# DG43B – A PAIN IN THE ASSET

*Jeremy Boxall (City Care Ltd) and Hugh Blake-Manson (City Care Ltd)*

## ABSTRACT

A partnership between the Christchurch and Government agencies was established in 2011 with the intention of repairing earthquake damaged horizontal infrastructure. The earthquakes weakened 1600km of brittle pipes, ~65% of the total wastewater infrastructure, but left them in a "just operational" level of service. Under the Design Guide (43b) the basic principle was, if a pipe could last more than five years it was left to the Asset Owner to manage, which has resulted in inconsistencies to repairs in parts of the network. With wastewater overflows to waterways being unacceptable and a programme of maintenance required, a multi-pronged team approach including regular detailed monitoring of 20 targeted wastewater pipe reference sites was employed. This was overlaid against the wastewater network with approximately two thirds having CCTV at 95% or greater accuracy against the NZPIM.

Findings include conclusive evidence of pipe decay rates, on the edge of performance failure but still operating acceptably. Assets that show large signs of earthquake damage but would have otherwise remained in good condition for the majority of the service life are in critical but stable condition. Whereas assets with a combination of earthquake and significant service damage (high level roads, liquefiable areas, higher number of connections) have evidence of linear or non-linear increases to deterioration rates.

With this data, the Asset Owner can improve its maintenance scheduling efficiency, decisions on renewals and minimise assumptions of remaining asset life with confidence. In particular the Asset Owner is able to target its maintenance spend and sweat the asset. The valuable evidence obtained allows accurate profiling of decay, directly informing operations and multi-million dollar renewals profiles for these pipes. The Asset Owner can then refine its funding profiles and target its limited funding to areas where dry weather wastewater overflows have affected aquatic systems and water users.

There are nationally significant outcomes, including adoption of the assessment model and methodology for networks with little asset information. With five years of data for selected wastewater reference sites, strong correlations can be made between the ratio of earthquake to normal service damage and the remaining life of the asset. The results of this have large implications on priorities for operation teams and criticality for asset management services.

## KEYWORDS

Resilience, asset sweating, deterioration, criticality, prioritisation

## NOMENCLATURE

| | |
|---|---|
| EW | Pipe material, Earthenware |
| RCRR | Pipe material, Reinforced Concrete Rubber Ring |
| PVC | Pipe material, Poly Vinyl Chloride |
| AC | Pipe material, Asbestos Cement |
| CONC | Pipe material, Concrete |
| CCC | Christchurch City Council |
| CCL | City Care Limited |
| CCTV | Closed Circuit Television |
| SCIRT | Stronger Christchurch Infrastructure Rebuild Team |
| CERA | Canterbury Earthquake Recovery Authority |

| | |
|---|---|
| KPI | Key Performance Indicator |
| DG | Designer Guidelines |
| SQL | Structured Query Language |
| NZPIM | New Zealand Pipe Inspection Manual |

# 1 INTRODUCTION

Environmental overflows – untreated wastewater entering waterways is considered to be unacceptable. While it can happen, intensive and sustained effort is required to minimise if not eliminate the potential for these dry weather events. This driver, combined with two other factors - a contract based shared risk and demand for cost reductions, has driven innovation in wastewater network management.

A "cold eyes" analysis of the Christchurch wastewater networks high criticality attributes resulted in agreement that reference sites should be set up, monitored and their deterioration reported on. This required obtaining and analysing network pipe attributes, overlain with waterway proximity, ground liquefaction likelihood and other key factors. A methodology and results are outlined below.

# 2 CANTERBURY EARTHQUAKES

The Canterbury region has experienced several major earthquakes ever since September 2010. These seismic events caused permanent damage to Christchurch's wastewater network. Of the 50,000 wastewater assets in Christchurch a large majority are considered to be brittle (earthenware, concrete) and of small nominal diameter (150-225mm).

Rather than moving through the ground as a monolithic section, wastewater pipes presented misalignment and displacement resulting from the dissipation of stresses at pipe joints. These were mostly observed as compressive (circumferential multiple cracking, dips), tensile (open and displaced joints) and shear forces (longitudinal cracking in pipe barrel). Lateral spreading was also seen to have a strong negative impact on the alignment of wastewater pipes over several adjoining lengths of pipe joints.

*Table 1: Wastewater Network Diameter and Length*

| *Diameter (mm)* | <100 | 100-199 | 200-399 | 400-599 | 600-799 | 800-999 | 1000-1099 | >1099 | Total |
|---|---|---|---|---|---|---|---|---|---|
| *Length (km)* | 13.1 | 1106.1 | 504.2 | 74.8 | 52.1 | 18.1 | 8.1 | 16.6 | 1793.1 |
| *% (of total)* | 0.70% | 61.70% | 28.10% | 4.20% | 2.90% | 1.00% | 0.50% | 0.9% | 100% |

*Table 2: Wastewater Network Material and Length*

| *Material* | RCRR | EW | uPVC | AC | CONC | PVC | Other | Total |
|---|---|---|---|---|---|---|---|---|
| *Length (km)* | 628.6 | 371.4 | 356.3 | 147.9 | 129.7 | 62.7 | 96.5 | 1793.1 |
| *% (of total)* | 35.1% | 20.7% | 19.9% | 8.2% | 7.2% | 3.5% | 5.2% | 100% |

The degree of liquefaction was considered the greatest factor effecting pipe performance in the Canterbury Earthquake, (Noell, 2015). The intensity of pipe damage observed alternated from often extensive, or total, in liquefaction or lateral spread zones, to examples of minimal or no damage observed in the same pipes in adjacent non-liquefaction areas, (O'Callaghan, 2015). Since then the reticulation network suffers from regular dry and wet overflows. Highly variable structural and service issues widely spread across the wastewater network pose long-term negative effects to wastewater network operation.

# 3 COLLABORATIVE RESPONSE

## 3.1 SCIRT DESIGNER GUIDELINES

Canterbury Earthquake Recovery Authority (CERA) tasked an alliance project, Stronger Christchurch Infrastructure Rebuild Team (SCIRT) as a partnership with Christchurch City Council (CCC) in the investigation, planning and rehabilitation of the wastewater network. City Care Ltd (CCL) was a primary contractor in undertaking Closed Circuit Television (CCTV) inspections of pipes. This information was crucial for early analysis of earthquake damage and initiated a top-down approach to programming repair works.

