Case Study

Sewer Blockage Management: Australian Perspective

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Abstract: The functions performed by sanitary sewers can be disrupted by blockages in the pipeline, especially in cities with aging systems and deteriorating pipes. The problem is acute in Australia, where the principal blockage cause is tree root intrusion. This paper presents an overview of the causes of sewer blockages, the scope of the asset management challenge, and the management practices employed by Australian water utilities. These views were developed through reviews of the literature and current management practices elicited in a collaborative research project involving a range of water sector partners and using qualitative techniques such as surveys, interviews, and workshops. This paper highlights that blockages occur because of a range of factors, of which root blockages are the most common in Australia. Issues that confound management of blockages are also described, along with a summary of management strategies. Optimizing the balance between proactive and reactive interventions was found to be a good management strategy to maximize service outcomes. **DOI: 10.1061/(ASCE)PS.1949-1204.0000084.** © *2011 American Society of Civil Engineers.*

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Introduction

Sewer networks perform the vital function of conveying sanitary and household wastewater to treatment and discharge locations. These functions can be disrupted by blockages (or chokes), which can, in turn, lead to release of sewage to the environment (spills or overflows). The cost of clearing these blockages can be a significant expense for a water utility, as can preventative measures. In addition, there are a range of intangible (nonmonetary) costs associated with blockages that result in spills, including contamination of waterways, social and commercial disruptions, as well as public health impacts. The challenge for a water utility is to deliver the best service outcome with available budgets and considering regulations by prioritizing available resources to minimize the incidence of both acute and chronic blockage events.

In Australia, blockages affect a large number of properties every year and occur at an average rate of about 40 blockages per 100 km of sewers [Water Services Association Australia (WSAA) 2009]. The blockage rate, however, varies from company to company and over time. For example, Fig. 1 shows the blockage rate for four companies with network lengths greater than 2,000 km. Utility 4 experiences a rate greater than four times Utility 1, and it varies much more over time.

To help understand what causes the differences in blockage rates observed across the sector, and to align the management approaches used with appropriate practice, and best practices where appropriate, a collaborative research project was developed under the auspices of the Water Services Association of Australia. The project was delivered over a 15-month period and involved collaboration with water utilities across Australia, using qualitative research techniques to elicit industry opinion and practices. Research techniques applied included a web-based survey, plus detailed interviews with asset managers and maintenance practitioners from seven participating utilities and three national workshops.

This paper presents results from this qualitative research and seeks to highlight the management challenge faced by water utilities. To this end, the paper provides an overview of blockages and their relevance to utilities, drawing on the literature. A description of the research and research approach is then given. Insights into the management challenge are then presented in terms of the factors that influence blockages that utilities can and cannot control, and insights into management strategies and interventions.

Research Context: Management of Sewer Blockages

The primary function of gravity-flow sewers is the transport of wastewater. Under normal operating conditions and with appropriately sized pipes, the hydraulic capacity of a sewer is able to contain the flow of sewage. Abnormal flows (e.g., because of storm events) can, however, result in spills to the natural and built environment. Spills can also occur under normal flow conditions if there is a reduction of hydraulic capacity attributable to restrictions in the pipe; such restrictions are usually termed "blockages" or "chokes." A range of factors can cause blockages, including sediment buildup, physical objects within the sewer, sewer defects, the accumulation of fats, oils, and grease (FOG), and tree roots, as discussed in the next sections. Causes of blockages can compound one another. For example, the Water Environment Research Foundation (WERF) (2008) found that a single, highly concentrated FOG discharge was sufficient to accumulate on tree roots and cause a sewer blockage.

