.2012 (12.12)
In between manhole 14233 and 14232	N	Moisio 1	27.04.2012 (10.25)
Fire hydrant 119	N	Moisio 1	27.04.2012 (10.22)
Fire hydrant 50	N	Myllyranata	03.05.2012 (12.10)
Near the pump station and man-hole 18201	N	Myllyranata	07.05.2012 (11.40)
Fire hydrant 55	N	Ryynikka	03.05.2012 (12.07)
Fire hydrant 53	N	Ryynikka	03.05.2012 (12.13)
Fire hydrant 54	N	Ryynikka	03.05.2012 (12.14)
Fire hydrant 52	N	Ryynikka	03.05.2012 (12.20)
Fire hydrant 56	L	Ryynikka	07.05.2012 (11.30)
Close to manhole 22211	N	Ryynikka	07.05.2012 (11.35)
Fire hydrant 54	N	Ryynikka	22.05.2012 (08.29)
Close to manhole 22228	L	Ryynikka	22.05.2012 (08.28)
Close to manhole 22227	N	Ryynikka	22.05.2012 (08.28)
Near manhole 30117	L	Vanattara	23.04.2012 (11.42)
Fire hydrant 148	N	Vanattara	24.04.2012 (09.03)
Fire hydrant (201)	N	Välimäki	20.04.2012 (08.10)
Välimäenranta, close to manhole 29204	N	Välimäki	24.04.2012 (08.50)
Välimäenranta, close to manhole 29201 and the pump station	N	Välimäki	24.04.2012 (08.49)
Fire hydrant 223	N	Välimäki	24.04.2012 (08.58)
Fire hydrant 224	L	Välimäki	24.04.2012 (08.48)
Fire hydrant 226	N	Välimäki	24.04.2012 (08.49)
Höytämöntie, near manhole 29115	L	Välimäki	24.04.2012 (08.49)
Mäyräahteentie, near manhole 29114	N	Välimäki	24.04.2012 (08.49)
Fire hydrant 227	N	Välimäki	24.04.2012 (09.07)
Fire hydrant 225. Does not exist	N	Välimäki	25.04.2012 (12.10)
Fire hydrant 221	N	Välimäki	25.04.2012 (12.50)
Telinetie, near manhole 29322	N	Välimäki	25.04.2012 (12.53)
Fire hydrant 229	N	Välimäki	26.04.2012 (12.00)
Höytämöntie, near manhole 29137	N	Välimäki	26.04.2012 (12.03)
Next valve of fire hydrant 224	N	Välimäki	27.04.2012 (10.05)
In between manhole 29158 and 29115	N	Välimäki	27.04.2012 (9.25)
Close to manhole 29204	N	Välimäki	14.05.2012 (08.39)
Close to manhole 29213	N	Välimäki	14.05.2012 (08.39)
Close to manhole 29201	N	Välimäki	14.05.2012 (08.36)
Close to manhole 29114	N	Välimäki	14.05.2012 (08.30)
Close to manhole 29144	N	Välimäki	14.05.2012 (08.29)
Fire hydrant 227	N	Välimäki	14.05.2012 (08.34)

Fire hydrant 221	N	Välimäki	15.05.2012 (13.00)
Close to manhole 29324	L	Välimäki	15.05.2012 (11.48)
Fire hydrant 201	N	Välimäki	18.05.2012 (10.10)

According to the data among 121 places; 16 places got the leak suspection where 3 Suspection in Ahosti, 2 suspection in Höytäämö, 2 suspection in Jv-puhdistamo, 1 suspetion in Kulju, 2 suspection in Majausleahti, 2 suspection in Ryynikka, 1 suspection in Vanattara and 3 suspection in Välimäki. TABLE 5.2. shows the suspection areas.

TABLE 6.2. Leak suspection found with noise logger

Place	Lk	Area	Time
Fire hydrant 202	L	Ahosti	20.04.2012 (08.28)
Fire hydrant 202	L	Ahosti	25.04.2012 (01.12)
Fire hydrant 197	L	Ahosti	18.05.2012 (10.10)
The end of Höytämönkuja	L	Höytämö	25.04.2012 (12.12)
The end of Höytämönkuja, another valve	L	Höytämö	26.04.2012 (11.52)
Fire hydrant 94	L	Jv-puhdistamo	26.04.2012 (11.03)
kiertolahdentie, near manhole 32403	L	Jv-puhdistamo	30.04.2011 (11.01)
Near manhole 11314	L	Kulju	23.04.2012 (11.21)
Close to manhole 13104	L	Majauslahti	02.05.2012 (11.20)
Fire hydrant 57	L	Majauslahti	03.05.2012 (12.03)
Fire hydrant 56	L	Ryynikka	07.05.2012 (11.30)
Close to manhole 22228	L	Ryynikka	22.05.2012 (08.28)
Near manhole 30117	L	Vanattara	23.04.2012 (11.42)
Fire hydrant 224	L	Välimäki	24.04.2012 (08.48)
Höytämöntie, near manhole 29115	L	Välimäki	24.04.2012 (08.49)
Close to manhole 29324	L	Välimäki	15.05.2012 (11.48)

6.2 Leakage identified with listening stick (DATA)

Among the 16 leak suspection places, 9 places had been checked with the listening stick. Among them 1 from Ahosti, 2 from Höytämö, 1 from from Jv – puhdistamo, 1 from Kulju, 1 from Majauslahti, 1 from Vanattara and 3 from Välimäki. The other places were skipped because the areas were supposed to be renovated in the near future or the noise came from the closest manhole.

TABLE 6.3. Leak suspection check with listening stick

Place	Lk	Area	Checking with listining stick
Fire hydrant (202)	L	Ahosti	x
The end of Höytämönkuja	L	Höytämö	x
The end of Höytämönkuja, another valve	L	Höytämö	x
Fire hydrant 94	L	Jv-puhdistamo	x
Near manhole 11314	L	Kulju	x
Close to manhole 13104	L	Majauslahti	x
Near manhole 30117	L	Vanattara	x
Fire hydrant 224	L	Välimäki	x
Höytämöntie, near manhole 29115	L	Välimäki	x
Close to manhole 29324	L	Välimäki	x

6.3 Leakage identified with noise correlator (DATA)

After checking the valve and fire hydrant with the listening stick, three places were decided to do the correlation. The first correlation was done in Telinetie (Appendix 1) to check the leak in the valve near the manhole 29324. The first device was installed in the suspicious valve near the manhole 29324 and the second one in the valve near the manhole 29322. The distance between these two valves was 71.47 m and the diameter of the pipe was 100 mm and the material of the pipe was cast iron. According to the correlation graph, visible peak was found and it seemed that the leak might be very close to the first valve near the manhole 29324. Then, the first device kept on the same place and the second one placed in the valve near the manhole 29362. It was 153.13 m away from manhole 29324 and the diameter of the pipe was 100 mm and the material was cast iron. But this time no clear peak was found in the graph.

The correlation was done in Lähdenkorventie (Appendix 2) to check the fire hydrant 202. In this case the first device was placed in the fire hydrant and the second device was placed in the house connection valve on the road Lähdenkorventie. The distance was 21.7 m and the diameter was 100 mm and the material of the pipe was cast iron. According to the correlation graph no clear peak was found. Then the fire hydrant was checked again with the listening stick. Finally it was decided that the fire hydrant itself was leaking very little. Basically, the main valve in the fire hydrant leaded the water to the fire hydrant valve produced the noise which is identified by the noise logger.

The third correlation was done in katepalintie (Appendix 3). The first device was placed in the valve near the manhole 13105 and the second one in valve near manhole 13104. The distance was 57.68 m. The diameter of the pipe was 315 mm and the material was PVC. In this case; no visible pick was found and then the valve near manhole 13104 was checked with the listening stick and finally decided that there was no real leakage here. The noise identified by the noise logger is from the manhole 13104.

6.4 Step after identifying the leaks

After doing the correlation, it was decided that there was a leak in Telinetie and it was very close the valve near manhole 29324. And as the valve was about 60 years old, so it might happen that the valve itself is leaking. So the place was excavated but it was difficult to find the actual leaking place because lots of water was coming from the wetland on the opposite side of the road. Then the pipeline between manholes 29325 to manhole 29324 was checked with pipe checking camera to make sure that the leaking water was not discharged to the closest manhole but no surprises were found. The place was checked with the ground microphone. Finally the excavation holes were filled because the leak was never found.