Designer Guidelines 43, A & B were developed by SCIRT to ensure that funding was spent efficiently. The methodology of DG43 was to identify damaged gravity wastewater and stormwater pipes that had at least 15 years of assessed remaining asset life through no or limited immediate repairs to critical structural pipe defects. With limited resources the aim was to utilise the asset's remaining life and avoid the repair of non-critical defects. The second revision, DG43A, provides further guidance on how to consider the remaining critical defects.

DG43B deviates from the original DG43 thresholds and determines what critical defects should be repaired. Essentially if an asset acted as a conduit and did not fail in the next five years, it would be left to the asset owner to manage. Making decisions on renewals and repairs based upon structural issues became very difficult. Grade change effectively rendered gravity pipes of any material non-functional, and imposed ease of repair as the essential consideration, not the choice of pipe material or joint system, (O'Callaghan, 2015).

The consolidation of repairs into work packages was important to maximising available staff and resources, but poorly completed repairs in some areas have compromised the long-term benefits. In conjunction with this, maintenance rounds were heavily invested in to keep a hold on persistent service issues such as overflows, blockages, root intrusions and silt deposition (Figure 1).

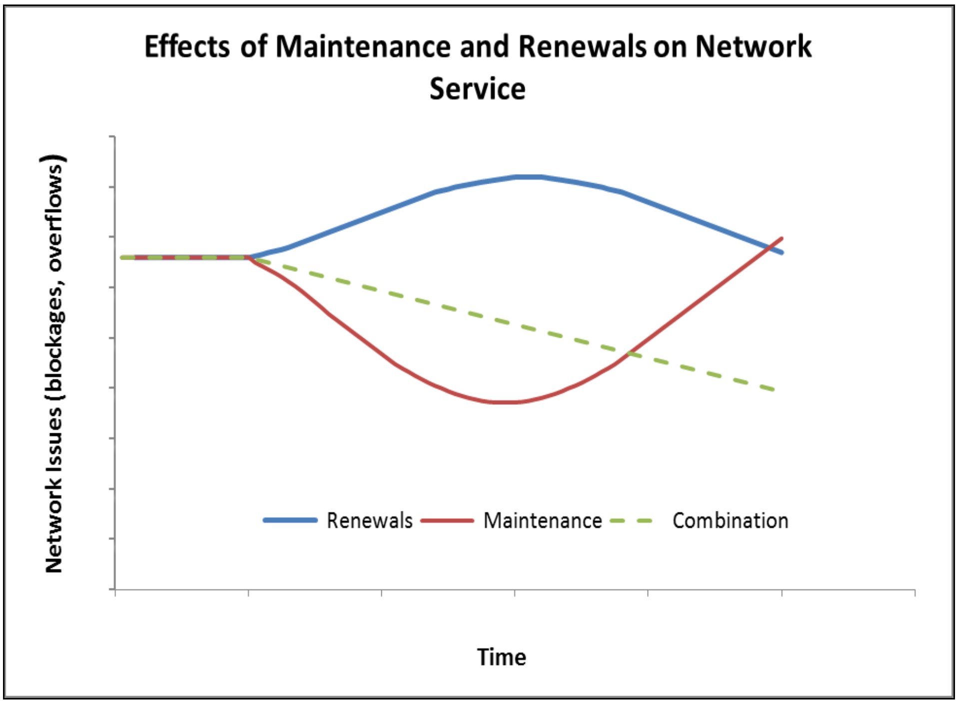



*Figure 1 – Effects of Maintenance and Renewal Works*

In 2010 it was estimated that it would cost $500 million to restore the wastewater network, by 2012 this figure increased to ~$2.2 billion. With widespread deterioration of structural defects, recently omitted pipes from the original analysis needed to be reconsidered. SCIRT proceeded with DG43B to deliver on adequate network performance, serviceability and functionality outcomes.

### 3.2 DEFINING ASSET LIFE

The remaining life of an asset is the estimated duration during which the asset is able to deliver a given level of service. The values determined by SCIRT under the Remaining Asset Life analysis (2, 5, 10 years) and their assigned critical defects relate to the period of expected use for an asset and the ability to deliver a given level of service.

This pertains to an asset use up to the point where a segment repair or a relay is used otherwise these two expectations are compromised. Often these repairs were completed because there were the resources available prior to the 2010 earthquakes. Consequently the acceptable performance and condition standards for assets were higher. In order to achieve value for money post-Quake it was demonstrated that assets at the end of this ‘useful life’ still operate as a conduit. This is especially the case for assets with no history of serviceability issues (roots, fats, silts, dips) that still operate as effectively as other assets in good condition.

The residual asset life remaining directly correlates to the amount of risk burden that is willing to be carried. The amount of associated risk will change over time as the reticulation network is rehabilitated. CCC is left with a critically damaged network to maintain on the pre-Quake budget. In order to make effective maintenance and renewal decisions, deterioration analysis is essential for narrowing the window on ultimate pipe failure estimations.

## 4 WASTEWATER REFERENCE SITES

### 4.1 BACKGROUND

Measuring, recording and understanding asset condition is a key to successful asset management practice and the percentage of surveyed assets in Christchurch is one of the highest in the world. The reference sites are mains that were left with structural faults that would likely have been repaired early on in the SCIRT programme, before DG43B. The inspections consist of CCTV and review in accordance with the New Zealand Pipe Inspection Manual (NZPIM).

The primary goal of the ongoing reference site monitoring programme is to provide a robust and cost effective criticality based wastewater network management programme. With secondary goals of:

- Accurate information for maintenance and renewal decisions
- Accurate modelling of the relationships between blockages and overflows and the primary contributing factors
- Determine indicators for accelerated development of structural defects and estimations on remaining service life
- Effects of maintenance and repair works on assets (root cutting, patch liners, high pressure cleaning)

## 4.2 SELECTION

Figure 2 details the selection criteria for determining the final reference sites from an original 50,000 assets.

