USING A CONDITION MODEL FOR IMPROVED RENEWALS FORECASTING OF STORMWATER PIPELINE ASSETS

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ABSTRACT

Managing limited fiscal resources to maintain service levels on ageing buried infrastructure requires a sound understanding of the condition of the assets, and how they deteriorate. The prohibitive cost of obtaining condition data and the need to improve renewals forecasting provided the impetus to develop a deterioration-based condition model for the Hutt City stormwater pipeline network.

This paper outlines the approach adopted and presents the fiscal and operational benefits of adopting a rigorous approach to renewals forecasting.

Deterministic analyses are used to define deterioration profiles that reflect the actual materials and operating conditions and require limited calibration. Modules developed within the InfoNet environment apply the deterioration profiles to the asset attribute and unit rates databases. The Infonet tools enable spatial representation of network condition profiles and provide broad reporting functionality. This provides the asset planning team with the ability to:

- Forecast asset renewal requirements based on physical deterioration
- Identify problem areas of the network in a spatial context
- Assess renewals requirements against criticality

Using a physical deterioration-based model demonstrated a significant adjustment of forecast renewals requirements, enabling the asset managers to defer renewals with added confidence that service levels will not be significantly affected.

KEYWORDS

Condition Model, Forecast, Pipeline, Renewals, Stormwater

PRESENTER PROFILES

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Yon holds a Bachelor of Chemical Engineering degree and Diplomas in Strategic Asset Management and Environmental Health, and extensive experience in the water services sector. Yon and her team are responsible for developing asset management plans, continuous improvement in asset management practices, policy development, performance measurement and benchmarking across Wellington and the Hutt Valley.

1 INTRODUCTION

Managing limited fiscal resources to maintain service levels on ageing buried infrastructure requires a sound understanding of the condition of the assets, and how they deteriorate.

Increasing fiscal pressures, an ageing network and the desire to continue to strengthen asset management were the key drivers for improving processes for assessing condition, forecasting renewals and longer term asset planning.

This paper describes the drivers behind the development of a more robust deterioration model that can be used to inform renewals forecasts.

2 BACKGROUND

2.1 PREVIOUS FORECASTING APPROACH

The previous forecasting approach adopted by Hutt City Council was based on an assumed base life (dependent on the material of interest) and defined residual life as the difference between the assumed base life and the age of the asset (based on the install date). As assumed base-lives are generally conservative, the renewals forecast developed using this approach is typically conservative.

Renewals models are a tool for renewals decision-making, therefore a conservative approach may result in premature renewals for a particular asset, while not necessarily improving service levels (1).

2.2 PROJECT DRIVERS

With a significant investment in buried pipelines, HCC asset owners and Capacity asset managers have an interest in understanding how these assets will deteriorate over time as this is an important factor in determining how service levels will be affected and in defining capital requirements for renewals over the medium to long term.

While short-term programmes typically use evidence-based approaches to derive renewals requirements, medium to long-term renewals programmes are typically driven by residual service life forecasts. Forecasting residual life over the longer-term requires an understanding of likely service lives and deterioration rates and balancing asset performance with the need to maintain agreed service levels (i.e. minimising bursts, supply contamination and resultant service outages).

2.3 PREVIOUS RESEARCH

In New Zealand there is limited historical data on pipe condition across all material types and exposures upon which we can model deterioration. Having said that it is possible to estimate the remaining service life based research work undertaken in Canada through the National Research Council Canada (NRC) and Australia through Commonwealth Scientific and Industrial Research Organisation (CSIRO). The models developed as part of this study build on this work, and use available international data as a basis for defining expected materials performance that can then be used to estimate remaining useful life. Defining the remaining useful life in the context of this paper is the difference between the current age of the asset and the forecast failure (i.e. structural failure/collapse) date.

3 DEVELOPING THE MODEL

3.1 PIPELINE DETERIORATION

Buried assets are subject to environmental degradation caused by exposure to differing soil environments, loading from expansive soils, traffic (where installed beneath roads) and building. They are subjected to various internal stresses as a result of operating conditions including pressure, flow and water quality and their structural performance can be affected by material choice, size and installation quality.

