

Spatial analysis of failure data from Dutch water companies

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ABSTRACT

Failures of water mains can result in unwanted effects but also offer a great opportunity to obtain network information. As low failure frequencies prevail within the Dutch water utilities, limited knowledge can be derived from the individual failure occurrences. One way to overcome this problem is by sharing failure information between water utilities. In the Netherlands, a system has been developed to enable uniform failure registration and an exchange of information between water companies. Spatial analysis of these failure data can reveal relationships between asset failures and environmental factors such as soil characteristics. The KWR Watercycle Research Institute investigated the failure databases of five Dutch Water Companies. The databases' values were considered separately as well as combined to determine whether there is a relationship between the failures and environmental factors. This knowledge can help determine the condition of the distribution network and help improve the registration system.

Keywords: Failure data, soil, settlement, GIS, spatial analysis, drinking water, Netherlands, asset management

INTRODUCTION

The aim of drinking water companies in the Netherlands is to supply the highest quality drinking water at the lowest cost. Pipe bursts can lead to unwanted consequences such as a negative impact on the surrounding area and the associated remediation costs. In order to keep the number of failures as low as possible, it is essential to develop appropriate and effective maintenance and replacement activities. Geographical circumstances of mains have a strong relation to these activities. For example, characteristics of the subsoil influence the main condition. The geographical characteristics become more explicit with the availability of geographical information systems (GIS). As water companies have digitalised their subsoil assets, analyses based on geographical information come into perspective. Spatial analysis of failure data can reveal relationships between asset failures and environmental factors such as soil characteristics. In this way failures of water mains also offer a great opportunity to obtain network information and add value for asset management.

GEO INFORMATION

The analysis in this study involves a combination of analysing failure data on drinking water mains and soil data using GIS. The total length of the water distribution network in the Netherlands is approximately 117,600 km, of which more than half (51%) consists of PVC. Asbestos cement (AC) takes a second place with 28% (see Figure 1) (Geudens, 2012). It is assumed that asbestos cement water mains are more sensitive for aggressive soils and are more likely to fail in more acid soils (low pH). PVC water mains are considered to be more sensitive for soil settlement. If the movement of the soil is uniform, no problem will arise with the pipe since the whole pipe will move as a single structure. However, in case of variable soil settlement, different sections of the pipe will experience different levels of settlement which is believed to cause extra failures (Arsénio et al., 2013). The study focused on failures in asbestos cement water mains related to acid soils and failures in PVC water mains related to soil settlement.

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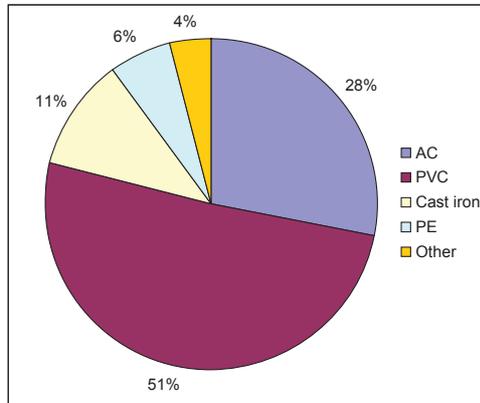


Figure 1. Structure of the drinking water network in The Netherlands

Failure data

One of the sources of information on mains is provided by analysing the history of bursts. In order to use this data for underpinning asset management decisions, it is essential that the failure data is obtained uniformly, with clear definitions and defined procedures for registration, data-handling and analysis. This becomes even more important if data is shared by several companies. Within the Joint Research programme of KWR and the Dutch water companies, the project USTORE is executed. In USTORE the water companies have decided on a uniform registration of failures (Vloerbergh, 2011).

KWR started the USTORE initiative in 2009 with the aim to define a system for uniform registration of main bursts. Failure data and general information of mains of water companies are uploaded to a web based database (USTOREweb). In november 2011, approximately 4,000 bursts by five water companies have been uploaded to the web portal USTOREweb. At the moment (May 2013) the number of bursts has increased to 10,000 uploaded by seven water companies.

Not only data on bursts and a number of attributes of the bursts are registered in USTORE. Also asset characteristics, information on the surroundings and situational factors are considered having an influence on the occurrence of failures and are therefore registered in USTORE (see Figure 2).