6.5 Leak renovation and cost

The TABLE 6.4. shows the leak renovation and related data. The map of the leaking place is placed in the appendix (Appendix 4). The renovation data from 27th may 2010 to 13th June 2012 is placed in the table. The person found or informed about the leak was also marked. The repair cost was approximately calculated for the repair work, done during 7th July 2011 till 13th June 2012. The repair time and isolation time is also marked. During the repair work, the number of houses without water is also placed in the table.

TABLE 6.4. Leak renovation cost

Repaired	received by	Repair costs	Repair time	Isolation time	Houses without water
27.05.2010	Jukka Patronen	N/A	0	N/A	N/A
12.03.2011	Lasse Sampakoski	N/A	4.5	2	12
13.10.2010	Patronen	N/A	0	N/A	30
13.03.2011	Arvi Oksala	N/A	5	18.75	10
15.04.2011	Patronen	N/A	9	23	0
07.07.2011	Arto Löppönen	1500	11	4	20
26.07.2011	Arto Löppönen	1000	7	N/A	0
11.07.2011	Arto Löppönen	1500	6	6	20
09.08.2011	Arto Löppönen	1500	15	7	20
12.03.2012	Arto Löppönen	5000	0	N/A	15
29.03.2012	Arto Löppönen	1000	6	3	50
17.04.2012	Arto Löppönen	500	3.25	2.5	1
13.06.2012	Arto Löppönen	1200	8.25	3	20

6.6 Lost water and economic affect

The TABLE 6.5. shows the approximate water lost. It was calculated assuming the day; it starts leaking and the day it repaired. The database monitoring system was used to calculate the total water loss per day. Basically, when the repair work was done the total input water from the pressure boost station goes down. The amount of water consumption reduced after the repair work is the approximate water loss per day on that area. The monitor system observation also gives information about the day when the water consumption was increased. The table also explains about the temporary water supply during the repair work. In most of the cases there were no water supply during the repair work but in some cases water was provided with the water tank.

TABLE 6.5. Water loss due to leakage

Repaired	received by	Person responsible	Houses without water	Temporary water supply	Lost water m3
27.05.2010	Jukka Patronen	Patronen	N/A	N/A	N/A
12.03.2011	Lasse Sampakoski	Lasse Sampakoski	12	water tank	700
13.10.2010	Patronen	Patronen	30	water tank	N/A
13.03.2011	Arvi Oksala	Patronen	10	water tank	N/A
15.04.2011	Patronen	Patronen	0		N/A
07.07.2011	Arto Löppönen	Tommi Saajakoski	20	No water supply	70000
26.07.2011	Arto Löppönen	Lasse Sampakoski	0	No water supply	6500
11.07.2011	Arto Löppönen	Lasse Sampakoski	20	Other	100
09.08.2011	Arto Löppönen	Jukka Patronen	20	No water supply	400
12.03.2012	Arto Löppönen	Lasse Sampakoski	15	No water supply	4500
29.03.2012	Arto Löppönen	Arto Löppönen	50	No water supply	200
17.04.2012	Arto Löppönen	Arto Löppönen	1	No water supply	20
13.06.2012	Arto Löppönen	Arto Löppönen	20	N/A	8750

The TABLE 6.6. shows the cost of lost water due to leakage in the water network. The price of water €/m^3 is multiplied with the lost water and the total price of the lost water is calculated. LMWS buy most of the water from Tampere. So, the price for per cubic meter water is determined 0.78 €, according to the buying rate. It includes 23% of VAT (Value Added Tax).

TABLE 6.6. Price of the lost water volume

Received	Lost water m3	price of water €/m3	price of lost water in €
27.05.2010	N/A	N/A	N/A
21.03.2011	700	0,78	542,4
13.10.2010	N/A	N/Av	N/A
12.03.2011	N/A	N/A	N/A
14.04.2011	N/A	N/A	N/A
08.07.2011	70000	0,78	54243
01.08.2011	6500	0,78	5036,9

01.08.2011	100	0,78	77,5
16.08.2011	400	0,78	310
01.04.2012	4500	0,78	3487,1
01.04.2012	200	0,78	155
17.04.2012	20	0,78	15,5
13.6.2012	8750	0,78	6780,4

The amount of leaked water from the system can be identified from the database. Basically, there is a sudden fall of water flow in the pure water system on the day it repaired. The same case happens in the waste water pumping system (only if the leaked water enters to the waste water network).

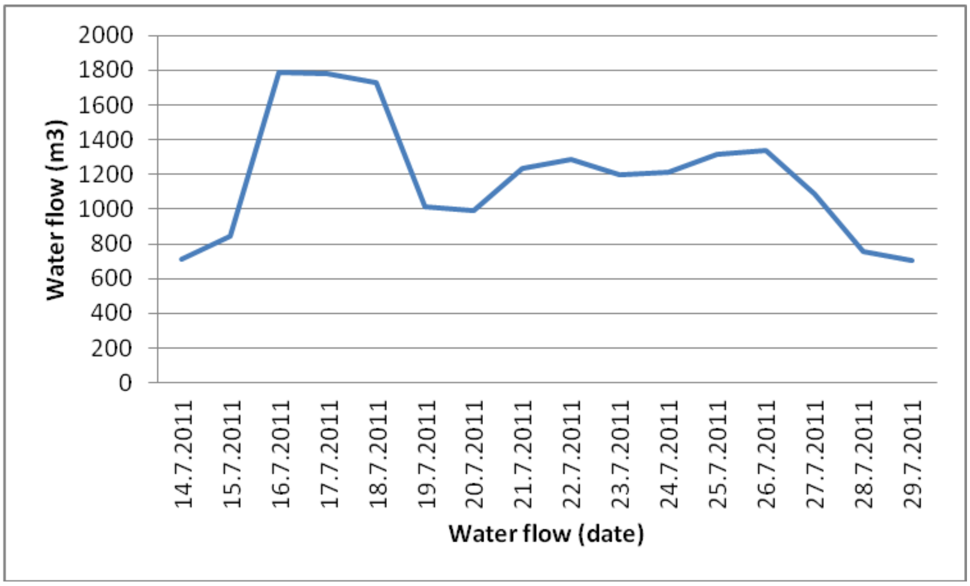

FIGURE 6.1. The volume of water flow in the pure water network

FOGURE 6.1. shows that the water flow started increasing from 14th July 2011 and as it was repaired on 26th July 2011, the flow rate stared to decrease. The leakage generated 6500 m^3 of lost water.

In two cases, the water entered into the waste water network. In both case, the water went to the Välimäki waste water pumping station. Then, the water travelled through Ahosti, Kulju, Vanattara, Moisio and Koivunokka pimping station to the treatment plant. In the First case, the volume of pumped water was 70000 m^3. The increased volume of the pumping waste water can be observed from the database.

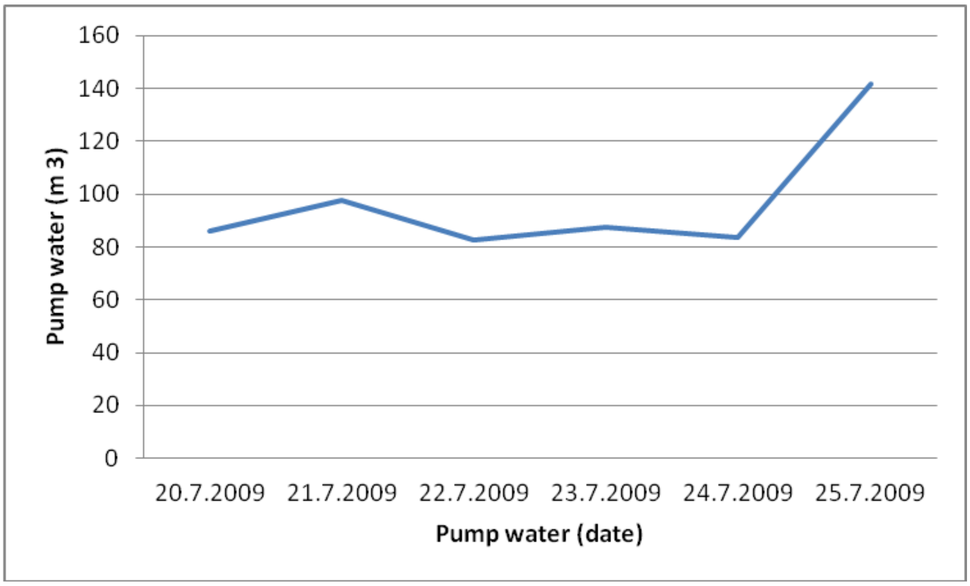

FIGURE 6.2. The volume of pumped water in the waste water network

From the FIGURE 6.2., it can be easily identified that the volume of pumping water suddenly increased from 24th July 2009. It continued till 7th July 2011, when the leak was repaired.