3.2 INFONET

The model was developed within the InfoNet environment. InfoNet is a purpose-built asset management modelling and data analysis system for the three water networks. Structured Query Language (SQL) modules developed within InfoNet are used to automate complex selection criteria on large asset datasets.

The tool developed applies recent research into predictive modelling of buried gravity pipes and enables generation of deterioration curves within the InfoNet environment and enables integration with units rates databases and criticality frameworks. In addition to being able to generate renewals forecasts, InfoNet can be used to interrogate the dataset further to schedule survey work, manage data returned from asset surveys, and analyse and report on network and condition data using standard and custom reports. Further detail of the customised reports generated as part of the renewals model is presented later.

3.3 FORECASTING SERVICE LIFE

3.3.1 MODEL ADOPTED

The model adopted for gravity mains (Stormwater) is based on a deterministic regression analysis of a significant dataset from Canada described in more detail by NRC (2). Figure 1 presents a schematic of the model adopted for estimating condition grade and ultimately the renewals expenditure profile.

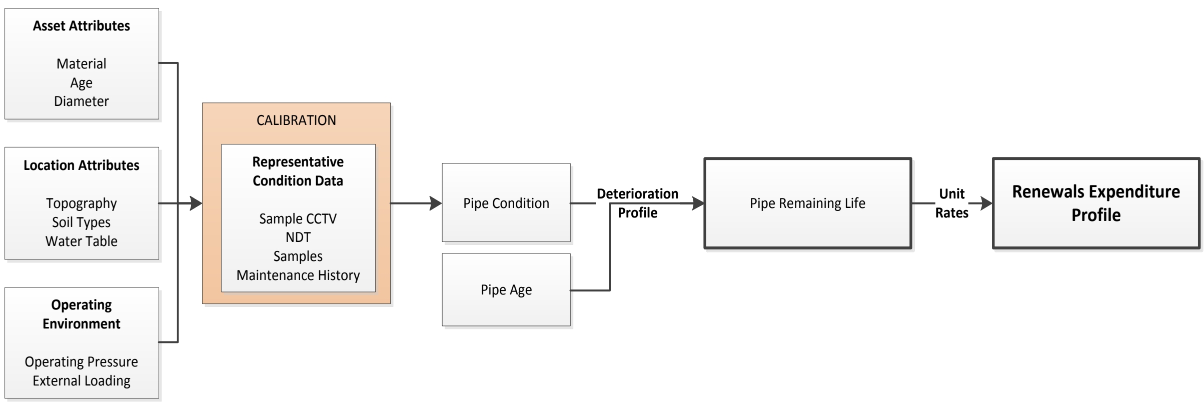

Figure 1 **Schematic of model adopted**

This model allows actual condition and age data gathered from local networks to be used to refine the assumed deterioration profiles and ultimately the renewals forecasts. This type of approach is typical for non-pressure networks, where internal access for CCTV inspection is possible.

3.3.2 ASSIGNING LIFETIMES

Non-pressure networks generally have less uniform deterioration characteristics because of the variability of flows within the pipes – generally resulting in pipes not being completely full. This variability in internal environment is difficult to model without access to significant datasets of condition and attributes for previous assets – something not readily available to local asset owners. The authors identified research from NRC of Canada (2) that describes mathematical models for various materials exposed to sewer environments and facilitates the estimation of condition grade based on age. These mathematical models (developed using an extensive dataset from Canada) were used to provide estimation of network condition grade based on the reported installation dates and physical pipe attributes. While it is recognised that wastewater and stormwater environments differ, the general approach was considered appropriate given the adoption of a number of selectable deterioration profiles within the model.

A range of predicted lives have been reported for various materials by NRC (2) – see the grey shaded cells in Table 1.

