Do you know how many of your colleagues will come to your funeral?

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Abstract

A number of leakage practitioners will relay experiences that increased leakage activity appears to increase the number of leaks on the system. This paper explores evidence for this phenomenon using case studies from two major UK companies. The paper explores whether this phenomena explains studies which have shown very poor returns from leakage control activity and quantifies the extent of the problem. It shows how the information can affect estimates of the natural rate of rise of leakage and the estimates of the average flow rate for leaks. The paper also makes recommendations on how allowances can be made for the phenomena in leakage control strategies and policies within a company.

Introduction

A number of leakage practitioners report that there is evidence that there is little reduction in night flows from a large number of leaks that are found and repaired. A figure of 35% was quoted at a UK conference in 2006 (Hall et al., 2006) as the number of leaks located and repaired that resulted in no apparent drop in leakage. A number of attempts have been made to establish average flow rates by looking at the reduction in nightline and this has shown evidence that in some cases night flows in fact increase when leaks have been located and repaired. Can this be correct?

In addition, a significant number of leakage practitioners believe that they have experienced increased burst frequencies when there has been an increase in active leakage detection. Work carried out in Canada has shown a strong relationship both spatially and temporally between bursts – but is this due to asset condition or other factors? The author is not aware of any work that has been carried out to look at the possible relationship between proactive leakage control activity and burst frequency.

Evaluating leak flow rates

Knowledge of typical and average flow rates of leaks is of benefit in a number of areas of water loss management. For example, with the cost benefit analysis of leakage detection activity and the economic level of leakage. A number of studies (WRc, 1994), (Thornton, 2002) have been carried out with the intention of evaluating typical flow rates.

The most common methodology adopted for this type of analysis in areas covered by district metered areas (DMAs) is to look at the change in net night flow recorded on the DMA following the repair of a leak. In this approach the average nightline for a few nights before a leak is compared to the average after the repair. An average has to be taken in order to smooth out small variations due to changes in night use. The analysis can be automated in the case of large volumes of data. The results can be split between type and category of repair, for example, mains repair, service pipe repair and fitting repair and whether the leak was reported by customers or found by proactive detection.

Figure 1 shows the result of the analysis of over 200 mains leak repairs carried out in a utility in the UK. The drop in nightline following the repair of the leak has been ranked in ascending order and plotted. As can be seen from the graph in some cases there was a significant ***increase*** in the nightline following the repair – as much as 15m3/hr in one case. In fact the graph shows that nightlines increased in about 40% of cases. This is surprising as one would expect the nightline to drop in all cases. It could be argued that the drop may be caused by short term stochastic variations in night use. If this was the case then these fluctuations would be negative in 50% of occasions and therefore enhance the drop in nightline in these cases. In order to compensate for this the full population should be taken in evaluating the average size of leak and not a biased sample by only taking those where the drop has been positive.

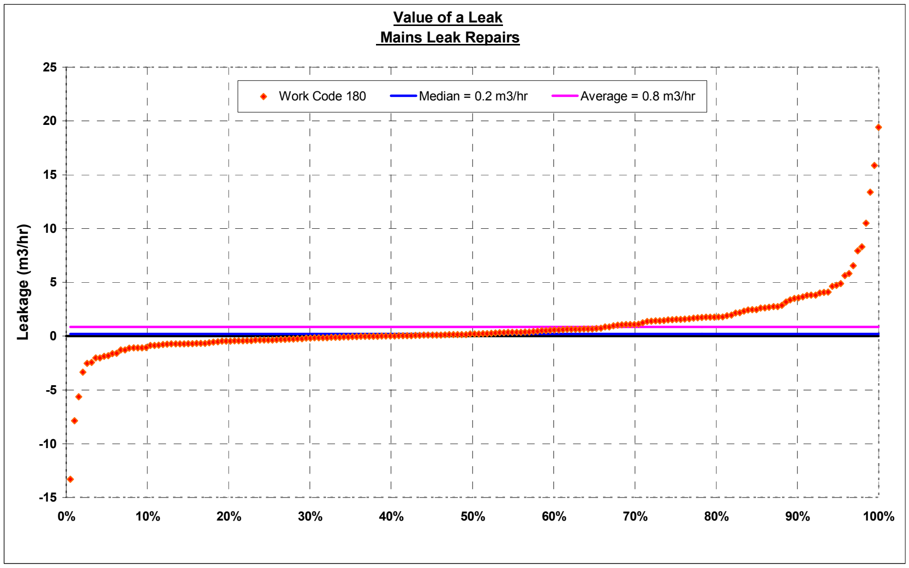

Figure 1 Changes in nightline following leak repair

If the full population plotted in Figure 1 is used to estimate flow rates then the average leak size is 0.8m3/hr and the median is 0.2m3/hr. It could be argued that the median is more representative of leak size in this case because the average is skewed by a very small number of large reductions. The flow rate of 0.2m3/hr is very small, particularly for a mains repair.