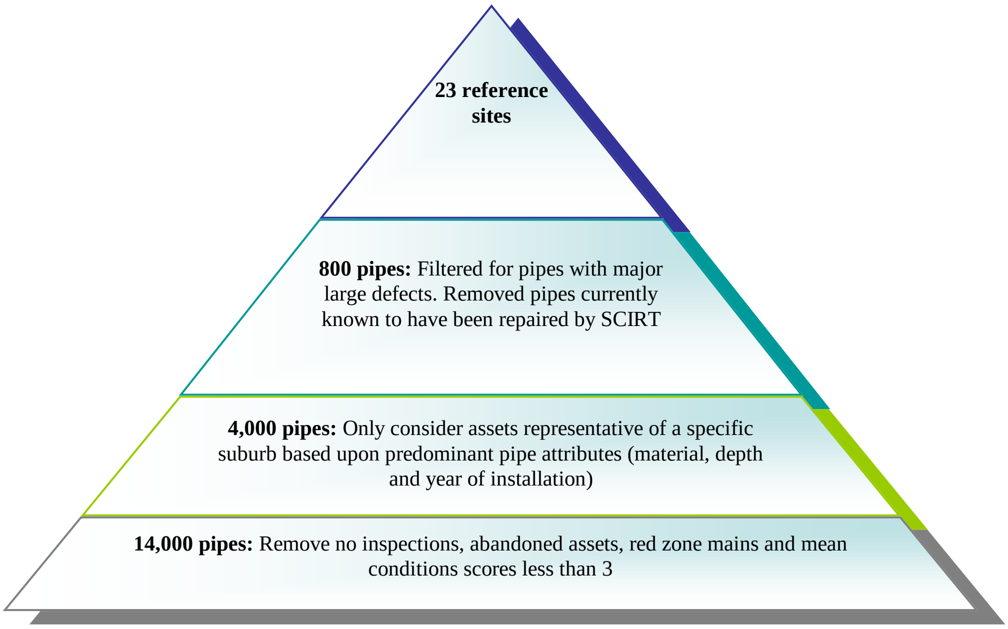



*Figure 2 – Wastewater Reference Site Selection Methodology*

The reference sites selected represent the most damaged assets in the city that were to be omitted from repairs. For this reason the majority of new SCIRT repairs conflicted with the sites selected. Although some assets have patch and segment repairs, this only affects a small length of the pipe and is still useful in the investigation. Final reference sites were selected with strong consideration for even distribution over Christchurch (Figure 3).

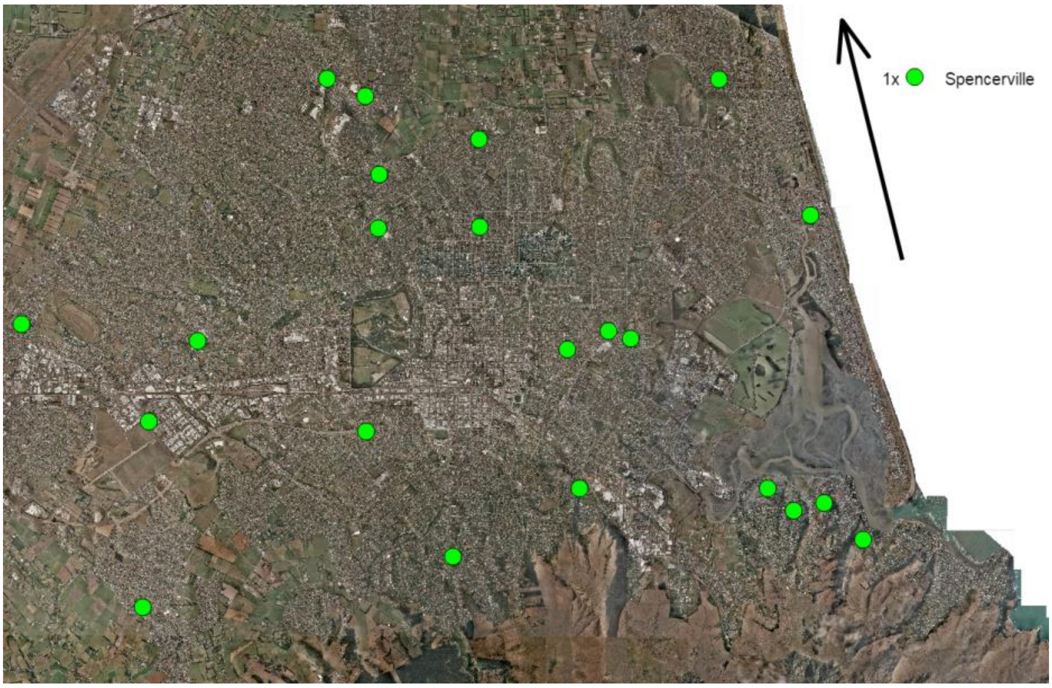



*Figure 3 – Distribution of Wastewater Reference Sites across Christchurch*

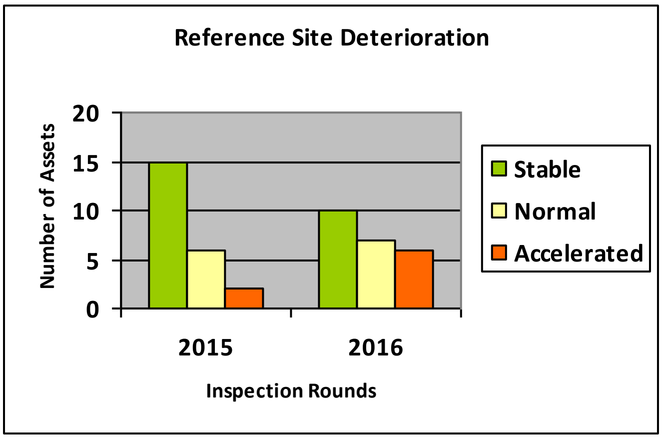
## 4.3 RESULTS

### 4.3.1 CCTV INSPECTIONS

For the 23 reference sites that already had previous CCTV footage, inspection rounds were completed in 2015 and 2016. CCTV inspection involve the completion of a logsheet that records structural and service defects and scores them based on severity. Final total structural scores are often used to assess the level of damage in the pipe. The mean score is usually of significant interest and is determined by the total structural score divided by the pipe length. However the review process can be unreliable at times with defects such as surface damage and joint faults attributing much larger scores across an assets length. Also CCTV assessment does not always address the performance of non-structural/service related defect such as dipped pipes, or provide positive identification from displaced joints, or deformed pipes, (Noell, 2015). So defect comparisons were made for each asset where all defects were lined up and assessed on the following criteria:

- Same code in same position
- Same code and different severity
- New code
- Different code in same position
- Different code

Some badly broken assets were over 100m in length and this analysis made it significantly easier to assess the assets on a no change or change basis. Figure 4 details the overall deterioration of the reference sites from 2011-2016. It shows that although some badly damaged assets are in stable condition, an increasing amount present accelerated deterioration.