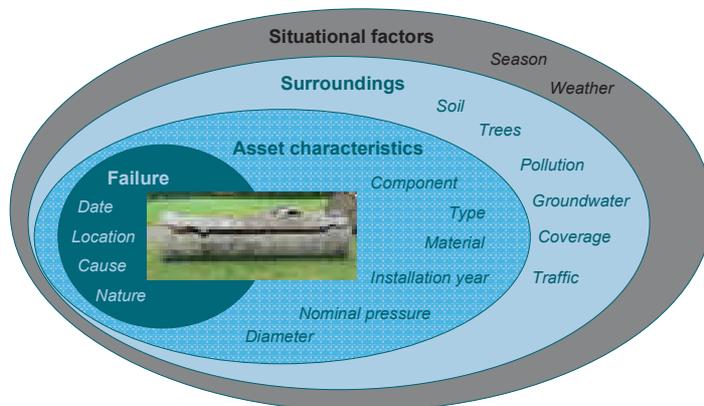


Figure 2. Factors with a possible influence on the occurrence of failures. By including this site specific data in the registration it will become possible to study the assumed influence.

Figure 3 presents the different causes of pipe bursts. Most bursts are registered as cause 'Unknown', indicating that in many cases the cause is not known or not registered correctly. Apart from 'Unknown' the main cause of failure is 'External load', followed by 'External leaching'. In many cases it will be difficult to distinguish between these causes.

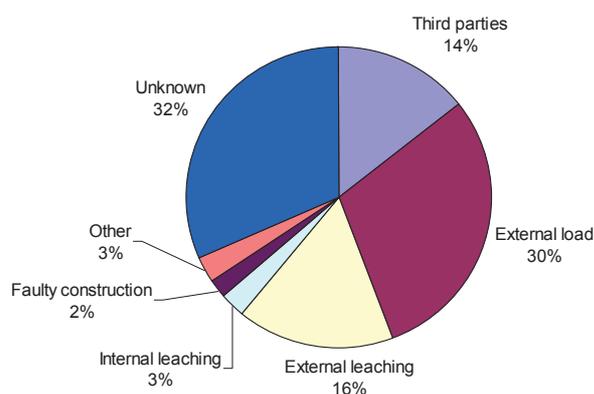


Figure 3. Bursts of AC mains grouped by cause, source USTORE.

Soil Data

The study focused on failures in asbestos cement water mains related to acid soils and failures in PVC water mains related to soil settlement. The surrounding soil is found to be aggressive in case of a low pH and the presence of sulphates (Conroy et al., 2005). In the Netherlands leaching is however mostly related to the absence of lime (or calcium-containing inorganic materials) in the soil (Slaats and Mesman, 2004). Soils low in lime are in general more acid (low pH). Information on acid soils is based on a soil map of the Netherlands (Figure 4).



Figure 4 Soil map of the Netherlands (© Alterra)

For soil settlement a Deltares map with data on soil settlement for the Netherlands is used. The soil settlement is calculated by using a 3D geological model. The inaccuracy in the calculated settlement is approximately 30% (RCE, 2011).

ANALYSIS and RESULTS

A subset of the USTORE data from two water companies is used for the GIS analysis study. Only 77% of the USTORE data proved to be complete and suitable for direct use in GIS. The other 23% were examined more closely. It turned out that in many cases the XY coordinates were not properly registered for example by incorrect use of the decimal separator. After manual correction 99% of the data could be used for the spatial analysis.

Influence of soil characteristics on failures in Asbestos cement mains

The soil map of the Netherlands (scale 1 : 50.000) could be reclassified as follows:

- Low lime content: corresponding to more acid soils, mostly peat and some sandy soils;
- Medium lime content: corresponding to medium acid soils
- High lime content: corresponding to non-acid soils, mostly marine deposits.

Figure 5 presents the burst frequencies in asbestos cement mains of the two water companies grouped by pipe age and soil type. For mains constructed until 1965 the median burst frequency in soils low in lime (0.112 bursts per kilometer per year) is considerably higher than in soils high in calcium (0.055 bursts per kilometer per year). There are no big differences in the burst frequency for mains constructed after 1965. The reason for a higher burst frequency in older mains in low lime soils can be that those mains have been subject to leaching for a longer period. However, a more logical explanation is that the quality of older AC mains is poorer. The error bars in Figure 3 represent the 95% confidence interval, based on the assumption that the appearance of bursts can be described with a Poisson distribution and the upper and lower limits of the confidence interval can be calculated using the χ^2 distribution (Vreeburg et al., 2012). The wide range of the 95% confidence interval (0.07 and 0.18 bursts per kilometer per year) suggests that for older AC mains in low in lime soils also other factors play a role in the occurrence of bursts.