This flow rate could be corroborated by looking at the Natural Rate of Rise of leakage (NRR). The NRR is the rate at which leakage would rise if no proactive leakage detection was carried out (Lambert et al., 2005). In this case unreported leaks accumulate on the system and the rise in leakage is equal to the sum of the product of the number of leaks and their average flow rate. When this check was carried out on the system taking into account the average number of unreported mains, service pipe and fittings and their respective average flow rates derived by the method outlined above, the predicted rate of rise in leakage was significantly lower than that experienced when leakage detection was reduced. This implied that the average flow rates derived by the method above were underestimating the average flow rates for some reason.

Alternative method of assessment

An alternative method of estimating the average leak size was therefore sought with the intention of verifying or otherwise the results of the approach described above. It was noted that leakage detection activity had varied significantly over a four year period at the operating company whose data had been analysed in the study above. Due to these changes in resource levels devoted to leakage detection, the number of leaks repaired and leakage levels had fluctuated over the period. Figure 2 shows the number of full time equivalent (FTE) personnel devoted to proactive leakage detection, the number of leaks detected and the company leakage level. The company leakage level is the sum of leakage assessed on 2500 district meter areas (DMAs).

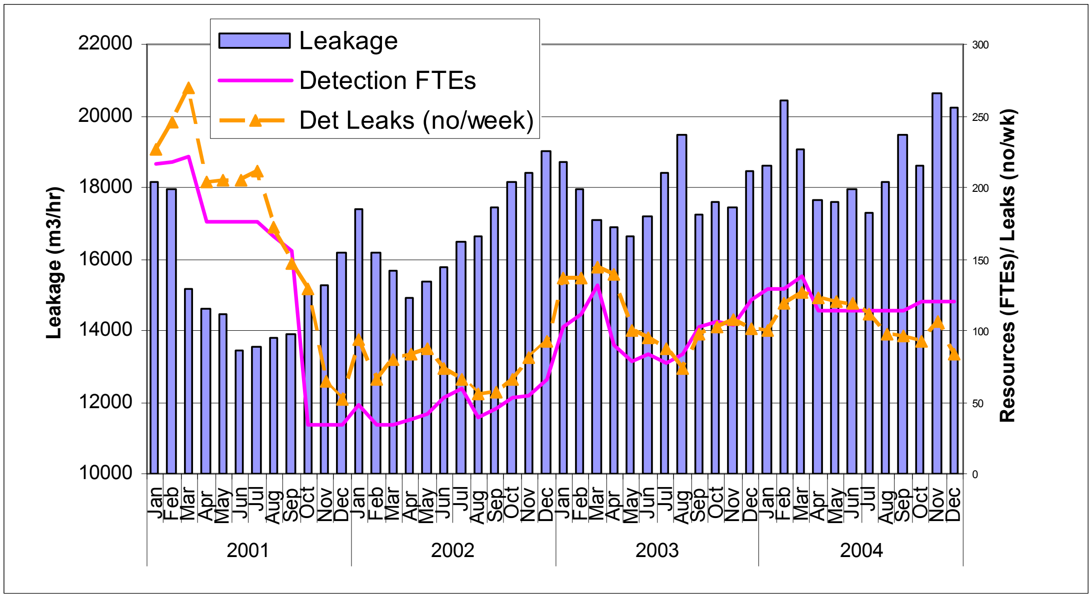

Figure 2 Historical pattern of leakage control activity and corresponding leakage levels

The graph clearly shows that in the early part of 2001, when over 170 FTEs were employed on leakage detection, leakage reduced significantly. At this time approximately 200 leaks per week were located and repaired from this activity. In the latter part of 2001 resources were reduced significantly and during 2002 approximately 50 FTEs were deployed on leakage detection. During this period the number of leaks located dropped to approximately 75 per week and leakage rose significantly. During 2003 and 2004 resources were restored to about 100 FTEs. Leakage continued to rise but at a much lower rate. It was clear that there was a relationship between detection resources, leaks located and leakage levels, and that investigation of this may yield information about the average leak flow arte.