**Observations between CCTV inspections**

- **Stable:** little to no change regardless of the level of damage in the asset.
- **Normal:** Attenuation of current damage throughout asset, steady development of structural defects, new defects are only minor severity
- **Accelerated:** Fast development of defects (crack to broken section), new defects can be major severity

*Figure 4 – Distribution of Wastewater Reference Sites across Christchurch*

Five representative reference sites are detailed in Table 3. Brittle assets with many severe cracks throughout experienced differing levels of deterioration. For example Site 12 showed large staining around circumferential cracks while 7 and 18 did not. In Round three some of these circumferential cracks developed rapidly into broken sections. Site 16 is an example of non-linear deterioration as a result of existing defects. The pipe was in relatively good condition with the exception of one hole halfway down the pipe. A fine mass of roots intruded from this area and covered the internal surface area of the pipe extending several meters either side of the whole. The roots were cut and the hole was patched but in the 2016 footage the roots had grown back thicker, intruding from the full circumference of pipe joints and now poses a larger blockage risk. Site 14 is representative of assets with a moderate amount of damage that have remained stable since the initial injection of damage previous to 2011. While the development of some defects are more predictable than others (surface damage), the large majority of service and structural defects in these assets develop at a highly variable rate.

The development of defects over a long length of time is predictable:

- Cracks, multiple cracks, broken section, deformed pipe, collapsed pipe
- Dips, displaced joint, open joint, pipe hole, tomo/root intrusion

Initial analysis of the reference sites show that the rate at which these developments occur is sensitive to external and internal variables such as the Liquefaction Resistance Index (LRI), pipe material, groundwater level and the level of service of the asset.

*Table 3: Representative Reference Site Inspections (2015-2016)*

| REREFENCE SITES | | EXSISTING CCTV | | ROUND TWO (2015) | | ROUND THREE (2016) | |
|---|---|---|---|---|---|---|---|
| # | Key Issue | Year(s) | Mean Score | Mean Score | Change/No Change | Mean Score | Change/No Change |
| **7** | Compression movement, shattered joints | 2011 | 8.76 | 13.59 | Normal deterioration | 13.69 | Normal deterioration |
| **12** | Broken sections | 2012 | 13.28 | 18.21 | Normal deterioration | 5.67 | Accelerated deterioration |
| **14** | Cracks and surface damage | 2011 | 5.83 | 5.59 | Stable | 22.15 | Stable |
| **16** | Large root growth | 2013 | 6.45 | 7.37 | Accelerated deterioration | 3.73 | Accelerated deterioration |
| **18** | Compression movement, shattered joints | 2011 | 21.14 | 21.87 | Stable | 20.44 | Normal deterioration |

The indicators for the rate at which these developments occur can be a good prediction tool. Staining around cracks is evidence that the crack has extended through the pipe wall which often occurs just before broken sections are formed. Thick roots are evidence that they may already have been cut and can grow for several meters (small repair patches are a poor choice of repair). These failure modes would indicate that ground conditions and detailing issues are more prevalent than material deficiencies. Figure 5 is an example of a poor choice of repair as the rate of deterioration was underestimated. In the first photo a patch liner was applied to a section of pipe with large multiple cracking. The color of the liner shows major staining in the cracking behind it suggesting that broken sections had already developed through the full thickness of the pipe. The second photo on the right confirms this as the pipe behind the liner has deformed further and severe infiltration is occurring where the liner has teared.


*Figure 5 – 2015 CCTV Survey (left), 2016 CCTV Survey (right)*

### 4.3.2 RATES OF DETERIORATION

Many contributing factors can lead to damage in an asset, but unforeseen events are the most concerning as it cannot be disproven that such events are the cause (poor construction, random undistinguished third party damage, damage from transported foreign objects etc.). For these reasons it can never explicitly be said what caused damage without suffice evidence, specifically anomalies in a pipe lengths condition. These events are impractical to predict as they do not fit into a deterioration rate profile. These events must be seen as risk contingencies. Pipes damaged from spatial and serviceable impacts will have an ongoing effect, possibly when a pipe is replaced also depending on depth and pipe material.

Likewise it is difficult to attribute all of the critical damage to assets in stable conditions to the EQ’s. While the severe damage seen in brittle assets is highly likely because of the earthquakes (severe broken sections shown to stay structurally stable for over three years in some cases), without footage before the earthquake events it is difficult to prove this hypothesis.

SCIRT has reported that broken sections have less than two years of life remaining and failure is imminent. Every reference site with a broken section (PB) or tomo (TM) has either been repaired or lasted longer than this period so far. This is too be expected as the SCIRT remaining asset life was calculated conservatively from the normal deterioration rates of pipes for which spatial, construction and serviceability conditions have played a very large part in the development of damage in the asset. This gives solid reasoning to the 'two years remaining' on the most critical assets as the pipe in question appears unstable and theoretically the deterioration should be at its highest rate (seen in the yielding of most engineering materials.)

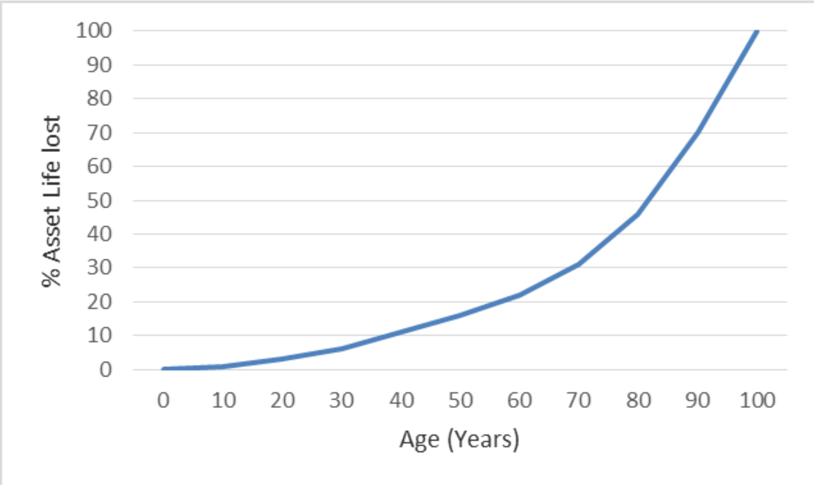



*Figure 6 - Normal Deterioration Rate for Wastewater Pipe Assuming Life of 100 Years*

Assets that have not failed after the earthquakes and are severely damaged are likely to be in a stable condition, meaning that the deterioration rates need to be deflated to account for misrepresentation of remaining asset life from visual inspection. Visual inspections only provide a snapshot of an assets lifetime, where one early period can look very similar to a later period with different deterioration rates. For this reason the reference sites are crucial for building information to confidently move forward with the analysis of visual assessment so that assessments results accurately fit into profiles where deterioration rates can be predicted. The reference sites have shown evidence of three distinct deterioration profiles for damaged wastewater assets.

