This article was originally published in Strategija Smanjenja Gubitaka UVodovodnim Sistemima in 2020.
Authored by: Stevo Savic.

Leak Detection In Water Supply Network Using Satellite Technology

Pančevo, Kovin, Kovačica

KEY WORDS: Satellite imaging, leak, water supply network, acoustic recording, Real Losses, Apparent Losses

ABSTRACT: Satellite imaging of the water supply network is a new technology in detecting leaks, i.e. water losses, in distribution networks of water supply systems. The precision and power of this technology helps to find and repair individual undiscovered groups from both categories of Real and Apparent Losses with field acoustic devices. The first local research, with new technology, and with the presented results, was performed in the area of Pančevo, Kovin and Kovačica.

Introductory Remarks

All researchers around the world have long known the fact that the distribution part of any water supply system is a key factor in terms of protecting the quality and quantity of water supply. Because of all this, experts in these fields have given these aspects great importance due to the global problem produced by the two mentioned key factors of water supply systems, Q&Q (quality and quantity). As it can be seen by experienced researchers, this complex nature of the problem of network infrastructure, related to the preservation of quality and quantity of water, and in the phase of its distribution, can be expressed in an extremely clear and simple way... „the distribution system, as the final phase of supplying consumers with drinking water, is important in terms of preserving the quality and quantity of distributed water, as much as the treatment of raw water to the level of drinking water according to all required parameters“. In that sense, when it comes to the quantity of supplied water, many researchers around the world have focused a significant part of their research activities on the network part of water supply systems, as the main place of a wide range of risks and the biggest water losses.

In previous years, many researches have been conducted in this area in connection with all aspects of detecting and repairing both categories of Real and Apparent Losses, all in the desire to put the problem of losses in the place that belongs to it in importance. At that time, one could often hear a clear, and based on experience, statement that the fight against losses has no alternative, and that in that sense the question of its justification cannot be asked, or more precisely, only the question of ,,bottom point" of the economic level of losses can be asked, which does not justify further investment in order to reduce them.

This apostrophized "bottom point" or "acceptable level" of the mentioned losses, promotes a clear perception of this problem by local researchers, as a trace of many years of experience in combating all types of losses. Thus, in connection with that, for the rehabilitation of Apparent Losses, some other activities were needed, and they referred to the legal-technical aspect, i.e. the adoption and implementation of regulations related to technical conditions regarding the selection and installation of measuring devices, and then problems with illegal water consumption, etc. However, underground-base, invisible and undetectable losses in the form of leaks on cracks (Background Losses), as part of the Real Losses, are immeasurably more demanding both technically and financially and they reflect the true picture of the complexity of combating this type of loss. Since leakage is one of the manifestations of these losses, in the next part of this chapter, attention will be focused on this group of losses and the application of innovative technologies in order to detect and repair them, as applied in Pančevo, Kovin and Kovačica.

However, an extremely long period of time had to pass for this new technology to appear, which could detect and make available a significant part of the group of Real (undetectable-base!) Water losses in the distribution part of water supply systems. Thanks to experts and enthusiasts in these fields, a powerful satellite technology has been transferred, from space research activities, to planet earth and earthly problems. The importance of preserving the most important living resource is shown by experts around the world, giving global significance of the problem of healthy and drinking water losses. In that sense, the most important world water association - **IWA**, declared **December 4th as the World Water Loss Day!** The reason for giving all this special significance is the knowledge that these losses in this area have reached unacceptably high percentages, in the range of 30-80% of lost, purified water. And it is also true that these same losses are the basic and indisputable generator of the reduction in invoicing, which, in addition, generate all the other problems of poor financial operations of water supply companies. Hence, it is no surprise that the most contemporary technologies are used around the world in order to protect this resource, from all categories of losses. This is something that should be recognized in this area, with such a high percentage of lost drinking water, so that finally, the agony of large losses descends to the lowest acceptable level ("bottom point" of the economic level of losses). Finally, all this should be understood and accepted (!), especially by the competent management structures in water supply systems, in order to detect and rehabilitate the most demanding groups of losses, and raise the overall efficiency, primarily expressed, through successful financial operations and, in addition, more successful overall maintenance of the water supply systems.