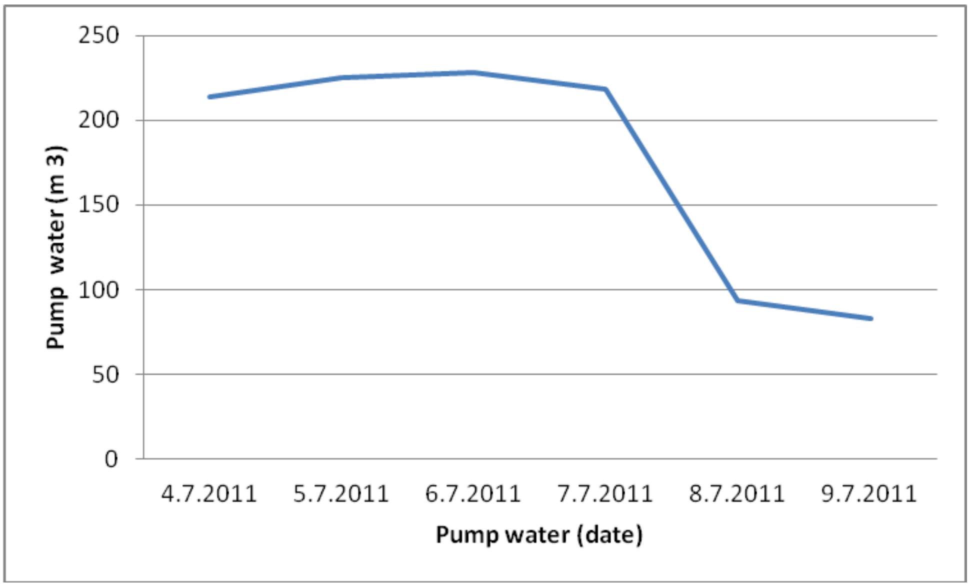

FIGURE 6.3. The volume of pumped water in the waste water network

FIGURE 6.3. shows that the volume of pumping waste water suddenly decreases on 8th July 2011. It happened just after the next day of repair work.

In second case, the volume of water entered into the waste water network was 4500 m^3. The water also went to Välimäki pumping station and in the same way, reached to the treatment plant.

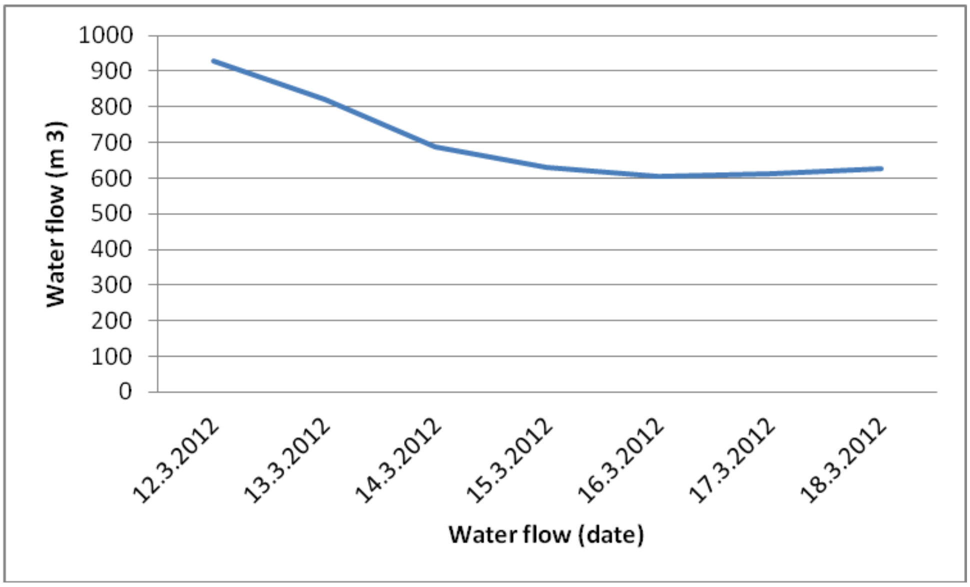

FIGURE 6.4. The volume of water flow in the pure water network

FIGURE 6.4. shows that the water flow in the pure water network started to decrease after the repair work done on 12th March 2012.

The cost of pumping water is calculated in TABLE 6.7. .The power of the pump is also included to the table. Then running time and electricity cost was determined. Finally the cost was calculated. Here the electricity cost is determined 0.23 € which includes transport and tariff. On the First case the volume of pumped water was 70000 m^3.

TABLE 6.7. Electricity cost for pumping waste water

Name of the pump-ing station	Power kw	volume of water loss (m^3)	Flo w rate l/s	Running time (h)	Electric-ity con-sumption kWh	Electric-ity cost €/kwh	Finan-cial cost
Välimäki	7,5	70000	15	1296,3	9722,2	0,23	2222,5
Ahosti	5,5	70000	37	525,5	2890,4	0,23	660,74
kulju	13,5	70000	30	648,2	8750	0,23	2000,3
Vanattara	13,5	70000	15	1296,3	17500	0,23	4000,5
Moisio	13,5	70000	15	1296,3	17500	0,23	4000,5
Koi-vunokka	13,5	70000	42	463	6250	0,23	1428,8

On the second case the volume of pumped water was 4500 m^3. In this case the cost was calculated in the same way.

TABLE 6.8. Electricity cost for pumping waste water

Name of the pumping station	Power kw	volume of water loss (m^3)	Flow rate l/s	Running time (h)	Electricity consumption kWh	Electricity cost €/kwh	Financial cost
Välimäki	7,5	4500	15	83,3	625	0,23	142,9
Ahosti	5,5	4500	37	33,8	185,8	0,23	42,5
kulju	13,5	4500	30	41,7	562,5	0,23	128,6
Vanattara	13,5	4500	15	83,3	1125	0,23	257,2
Moisio	13,5	4500	15	83,3	1125	0,23	257,2
Koivunokka	13,5	4500	42	29,8	401,8	0,23	91,9

7 CONCLUSION

The leak detection survey started with the noise logger installation. The noise logger had been installed in 121 places in 11 different areas. All of these areas have got cast iron or asbestos cement pipe connections. These pipe connection networks are considered to do leak survey because these are the most problematic pipe connection. The survey with noise logger identifies 16 leak supection where 9 places had been checked with the listening stick because some of them were in the renovating areas which are being renovated in the current year. There were also some valves which were already detected to be leaked. Then among 9 places only three placed were considered to do correlation though only one correlation found the exact suspection of leakage. But the excavation could not lead to find the exact leak.

According to the leak reports, from earlier year 2010 to 2012, the volume of lost water and prices of the lost water had been calculated. It summarises that the total lost water due to water leakage is 91170 m^3, where leaks repaired on 27th May 2010, 13th October 2010, 12th March 2011 and 14th April 2011 did not provide the volume of lost water. The price of the lost water due to the leakage is 53270,6 euro. Here the price is calculated according to the water price charged by Tampere water because the water which goes through that network is bought from Tampere.

The electricity cost for pumping the leaked water which managed to enter the waste water network is also calculated. As the water travelled from Välimäki pump station to the water treatment plant, the total electricity cost for pumping this volume of water is calculated. The estimated cost for pumping this water is 15233,2 euro.

According to the key figure of LMWS in 2011, it is figured out that the total pumped water in the system is 1063000 m^3. The water sold to the customers is 797000 m^3 which includes the residents of Lempäälä, the water sold to Pirkkala and vesilahti. The estimated water lost or NRW in the system is 266000 m^3. It is 25 % of the total pumped water which consist of apparent loss and real loss. The LMWS does not use water balance to evaluate the NRW but it is estimated that 10 % (26600 m^3) of the NRW is apparent loss. It is due to under-registration of water meter and unbilled authorised consumption. The rest 90 % (239400 m^3) of NRW is due to water leakage. The price of this volume of leakage water is 139869,5 euro.

The overall research identifies, that the leakage in the water network is the main reason of generating 25% of NRW. As explained in chapter 2, the methods of controlling the NRW can be followed for reducing the NRW in LMWS. But the pressure controlling methods to cut down the water losses is not quite favourable because the network is struggling with very low pressure level in many parts of the network. The accuracy of the meter can be checked to reduce the apparent loss. To control the leakage, regular basis network checking should be considered because in some cases, if the amount of leaked water is very small or in the beginning position, it cannot be identified from the night flow analysis. According to research, the total leak repair cost is 13200 euro and it is estimated that the total financial loss due to the leakage is 68503,8 euro. Finally, it can be calculate that the repair cost is around 20% of the financial loss. So, regular basis active checking of the valves or fire hydrant using leak locating devices and repairing the leaks can reduce the volume of NRW and financial loss.