It should be noted that this effect is in fact only a short term effect. With time, leakage would stabilise at a given level for a given resource – represented by a point on the Active Leakage Control (ALC) curve (Figure 3). At any point on the curve the number of leaks detected will be the same, otherwise leakage would not be stable. However as one moves from one point to another on the curve the number of leaks detected will change in the short term and will be reflected in either a drop or increase in leakage levels until a new stable level of leakage is attained.

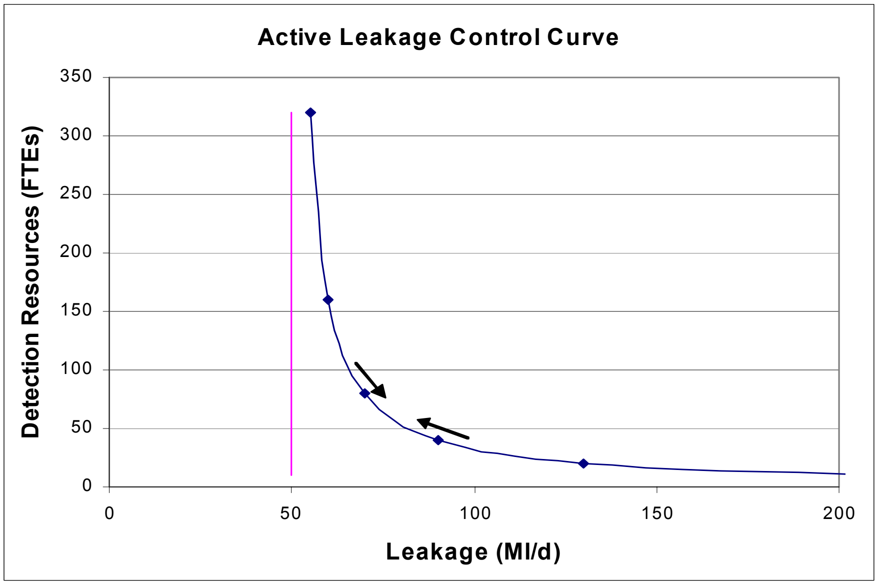

Figure 3 Active leakage control curve

In order to carry out the analysis, the four year record was split into periods where the resources were approximately constant. Four periods were identified, namely January to October 2001, November 2001 to December 2002, January 2003 to April 2003 and May 2003 to December 2004. These are shown in Figure 4.