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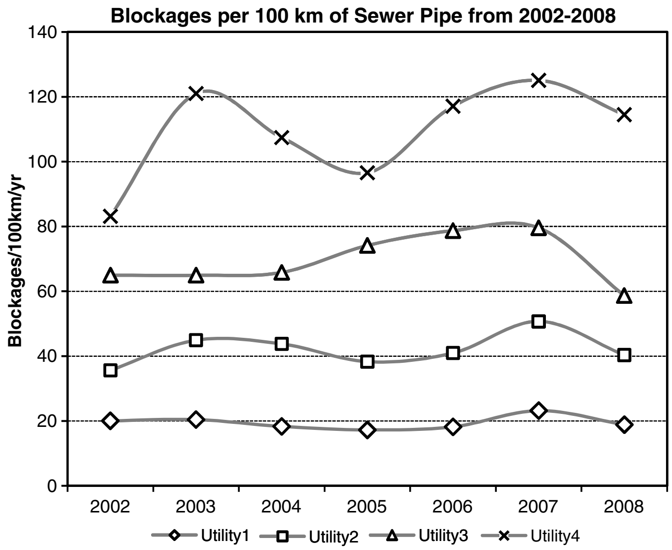

Fig. 1. Variation in blockage rates for four utilities with network lengths > 2,000 km

Sediments, Other Solids, and FOG

Although the primary function of gravity-flow sewers is the transport of wastewater, a secondary function is that of sediment transport (Bertrand-Krajewski et al. 1993). When sediment is allowed to accumulate, either through system failures or design faults, the reduced sewer capacity can result in blockages (Ashley et al. 2000, 2003). Rushforth et al. (2003) discussed problems presented by sediment accumulation, noting that increased hydraulic resistance results in unnecessary sewer overflows and associated flooding events. Foreign objects (or inappropriate solids) regularly flushed down toilets also contribute to blockages in sewer systems, as shown in the United Kingdom study by Friedler et al. (1996).

The disposal of FOG is another challenge for the operation and maintenance of sewer systems (Bowen 2006). When discharged into a sewer, FOG coagulates to form a gel that adheres to pipe walls and root masses. Over time, the deposit grows, again resulting in a reduction in the pipe cross-sectional area. Fats, oils, and grease can also be transported through the system and impinge on the normal functioning of level control units and pumping equipment within storage wells, pumping stations, and treatment facilities (Bowen 2006; WERF 2008).

It is thought that blockage problems are worsened by water conservation measures widely adopted in Australia (WSAA 2009; Victorian Government 2008), which have the effect of reducing flow volumes so that flushing velocities are not achieved frequently enough (Brown et al. 1996; Dezellar and Maier; 1980; Littlewood and Butler 2003).

Tree Root Causes

Tree-root-related blockages are considered to be the most prevalent problem in Australian cities, with some utilities reporting that 50–95% of blockages as tree-root-related (Marlow et al. 2009b, c; Beattie and Brownbill 2007). Similarly, the literature suggests root blockages are widespread in the United States (House and Pomeroy 1947; Leonard et al. 1974) and several European cities (Brennan et al. 1997; Stal and Rolf 1998). As such, it is worthwhile considering root-related blockages in a little more detail.

Along with anchoring the tree, the primary purpose of roots is to exploit water and nutrients in the soil. In urban environments, readily available sources of nutrients and moisture may be scarce, as a relatively large portion of the soil surface is paved and impervious. Furthermore, as a result of Australia's drying climate (Nowak 2007), plants are often deprived of water for long periods, promoting the development of extensive root systems (Moore 2001; Streckenback 2007). In contrast, sewers represent a ready source of both moisture and nutrients, and roots rapidly take advantage of the situation and proliferate around and within the pipe. It is, however, a common misconception that tree roots "attack" or seek out sewers. In reality, roots grow in response to a range of external conditions generated around a sewer. These include water and oxygen gradients, the disturbed nature of soil in the pipe trench (e.g., increased soil porosity, offering a path of least resistance for root growth, especially when the native soil is compact), and condensation and warmer temperatures surrounding sewer pipes (Roberts et al. 2006; Bosseler et al. 2007).