Reducing the volume of NRW is the target of all municipality water distribution systems because it is not only the waste of water but also financial loss. In LMWS, the volume of NRW is quite enough to take attention. The research was done only on some specific pipe network which is not enough to come up in an accurate conclusion. To get more specific conclusion, further research is needed and it should be done in the broad scale.

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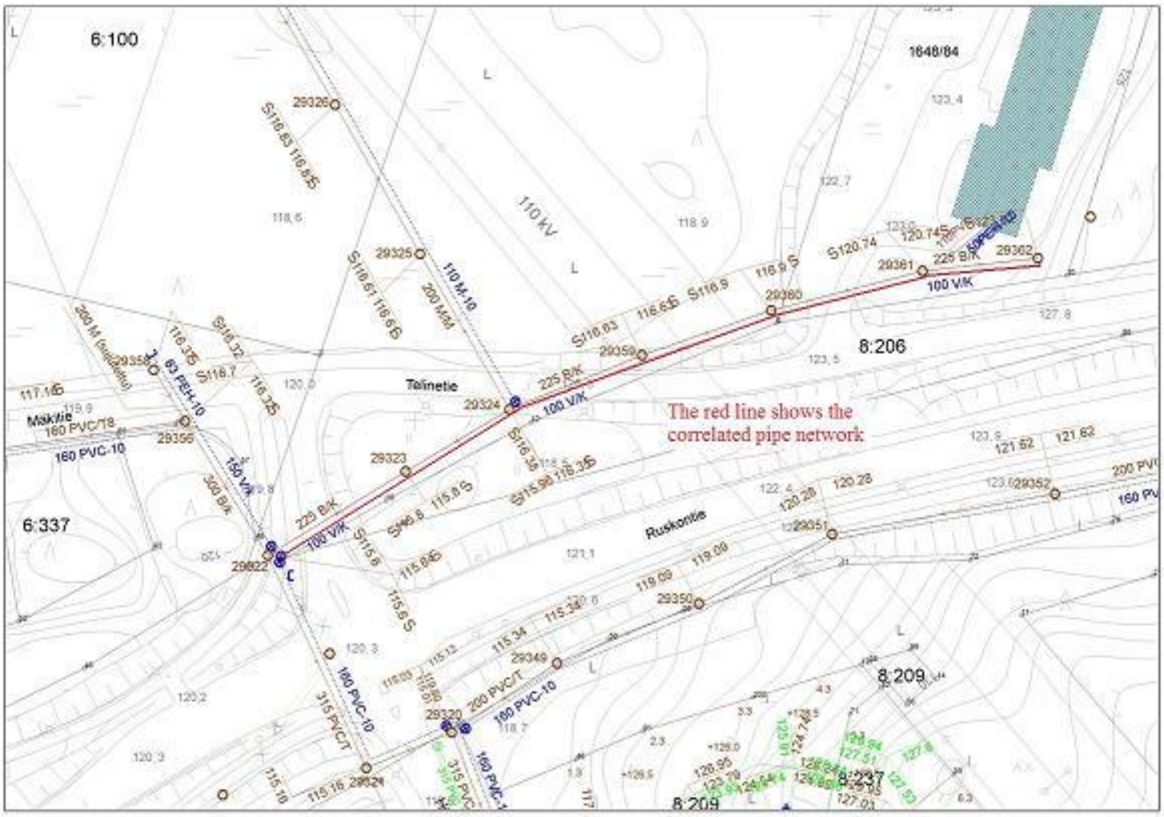
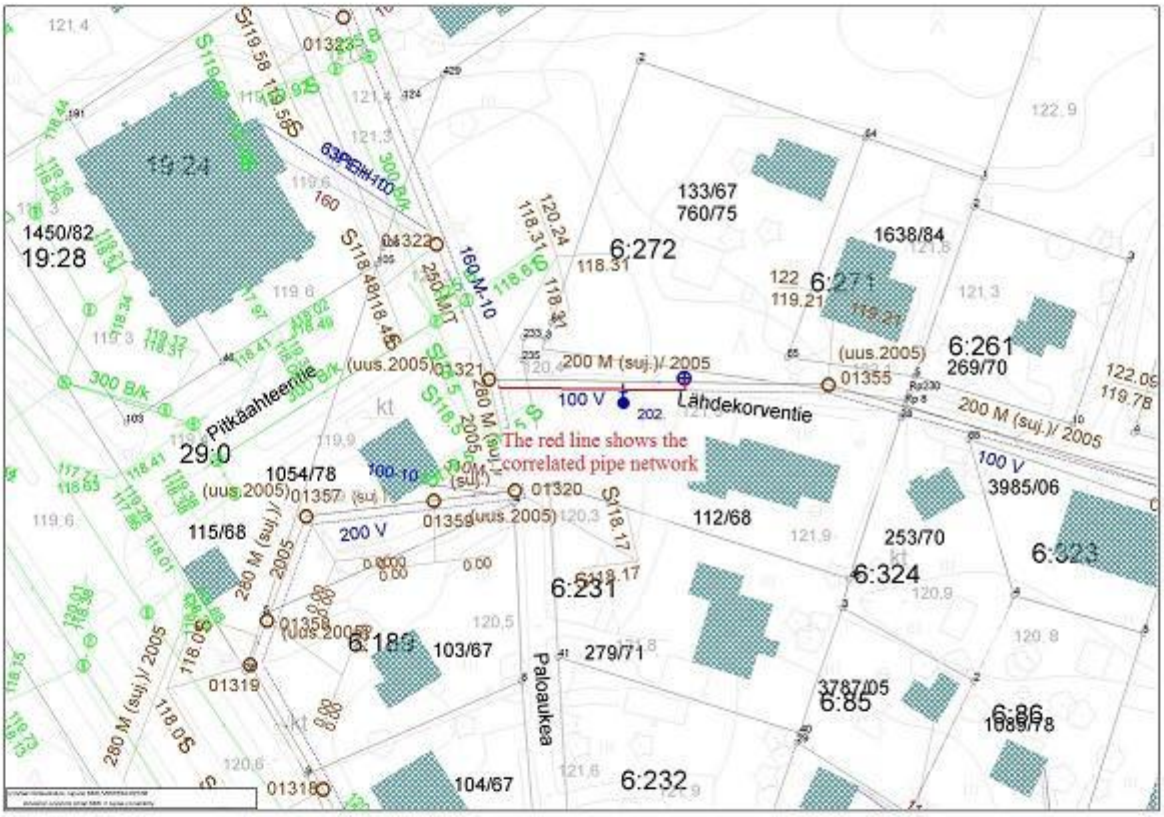
APPENDICES

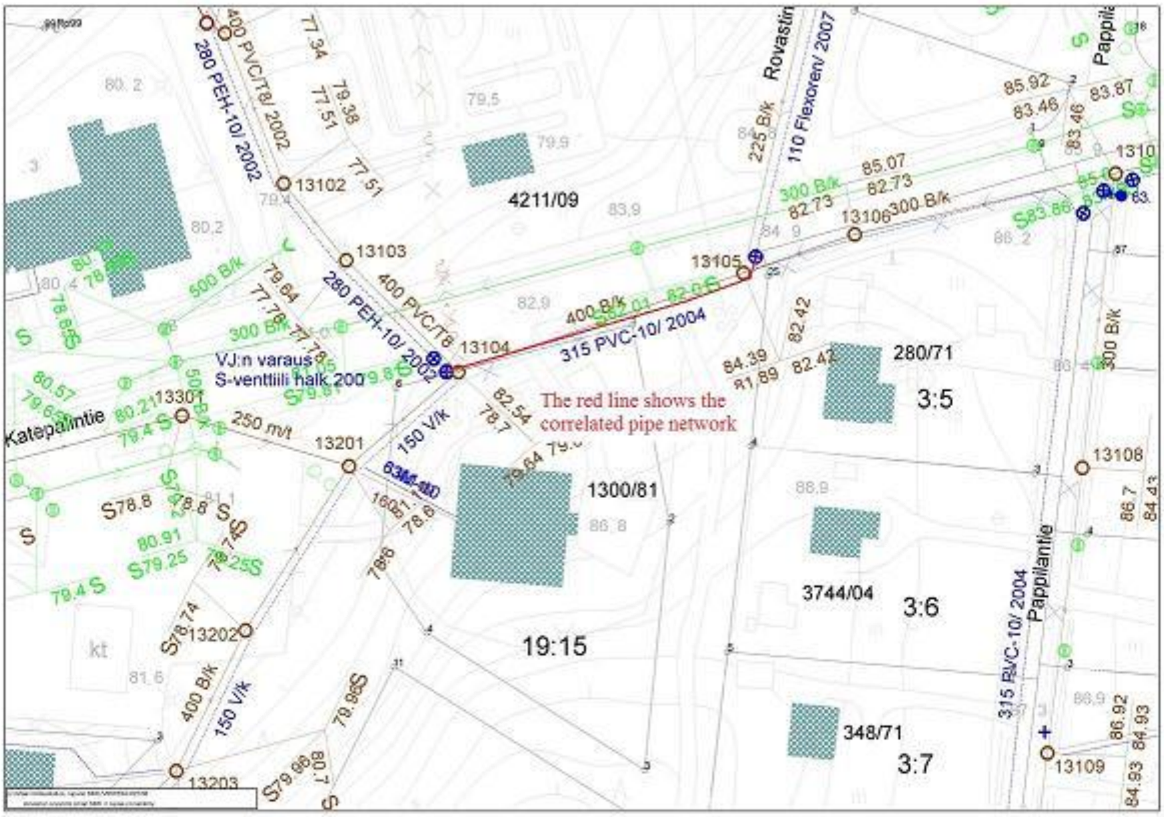
Appendix 1: Map of first correlated pipe network