Table 1 Range of predicted service lives for gravity mains

Material	Range of Predicted Service Life (years)				
Lifetime Group	**1**	**2**	**3**	**4**	**5**
Asbestos Cement	50	75	90	115	130
Pitch Fibre	40				
Concrete	75	90	115	130	140
Concrete < 225 mm	60	70	80	90	100
PVC	60	70	80	90	100
Earthenware	60	90	120	135	160
Metal	50	55	60	70	80

In order to assist future validation of the condition model a range of regression curves were developed based on a scale of 1 to 5.

Regression calculations for group 1 indicate a short lifetime whilst group 5 calculate longer lifetimes similar to those experienced by NRC (2).

The lifetime groups describe the series of deterioration curves (condition grade versus age) based on previous research that can be applied to gravity pipes depending on:

- The prevailing exposure conditions (such as soil type)
- Failure history
- Material type
- Reported quality of construction

An example of the curves used for concrete pipe is presented in Figure 2.

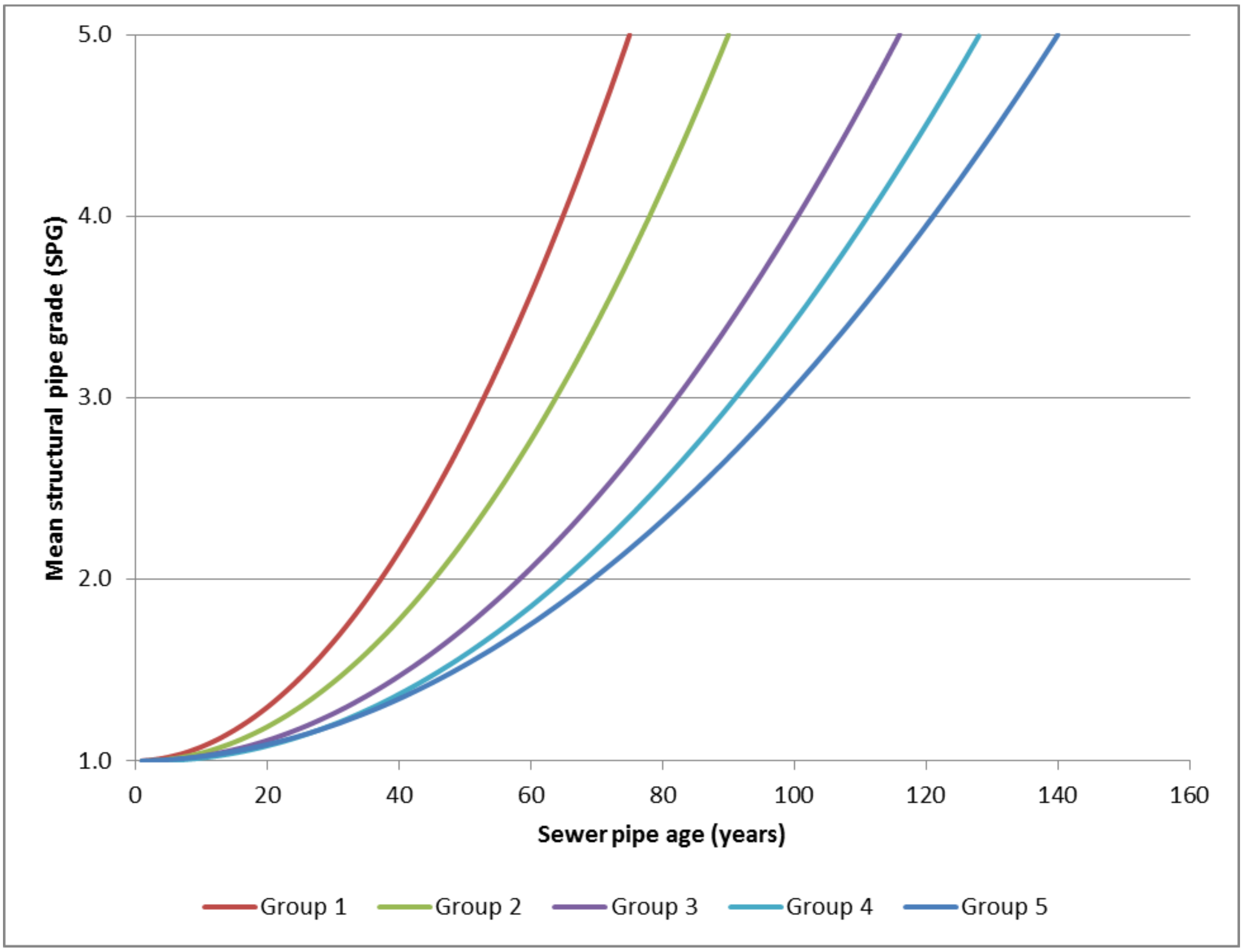

Figure 2 **Deterioration curves for concrete sewer pipe.**

3.3.3 CALIBRATION

Preliminary calibration of the condition model for the Wainuiomata area shows that the majority of estimates are well matched to within ± 0.5 condition grade (± 5%) – for assumed lifetime group (deterioration profile).Once sufficient good quality CCTV data is collected for the Hutt City catchments, it will be possible to further calibrate the results of regression analysis by simply changing the lifetime group (groups illustrated in Figure 2).

4 OUTCOMES

4.1 COMPARISON OF RENEWALS FORECAST

Renewals forecasts are a function of the residual life of the assets. As such, any variation in the lifetime distribution of the asset portfolio will have an impact on the distribution of renewals expenditure and will affect the decision making based on these forecasts.

The key outcome from the development of the statistical deterioration models was to identify a more robust renewals forecast that would enable more effective planning decisions with regards to the use of capital and operational funding across the network over the short, medium and long term renewals horizons.

The forecasts generated using the model consider the likely deterioration mechanisms associated with the various materials of construction, as well as the impacts of installation methods and prevailing ground conditions, as opposed to an assumed asset base-life with the residual life being the result of the difference between age and base-life (see Figure 3).