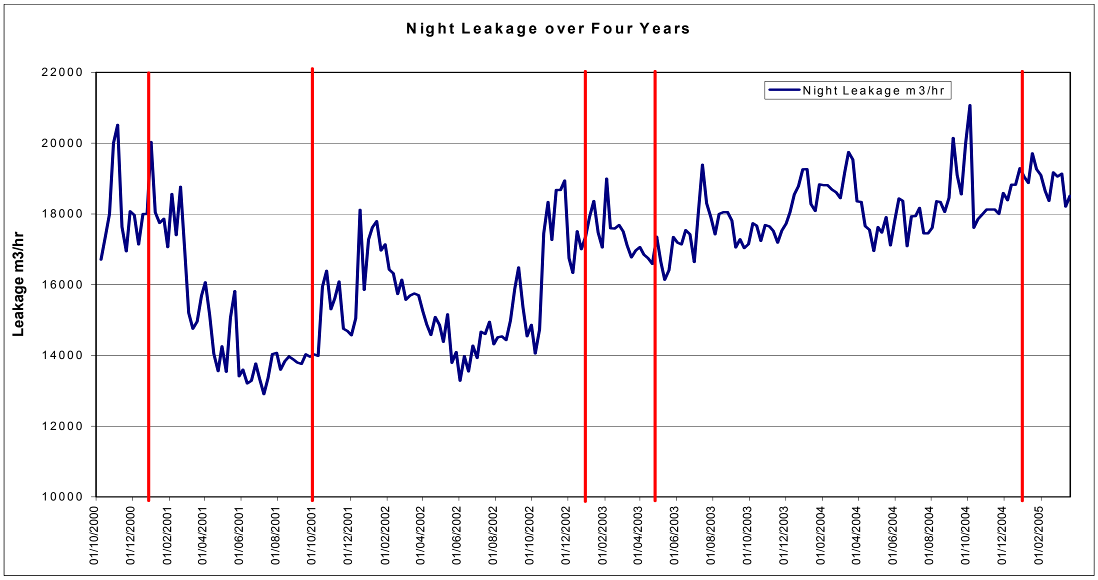

Figure 4 Selected periods of leakage detection activity

Table 1 Results of detection for four periods – 2001-2004

Period		Weeks	Jobs No	Jobs No/week	Leakage (m3/hr) Start	End	Change m3/hr/wk	Change Ml/d/yr	Jobs no/year	All no/week	Detected no/week
						18000					
Jan-01	Oct-01	43	21773	503	18000	13000	-116	-139.4	26156	503	186
Nov-01	Dec-02	61	20289	334	13000	19500	107	129.2	17377	334	67
Jan-03	Apr-03	17	8087	476	19500	17500	-118	-141.9	24737	476	131
May-03	Dec-04	87	34343	394	17500	19000	17	20.8	20493	394	97

The leakage, the number of leaks detected and the total number of leaks repaired was abstracted for these periods and are shown in Table 1. Table 1 also shows the calculated rate of change in leakage for these periods.

Interpretation of Results

The rate of change in leakage was plotted against the total number of leaks repaired. This is shown in Figure 5. The points showed a linear relationship. A straight line regression was therefore fitted through the points.

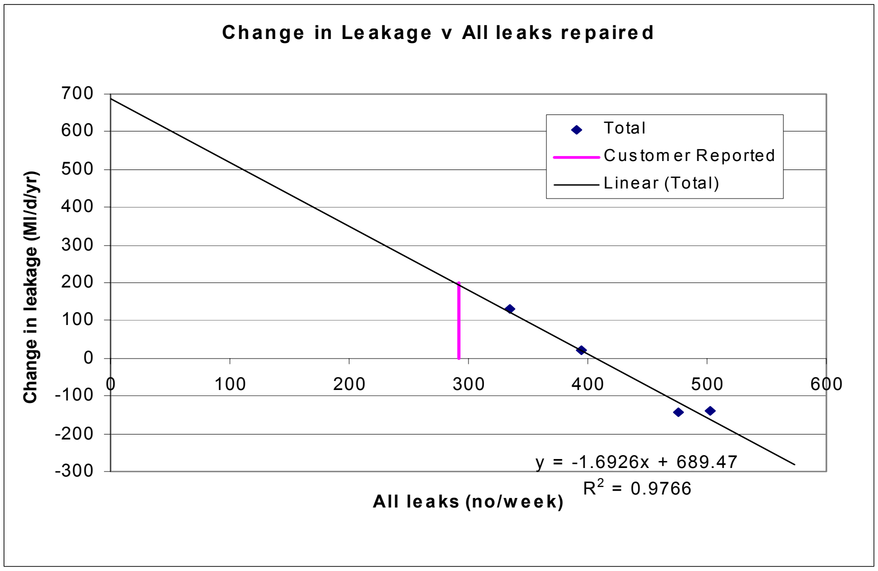

Figure 5 Rate of change in leakage compared to total number of leaks repaired

The intercept on the Y axis can be interpreted as the rate at which leakage would rise if no leaks at all (including customer reported leaks) were repaired. This is sometimes referred (UKWIR, 2005) to as the Gross NRR. It can be seen that this is 700Ml/d/yr.

The intercept on the X axis can be interpreted as the total number of leaks that have to be repaired in order to hold leakage stable. This is just over 400 leaks per week.

The slope of the line can be interpreted therefore as the average leak flow rate. This is of all types of leaks – i.e. both reported and unreported mains and service leaks. This was found to be 1.4m3/hr. Average system pressure is 40m so this flow rate is equivalent to 1.75m3/hr if adjusted to 50m pressure using n1=1 (Thornton et al., 2005). Unfortunately it is not possible to estimate flow rates by type or category using this method. However this flow rate is not unreasonable compared to flow rates previously quoted (WRc, 1994) taking into account the mix of mains and service pipe leaks and the generally accepted belief that average flow rates are now lower following intensive active leakage control carried out since 1994.