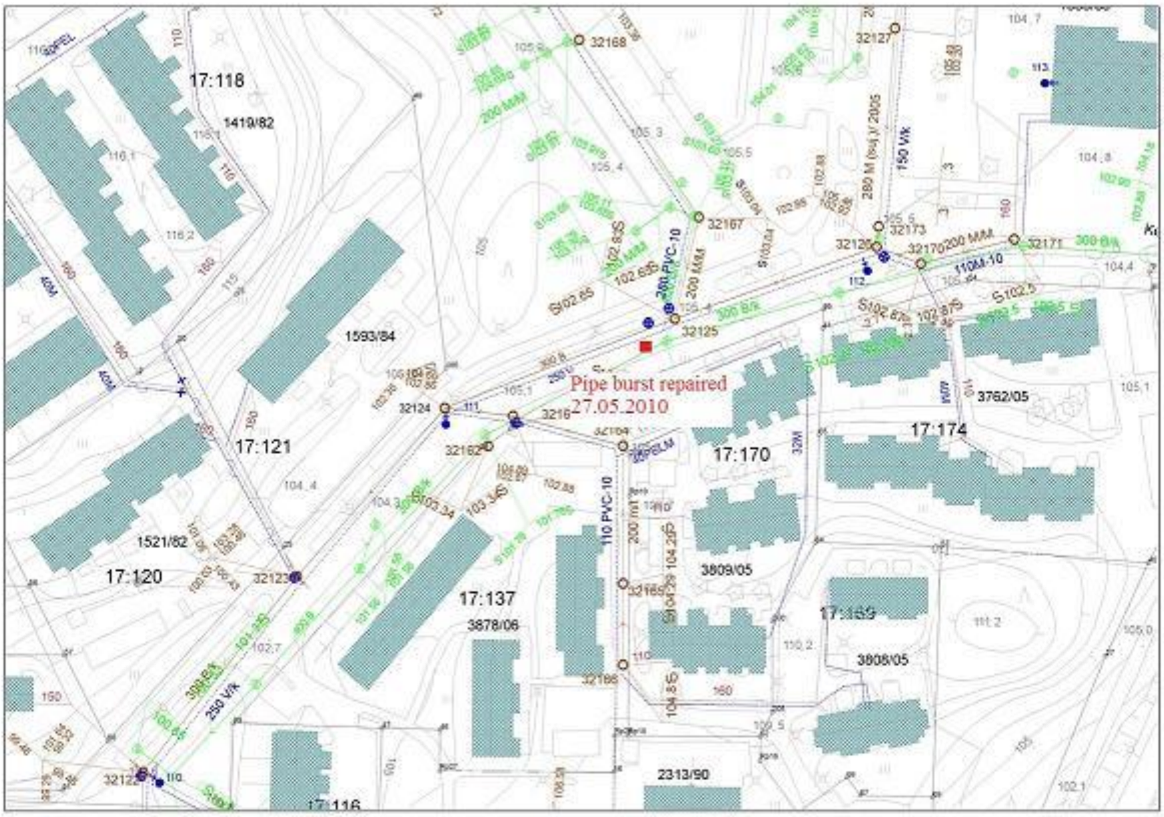
Appendix 2. Map of second correlated pipe network