Unfortunately, in these times, instead of starting with all available technologies, in discovering and repairing, now significantly more accessible groups of losses, all these losses are still at all costs, only verbally minimized (!). At the same time, they are shown in such a low percentage of lost water, up to the level of the best maintained water supply systems, even in the wider European environment (!?). However, loss recovery activities, especially those of groups that have had the status of unavoidable losses for decades (Real and Apparent Losses groups), have no alternative, especially not in these times, when powerful satellite technology is involved in all these challenges.

What all and how much data can help, from satellite images of the underground water supply network, will be discussed in this chapter.

Expectations From New Satellite Technology...

It all started when a group of researchers from Hebrew University and Ben Gurion University in Israel, who used to search for water on the nearest planets (Mars and Venus), realized that these same powerful devices could be used to search for water losses on Earth. It did not take long for a significant number of these researchers to turn to a new challenge, the detection of drinking water losses in the distribution networks of water supply systems. The first research gave very optimistic results and began the application of these technologies in various parts of the Earth, on almost all continents. Thus, the new space monitoring technology passed to the planet Earth and then from the surface layer of the earth, it passed to the first layers of the subsoil of 1-3 m, and even lower, with the fascinating accuracy of information of satellite radar devices, which could register the lowest level on distribution networks of water supply systems. What is the power of these devices, if they can register so low leakage on the network to a level of **0.1 l / min ?**

LEAKAGE (number of drops in 10 seconds)	FLOW (l/h)	FLOW (m3 / month)
7	0.5	0.36
20	1.8	1.31
37	4.0	2.92
jet diameter 1.5 mm	18	13,133
jet diameter 3.00 mm	36	26,266

Table 1. Drip phases and formation of the first leakage jet

From this paper, which was worked on by researchers (Lewandowski and Krieger), it is easy to find out what the actual level of losses of 0.1 l/min, compared to the research experience, is shown in the graphic paper (Table 1), from the chapter **Justification analysis, Jahorina 2009.**

The phase of the fastest drip (37 drops in 10 sec) is 0.07 l/min

The phase of formation of the first jet (... in 10 sec) is 0.3 l/min

As can be seen from the previous appendix, the registered level of losses of 0.1 l/min., can be placed between the phase of the fastest dripping and the phase of forming the first jet, noting that it is still much closer to the dripping phase and that means the category of Base, undetectable losses (Background Losses)! The importance of this group of losses is also indicated by the fact that all these Base-undetectable leaks, on the street distribution network, were the subject of research by many world experts. Researchers from the former IWSA (today's IWA), Lambert et al., gave the significance to this group of leaks, ie losses, where they are expressed in a higher percentage than the other two groups together, visible (reported) and detectable (unreported) leaks (Table 2).

Infrastructure component	Undetected (Base) leak	Unregistered (unreported) leak	Registered (reported) leak	UARL total	UARL total
Pipeline	9.6	26	5.8	18	L/km of pipeline/ day/m pressure

Table 2. Water losses for the three listed group on the distribution pipeline seen by the researches from IWSA

In short, this methodology is based on the technological power of the Satellite, (located at an altitude of about 650 km away from the Earth), which carries a SAR (Synthetic Aperture Radar) sensor and has powerful L-rays, which sends to the Earth, and which can penetrate into the soil of the country, to register the existence of traces of drinking water, leaked from the water supply network. Radar technology recognizes all this, in the form of so-called spectral "signature", which symbolizes all the peculiarities and differences, characteristic of the required drinking water and which, more precisely, represents the relationship between the electromagnetic wavelength and its interaction with water. The peculiarity of this drinking water (dielectric constant) is that it produces high dielectric constant in the soil, unlike other types of water (salt water, polluted water, lake water, etc.), and such a signal is returned to the radar sensor where the triage of all types of water was performed, with the help of a special algorithm, and only that recognizable, arrived "signature" of the requested drinking water was retained. Thus, powerful radar devices will provide locations of leaked drinking water, in the form of "spots", on the surface of the recorded space, which, after overlapping with GIS maps, will provide approximate street locations (Figure 1), or points of interest (POI) where with field acoustic devices, the detected exact leaks are marked in green, then suspicious places are marked in yellow, silent signals are marked in red and finally, in the unverifiable state, they are marked in blue.