### 4.3.3 LINEAR DECAY

Linear decay is a predictable decay where defects steadily develop and deteriorate. It is common with surface damage in concrete and the development of broken sections in brittle assets around joint faults. Consistent deterioration in pipes is likely due to a normal, but high level of service, ground movement or changing ground water level factors. Figure 6 shows linear deterioration of a wastewater pipe with respect to the normal expected deterioration. Consistent use of the asset means the development of defects happens earlier in the assets life due to the sudden injection of damage from earthquakes.

A common scenario for Figure 7 would be the introduction of a large circumferential crack from earthquake damage. This crack develops into multiple cracks, then a deformed section, then a broken section with displaced blocks before finally causing a pipe collapse or complete blockage.

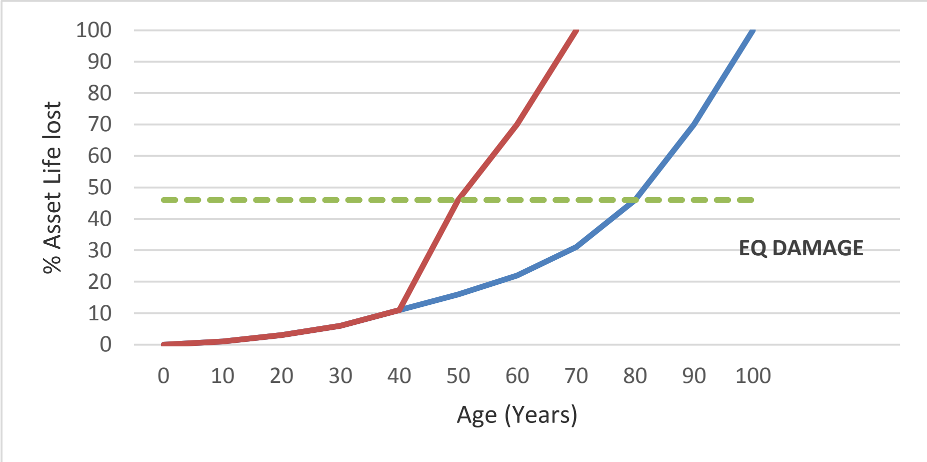



*Figure 7 - Linear Deterioration Rate for Wastewater Pipes Suffering from Earthquake Damage*

### 4.3.4 NON-LINEAR DECAY

This is deterioration accelerated by present defects to the point of rapid pipe failure, usually in the form of a blockage. Conditions are likely to be a complex interaction of level of service ground movement, changing groundwater levels and service issues (fats, roots, silts). The red line in Figure 8 shows non-linear behavior and rapid failure of a pipe from large earthquake damage, years after the event. One scenario is that a hole in the pipe is caused from earthquake damage and before any normal structural deterioration occurs the pipe is completely blocked with roots in three years. An event such as this will require some form of repair to prevent the roots from coming back.

Another scenario is that a small cracked section develops in a wastewater pipe. A high amount of ground movement in the area displaces the joint near the cracked section horizontally. This pipe also accumulates too much fat and requires high pressure cleaning, dislodging the cracked section creating a hole to the pipe backfill. These types of interactions accelerate pipe decay faster than a normal deterioration rate regardless of the level of damage.

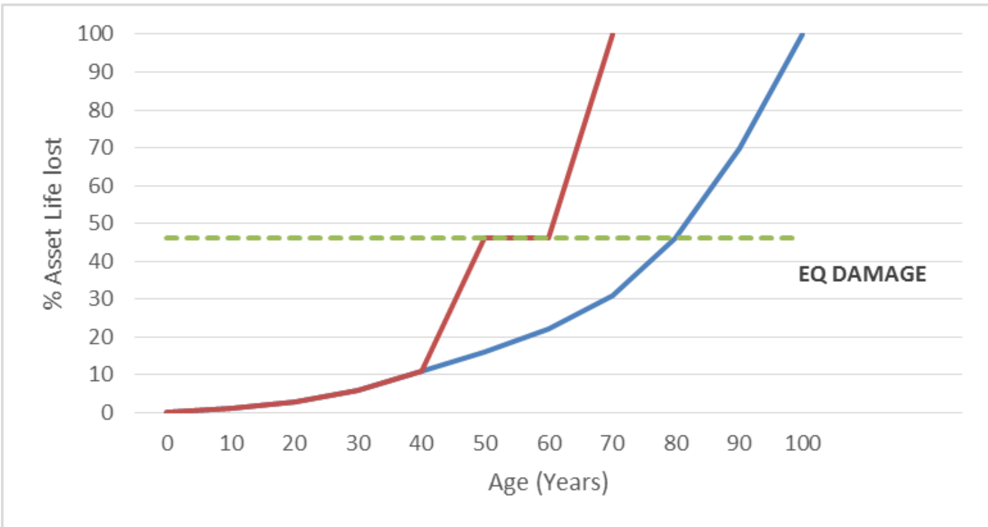



*Figure 8 - Non-linear Deterioration Rate for Wastewater Pipes Suffering from Earthquake Damage*

### 4.3.5 NO DECAY

These assets are critically damaged and likely to fail but are in stable condition. The stable conditions are likely due to a combination of low level of service, ground movements and changing external conditions. Whether the pipes are designed for higher capacities or were not affected by the earthquake, assets that fit this profile show no signs of change over five years. Current level of damage is likely due to a range of reasons:

- Earthquake damage distributed through asset
- Earthquake damage localised at one point leaving the rest of the asset in good condition
- Third party damage
- Poor construction
- Part of a re-designed network

The red line in Figure 9 represents a critically damaged asset that shows no or very little signs of deterioration. Examples in the reference sites show assets that have large surface damage and broken sections that fit into this profile. The risk is that these assets could still fail at any point in the near future, the next step is determining whether a repair or renewal is more beneficial long-term.