Appendix 3. Map of third correlated pipe network



Appendix 4. Maps of repaired leaking pipes

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17:172
17:160
17:160
17:164
17:158
17:146
6:198
6:318
6:319
2:19
Tampereentie
Kiertolahdentie
Paperintehtaantie
250 V/K
400 B/K
150 V/K
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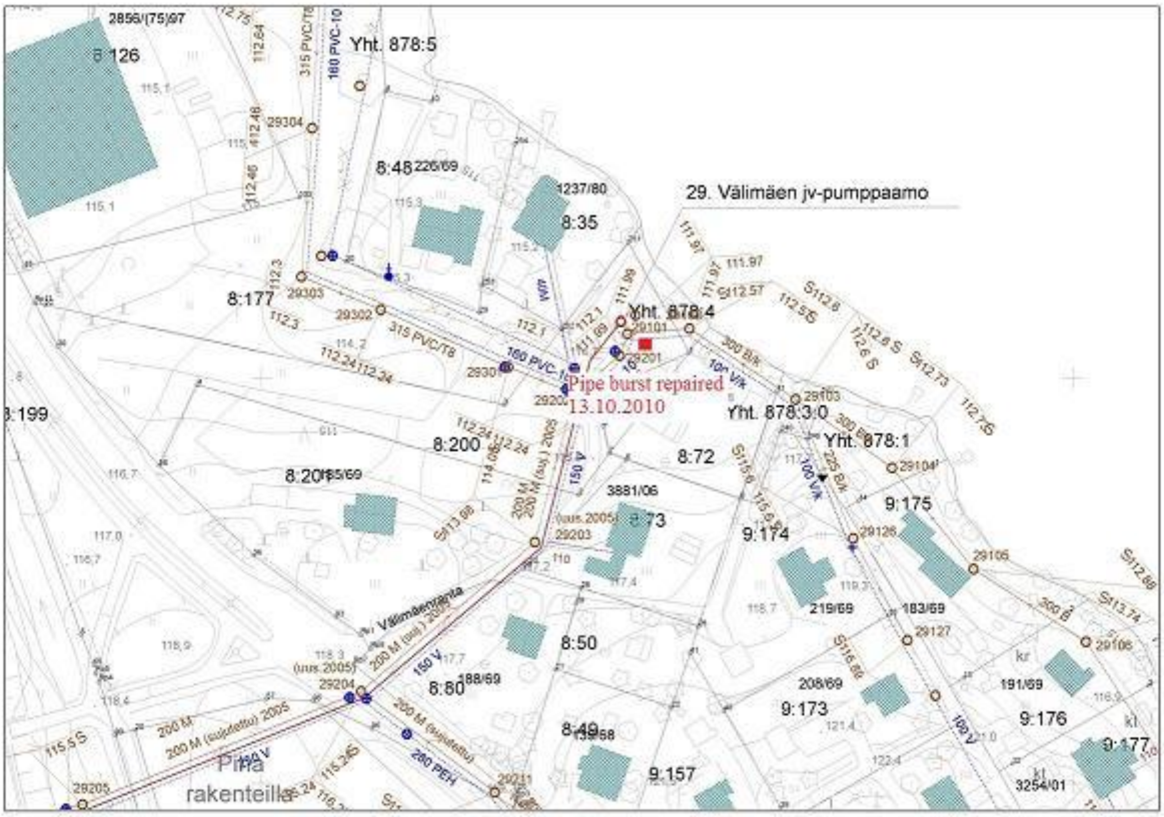
200 PVC/ 2007
100 V/k
3428/02
3117/00
3293/01
3857/05
3856/05
403/72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Yht. 878:3:0
Yht. 878:1
8:48
8:35
8:177
8:200
8:72
8:73
8:50
8:80
8:49
9:175
9:174
9:173
9:176
9:177
9:157
Välimäenranta
Piha
rakenteilla
315 PVC/T8
180 PVC-10
200 M (sujutettu) 2005
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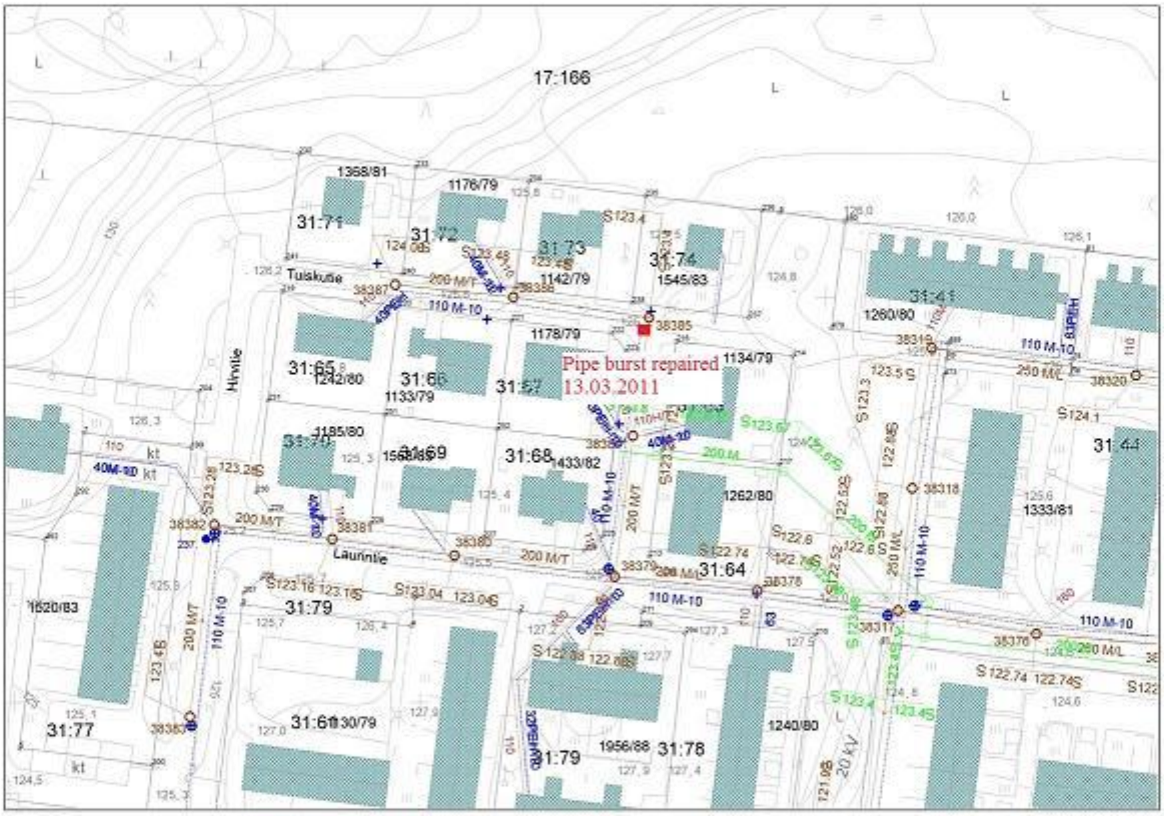
208/69
191/69
188/69
226/69
3254/01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Tuiskutie
Hirvitie
Laurintie
Pipe burst repaired
13.03.2011
31:71
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31:74
31:41
31:65
31:66
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31:70
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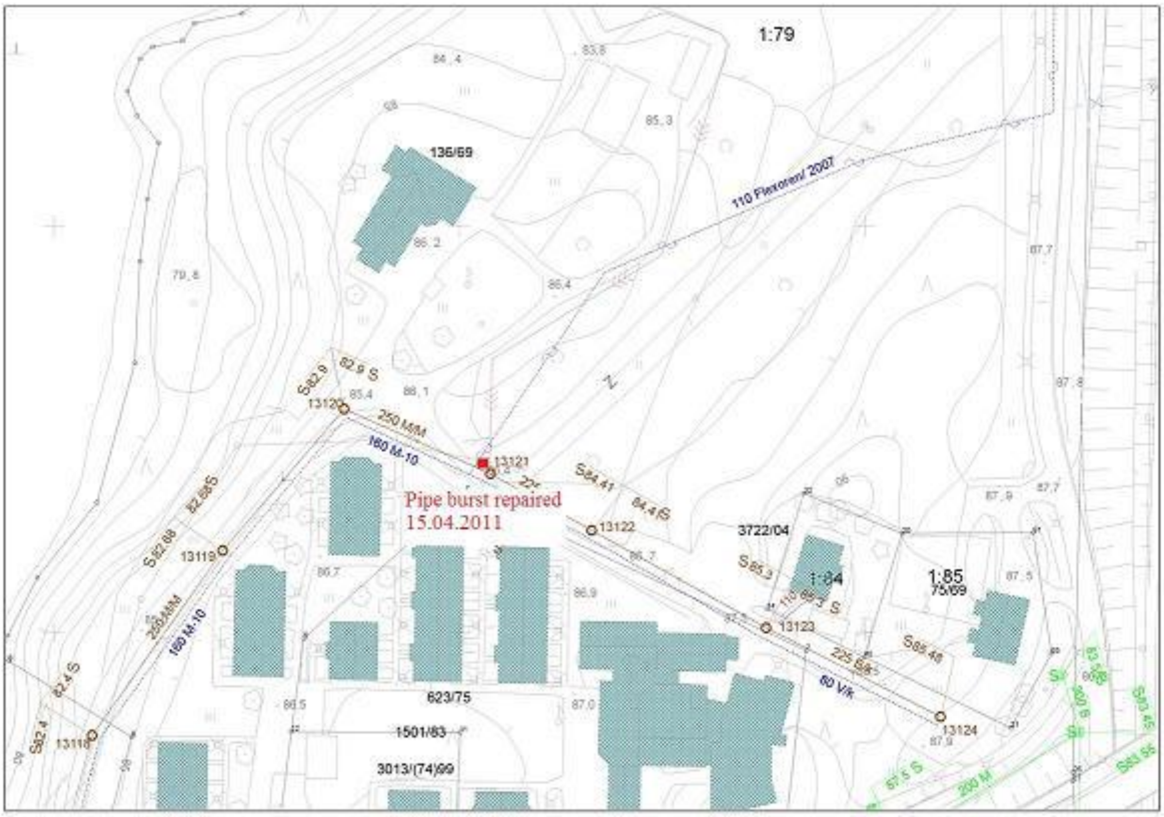
31:61
31:78
110 M-10
200 M/T
20 kV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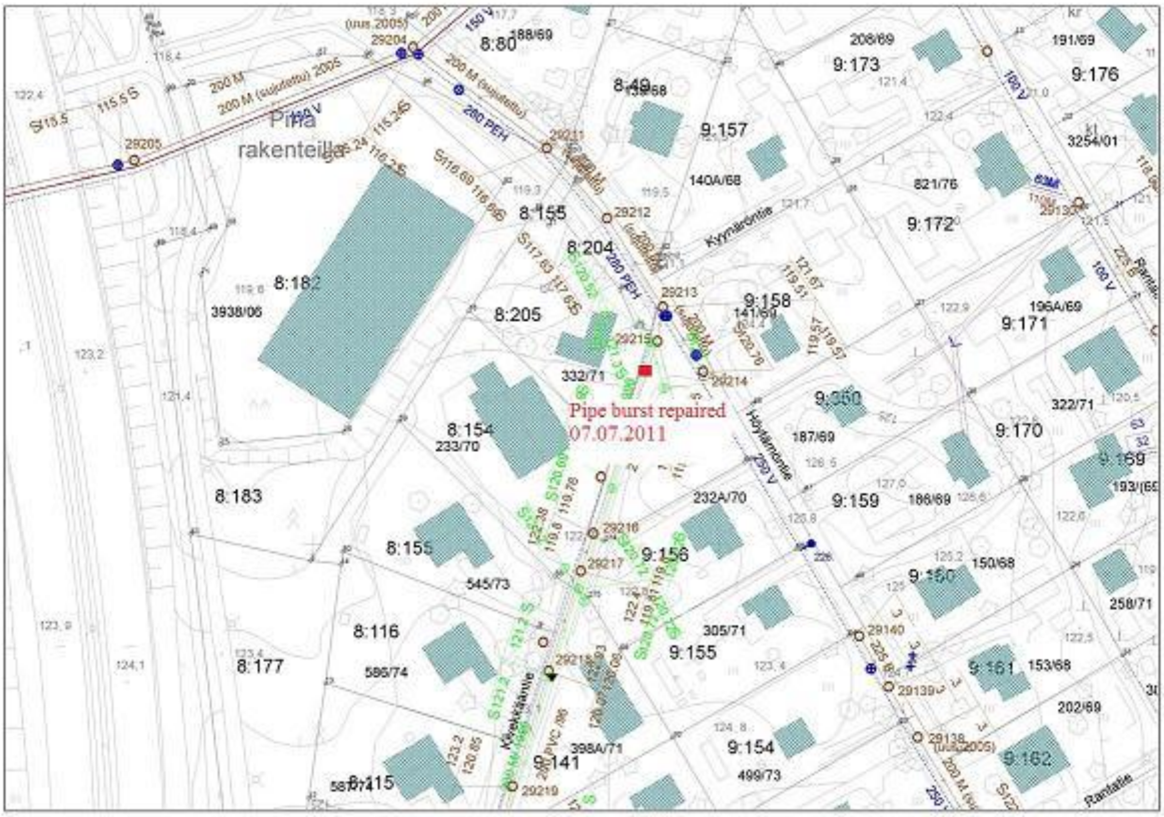
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Piha
rakenteilla