Pipe joints have been observed to be a weak link and particularly vulnerable to root intrusion (Lu et al. 2000). Joints sealing methods have changed from clay-cement-mortar and yarn in the pre-1960s to elastomeric rubber in post-1960s installations (Brennan et al. 1997; Randrup et al. 2001; Rolf and Stal 1994). The clay-cement-based rigid joints are susceptible to drying, cracking, and subsequent dislodgment as a result of pipe movement associated with soil shrinkage and settlement (Davies et al. 2001). Elastomeric seals are reputed to offer superior performance (Lu et al. 2000), but recent research (Ridgers 2007; Stal 2007) suggests the solution is not that simple on account of slight imperfections on the pipe-seal interface, which has the effect of only delaying root intrusion. In any case, it can be anticipated that the seal efficacy of elastomers is dependent on the long-term elasticity and memory of the polymer, which, like any other material, is subject to degradation on aging.

Asset Management Practices

In general, asset management is undertaken in an attempt to reduce both risk and cost while providing appropriate levels of service (e.g., WERF 2007, 2009). For the purposes of this discussion, asset management must require consideration of two interlinked processes, namely:

1. Development of the management strategy to apply to a specific asset and a group of similar assets, and
2. Development of an appropriate maintenance regime, including types of interventions.

Managing the risk of failure is a key aspect of asset management, and the level of asset-related risk should dictate the overarching management strategy adopted. In simplified terms, there are two strategies generally available to asset managers: a proactive (avoid failure) strategy and a reactive (run-to-fail) strategy.

As discussed by Buckland (2000), pipe network assets with low consequence of failure can generally be managed reactively, i.e., they can be operated until failures start to occur. Once a failure occurs, there is a need to respond in some way. For example, with respect to sewer blockages, sewers can be returned to service through a maintenance intervention like rodding, jetting, or root cutting, which releases the blockage and removes its immediate cause; i.e., clearing roots, sediment, and debris from the sewer (WERF 2008; Marlow et al. 2009a). In more detail:

1. Rodding uses flexible steel rods with attached rotating blade cutters, augers, or corkscrews to clear the sewer.
2. Jetters consist of a high-pressure water pump, water tank, hose reel, and 12 to 25-mm hose terminating in a special nozzle. Orifices in the rear of the nozzle propel the hose through the sewer as the nozzle blasts through obstructions. As the hose and nozzle are retrieved, debris is flushed back to the insertion manhole for removal.

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3. Root Cutters can be attached to jetters, which use the force of water to spin blades.

Following on from necessary corrective actions, a decision must be made about how to manage the pipe into the future. For example, the initial run-to-fail strategy could be continued, but if the sewer continues to block periodically, it may be considered prudent to undertake preventative maintenance at a specified frequency.

Preventative maintenance can include monitoring of asset state, usually through asset inspections using closed-circuit television (CCTV) or visual assessment. With this information, utilities can program additional interventions to remove the causes of blockages before they actually cause failure. A range of techniques can also be applied periodically to control the occurrence of blockages. These include the control methods such as jetting and root cutting previously mentioned, but undertaken as part of a sewer maintenance program (e.g., once a year), rather than as a means of addressing a blockage once it has occurred. These techniques can also be augmented by chemical control methods (also called root foaming), which involve the use of herbicides to retard root regrowth (Pohls et al. 2004). Ultimately, ongoing failures in the face of such interventions indicate that a sewer will need to be replaced. Although the maintenance interventions develop and change over time in response to asset performance and cost considerations, the initial strategy is still reactive (run-to-fail); i.e., preventative measures are only undertaken once a failure has occurred.

In contrast to this reactive approach, the particular circumstances of some assets can mean it is prudent to adopt a proactive strategy, and actions such as inspection and periodic cleaning, jetting, root cutting, and chemical treatment are then programmed into the maintenance regimen in an attempt to prevent any failure from occurring. Such a strategy is generally applied to assets when the consequences associated with failure are large, and there is thus the potential for water utilities, municipalities, and other segments of society to incur high costs (tangible and/or intangible). In summary, utilities will use a mix of three strategies for managing blockages:

1. Run-to-fail (reactive maintenance only),
2. Blockage prevention: prevent future blockages through planned maintenance actions, and
3. Blockage avoidance: avoid any blockage through planned maintenance, including asset monitoring and other interventions.