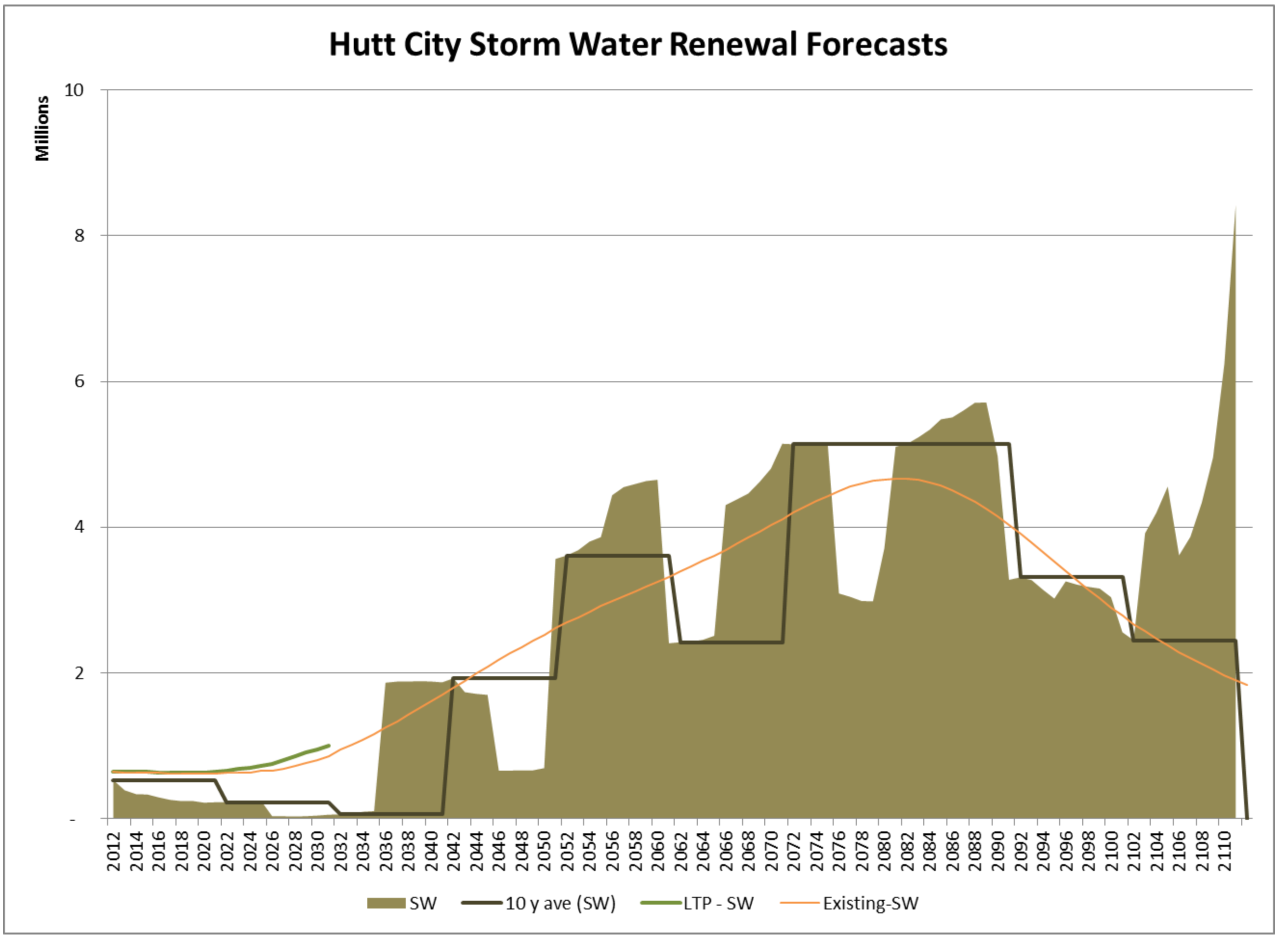

Figure 3 Comparison of previous and modelled renewals forecasts for stormwater

It can be seen that while the model forecast fewer short term renewals compared to the profile report in the council's asset management plan (3), it also broadens the spread of medium and long-terms renewals – suggesting an opportunity to defer some short term renewals and conserve capital funds without significantly affecting the levels of service committed to in the council's asset management plan.

4.2 SPATIAL REPRESENTATION OF RENEWALS

The tool demonstrates a more robust approach to renewals forecasting by considering factors other than base-life and age. It also identifies capital management opportunities, and the GIS-enabled environment provides the asset management team with the ability to view the network information related to condition and renewals requirements spatially. This allows the asset management team to quickly identify problem areas and provides them with a powerful communications tool that can be used across the organisation for planning and reporting on network renewals requirements.

The visual representation can also be used to identify areas where further data may be required to validate the outputs or can be used to compare observations from the field with the outcomes predicted by the model for on-going calibration and validation of the model.

4.3 CUSTOMISED REPORTING

As noted previously, the InfoNet environment also allows the user to generate a number of customised reports from the tool that provide the asset manager with greater levels of detail that can be used to better inform renewals decision making.

For renewals forecasting and broad asset planning purposes (and to demonstrate the capabilities of the tool), a number of reports and associated charts were developed.