Figure 1. Points of Interest **(POI)** up to 100 m in diameter

In terms of the previous, it is extremely important to mention that the color on the satellite image does not show the size of the leak, but how strongly the "signature" of the required drinking water is registered, in contact with the ground, which again indicates only the probability of its existence. An example is the researcher's experience, "that a large leak that lasts, say, a few days, can give the same "signature" as a very small leak that lasts several years" (!).

It is also important to keep in mind that the leak detection methodology presented above does not exclude the traditional acoustic leak detection, known as Active Leak Control (ALC), but rather helps it to avoid bypassing the overall network infrastructure by approximate satellite location of these potential leaks. Also, Active Leak Control (ALC) involves the use of the highest quality acoustic devices for leak detection and with special emphasis on the choice of time for this research, in order to avoid all disturbing sound factors, characteristic of the centers of larger urban areas.

What and how big are the effects of the new way of searching for lost water, can be seen and recognized in the graphic appendix Figure 2. A significant part of the group of Undetectable (Base) leaks, which were previously unavailable, for the then Active Leak Control (N), with new technology they became available D, and as such they moved into the group of Detective Leaks.

Unfortunately, a part of these Base losses remains inaccessible, for the current power of acoustic devices, primarily in the form of low levels of drip phases, which are located mostly at pipe joints (Figure 3), where due to subsidence of wet terrain under the pipeline in the street profile, most often as a consequence of the dynamics of heavy traffic, would come to the stretching of pipes at the joints from the bottom (base) side, is creating conditions for the appearance of potential places, with various levels of leaks, from low drip phases to the formation of the first jets (Table 1).

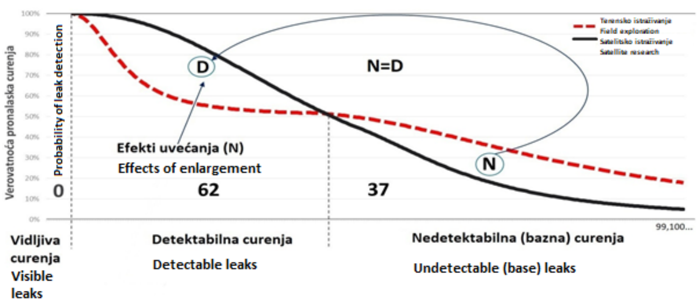

Figure 2. Graphic representation of the effects of the application of satellite technology

When you look at both graphic attachments (Figure 2 and Figure 3), you can clearly see the places of occurrence of all three groups of Real Losses, as well as the effects of satellite imaging, i.e. regrouping of a significant part