Proactively Detected Leaks

Further analysis of the data was carried to see if the data could be used to estimate the flow rate of unreported leaks only. In this case the change in leakage was plotted against the number of proactive leaks only. The result is shown in Figure 6.

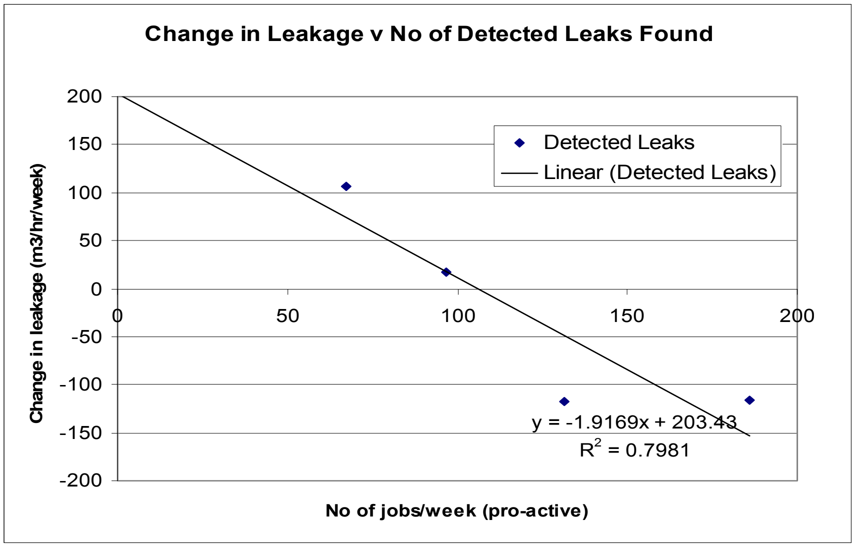

Figure 6 Change in leakage compared to number of proactive leaks repaired

In this case the Y intercept could be interpreted as the net or unreported NRR, i.e. 200Ml/d/yr, and the X intercept as the number of leaks that have to be proactively detected to hold leakage stable, i.e. 110 leaks/week. The slope of the line would be the average flow rate of unreported leaks. This worked out as 1.9m3/hr. This was surprising as one would normally expect unreported leaks to have, if anything, a lower flow rate than reported leaks and therefore should have been less than the 1.4m3/hr identified earlier.

In order to investigate this result further, the number of proactive leaks was plotted against the total number of leaks. This is shown in Figure 7.

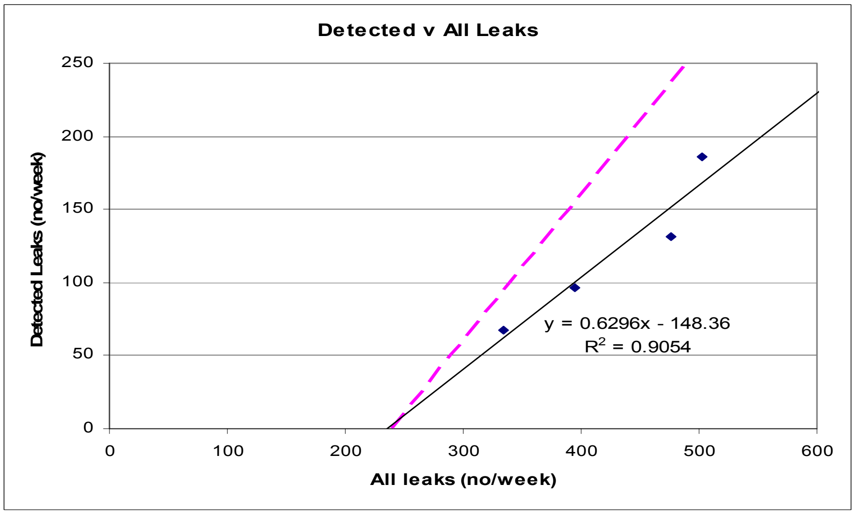

Figure 7 Comparison of proactive detection leaks to total number of leaks repaired -Case Study 1

On the basis that the number of reported leaks should be independent of the level of active leakage control, it was expected that the relationship should be of the form of a straight line at a ratio of 1:1 after some intercept on the X axis. Furthermore it was expected that the intercept should be of the order of 290 leaks per week (the difference between 400 and 110 in the analyses above). A line was fitted to the data and this had a slope of 0.63 and an intercept of about 230 leaks per week. A line at a slope of 1:1 was drawn from this intercept. This is shown by the dashed line in the Figure 7.It can be seen that all the results fall below this line.