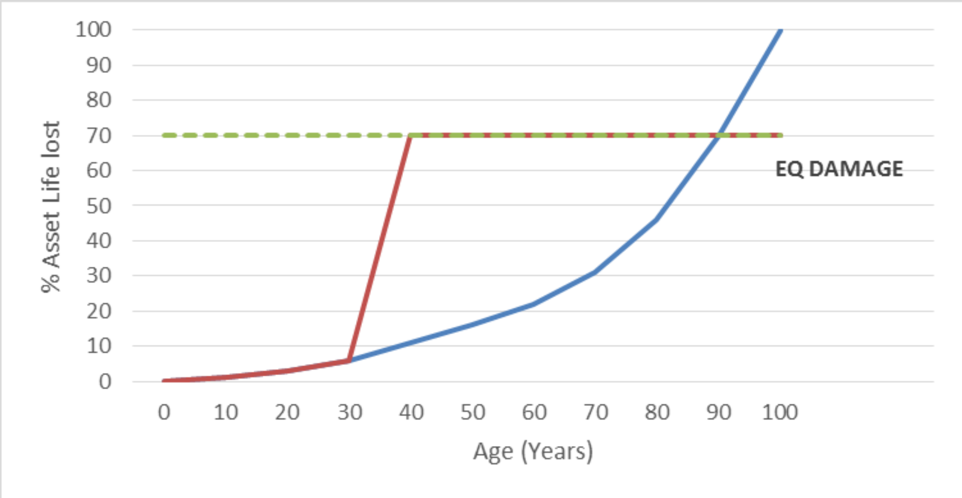



*Figure 9 - No Deterioration of a Wastewater Pipe Suffering from Earthquake Damage*

# 5 TARGETED INSPECTION AND MAINTENANCE PROGRAMME

## 5.1 BACKGROUND

Wastewater overflows result in environmental and financial damage at the cost of CCC and CCL. There has been no consistent holistic focus on monitoring wastewater network condition and performance. Despite the 1300km of CCTV undertaken via the SCIRT programme, this “one off” task did not provide for follow up works. Some sites were surveyed in 2010, and deterioration can be expected in the period to date. From historical data and reports, overflows are caused by a combination of:

- **Design:** Exceedance of design flow capacity from newly installed lateral connections or newly laid assets into manhole junctions
- **Poor condition and performance:**
  - High flows: responsive wet weather conditions (internal pipe infiltration, stormwater) and delayed wet weather conditions (slow rising groundwater level from increased river flow)
  - Debris: fat accumulation, rags, root intrusions, debris (pipe material, rocks, etc.)

Often blockages are from a combination of all of these factors, an overflow can be caused by a restricted flow (i.e. flow not 100% downstream) so high water levels are of high importance.

## 5.2 CRITICALITY MATRIX

This is an algorithm in InfoNet using Structured Query Language scripts (SQL’s) to score all assets over a range of internal and external variables. This simulates the complex interaction between variables that control pipe deterioration and resilience to damage. These variables are all sensitive to the governing issue, overflows and blockages (Table 4).

*Table 4 – Criticality Matrix Variables*

| Variable | Confidence (H, M, L) |
|---|---|
| Diameter Material (mm) | H – CCC Records have high accuracy |
| Year of Installation | M – Contractor has found some pipes with dates out by 20-30 years |
| Distance to nearest waterway (m) | H – Position of pipe and waterway known to +/- 2 m |
| Large severity defects | H – Survey results are reviewed and audited under the NZPIM to a minimum accuracy level of 95% |
| Peak score | |
| A positive return for a search on the string 'high water level' in the general comments section of logsheets | L – Water level is not always commented or may be described as an alternative string of words. Water level may be subjective to jetting work and daily min/max flows and number of laterals |
| Consented and non-consented tradewaste connections | M – Uncertainty with quality of grease trap devices in tradewaste sources which creates bias. The possibility of unknown connections and other fat sources |
| Liquefaction Resistance Index zones (LRI 0, 1, 2, 3 or none) | M – Extensive and robust project to determine LRI zones by the University of Canterbury. Low confidence in areas in <50m resolution between interpolation of different zones |
| Blockages in asset, adjacent assets and pump catchments | M – Exact position of previous blockages is known from surveys and cleaning. There is a small chance that InfoNet may attribute a blockage to an incorrect asset as the blockages are given coordinates and need to be assigned to the nearest asset. |
| Odour complaints | M – Similar to the confidence for blockages. The exception is that odours are difficult to source but have a wider range of effect. |

The scoring system will consist of scores assigned for each variable for each asset as shown below in Table 5. For each asset these scores will be summed for final prioritisation by the final scores. The table shows three distinct scoring options for each variable with appropriate weightings representing the sensitivity of specific variables.

*Table 5 – Criticality Matrix*

| Attribute | Weighting | Criticality A<br>(Score 10) | Criticality B<br>(Score 3) | Criticality C<br>(Score 1) |
|---|---|---|---|---|
| Material | x0.5 | EW/CS/CONC/RCRR | AC/CI | VCP/VC/SL/RL/CP/CIS/CIPP |
| Diameter (mm) | x0.75 | 100/150/225 | 300/375/450 | 200/250 |
| Distance to nearest waterway | x0.75 | 0-149m | 150-499m | 500-1000m |

| | | | | |
|---|---|---|---|---|
| Year of Installation | x0.50 | 1880-1950 | 1951-1976 | 1977-2010 |
| Infiltration Present | x1.0 | Large | Medium | Small |
| Tradewaste and fat issues | x1.0 | Distance to CCC Trade Waste connection 0-250m | Distance to CCC Trade Waste connection 0-500m | Distance to CCC Trade Waste connection 501-1000m |
| Peak score | x1.0 | > 65 | > 45 | > 30 |
| Odour | x1.0 | Distance to nearest ‘’odours or offensive smells’’ 0-149m | Distance to nearest ‘’odours or offensive smells’’ 150-299m | Distance to nearest ‘’odours or offensive smells’’ 299-500m |
| LRI Zone | x1.5 | 0 | 1 OR 2 | 3 OR 4 |
| Inspections abandoned | x1.5 | IA in asset | IA within 1 manhole | IA within 4 manholes |
| Blockages | x1.5 | Distance to nearest ‘’blockage’’ or ‘’spillage’’ 0-149m | Distance to nearest ‘’blockage’’ or ‘’spillage’’ 150-299m | Distance to nearest ‘’blockage’’ or ‘’spillage’’ 300-500m |
| Defects | x2.0 | ANY two of large PB, OP, TM , PH, RI, CM, DF or DP | ANY of large PB, OP, TM , PH, RI, CM, DF or DP | ANY of large PB, OP, TM , PH, RI, CM, DF or DP within 1 manhole |

## 5.3 POLE CAMERA PROGRAMME

Without sophisticated modelling software, targeted inspection and maintenance works should be invested in. Pole camera inspections are a low-cost inspection method that will rapidly increase the percentage of the network surveyed. A typical pole camera inspection involves lowering a camera on the end of a pole into a manhole which obtains footage for the first 20 meters of the pipe length. There is bias to grouping surveys together and inspecting all pipes in a manhole to maximise efficiency, although it is essential to retain a good distribution of surveys.