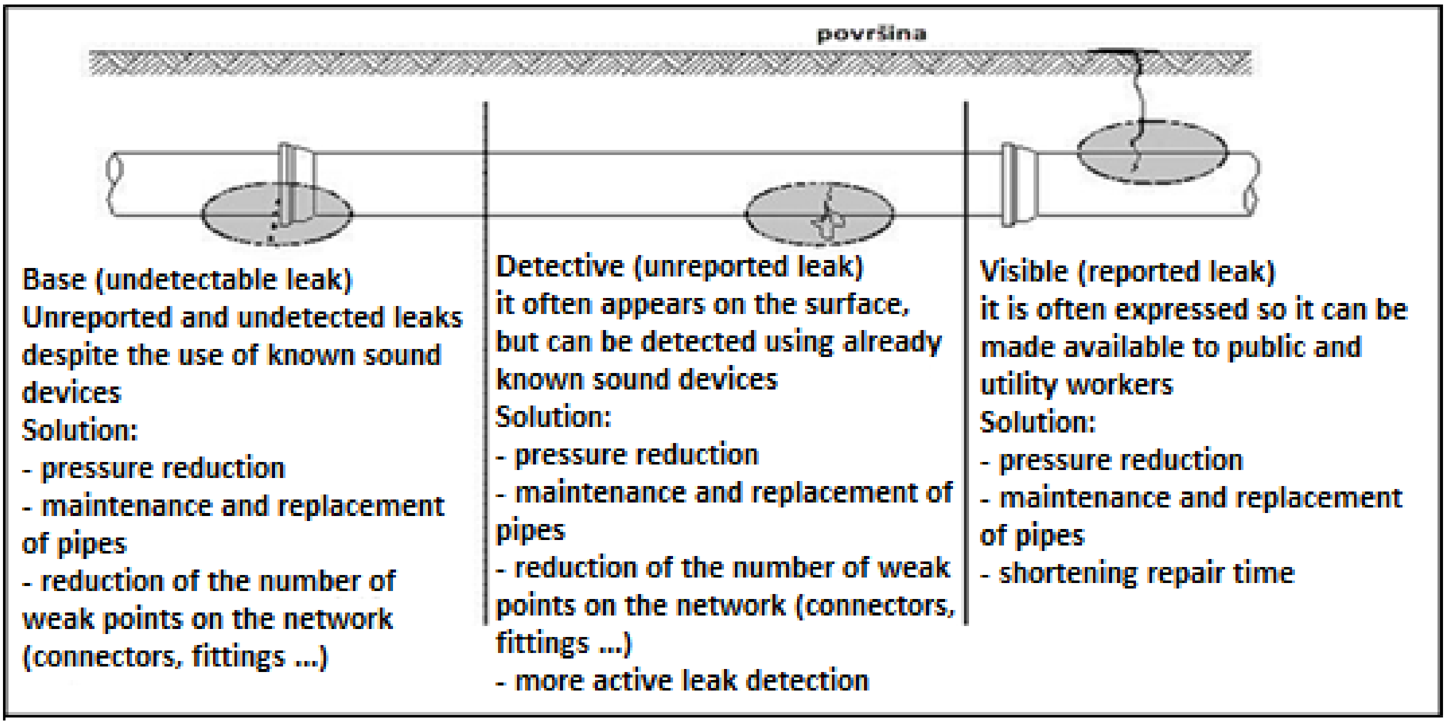

Figure 3. Showing locations for all three groups The actual losses (leaks)

from the group of Base (undetectable leaks) to a group of Detective (unreported leaks). It is empirically known that this inaccessible low phase of dripping in a certain period of time grows into the phase of formed jet (Table 1) and thus becomes available to the technology of field acoustic research. Satellite monitoring implies that certain new types of located potential leaks (suspicious, silent and unverifiable) unavailable for existing acoustic technology must be constantly monitored, so that in an indefinite period of time, they could become available and then, with precise location of the leak, their rehabilitation could be also possible, if there are urgent and justified reasons for the same.

All researchers from these areas agree that the weakest points of the network system are the places of connections, from street pipes to water meter shelters, and that the largest percentages of lost water are at those connections and water meter shelters. Sooner or later in the research phase, when satellite imaging correlates with GIS data, then performs acoustic detection and detects the exact location of the leak, many places of illegal connections will be discovered, which are not registered as legal consumers and where it is one of the types of illegal consumption. All these leaks at these connections are the expected consequence of unprofessionally and technically incorrectly made connections, regardless of whether it is an illegal connection to a street water pipe ("wild connection!"), or an illegal connection, without a measuring device, to the legal connection in front of the water meter shelter ("blind connection!"), etc.

Unfortunately, this is already a domesticated practice of water theft, which a significant number of consumers consider a legal "people's good", which is a reflection of recurrence, from our long past, and for which, in addition, no responsibility is laid! It is reliably known that there are hundreds of kilometers of illegally constructed network in Belgrade, which is often not in the street profile, but through private properties it reaches illegal consumers, and for whose existence official operatives have no information (!?). In that sense, GIS data for such consumers do not exist reliably. It is part of that Illegal Consumption in Apparent Losses, ie the third group presented in the form of Unidentified Consumers (Figure 4), which by number, and based on research experiences in this area, are not to be neglected.