Sewers that are vulnerable to blockages are of a relatively small diameter; i.e., generally 300 mm or smaller (Pohls et al. 2004; Beattie and Brownbill 2007). In contrast, proactively managed sewers tend to be of larger diameter, but this may not always be the case. Small-diameter sewers can be in locations or have an operational context that means their failure would be unacceptable, but this would not be the norm. Hence, only a small proportion of assets, if any, are managed under an "avoid-fail" blockage strategy.

Research Approach

As discussed previously, sewer blockages occur because of the complex interaction of a range of factors that vary spatially and over time. Given that sewers are hidden from day-to-day sight, coupled with the length of sewers operated by water utilities and the fact that utilities only have limited budgets for inspection and maintenance, the effective management of blockages represents a challenge. Improved management approaches would allow more cost-effective management of sewers and could provide significant benefits to water utilities, communities, and both the natural and urban environment.

Table 1. Summary of Responses to Survey

State	Total
Australian Capital Territory	1
New South Wales	4
Northern Territory	1
New Zealand	1
Queensland	5
South Australia	1
Tasmania	2
Victoria	11
Western Australia	1
Total	27

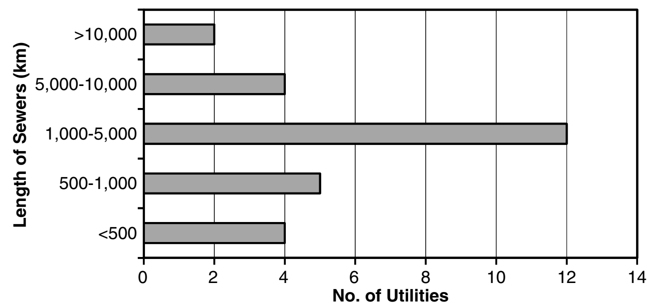

Fig. 2. Utility size by length of sewers managed

As intimated previously, these potential benefits led to the development of a research project. The basic goal of the research was to provide participating utilities and WSAA with insights into blockage management practices across Australia. To achieve this, a review of available literature was undertaken, and insights gained were augmented through the application of qualitative research techniques to elicit industry knowledge and opinion. Techniques used included a web-based survey, the results of which were augmented by face-to-face interviews at a sample of participating utilities. The issues addressed in the survey and interviews were agreed to with an industry advisory group, and included:

- Identifying factors that influence blockages;
- Identifying problem cohorts of sewers;
- Determining management strategies; and
- Considering the effectiveness of different maintenance actions.

The survey was implemented on a web-based internet portal (http://www.surveymonkey.com/), which provided a flexible and cost-effective platform. As shown in Table 1, 27 water utilities volunteered to participate in the survey, which represented 78% of the WSAA's full members (21 out of 27 in 2007–2008) plus an additional six associate members. Water utilities who responded to the survey varied in size, both in terms of the population served and length of sewers managed (e.g., see Fig. 2).

Once the results of the surveys were analyzed and reported, follow up face-to-face interviews were then undertaken at seven of the 27 utilities, chosen principally to capture variation in geographic effects (i.e., location and climate). Personnel from each of the organizations were interviewed using a set of questions expanding on the scope of the web survey.

Results

Detailed presentation of all the results gained from the survey and interviews is beyond the scope of this paper. Instead, an attempt is

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made to highlight the management challenges faced by water utilities and the differences in their management context.

Factors that Influence Blockage Management

Respondents were asked what the critical drivers for blockage management were within their company, and Fig. 3 shows the results. The drivers vary across the 27 respondents, and none of the drivers is applied universally. This reflects the difference in governance and regulatory regimes across different Australian states and individual water utilities. This was a key issue in the research, as management strategies have to be tailored to these different needs. Customer service features prominently among most.

Respondents were also asked to identify factors that influence blockage management in terms of three separate categories, namely:

1. Factors associated with current policies,
2. Factors associated with legacy policies, and
3. Factors that the company has little or any management control over.