Immediate results show a steady decrease on ‘no action’ decisions upon review of the inspection footage (Figure 10, 11). These decisions reflect the quality of the inspections, having been targeted at high risk assets. Previously there were a large proportion of ‘no action’ decisions, but this was representative of inspecting pipes with no damage.

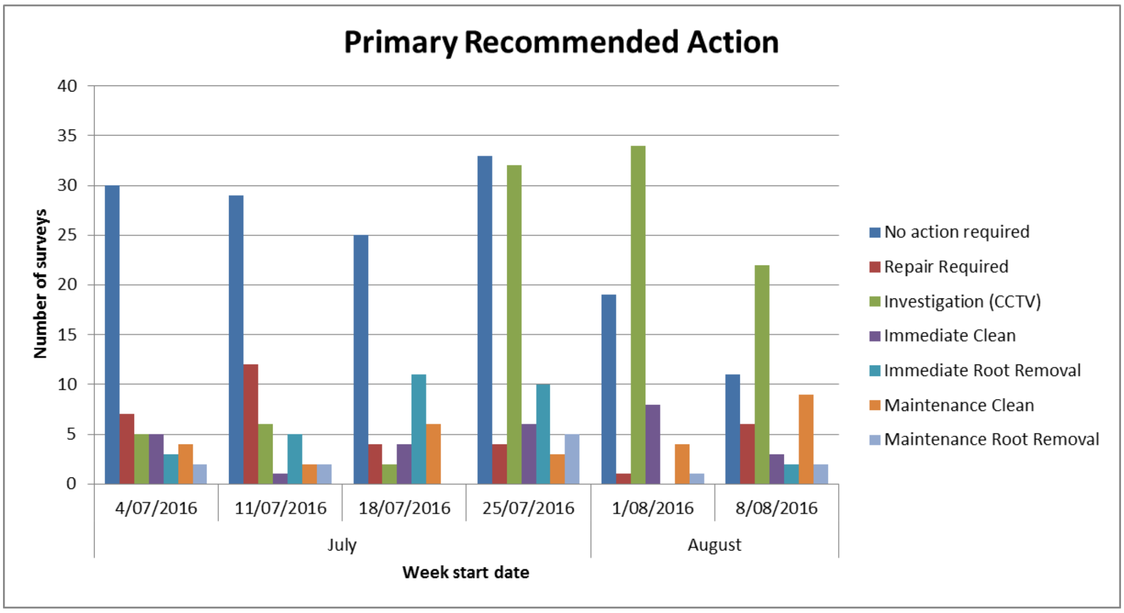



*Figure 10 – Primary Recommended Actions for Assets (July and August 2016)*

Immediate actions have increased with frequent operational improvements to the programme (includes immediate investigation with CCTV). The variance in repairs and root maintenance are dependent on the area being inspected in a given week. This is because daily and weekly inspections are grouped by suburbs to minimise travel time. These results are generating plenty of work for CAPEX repairs, CCTV/push cam/pole cam inspections and maintenance work for contractors. With constant work packages for repairs and renewals in conjunction with decreasing overflows there is high confidence in the long-term trend of increasing the quality of wastewater reticulation across the city. With efficient and effective pole cam surveying we can do more with less.

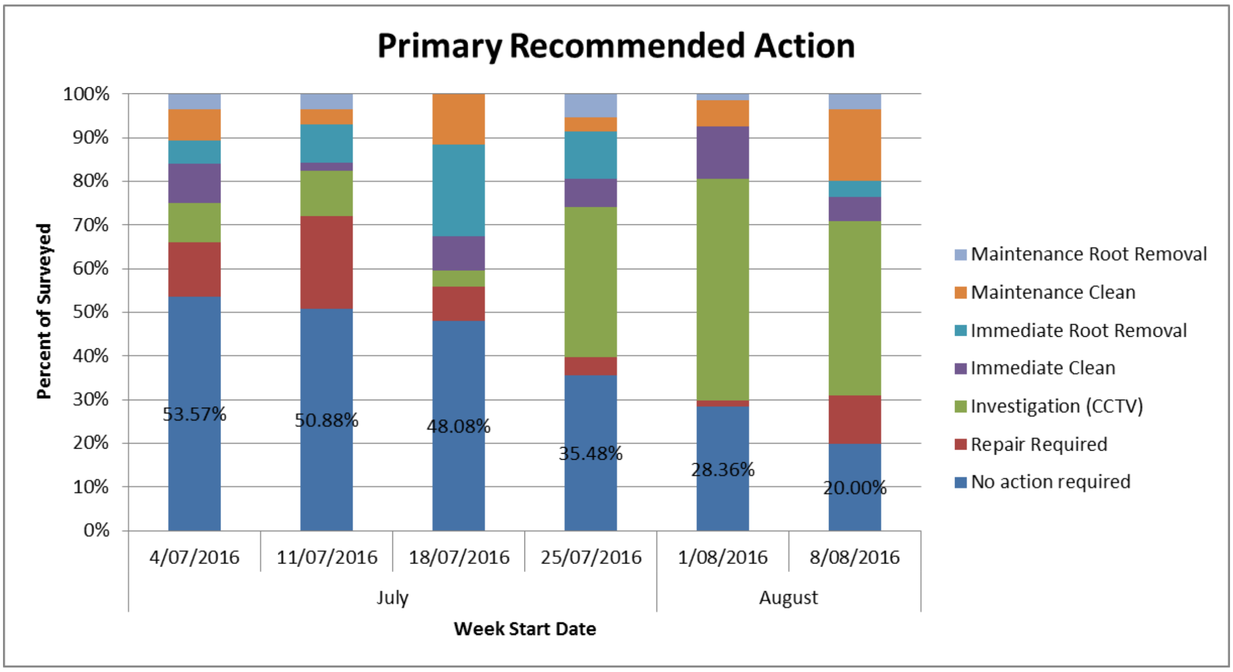



*Figure 11 – Primary Recommended Actions for Assets (July and August 2016)*

Figure 12 shows a breakdown of completed pole cam surveys against blockages and dry weather overflows for each week of the programme. Since the start of the pole camera programme there has been zero dry weather overflows. We have successfully located and cleared many blocked manholes in our targeted maintenance, some of which would have eventuated in overflows.