As previously mentioned, that the connections have a convincingly highest percentage of failures, compared to all other types of failures in the water supply network, this further indicates how important it is that all these leaks can be recognized, and then adequately responded, because the consequences in that case, are very favorable for water supply systems, especially in our circumstances. Also, it is important to note, in the context of suburban settlements, that a significant number of these illegal pipelines pass through uninhabited and unmaintained areas, and where significantly larger leaks, which are even evident on the ground, are usually not reported because they have not been noticed by local residents and not by the competent operatives, who do not even visit that pipeline. Especially not, with acoustic devices to detect potential leaks!

Therefore, Satellite Information, about the (high!) probability of an underground leak on such pipelines, is extremely important information, as a guide to the right reaction, tour and recording of these less controlled locations, for prevention of major accidents and detection of possible new unidentified connections, illegal networks, etc.

Finally, for all this it is necessary to create a detailed and adequate algorithm, which would precisely define the procedure, "step by step", to solve the problem, and where

Apparent Losses	UNAUTHORISED CONSUMPTION	ILLEGAL CONNECTIONS UNREGISTERED CONNECTIONS UNIDENTIFIED CONNECTIONS	
	CUSTOMER METERING INACCURACIES	UNREGISTERED CONSUMPTION WATER METER PROBLEMS	METERING INACCURACIES
			BLOCKED WATER METERS
			BLOCKING WATER METERS
			OVERSIZED WATER METERS
		WATER METER READING ERRORS	INCORECT DATA READING
		USED WATER CALCULATION ERRORS	
		EXTENDED CLASSIFICATION OF APPARENT LOSSES	

Figure 4. Part of the known IWA-classification-non-revenue-generating water (NRW) relating to Apparent Losses

each "step", ie each individual binding activity, would be fully defined and ready for implementation, in order to be able to react quickly and efficiently to information on all suspicious places of detected leaks and possible risks, and to finally check what could be hidden behind these leaks in terms of network status and connections, and the possibility of occurrence of adverse events.

Otherwise, this innovative software approach for leak detection primarily uses the Triage Methodology of satellite imaging systems and then the use of best practices, ie experience from operational, field activities of acoustic recording at target locations, ie Points of Interest (POI). What all and how much can be contributed by well-trained field operatives with state-of-the-art acoustic devices, in precisely defined locations, after a detailed triage of satellite images, **are the following benefits:**

- Reducing the cost of finding a leak.
- Increased efficiency of leak detection
- Detection of leaks in the area of end water users.
- **Detection of leaks at places of illegal connections to the water supply network.**
- **Detection of leaks on illegal water supply networks.**
- Shortening the work of field operatives with better results.
- Reduction of underground leak levels.

RESULTS OF APPLICATION IN THE FIELD OF PANČEVO, KOVIN AND KOVAČICA

During 2019, satellite imaging of the area was performed, which included the area of Pančevo, Kovin and Kovačica, and whose ultimate goal was the detection of leaks in the water supply networks of these places. After the satellite recording of the observed terrain, that satellite image was overlapped with GIS maps of the mentioned places and wider locations of potential leaks were obtained, i.e. points of interest (POI), with a diameter of up to 100 m (Figure 1), and at the end field search with acoustic devices was conducted, based on already located points of interest (Points Of Interest), and many new leaks were found on the treated distribution infrastructure. It is certain that at first glance it can be noticed (Table 3) that in the considered area, out of the total number of potential leak sites (Σ = 99), more than 60% of new, detectable leak sites were found (62), which is very favorable result, if it is known that these are the results of only one satellite image. It is reliably known that by repeated recording, at some time interval, a significant number of these, currently undetectable (base) leaks (37), would be detected and available for eventual remediation. Finally, it can still be stated that no visible (reported) leaks were registered on this satellite image of the network (Figure 5).

