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EXECUTIVE SUMMARY

Introduction
The structural integrity and performance of our towers and poles is essential to maintaining reliability of supply to customers and to ensuring public safety.

Our asset management approach for transmission lines seeks to maintain them in perpetuity, and to achieve least overall lifecycle cost. We have long-term programmes of work in progress to maintain the asset health of steel tower structures and replace deteriorated poles.

Asset fleet and condition assessment
Our transmission line conductors are supported by approximately 25,000 towers and 16,000 pole structures.

Our towers and poles are designed to withstand severe climatic loading conditions, and we monitor and maintain them to ensure satisfactory performance. Structural failures of towers and poles are rare, typically less than one each year, and are usually associated with extreme weather events.

Our condition assessment programme monitors and records the condition of transmission line structures. We forecast the future condition of each structure based on its current condition and our knowledge of the expected rate of degradation at each location. The forecast of future condition provides the basis for asset management decision making.

Our condition assessment programme is risk-based, and the intervals between inspections are adjusted based on the condition of the structure and its criticality. Assessments are performed more frequently as the structure condition approaches the replacement criteria. Structures located in unusually aggressive environments, or deemed to be highly critical, either to the Grid or for safety reasons, are also assessed more frequently.

Tower strategies
The main mode of deterioration of our fleet of steel lattice towers is corrosion. Our studies have shown that to mitigate the effects of corrosion, in most cases it is more cost-effective to paint steel lattice towers than to undertake piece-wise replacement of the steel members, or to completely replace the tower. Lifecycle cost analysis has shown that the economically optimum strategy for painting of towers differs based on the environmental conditions at each location. For towers in extreme environments, the most economic strategy is to paint the tower at an earlier point on the degradation curve than for towers in benign environments.

We first began painting towers in the early 1990s, and we have painted approximately 3,300 towers. A long-term programme of tower painting work is now in place. We intend to increase the annual volumes from 250 towers painted each year during RCP1 to 530 each year during RCP2.

Over the past few years, we have made significant progress in developing and sustaining an appropriately skilled workforce of tower painting service providers to achieve the volume of work that we require. Even so, this remains a challenging area. Long-term tower condition
modelling shows that unless we increase the number of towers painted each year, a significant proportion of the tower fleet will be at risk of structural failure due to corrosion.

We give the highest priority to ensuring that this work is undertaken safely, and with appropriate standards of quality. The safe and effective delivery of the tower painting programme will be a continuing area of focus. We will strive to increase the availability of appropriately skilled resources to meet our forecast requirements throughout the RCP1 and RCP2 periods.

For some components of steel lattice towers, deterioration cannot be effectively mitigated by painting. Steel towers have insulator attachment points located at the end of crossarms that provide the fixing point for strain and suspension insulators. These attachment points are subject to corrosion and wear, and they ultimately need to be replaced to ensure reliable service. In addition, for some of our towers, it is cost-effective to replace corroded components such as steel bolts, or isolated individual steel members, and so defer the need for painting the entire tower.

In the period between 2010 and 2015, we expect to replace the insulator attachment points on 2,600 towers. We will continue this programme of work to ensure that we maintain the overall asset health of the population. We expect to replace around 520 attachment points each year over the RCP2 period.

Pole strategies

Our asset management approach for poles is based on replacing degraded poles and poles sited in unstable ground. Poles are scheduled for replacement at a point just before they are forecast to no longer be able to support their design load (this criteria still includes a factor of safety).

Our steel and concrete poles are generally in good condition, but a significant number of older hardwood poles are now reaching replacement criteria. We have been replacing about 250 pole structures annually, but this is forecast to decrease to around 200 each year during RCP2.

Improvements

In our planning for the RCP2 period we have made a number of improvements to the asset management of towers and poles, including:

- our planning decisions consider the whole-of-life cost of tower and pole assets covering planning, delivery, operations, maintenance and disposal, as well as their impacts on other assets, such as conductors
- asset criticality is being used as an important factor in planning tower asset works, in particular replacements
- cost estimation for projects in RCP2 has been undertaken using tailored ‘building blocks’ based on actual cost out-turns from completed or equivalent works.

