Building quake-resilient underground utilities

By Water New Zealand Chief Executive **John Pfahlert** and Opus Water Sector Leader – Asset Management, **Philip McFarlane**.

The Canterbury and more recent Kaikoura earthquakes have shown just how important it is to provide resilient utilities across the country.

The quakes in Canterbury caused extensive damage to 300 kilometres of sewer pipes and 124 kilometres of water mains. The cost to rebuild all horizontal infrastructure was estimated, in mid-2013, at just over $3.3 billion. This included roads, three waters and the Land Drainage Recovery Programme (LDRP). The LDRP alone was estimated to cover over $1 billion in a multi-decade programme.

A new report says that investing in improving infrastructure resilience not only demonstrates a legacy of leadership, but also provides economic growth and job creation along with more liveable communities.

The report sets out to understand why some utilities were significantly damaged in the Canterbury quakes while others remained unscathed.

Underground Utilities – Seismic Assessment and Design Guidelines, produced by Opus International in association with GNS Science and funded by the Ministry of Business Innovation and Employment, points out that the cost to benefit ratio of resilient infrastructure has been estimated by the United Nations to be up to 1:10.

In New Zealand, electricity company Orion spent an estimated $6 million on seismic strengthening which saved $30 to $50 million in direct asset replacement costs following the Canterbury earthquakes. The balance would have been even more pronounced if societal benefits had also been taken into account.

The guidelines aim to help improve the ability of underground utility networks to function and operate following a major earthquake. Specifically, they set out to enable practitioners to:

- Assess the vulnerability of existing underground utilities to seismic events.
- Identify and prioritise measures to improve the resilience of existing networks.
- Design and install new utilities that have an acceptable level of resilience to earthquakes.

Local Government Act requirement

Since 2002 local authorities have been required to prepare and adopt a strategy that identifies the significant infrastructure issues facing them as well as the options and implications for managing those issues.

The aim of the legislation is for all local councils to

Kaikoura.

create 30-year strategies around water supply, sewage treatment and disposal of sewage, stormwater drainage and flood protection and controls.

Key lessons from Canterbury

Some of the findings from the Canterbury quakes and incorporated into the guidelines include:

- The earthquake motion and the way the ground responds has far more influence on damage than shaking and other forces resulting directly from earthquakes.
- Axial forces along pipes cause the majority of damage. Most of the damage occurs at pipe joints. Bending and other transverse loading tend to only to cause damage in brittle pipes.
- All utility materials sustained damage in the earthquakes but modern flexible pipe material generally suffered a lot less damage than older, more brittle pipe materials.
- Larger pipelines typically sustain less damage than smaller pipelines. Service pipe connections sustain the most damage. Even modern PE service pipes sustained significant damage in the earthquakes. This was attributed to failure at mechanical couplings where inserts had not been used.
- Gravity pipes located in areas where liquefaction or lateral spread occurred experienced significant differential ground deformation, causing their grade to be reduced and dips to occur. This affected all pipe materials.
- The performance of the ground influences the ability of the system to remain in service. Experience in Christchurch was that if the ground liquefied then the wastewater system blocked regardless of the amount of damage sustained. This is because of sand and silt entering through gully traps and manholes even where pipelines were undamaged.
- The time it takes to restore service is affected by both the amount of damage incurred and by the ground conditions. Ground conditions affect ground stability and liquefaction during aftershocks which hinders access for repair and inspection.
- The quantum of damage sustained to non-critical pipes often controlled the time it took to restore service. For example the lifting of the boil water notice on the potable water system was largely governed by the time it took to repair the multitude of small leaks that occurred on service connections rather than the condition of the larger pipelines that the services were connected to.
- Alternative means of providing service, such as the provision of portable toilets can be used but they take time to install and the public can only tolerate them for so long.
- Restoration of service involves several phases. It may take many years to fully restore service to the pre-earthquake condition. Priorities and needs change as restoration progresses through these phases.

Improving resilience of existing systems

The report says improving the resilience of existing systems can be achieved by reducing exposure to hazards, increasing the speed and effectiveness of response, increasing the flexibility of the system to adapt and improving the robustness of utilities.

It says that through a combination of response planning, renewals prioritisation and capital expenditure works, the resilience of existing systems can be improved significantly. In many cases this does not involve significant capital expenditure.

Providing new seismically resilient utilities

In order to provide an acceptable level of resilience, the report says utility companies and local authorities should focus on:

- Locating utilities to avoid areas of poor ground performance, to avoid consequential damage to other utilities and features and to improve the ease of repair.
- Providing redundancy in the system.
- Providing robust utilities.

The guidelines specify increasing levels of design sophistication based on the importance level of the utility. For instance, most utilities will not require any further specific design but utilities in the two most important categories will require the equivalent static design method and finite element modelling. **WNZ**

- Further information on this report will be available on the Water New Zealand website and in our fortnightly newsletter *Pipeline*.