This relationship can be interpreted as the fact that reported leaks increased with the level of detection i.e. approximately one additional reported leak was created on 50% of the occasions when an unreported leak was repaired. When this is taken into account the average flow rate of unreported leaks would be less than 1.4m3/hr as expected.

Second Case Study

The work was repeated with data from another large company in the UK. The results are shown in Figure 8.

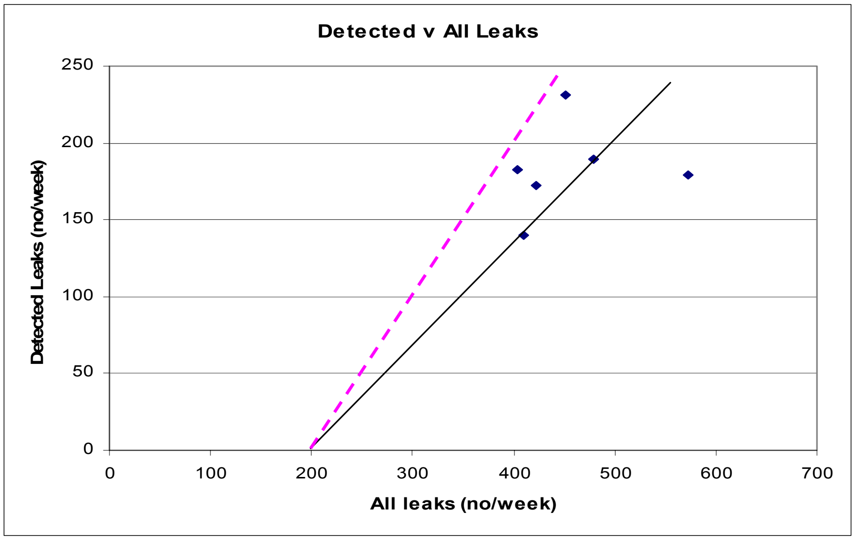

Figure 8 Comparison of proactive detection leaks to total number of leaks repaired -Case Study 2

Although the fit is not as strong as with the first case study the data supports the conclusion that additional leaks are caused by the repair of a previous failure.

Previous analyses

Goulter analyzed data on the occurrence of pipe failures in the city of Winnipeg in Canada. In this work he found (Goulter et al., 1988), (Goulter et al., 1989)) that there was a strong correlation both spatially and temporally between mains failures. He found, based on analysis of the data, for example, that “24% of all breaks were found to occur within 1m of a previous break” and that “43% of all breaks occurring within 1m of a previous break also occurred within 1 day of a previous break in the immediate vicinity”. He went on (Goulter et al., 1993) to postulate functions to predict the likelihood of a burst occurring as a function of it distance from and time following the repair of a previous failure. All this work showed a strong correlation of one repair following on from and being close to a previous failure.

Goulter did not draw any conclusion as to the reason behind this clustering save to quote a belief that it may be caused by ”disturbance to the surrounding ground and bedding caused both by the initial failure and its subsequent repair…..” . It is the author’s belief that another possible and perhaps stronger reason for the failures would be pressure fluctuations caused by the shut-off and subsequent recharging of the network in the vicinity of the leak in order to effect the repair.

Conclusion

This work has shown that leakage control activity can cause an increase in burst frequency – or as one leakage practitioner once said “when we repair one leak another comes to its funeral” (Arscott, 1985). This paper has shown that although it is not as bad as one for one it is significant (approximately one for every two) and should be taken into account in developing and costing leakage control strategies.

It is the author’s view that these subsequent failures could well be being caused by pressure fluctuations and that there could be benefit in carrying out short interval pressure logging at the time of leak repairs in order to investigate the pressure surges induced by shut-offs. If this is found to be a predominant cause then it would suggest that there could be significant benefit in investigating methods or procedures for the repair of leaks that eliminate such pressure surges.

Although this work has shown a link between reported bursts and unreported burst repairs this is only because of the approach taken. There is no reason to believe that the repair of a reported leak would not have the same effect and that in fact some of these subsequent leaks could be unreported as well as reported. The conclusion therefore is that the underlying “natural” burst rate of any system is significantly lower than the actual repair rate due to the fact that the intervention on the network necessary to repair the leak causes other leaks to break out.

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