The factors associated with current policy indicated by respondents are given in Fig. 4. In practice, any policy and strategy changes that influence these factors are therefore expected to influence the observed blockage rate. Furthermore, variations in these factors between utilities is likely to explain some of the differences in blockage rates observed across the Australian sector, as demonstrated in Fig. 1.

In terms of legacy policies, the level of historical funding and characteristics of assets (pipe/joint material type and design) used were the principal factors mentioned. Tree planting policy of local governments and householders was also identified by a number of respondents as a legacy factor. In terms of factors outside management control, respondents identified tree coverage, illegal discharges, climatic conditions (including drought and transition from dry to wet weather), and other environmental factors like predominant soil type.

Information was also sought on the characteristics of groups of pipe that were associated with high blockage rates (i.e., problem cohorts). Fig. 5 shows the results obtained. In summary, analysis of the results indicated:

1. Vitreous clay (VC) pipe was considered most problematic, followed by concrete, with some other materials mentioned particular to a given company's context;
2. Diameters in the range of 150 to 225 mm were commonly mentioned;
3. Shallow depth was also commonly mentioned; and
4. Join type was explicitly mentioned by some but not by other respondents; perhaps because the material-joint combinations are limited.

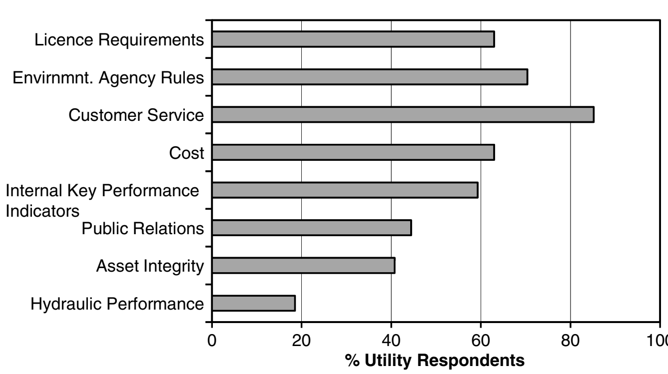

Fig. 3. Critical drivers for blockage management

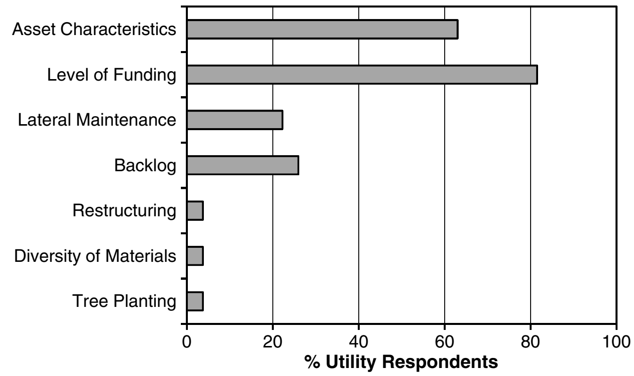

Fig. 4. Aspects of current policies that influence blockages (note: asset characteristics include the material of sewer construction and joint type; level of funds indicates budget availability; lateral maintenance refers to the management of connections that run from the main sewer to properties; the maintenance of these assets varies across Australia because some companies only have management responsibility for the main sewer; backlog refers to the backlog of sewer replacement; restructuring refers to changes to the utility's organization; diversity of materials refers specifically to the fact some utilities have or are still using a range of pipe materials, some of which are considered to be susceptible to blockages; tree planting policy refers to guidance and control of trees around sewer)

Some issues confound one another; e.g., the number of joints is higher for smaller diameter VC pipes; and the problem appears to be with the joints, not the pipe body, but the material is still commonly mentioned as the "problem."

The factors identified have a strong bearing on the difference in blockage rates observed across the sector, as illustrated by Fig. 1. For example, during the research, it became clear that one participating utility has a relatively new asset stock, generally constructed of unplasticized polyvinyl chloride (uPVC), and thus had a much lower company-level blockage rate compared with utilities that operate older asset stocks with significant proportions of VC and concrete pipe. Importantly, this difference in asset performance (and thus service provided) does not necessarily indicate any difference in relative management effectiveness; it is simply a reflection of differences in the asset stock operated.