	Place								
	Pancevo								
Revealed	Pancevo	Starchevo	Omoljica	Ivanovo	B. Brest.	Σ	Kovin	Kovacica	Σ
Leakage	24	5	5	0	1	35	19	8	62
Suspicious	3	0	0	0	0	3	2	0	5
Quiet	20	2	0	1	1	24	2	0	26
Unverifiable	2	1	0	0	0	3	1	2	6
									Σ=99

Table 3. Results of the number of detected and potential leaks in the recorded areas of Pančevo, Kovin and Kovačica

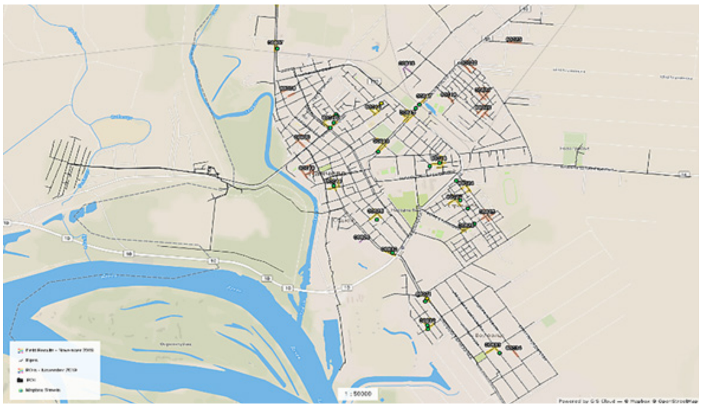

Figure 5. Water supply network of the city of Pančevo with places of detected (and potential) leakage

As can be seen in Table 3 and Figure 5, 24 leaks were discovered in the city of **Pančevo,** of which 3 were suspicious, 20 were silent and 2 were unverifiable. So, in the city itself, about 50% of leaks were found from the total number of potential leaks, and on 249 km of street pipeline and 17,500 connections (Table 5), there are 13 breakdowns on the street network and 11 on connections, which in this sense, is yet a rare case for water supply systems from these areas. In other suburban settlements, faults on connections dominate.

image of the local water supply network and only 5 leaks were detected, 2 of which are on the pipeline with a total length of 36 km, and three leaks are on connections (behind the water meter), of which there are 1650 in the settlement, (Table 3, Table 4 and Table 5).

The third settlement covered by this satellite image is **Banatski Brestovac,** and it is about 5 km away from the settlement of Omoljica, and on the local water supply network of 17 km long, with 950 connections, 1 leak was detected at the connection (to the water meter) and 1 is silent, (Table 3, Table 4 and Table 5).

And finally, the settlement of **Ivanovo,** about 5 km away from the settlement of Omoljice, was also covered by the same satellite image of the local water supply network, with one potential leak site detected (1 silent), on a pipeline 18 km long, with 405 connections, (Table 3, Table 4 and Table 5).

However, in the end, the results from the settlements of Kovin and Kovačica, even more impressive, will confirm the previously mentioned research experience, on the dominance of failures at connections, so that the final picture from this whole area would be...

	Place								
	Pancevo								
Lok. leaks	Pancevo	Starchevo	Omoljica	Ivanovo	B. Brest.	**Σ**	**Kovin**	**Kovacica**	**Σ**
Pipeline	13	0	2	0	0	15	5	0	20
To the water meter	7	3	0	0	1	11	8	6	25
Behind the water meter	4	2	3	0	0	9	6	2	17
									Σ=62

Table 4. Locations of leaks located on the networks of Pančevo, Starčevo, Omoljica, Ivanovo, Banatski Brestovac, Kovin and Kovačica

Finally, when we look at the results of failures (leaks) in the city of Pančevo and suburban settlements in Table 4, we get a picture of the dominance of failures at the connections (15 on the street pipeline and 20 on the connections).

The suburban settlement of Starčevo is about 9 km away from Pančevo, and was covered by this satellite image of the local water supply network. In the settlement itself, 5 leaks were detected, 2 are silent and 1 unverifiable, on a 24 km long pipeline, with 2200 connections, noting that all 5 leaks were detected at the connections (3 to the water meter and 2 behind the water meter), (Table 3, Table 4, and Table 5).