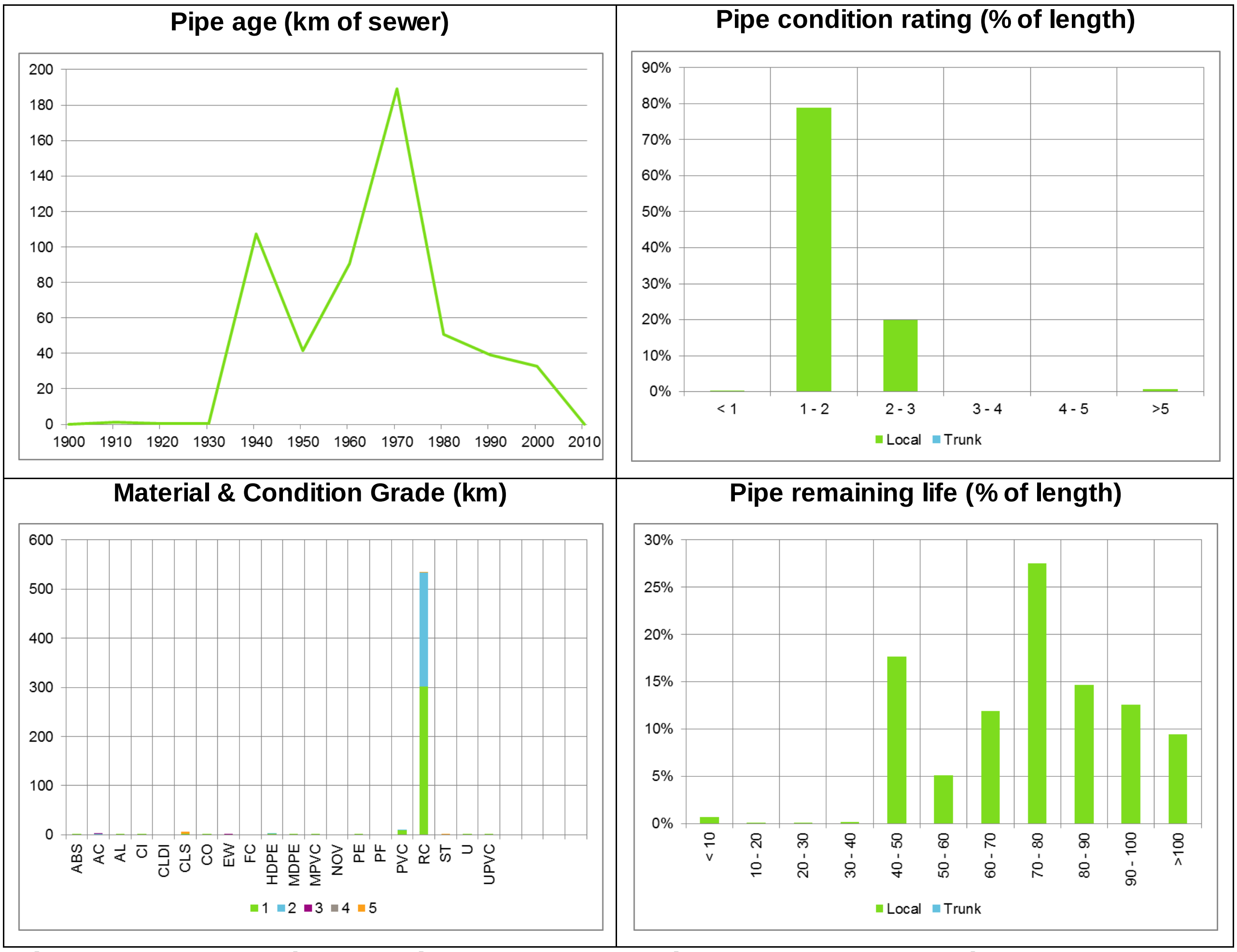

Figure 4 Example customise reports – Hutt City Stormwater network

Figure 4 shows an example of the charts developed using the customised reports. In addition to the charts presented above, reports were created to summarise the distribution of pipe diameters, critical assets and renewals across the network. These can be easily adjusted to drill down to catchment or suburb or to refresh data via a simple "drag and drop" process.

While not presented in this paper, the tool also has the capability to display the data with reference to the council's criticality framework to identify risk ratings that can be used to target critical renewals.

5 DISCUSSION

5.1 BENEFITS

5.1.1 IMPROVED FAILURE PREDICTION – A STEP FORWARD

Hutt City's Stormwater Asset Management Plan for 2012 notes that assets will not all fail at the same time (assuming they are installed together and have the same base-life) and assumes that the failures will be normally distributed around a mean failure date (3). While this assumption is generally valid, Davis et al (4), (5) note that typically the failure distribution of buried pipelines is better represented by Weibull distributions – where the shape of the distribution is a function of the expected base life for the material and the exposure and loading conditions to which that pipe is exposed (which affect the distribution of time to failure). While the current model uses a deterministic approach for gravity pipes (including stormwater), the implementation within InfoNet enables adjustment of the deterioration profile to account for prevailing exposure and loadings conditions and provide an improved distribution of forecast times to failure across the asset portfolio.