Insights into Management Strategies

Most respondents indicated that their management of blockages was initially reactive with only a few assets treated under an avoid-fail strategy, if any. One utility did, however, have a well-defined strategy for specifying sewers to be managed so as to avoid failure. Such sewers were designated in light of the potential for causing a spill to a waterway, which is assessed according to asset characteristics, namely a shallow asset, greater than 10 years old of vitreous clay, 150–22-mm diameter with greater than 30 kL flow/day (equivalent to > 300 dwellings). Interestingly, analysis had showed that the proximity to water was not a relevant characteristic, as there was generally a path to a waterway (e.g., via storm drains). Other factors taken into account include 150-mm pipes close to schools, day-care centers and hospitals, any pipe near or in a national park; and pipes crossing main roads.

As discussed previously, the most prevalent management strategy is to operate sewers until they block and then determine a course of subsequent action. If warranted, preventative measures such as root cutting and jetting are then used to manage blockages into the future. A utility's overall blockage management strategy is thus largely a question of optimizing the balance between reactive

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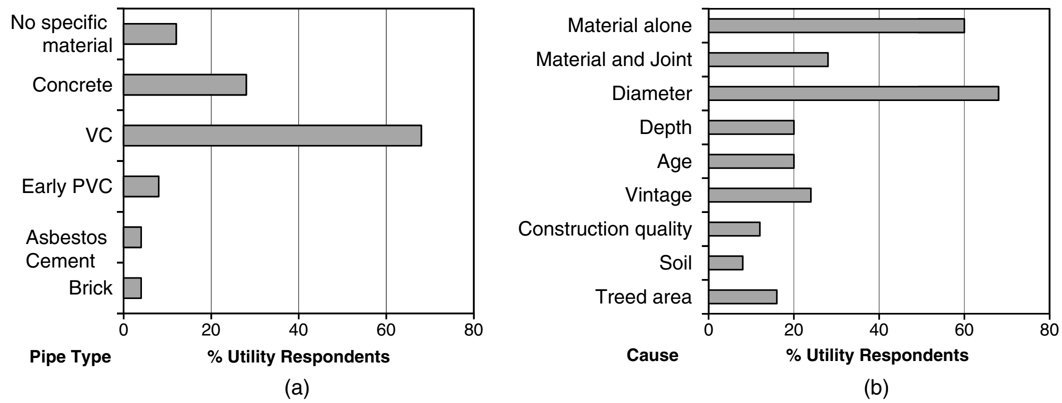

Fig. 5. Problem cohorts identified as responsible for problem: (a) pipe type; (b) causes

and proactive interventions to maximize the service outcomes at lowest cost and within operational and budgetary constraints. With this in mind, information was thus sought from participating utilities on the relative level of these interventions and the blockage rate that was then observed. For consistency, results from the same four utilities presented in Fig. 1 are given. The ratio of preventative to reactive maintenance spend by these companies is plotted against the blockage rates in Fig. 6. The comparison was not made with total expenditure or unit expenditure as utility size skews the data.

Results do suggest some relationship between the level of preventative maintenance and the resulting blockage rate. For example, in Fig. 6, the columns represent the ratio of proactive to reactive maintenance expenditure. When this ratio increases, there is more expenditure on preventative maintenance, and this tends to drive blockage rates down. The opposite is also true; i.e., blockage rates tend to increase when proactive spending falls. It can be anticipated, however, that the effect will be complex and depend on how effectively at-risk sewers are targeted and the return period of blockages compared with the frequency of interventions. Furthermore, there are a number of potentially confounding factors, including any changes in maintenance strategy or types of intervention used in both reactive and preventative work. In addition, changes in climatic conditions, and especially periods of drought, will also skew the interpretation of cost and performance data. Further investigation of these issues is therefore warranted.