The second settlement **Omoljica,** about 7 km away from the settlement Starčevo, was covered by the same satellite

20 failures (leaks) on a 475.5 km long street network and 42 failures (leaks) at 30185 connections, as shown in Table 3, Table 4 and Table 5.

Since all relevant data for all these settlements were obtained during these searches, it would be necessary to assess the real level of maintenance of these distribution systems (water supply networks and connections), where various types of leaks or losses occur after the failures. In this regard, standards have been developed in the developed part of the world, which have made it possible to assess the level of maintenance of the entire distribution system, expressed in three levels, through the level of damage (failures) in the network and connection (Table 6).

	SYSTEM								
	Pančevo						Kovin	Kovacica	Σ
Distributive	Pančevo	Starčevo	Omoljica	Ivanovo	B. Brest.	Σ			
Pipeline (km)	249	24	36	18	17	344	69.5	62	475.5
Attachments (pcs)	17500	2200	1650	405	950	22705	5120	2360	30185

Table 5. Display of network length and number of connections for each settlement of the recorded area

STANDARDS FOR THE LEVEL OF DAMAGE TO THE DISTRIBUTION NETWORK OF WATER SUPPLY SYSTEM			
FAULT LEVEL PER DVGW (W 400-3)	PIPE DAMAGE RATE		**RECOMMENDATION**
	MAIN AND SECONDARY NETWORK	CONNECTIONS	
	ANNUAL FAILURES ON 100 km NETWORK	**ANNUAL FAULTS ON 1000 CONNECTIONS**	
LOW	≤ 10	≤ 5	MAINTAIN THIS LEVEL
MIDDLE	10 to 50	5 to 10	IMPROVE THE LEVEL
HIGH	50	10	EMERGENCY REHABILITATION

Table 6. Standards for assessing the level of maintenance of distribution systems

If the technical standards, shown in Table 6, are applied to the city of **Pančevo** with all suburban settlements (Starčevo, Omoljica, Ivanovo and Banatski Brestovac), it is easy to see that the level of failures, which are expressed as leaks in the street water supply network, and connections, is at an acceptably low level with the recommendation to "maintain this level", which is confirmed by the DVGW standards, that the distribution water supply system in this area is maintained at the desired high level.

The settlement of **Kovin** (Figure 6) was covered by satellite imaging and on that occasion 19 leaks were detected, 2 suspicious, 2 silent and 1 unverifiable, noting that 5 leaks were detected on the 69.5 km long network, and 14 leaks were detected at the connections (8 to the water meter and 6 behind the water meter), of which there are 5120 in this system, as shown in Table 3, Table 4 and Table 5.

If the maintenance level of this distribution system was checked, according to the standards shown in Table 6, then a high level of maintenance of the street network and connections could be stated with the recommendation "maintain this level".

The settlement of Kovačica (Figure 7) was also covered by satellite imaging and in that area 8 leaks were detected at the connections (6 to the water meter and 2 behind the water meter), and 1 unverifiable, on the 62 km long network, with 2360 connections, as this is shown in Table 3, Table 4 and Table 5.

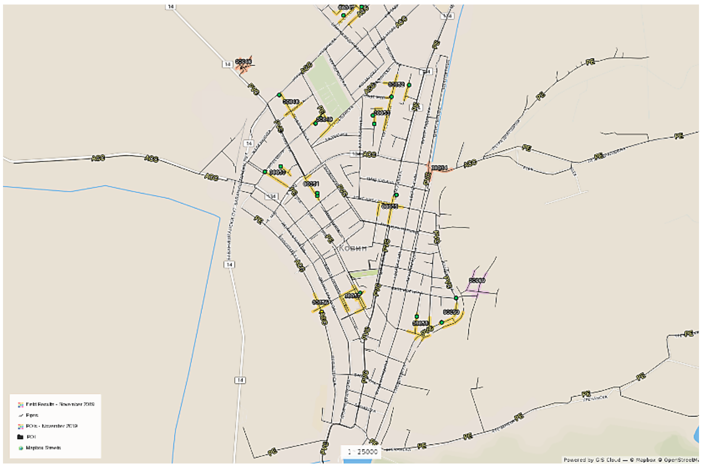

Figure 6. . Water supply network of Kovin settlement with locations of detected (and potential) leakage