Further improvements will include:

- refining degradation curves, condition assessment techniques and asset health models
- refining the asset criticality framework.
SUMMARY OF STRATEGIES

This section provides a high-level summary of the main asset management strategies for the tower and pole fleets. These reflect the need to manage an ageing asset fleet and the impacts of wear and corrosion while meeting objectives in relation to safety, performance and reliability.

Main strategies

The following summaries include the main strategies and their respective costs during the RCP2 period (2015–2020). Note that “CA” stands for condition assessment.

Capital expenditure (Capex)

<table>
<thead>
<tr>
<th>Strategy</th>
<th>RCP2 Cost</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paint Corroding Towers</td>
<td>$187.2m</td>
<td>A significant number of towers are nearing the level of corrosion where intervention is required to maintain the asset in perpetuity at an appropriate cost. The strategy is to paint towers prior to significant rusting and to re-paint prior to paint failure. We have undertaken analysis which supports painting as the preferred approach to prevent corrosion and extend life expectancy. This approach has a lower lifecycle cost than full tower replacement. Painting is triggered at varying CA scores depending on corrosion zones (for example, from CA 50 in extreme zones to CA 30 in benign zones). The plan will involve painting 530 towers each year on average over RCP2 at an annual cost of $37.4m. It is worth noting that this is significantly below an unconstrained requirement of 780 each year, the reason being restricted painting resource.</td>
</tr>
<tr>
<td>Replace at-risk Poles</td>
<td>$25.5m</td>
<td>Degraded poles and those in unstable ground are at a higher risk of failure. New Zealand’s Electricity Regulations require that any pole found to be unable to support its design loads must be replaced within 12 months. The strategy is to replace poles just before they have degraded to a point where they can no longer support their design loads, or where it is prudent to do so due to ground instability. Replacement is triggered at CA 20 for lines where work can readily be carried out de-energised (and CA 25 where live line replacement is preferred due to system constraints). We plan to replace approximately 200 poles each year over RCP2, at a total cost of $25.5m.</td>
</tr>
</tbody>
</table>
Replace at-risk Towers

<table>
<thead>
<tr>
<th>RCP2 Cost</th>
<th>$2.2m</th>
</tr>
</thead>
</table>

Towers on unstable ground or subject to slips are at higher risk of failure.

The strategy is to replace towers at risk of failure due to unstable ground or slips, or when they have failed.

We plan to replace 10 towers identified as being at risk of failure (due to unstable ground or slips) during the RCP2 period, at a total cost of $2.2m.

Operating expenditure (Opex)

Replace Corroding Attachment Points

<table>
<thead>
<tr>
<th>RCP2 Cost</th>
<th>$21m</th>
</tr>
</thead>
</table>

An increasing number of attachment points on towers are showing signs of corrosion and wear. If the attachment point fasteners become too corroded, the entire crossarm has to be lowered to the ground. This process is expensive and impacts transmission line availability.

The strategy is to replace insulator attachment points at the onset of section loss and before the fastener threads seize up. This relates to a replacement criteria of CA 30.

We plan to carry out attachment point replacements on about 2,600 towers, at a total cost of $21m.

Tower Steel and Bolt Replacements

<table>
<thead>
<tr>
<th>RCP2 Cost</th>
<th>$19.2m</th>
</tr>
</thead>
</table>

A number of towers have some severely corroded bolts and steel members, while most are in reasonable condition. By replacing the corroded items, structural integrity is maintained and painting of the tower can usually be postponed for several years.

The strategy is to replace severely corroded steel and bolts prior to significant loss of section. Members with CA scores approaching 30 are monitored, with member replacement targeted at CA scores of 30 or below.

In the RCP2 period, we plan to carry out steel and bolt replacements on 2,095 towers, comprising 1,670 major steel and bolt works, and 425 minor steel and bolt works. We also plan to carry out 470 tower crossarm works, and 80 major structural steel works. The total cost of the maintenance project will be about $19.2m.
### Step and Touch; and Transferred Potential

<table>
<thead>
<tr>
<th>RCP2 Cost</th>
<th>$5m</th>
</tr>
</thead>
</table>

Step and touch and transferred potential hazards from transmission tower structures are low probability events, but are significant because of the possible consequences. We take a risk-based approach to investigating and mitigating these hazards, in line with a published industry guide.

We plan to spend $5m over RCP2 on investigating, designing and installing risk mitigations at identified high-risk sites.