In terms of other management strategies, results from the research indicated that rehabilitation was undertaken only when preventative management was inadequate because of the high frequency and/or consequences of blockages, with the ultimate decision resting on the relative economic merits of either choice. Some respondents indicated that the rehabilitation option was rarely made solely on blockage issues, and usually multiple issues including structural condition and infiltration were necessary.

All of the respondents considered trade waste and FOG as issues requiring specific management strategies. Although these were undertaken primarily with regard to consideration of wastewater treatment processes and discharges, they had the added benefit of reducing blockages.

Maintenance Actions and Their Effectiveness

As discussed previously, a range of interventions are used in the management of blockages. Utilities were thus asked which interventions routinely used to manage blockages are considered the most effective and which are the least effective. The results are illustrated in Figs. 7 and 8. Interestingly, five companies found root foaming ineffective, and five found it effective. Of the companies who indicated root foaming was ineffective, one stated "rehabilitation" as the most effective intervention, another relining, jet rodding, and cutting, with the other three referring to jetting and/or root cutting.

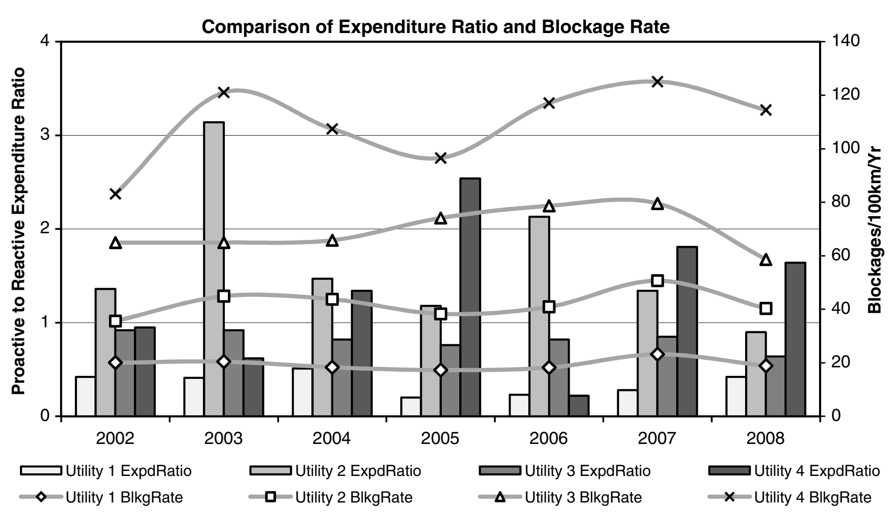

Fig. 6. Comparison of proactive/reactive expenditure ratio with yearly blockage rates

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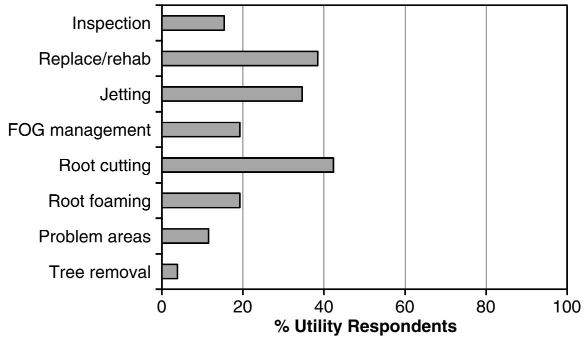

Fig. 7. Strategies considered effective (note: techniques are referred to in the text, except for problem areas, which indicates targeting areas with high blockage rate for preventative maintenance, and tree removal is the removal of problem trees)

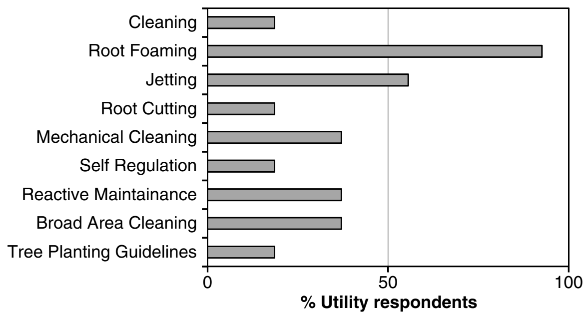

Fig. 8. Ineffective strategies (note: techniques are referred to in the text, except for broad area cleaning, which is undertaking preventative maintenance in areas of the network without targeting on the basis of blockage performance)