If the level of maintenance of the distribution system in the settlement of Kovačica was checked, then according to the known standards (Table 6), a conclusion would be made about the high level, with the recommendation to **"maintain this level".**

Figure 7. Water supply network of Kovačica settlement with locations of detected (and potential) leakage

INSTEAD OF CONCLUSION

When all previous activities are analyzed, the impression is inevitably given that the satellite image of a possible underground leak completes a wide range of searches for complex types of water losses, which were previously unavailable for the existing Active leakage control. The very way of such control meant occasional inspection of the entire network with acoustic devices, which was an extremely demanding activity, especially when it comes to networks of several thousand kilometers in length. Satellite technology has provided answers to all previous nightmarish questions, as it has offered short and marked locations, on the network system, with reliable indicators of the high probability of the existence of a leak trace, at those locations. However, some water supply systems have completely abandoned the distribution system sectors, despite the extremely high water losses, allowing even frequent occurrences of adverse events, in the form of major accidents, which in addition to large water losses, produce great damage in these areas. Finding out how many failures (leaks) there are in the distribution system, which of them are alarming, with a high risk of adverse events, as already explained by **FMECA** methodology in the work **Risk analysis and risk management in the distribution part of the water supply system**, (Jahorina 2017), is a capital knowledge, for all responsible and dedicated operatives and especially for the management of that company. How the authorities react to all this is shown by the data on unacceptably high percentages of lost water in their water supply systems.

Hence, it should be said that the competent managers and operatives from Pančevo, Kovin and Kovačica, have taken brave and responsible steps in the desire to, with the help of satellite technology, find out all the new potential shortcomings of their water supply systems. To their satisfaction, even the powerful satellite technology could not disturb the condition, preferably good maintenance, and find an unacceptably high number of leaks at the distribution parts of the mentioned water supply systems, because the levels of leaks were so low that they deserved status „maintaining that level", as recommended by the DVGW standard (Table 6).

All this, however, should not be taken as a big and unexpected surprise, because some previous research experiences from this area (Experiences in reducing apparent losses in the Belgrade water supply system, Vienna, WWC, 2008), have just shown that, in these regions, there is another category of losses, much larger and more devastating for water supply systems, in relation to all these, the so-called Real Losses, in the form of leaks on the damaged network and connections.

If the analysis of the water balance, measurements of the amount of water entering the distribution system, and the amount of water consumed (Input-Output), determines the existence of a significant percentage of uncontrolled water, non-revenue water, then we should turn to another category of water losses, known as Apparent Losses. This category of losses treats especially the problem of poor operation of measuring devices-water meters, then various types of illegal consumption, errors in invoicing of consumed water, etc. At first glance, it could be concluded that this satellite technology, in some of these activities, cannot significantly help? However, in previous research works from this area, it is precisely stated in which segments, this satellite technology, can help even in the detection of some groups from the category of Apparent Losses. **(Detection of losses on the water supply network using satellite technology, Jahorina 2019)** In other words, satellite technology can help with both categories, Real and Apparent Losses, and this would ultimately and significantly help to reduce large losses, as major generators of bad business, down to an acceptably low level, which should be understood (and accepted!) by all top managers of water supply systems, in this area.

This article was originally published in Strategija Smanjenja Gubitaka UVodovodnim Sistemima in 2020. Written by: Stevo Savic.

References:

1. Izveštaj o satelitskom snimanju područja Pančevo, Kovin i Kovačica, Kolektor, Slovenija.

2. Stevo Savić - Otkrivanje gubitaka na vodovodnoj mreži primenom satelitske tehnologije, Jahorina 2019.

3. Paul Schumi - Advanced Leak Detection Technology Utilizing Satellite, (Water Asset Management Conference, October, 2017.).

4. Shame Majetich, Lauren Guy - Satellite Imaging Offers Accurate, Cost Effective Distribution. System Monitoring, (USA)

5. Stevo Savić - Monografija - Strategija smanjenja gubitaka u vodovodnim sistemima, Beograd, 2018.