---

### Install fall arrest systems

<table>
<thead>
<tr>
<th>RCP2 Cost</th>
<th>$2m</th>
</tr>
</thead>
</table>

It is widely recognised that permanent attachment fall arrest systems have superior safety characteristics to the double lanyard method currently in use. A programme to install fall arrest systems on transmission towers began in 2010 and will continue throughout RCP2.

The strategy is to take a risk-based approach and retrofit permanent attachment fall arrest systems on high-priority towers to improve the safety of our employees and service providers.

We plan to install 450 permanent attachment fall arrest systems during RCP2, at a total cost of $2m.

---

Chapter 4 has further details on these strategies and a discussion of the remaining strategies.
1 INTRODUCTION
Chapter 1 introduces the purpose, scope, stakeholders, and strategic alignment of the towers and poles fleet strategy.

1.1 Purpose
We plan, build, maintain and operate New Zealand’s high-voltage electricity transmission network (‘Grid’) which includes the structures (towers and poles) that support conductors.

The purpose of this strategy is to describe our approach to lifecycle management of its tower and pole fleets. This includes a description of the asset fleet, objectives for future performance and strategies being adopted to achieve these objectives.

The strategy sets the high-level direction for fleet asset management activities across the lifecycle of the asset fleet. These activities include Planning, Delivery, Operations, and Maintenance.

This document has been developed based on good practice guidance from internationally recognised sources, including BSI PAS 55:2008.

1.2 Scope
The scope of the strategy includes the following components of the lattice steel towers:

- bolts, steel angle members, and plates
- insulator and earthwire attachment points, steel plates, and swivels
- signs, bird deterrents, fall arrest systems, and climbing deterrents
- tower paint.

The scope of the strategy also includes the following components of the pole structures:

- hardwood, concrete and steel pole structures
- steel and hardwood crossarms and earthpeaks
- guying including ‘deadmen’ (at angle points there are guy wires connected to long galvanised steel anchor bolts that, in turn, are connected to concrete or timber anchor deadmen buried in the ground)
- signs and bird deterrents.

1.3 Stakeholders
Correct operation and maintenance of towers and poles is essential for the safe and reliable transport of electricity from generators to customers and distribution networks across public and private land.
Key stakeholders include:

- regulatory bodies: Commerce Commission, Electricity Authority, Local and Regional Councils and the Environmental Protection Authority.
- service providers
- customers, including distribution network businesses and generators
- landowners.

1.4 Strategic Alignment

A good asset management system shows clear hierarchical connectivity or ‘line of sight’ between the high-level organisation policy and strategic plan, and the daily activities of managing the assets.

This document forms part of that hierarchical connectivity by setting out our strategy for managing the tower and pole assets to deliver our overall Asset Management Strategy in support of our asset management policy. This fleet strategy directly informs the tower painting, tower structures, and pole structures Asset Management Plans.

This hierarchical connectivity is represented graphically in Figure 1. It indicates where this fleet strategy fits within our asset management system.

![Diagram of asset management hierarchy]

Figure 1: The Towers and Poles Strategy within our Asset Management Hierarchy

1.5 Document Structure

The rest of this document is structured as follows.
Chapter 2 provides an overview of the tower and pole assets including fleet statistics, characteristics and their performance.

Chapter 3 sets out asset management related objectives for the tower and pole asset fleets. These objectives have been aligned with the corporate and asset management policies, and with higher-level asset management objectives and targets.

Chapter 4 sets out the fleet specific strategies for the management of the towers and poles fleet. These strategies provide medium-term to long-term guidance and direction for asset management decisions and will support the achievement of the objectives in chapter 3.

Additional appendices are included that provide further detailed information to supplement the fleet strategy.
2 ASSET FLEET

Chapter 2 provides a high-level description of the tower and pole asset fleets, including:

- **Asset statistics**: including population, diversity, age profile, and spares
- **Asset characteristics**: including safety and environmental considerations, asset criticality, asset condition, asset health, maintenance requirements and interaction with other assets
- **Asset performance**: including reliability, safety and environmental and risks and issues.

2.1 Asset Statistics

This section describes the tower and pole asset fleet population, along with their diversity and age profiles.