Pipe burst repaired
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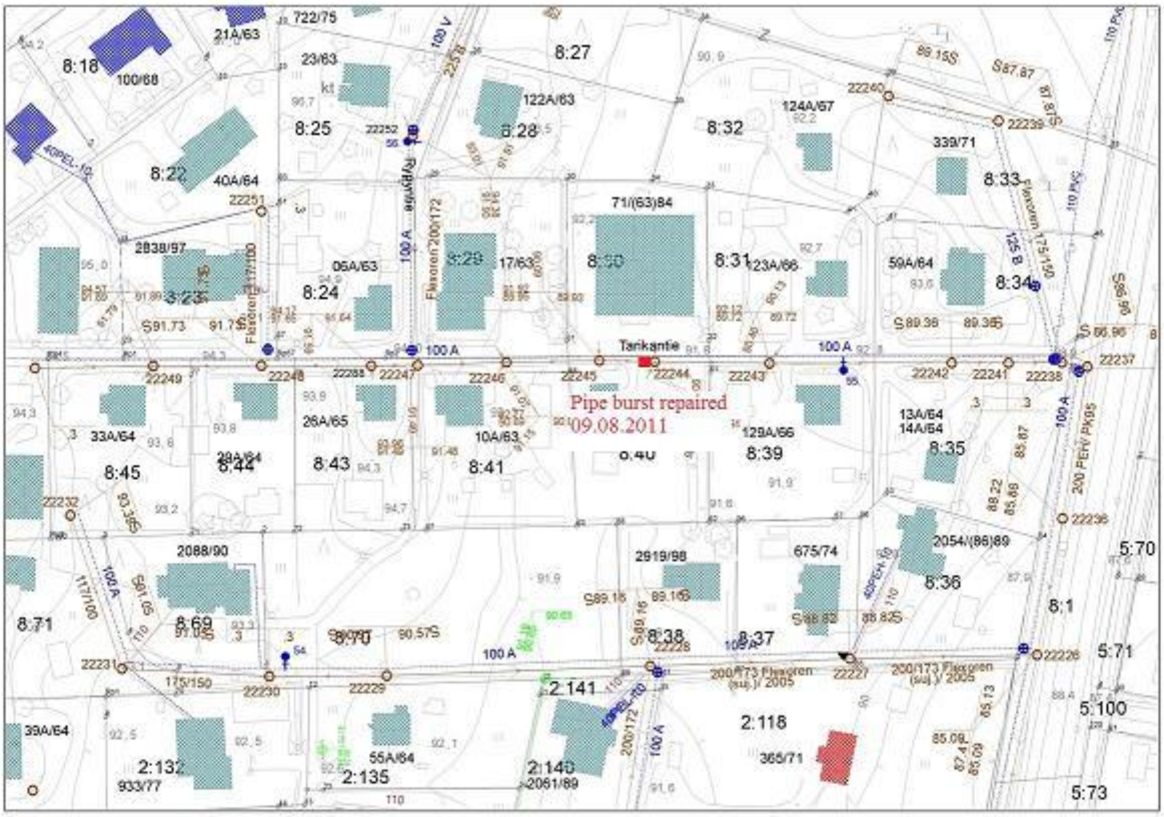
Kaupparaitti
Mattatie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8:31
8:32
8:33
8:34
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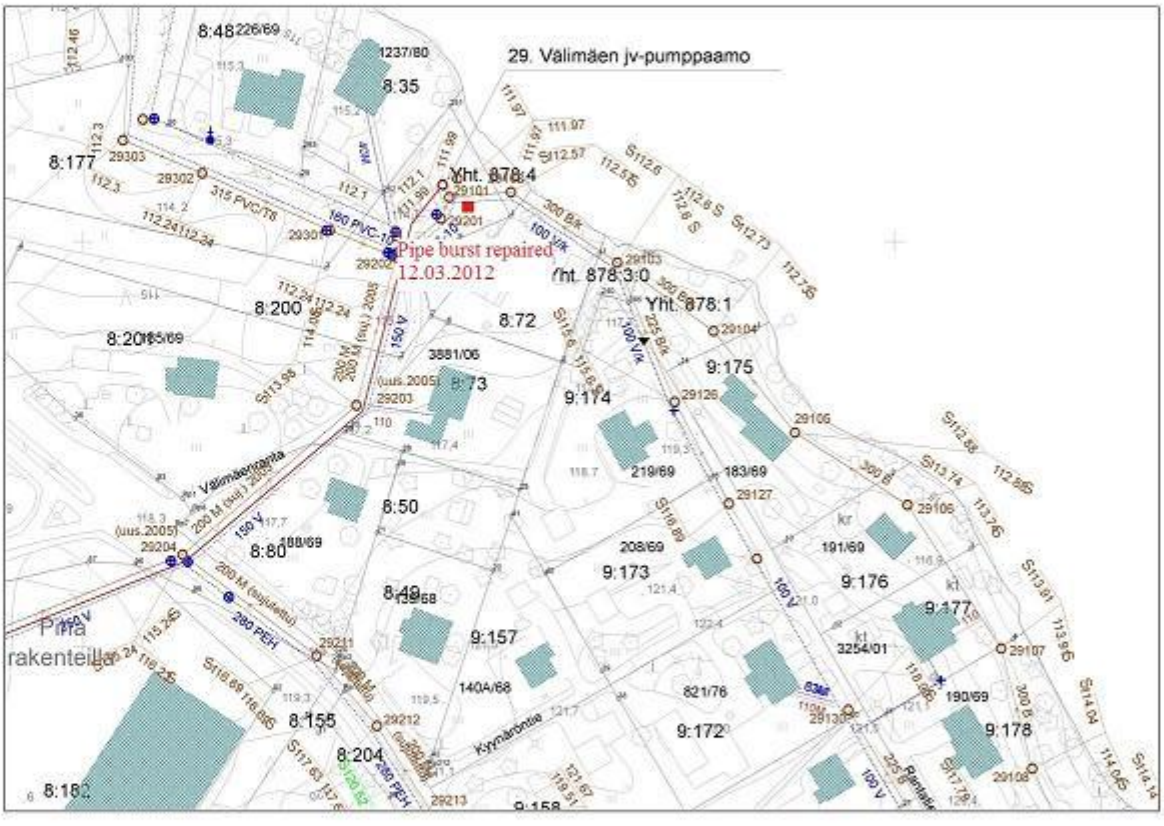
100 A
100 V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Yht. 878:3:0
Yht. 878:1
Välimäenranta
Kyynäräntie
Piha
rakenteilla
8:48
8:35
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8:200
8:201
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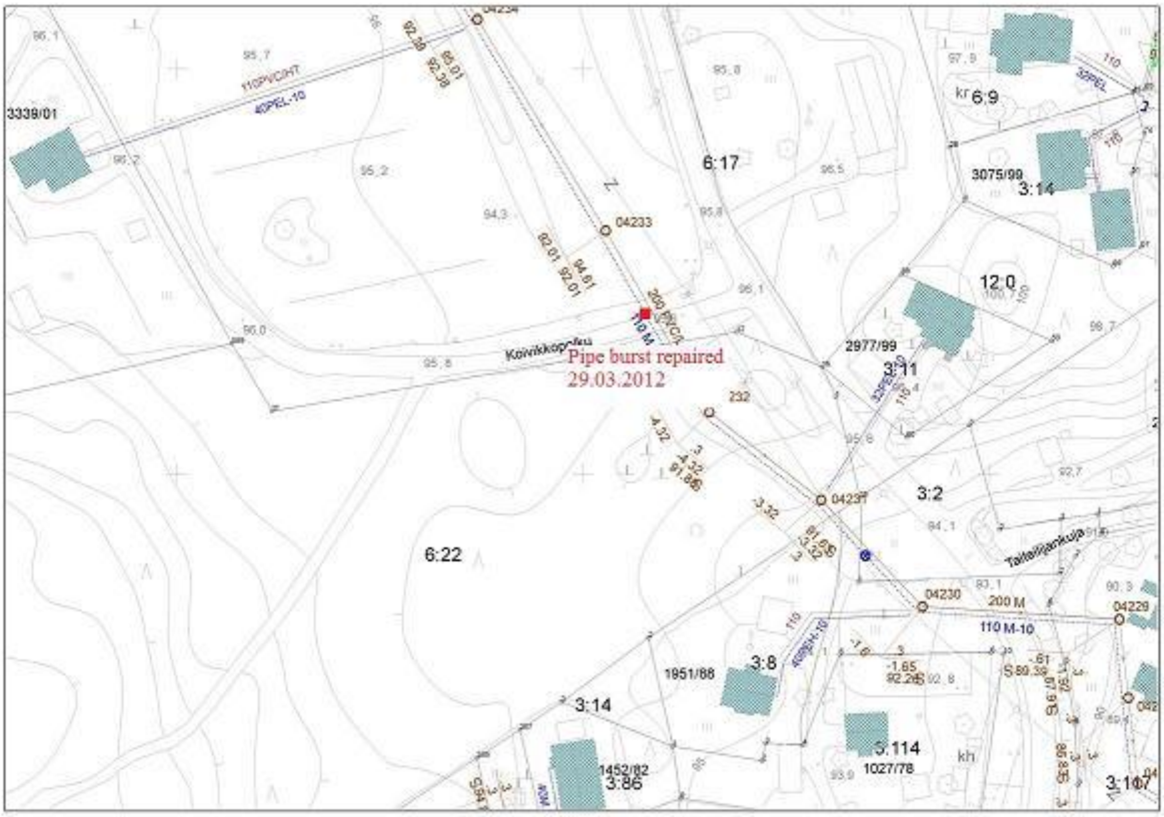
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29.03.2012