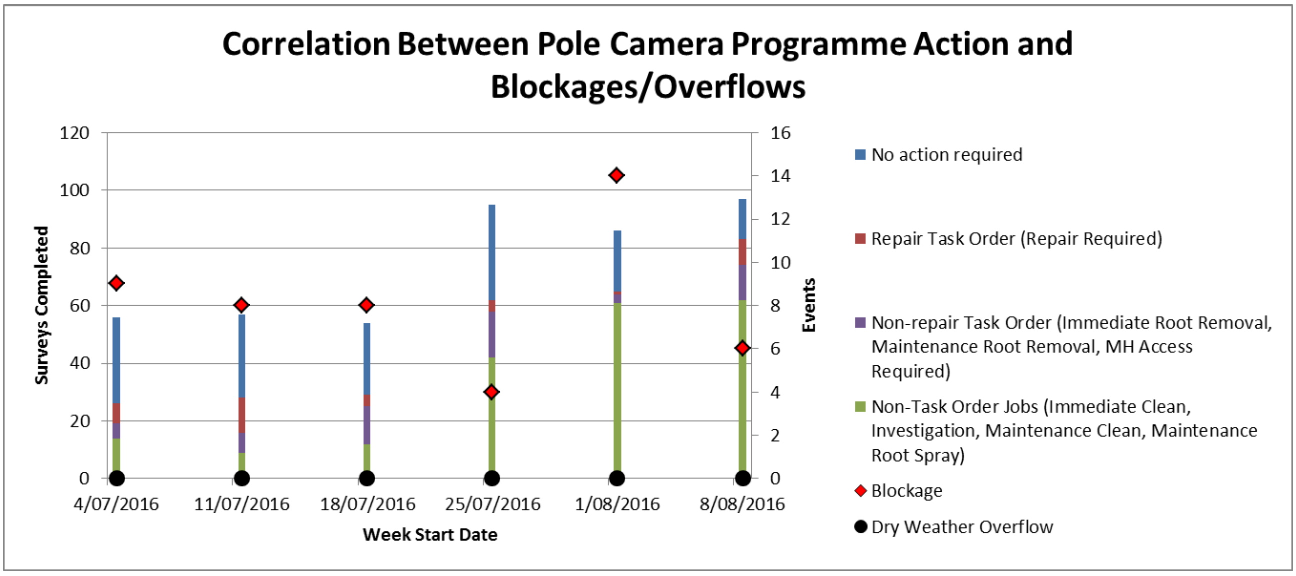



*Figure 12 – Trend of Dry Weather Overflows (July and August 2016)*

## 5.4 MAINTENANCE AND RENEWAL DECISIONS

Deterioration rates and profiles for assets (from wastewater reference site analysis) will be crucial in moving from recommendations in the PoleCam logsheets to final maintenance and renewal decisions. This information helps in determining whether it is more beneficial to extend the life of an asset by repairs or do a renewal, or when the practicality of decisions is in question for a particular asset (damage from pressure cleaning, PVC pipes in liquefied areas, longevity of a critically damaged asset in a stable environment etc.)

- **Condition:** For pole camera inspections this is assessing the likelihood of structural damage throughout the asset length either by extrapolation of defects seen close to the manhole or suspected defects based upon a combination of factors (old age, brittle material, liquefied soil, broken pieces in flow visible, large surface damage etc.)

- **Performance:** Inspecting for water level, obstructions restricting pipe flow (fats, roots, paper, organic, silt/stones, structural debris)

- **Longevity of damaged assets:** Deterioration rates (linear, non-linear, stable) and profiles (external/internal pipe attributes) dictate the balance of earthquake damage to environmental/business as usual damage and the subsequent changes over time.

- **Remaining asset life:** The definition of this has changed from before and after the earthquake and is likely to change further as the overall wastewater network is improved over the coming years. All current assets damaged from the earthquake have an estimated reduction of asset life in years.

*Table 6 – Final recommendations on maintenance and renewal decisions*

| Action priority | Action | Stream |
|---|---|---|
| Low | Routine maintenance/no action | Maintenance |
| Low | Further PoleCam | Maintenance |
| Low | Further CCTV | Maintenance |
| Medium | Planned HP/LP clean, root spray/removal (within 10 days, non-urgent) | Maintenance |
| Medium | Immediate HP/LP, root spray/removal (within 24 hrs, urgent) | Maintenance |
| High | Repairs < 6m (segment) | Renewal |
| High | Repairs > 6m (renewals) | Renewal |

# 6 CONCLUSIONS

The success of the reference sites, based on high quality data and robust assessment is considered to be an effective investment by both the maintenance contractor and asset owner. Utilising this data has had immediate benefits including targeting pipes susceptible to blocks early (before potential for overflow), identifying segments for repair and providing planned rather than reactive maintenance programming.

The programme replaces a “cleaning clean pipes” regime that had little rigour other than it was accepted practice.

There is now increased confidence that management of the network is being undertaken as effectively as possible. In maintaining this efficiency and effectiveness it is required to have minimum daily inspections in the network, a weekly review of gathered information and programming for review of reference and other sites in 12-36 months.

It is likely that a new target maintenance programme will be issued in 6-12 months. This will be based on review of the existing network data e.g. “how many overflows and blocks occurred, and why?” along with trends of action/no action resulting from the pole camera and where necessary CCTV work. Adaptation and documentation of any changes is essential, both for immediate maintenance and asset management lifecycle needs.

## REFERENCES

Noell, B. (2015) ‘Seismic Performance of Plastic Pipe Systems in 2010/11 Canterbury Earthquakes’

O’Callaghan, F.W. (2015) ‘Pipeline Performance Experiences During Seismic Events in New Zealand 1987 to 2015