2.1.1 Asset Population

The Grid is made up of about 12,000 route km of transmission line, which is supported by about 41,000 transmission line support structures. The majority of towers are on 110 kV or 220 kV lines. Transmission lines with voltage levels below 110 kV are generally on pole structures.

**Tower population**

The support structures include about 25,000 galvanised steel lattice towers. Table 1 provides a breakdown of the tower population by voltage level. As shown in the table, the majority of towers are used to support the higher voltage 220 kV lines.

<table>
<thead>
<tr>
<th>Voltage</th>
<th>≤66 kV</th>
<th>110 kV</th>
<th>220 kV</th>
<th>350 kV</th>
<th>400 kV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Towers</td>
<td>733</td>
<td>6,791</td>
<td>15,040</td>
<td>1,650</td>
<td>435</td>
<td>24,649</td>
</tr>
</tbody>
</table>

*Table 1: Tower Asset Fleet Population as of 30 June 2013*

**Pole Population**

The support structures include approximately 15,600 pole structures comprising some 23,000 individual poles. Table 2 provides a breakdown of the pole structure population by voltage level.

<table>
<thead>
<tr>
<th>Voltage</th>
<th>≤66 kV</th>
<th>110 kV</th>
<th>220 kV</th>
<th>350 kV</th>
<th>400 kV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Poles</td>
<td>2,349</td>
<td>13,166</td>
<td>106</td>
<td>0</td>
<td>0</td>
<td>15,621</td>
</tr>
</tbody>
</table>

*Table 2: Pole population as of 30 June 2013*

2.1.2 Fleet Diversity

**Diversity of the tower asset fleet**

The steel tower fleet consists of over 100 different designs dating from the original 110 kV lines built in the 1920s, to the 1950s flat-top 220 kV designs, to the double-circuit 220 kV
designs in use since the 1970s. We have always sourced our towers worldwide, usually on a design and supply basis specific to each line constructed. The size and shape of towers have varied with time, but so too have the design standards and specified design loads. Consequently there is large diversity within the fleet in terms of size, shape, attachment details and strength. The level of tower diversity does complicate certain design and construction processes when upgrading or strengthening, but is not considered a major asset management issue, as all towers perform and degrade in essentially the same way.

**Diversity of the pole asset fleet**

The two main types of structure configuration are single poles (which make up about 53% of the population) and Pi poles (two poles) (which make up about 46%). Triple pole structures are rarely used, making up less than 0.5% of pole assets. For the purpose of this document, poles are considered on a per structure basis irrespective of construction.

The predominant material types are summarised in the chart in Figure 2:

- new concrete (octagonal hollow cast prestressed)
- untreated hardwood (S1 Australian hardwood)
- old concrete (I beam, Verindeel, Hollow Spun)
- treated hardwood (S2 Australian hardwood)
- steel.

**Figure 2: Composition of Pole Asset Fleet as of 30 June 2013**

Preferred pole technology has changed over time, as shown in Figure 3.

<table>
<thead>
<tr>
<th>Installation Period</th>
<th>Hardwood Untreated</th>
<th>Hardwood Treated</th>
<th>Old Type Concrete</th>
<th>Steel</th>
<th>Concrete (octagonal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920–1970</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970–1992</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1992–current</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Crossarms**

The other main components of pole structures, besides the poles themselves, are the hardwood or galvanised steel crossarms that support the insulators. Deteriorated crossarms on wooden pole structures have generally been replaced by galvanised steel crossarms. All newer octagonal concrete pole structures have galvanised steel crossarms. Preferred crossarm lengths are: 5m for single pole structures and 10m for Pi pole structures. These
lengths provide a larger, safer climbing corridor than the shorter arms used on many older structures.

2.1.3 Age Profile

Our tower and pole assets have been installed progressively, with significant periods of Grid development in the 1930s and the 1950s to 1980s. Most towers are original. Very few have been replaced, as painting is used to manage corrosion.

Conversely, a significant number of poles have been replaced due to poor condition or when upgrading lines. Typically, loss of condition is due to rot and loss of cross-sectional area on wooden poles and spalling on older concrete poles.

Tower age profile

The average age of the transmission towers is approximately 48 years, with the age profile shown in the chart in Figure 4. The bars show the number of towers in each age group.