Koivikkopolku
Taiteilijankuja
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6:9
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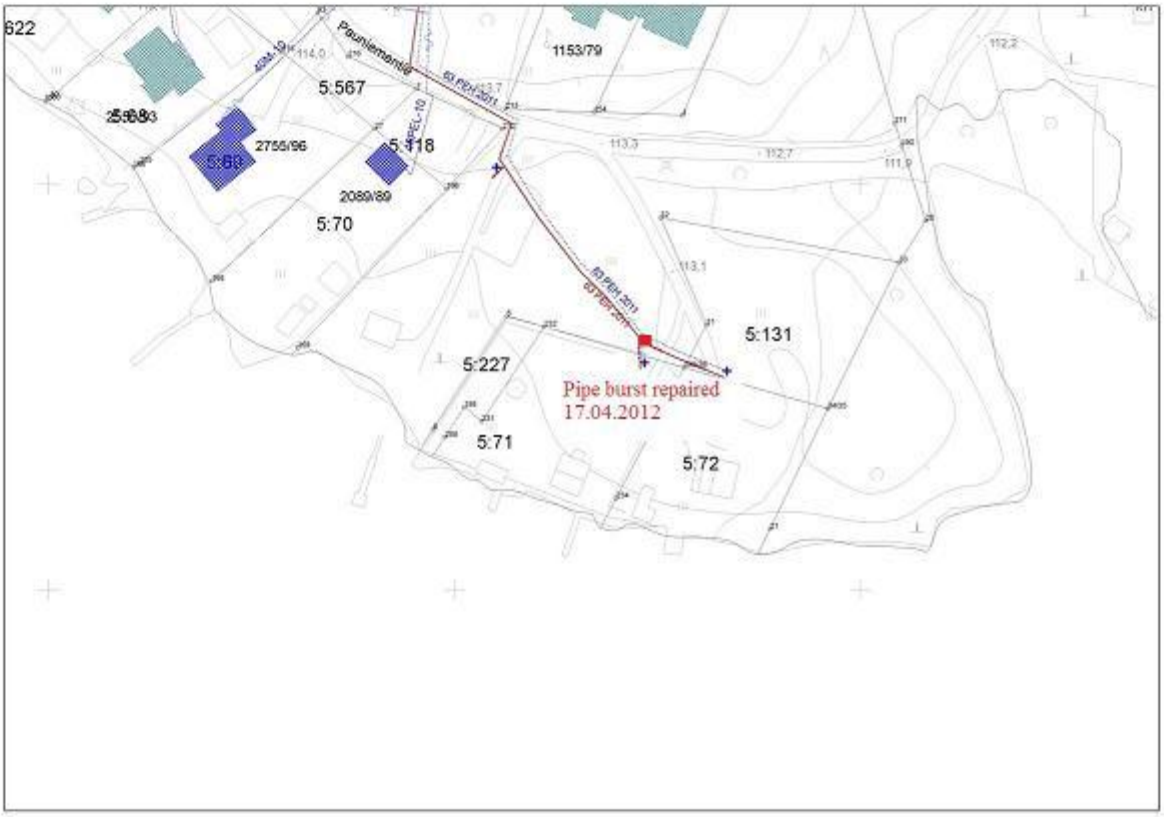
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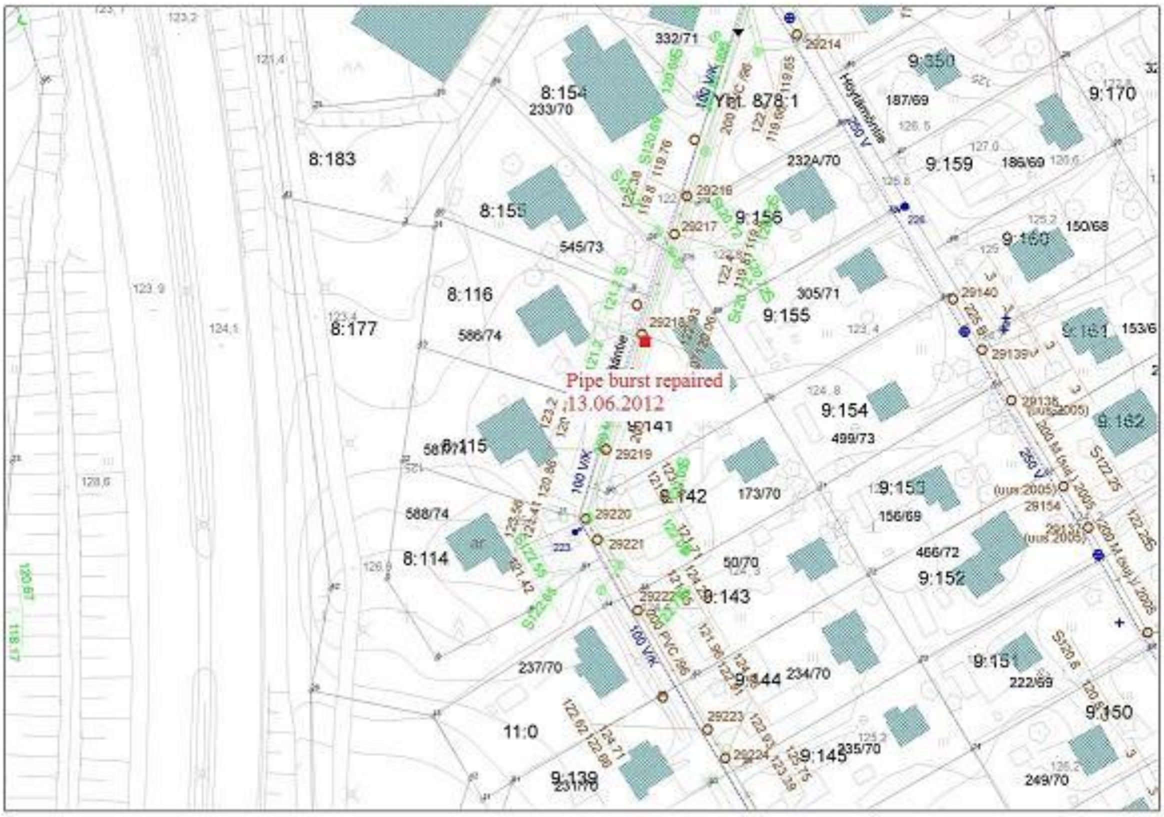
5:72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545/73
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586/74
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588/74
237/70
11:0
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29216
29217
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29219
29220
29221
29222
29223
29224
29140
29139
29136
29154
29137
100 V/K
200 PVC /96
250 V