On closer inspection of the responses provided, two respondents who claimed root foaming to be ineffective found it difficult to measure its effectiveness. One respondent stated "chemical treatment was only effective for a couple of years." The other respondent stated "it is thought that root foaming is least effective, however, it is difficult to assess the effectiveness due to maintenance jobs not being adequately linked to treated sewers to monitor the tree root growth after treatment over time." It is noteworthy that all the respondents who stated the use of root foaming (chemical treatment of roots using herbicides) used the strategy in conjunction with other interventions (e.g., root cutting and sewer jetting).

The mixed opinion of root foaming was also reflected in the industry interviews. Four (of seven) utilities interviewed found root foaming effective, with future plans to extend the root foaming program and expand trials to include different herbicide formulations. The remaining three companies found root foaming ineffective or considered the risks of use unacceptably high (i.e., potential risk of exposure to customers, operational staff, environment, and treatment plant); one of these companies did, however, state they were committed to try a variety of different (more benign) formulations and application methods (e.g., spot spraying).

Nine respondents indicated jetting to be an effective strategy when used in conjunction with either root cutting, root foaming, or a combination of strategies. However, three respondents stated jetting to be ineffective. Of these, one stated the use of jetting alone (without root cutting) to be ineffective.

With respect to root cutting and jetting, it was highlighted during the industry interviews that the quality of workmanship has a significant effect on the period of blockage mitigation that was achieved (e.g., blockages were reoccurring within 3 months of treatment in some cases where workmanship was poor). Root cutting and jetting were also considered to increase the incidence of sewer blockages when applied to sewers that are not structurally sound (e.g., further damaging pipes, increasing the likelihood of physical or tree related blockages).

Conclusions

A collaborative research project was undertaken to understand the causes behind differences in blockage rates across the wastewater service sector. To this end, qualitative research techniques were used to investigate the differences in management approaches across Australia. This paper presents results from this qualitative research and highlights the management challenges faced by the sector and the strategies that are applied to address blockage risk.

Overall, the study indicated that Australian utilities have a strong customer focus with service delivery at the forefront of their management goals. As such, the sector performance is continuously under regulator scrutiny, and the differences between blockage management performance is a significant concern to water utilities and their stakeholders. However, the research illustrated that many factors influence the occurrence of blockages and also the management of blockage risk, a number of which are either beyond the control of utilities or can only be changed with significant investment. Differences in blockage rates are thus likely to reflect differences in these factors across the sector, rather than just differences in management approach.

Management strategies adopted do, however, vary significantly across the Australian sector, and the research indicated that different drivers influence the formulation of the strategy adopted by a particular utility. Again, it can be anticipated that this will result in difference performance outcomes.

The research suggested that increasing expenditure on preventative maintenance relative to reactive maintenance has a largely positive impact on overall blockage incidence. However, the ability to undertake proactive maintenance depends on operational, budgetary, and regulatory constraints. In particular, a factor outside direct management control is broader policy direction, which directly influences the funding available for blockage management. A larger budgetary allocation would allow more preventative maintenance, whereas limited funds only allow reactive strategies to be implemented. Whatever the budgetary realities, a key asset management goal should be to try and optimize the balance between proactive and reactive interventions in light of imposed constraints.

There was a lack of clear insight into effectiveness of maintenance interventions across the sector. In part, this is considered to be attributable to poor data and the influence of confounding factors. In terms of the latter issues, the researchers heard anecdotal evidence that one company claimed success of a new blockage management strategy (measured as a decrease in blockage rate) following its introduction, but another located nearby saw the same fall without any change in strategy and attributed this apparent improvement to climatic effects. Further research to understand the effectiveness of different maintenance options is therefore required.

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