5.1.2 CAPITAL MANAGEMENT

With a more realistic distribution of forecast times to failure, the renewals profiles developed using the deterioration model are expected to provide a more realistic assessment of capital requirements. In the case of Hutt City, the outputs of the model suggest that capital expenditure for stormwater renewals will decrease beyond 2020 as renewals of the oldest assets are completed. The outputs also suggest that increased capital expenditure on renewals will not be required until at least 2035.

While the predicted average annual capital expenditure requirement over the next 100 years is $2.59 million per annum compared to a forecast of $2.6 million per annum in the current asset management plan, the revised renewals forecast profile suggests there is an opportunity to reduce capital expenditure on renewals for storm water assets over the next 10-15 years. The more robust condition profiles can also be used to feed back into asset valuations (by back calculation of base lives and residual economic lives), enabling refinement of liabilities associated with depreciation.

5.1.3 ASSET PLANNING

The spatial display capabilities of the tool as well as the ability to link the outcomes to a criticality framework provide asset managers and asset planners with a view of the network not currently possible using the previous forecasting techniques. By highlighting those areas where significant renewals are forecast, the asset management team can take a more focussed approach to future network planning including:

- Identifying those assets with the highest risk rating
- Identifying target areas for detailed condition investigations
- The development of targeted maintenance and renewals programmes
- Assess renewals requirements against criticality

5.2 LIMITATIONS

5.2.1 DATA COMPLETENESS

As with any mathematical model, confidence in the outputs is only as good as the confidence in the data input supplied. An assessment of the database indicated that the overall confidence in the input data was around 70%. While data infill rules were developed to overcome deficiencies in the data to enable analysis to proceed, the accuracy of the model could be expected to improve as the data quality and data management improves.

5.2.2 CALIBRATION

In order to calibrate the condition models for Hutt City Council's stormwater network, various materials performance data is required. Until such information is gathered, the condition profiles within the model rely on the underlying assumptions applied, however as noted preliminary calibration indicated the variation between the assumed deterioration profile and observed deterioration profile was within ±5%. As the model outputs can be displayed visually, areas with limited observed condition data can be easily identified and programmed for future inspection.

5.2.3 PERFORMANCE

The condition model defines the remaining useful life in terms of the structural condition grade. Therefore, the impact of deterioration on the level of service / hydraulic performance of the asset is not forecast by this model. However the analysis can be used in combination with a hydraulic model to provide a more informed assessment of capital requirements for on-going operation and development of the stormwater network.

5.2.4 FUTURE NEEDS

Future network capacity requirements are likely to be affected by urban developments and climate change. The condition model is designed to identify the likely quantum of capital expenditure required for renewals on a like-for-like basis, and therefore does not account for increasing the capacity of those assets being renewed to address future needs. However as the outputs can be exported to MS Excel or as a database file, they can be used in conjunction with growth forecasts and climate change forecasts to adjust renewals forecasts accordingly.

5.3 FUTURE DEVELOPMENT

Further development of the condition model is proposed to refine and extend the capabilities of the model as a renewals decision making tool. The proposed developments include:

- On-going calibration of forecast condition against observed condition to optimise the deterioration profiles within the model
- Applying the revised Hutt City Council Criticality Framework to inform the renewals forecasts and target higher risk assets
- Linking the impact of renewals forecasts and varying budget scenarios to changes in levels of service

6 CONCLUSIONS

Based on work completed to date, we can conclude:

- The renewals forecasts generated from the outputs of the condition model demonstrate that the previous approach to renewals forecasting is overly conservative.
- Preliminary calibration of the condition model indicates good agreement with actual observations from the field.
- The condition model is a powerful tool for informing future renewals expenditure programs for stormwater pipeline assets
- While there is on-going work required to improve the accuracy and confidence in the model outputs, the development of a condition model based on physical deterioration mechanisms represents a significant step forward in the long-term forecasting of renewals for buried stormwater pipelines.

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