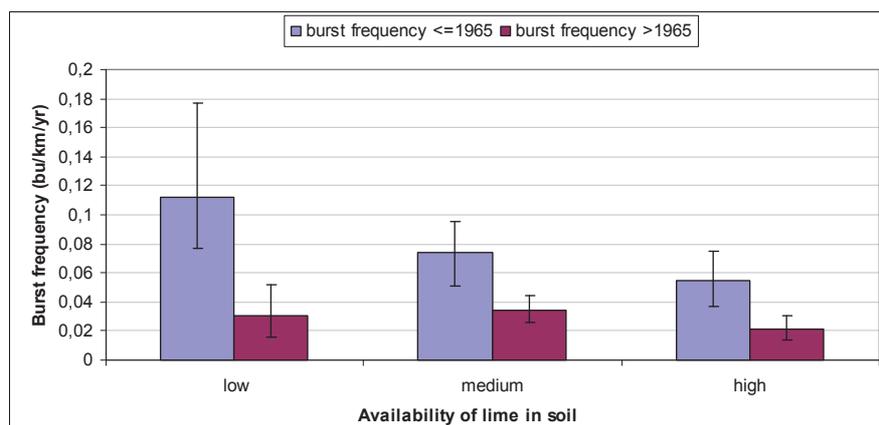


Figure 5. Burst frequency of AC mains grouped by soil characteristics, installed before and after 1965. The error bars represent the 95% confidence interval.

Influence of soil settlement on failures in PVC mains

The map with settlement data is a 100x100 meter raster with information on soil settlement. Various GIS techniques (i.e. focal statistics, raster calculator and mosaic functions) are used to translate the information on settlement into information on differential soil settlement (Daal, 2012). Using these techniques it was possible to determine the maximum difference with the eight neighboring cells for each raster cell (see Figure 6).

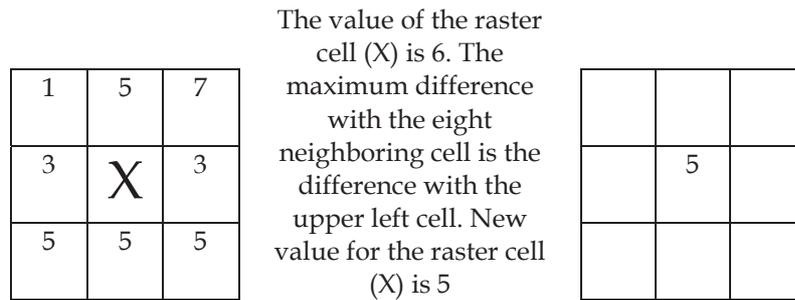


Figure 6. Translate the information on settlement into information on differential soil settlement using GIS.

Based on a the differential settlement the area is divided in parts with high differential settlement and stable parts with low differential settlement. Next the burst frequencies in PVC mains in areas with high differential settlement are compared with the burst frequencies in areas with low differential settlement. The average failure rate in stable ground (low differential settlement) is 0.017 bursts per kilometer per year. In areas with high differential settlement the burst frequency increases with 59% to 0.027 bursts per kilometer per year. The results (including a confidence interval of 95%) are plotted in a graph (Figure 7). These results show that the failure rate increases when there is more differential settlement.

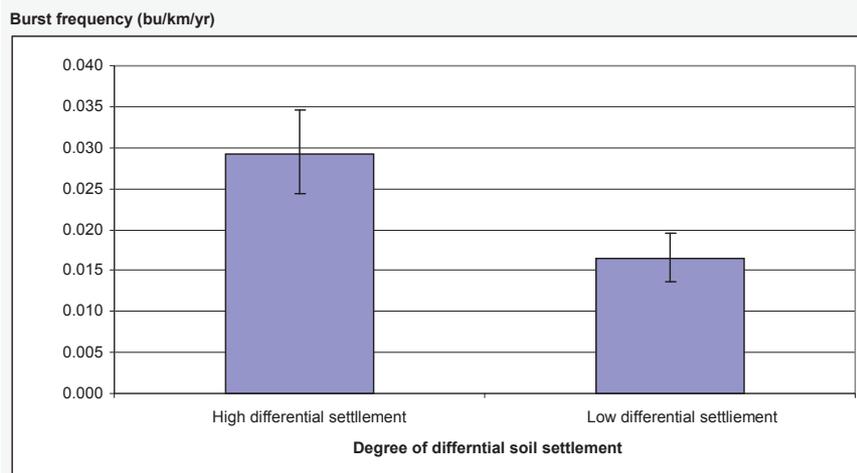


Figure 7. Burst frequency of PVC mains grouped by differential soil settlement class. The error bars represent the 95% confidence interval.

CONCLUSIONS

The analysis in this study shows that combining failure data with spatial data on soil characteristics provides useful information for asset management. Spatial analysis with GIS can be a useful tool for making decisions on replacement of mains.

It has been proven that the knowledge of bursts is of value. A burst is an opportunity to obtain information about the condition of a main. Uniform and shared data on pipe bursts provides useful information on the degradation of drinking water mains.

Effective replacement of mains is one of the main challenges for water companies in the Netherlands in the coming years. A considerable number of mains have to be replaced in the coming years. Since data on mains is scarce, combining information of different sources will be the most efficient way to move forward. Spatial analysis is used to gain more insight in the processes that affect the quality of water mains and therefore plays an important role for asset management.

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