Tower life expectancy

Life expectancy should be interpreted as the period after which the risk of failure is deemed unacceptable. In the case of steel towers, this is when members have corroded to a point where they can no longer be relied upon to carry their design loads. The life expectancy of unpainted steel lattice towers varies significantly in New Zealand and is primarily driven by the corrosiveness of the environment. In some severe conditions, for example the south Wellington coast, life expectancy of an unpainted tower is as low as 18 years. Conversely, in very benign conditions, as in Central Otago, tower life expectancy is 120 years. See Appendix A for further detail on the corrosion zones.

We have allocated each tower structure to one of six corrosion zones (in descending order from most to least corrosive):

- extreme
- very severe
- severe
The classification was determined by analysis of existing tower ages and current condition. Appendix A shows the geographical location of transmission towers by corrosion zone. Table 3 gives typical life expectancies for unpainted towers for the six corrosion zones.

<table>
<thead>
<tr>
<th>Corrosion zone</th>
<th>Typical exterior environment</th>
<th>Life expectancy (years)</th>
<th>No. of Towers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme</td>
<td>Geothermal/exposed</td>
<td>18</td>
<td>309</td>
</tr>
<tr>
<td>Very severe</td>
<td>Sea-shore (surf)</td>
<td>25</td>
<td>1,863</td>
</tr>
<tr>
<td>Severe</td>
<td>Sea-shore (calm)</td>
<td>44</td>
<td>3,772</td>
</tr>
<tr>
<td>Moderate</td>
<td>Sheltered/coastal with low salinity</td>
<td>62</td>
<td>13,191</td>
</tr>
<tr>
<td>Low</td>
<td>Arid/rural/inland</td>
<td>86</td>
<td>3,854</td>
</tr>
<tr>
<td>Benign</td>
<td>Dry, rural/remote from coast</td>
<td>120</td>
<td>1,660</td>
</tr>
</tbody>
</table>

Table 3: Life expectancy of unpainted towers

**Pole age profile**

The installation date of each pole structure was not recorded in a database until the introduction of our asset database in the early 1990s. So the exact age of many poles is unknown. However, pole material type can be used to estimate age for those poles that have not been replaced, by knowing the periods that they were used, as summarised in Figure 3. Using this method, the average pole age of the fleet is about 30 years.

**Pole life expectancy**

Table 4 shows the anticipated life expectancy for each pole type. The actual useful life will depend on pole type and quality, site specific weather exposure, structure loadings and soil properties. We note that the predicted life for treated and untreated hardwoods is the same. This is because the old untreated hardwoods were of very high-quality durable hardwood that is now essentially unavailable. Treating woods of lesser durability increases the expected life to that of the older hardwoods.

<table>
<thead>
<tr>
<th>Pole Type</th>
<th>Life expectancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardwood (untreated)</td>
<td>50 years</td>
</tr>
<tr>
<td>Hardwood (treated)</td>
<td>50 years</td>
</tr>
<tr>
<td>Concrete (old type)</td>
<td>70 years</td>
</tr>
<tr>
<td>Concrete (octagonal)</td>
<td>80 years</td>
</tr>
</tbody>
</table>

Table 4: Life expectancy of transmission poles

---

1 Significant reference was also made to research by the Building Research Association of New Zealand and corrosion maps and tables from the New Zealand Heavy Engineering Research Association.
2.1.4 Spares

Spare towers

As of 30 June 2012, we hold a stock of 28 emergency restoration structures that can be used in emergencies following a tower failure, or near failure. This equates to about 1.1 emergency towers for every 1,000 towers in service, which we accept as providing a prudent balance between maintaining an appropriate level of service while controlling costs. These temporary structures are designed to remain in place until a permanent replacement tower is available. A small number of spare towers are held at three warehouses that can be installed after an emergency event to replace an emergency structure with a permanent structure.

Appropriate stocks of spares, such as insulators and conductors, are held by regional service providers and at our three warehouses for use on these emergency structures.

Spare poles

Together with service providers, we keep a range of spare poles in stock. Reflecting on the requirements of the existing lines in the region, the stock includes standard hardwood, concrete and steel poles and associated conductors, insulator sets and hardware. Various families of pole structure designs are available from which to choose suitable replacements. It should be noted that, in many instances, spare poles can be used to replace a failed tower on a temporary basis.

2.2 Asset Characteristics

The tower and pole asset fleets can be characterised according to:

- safety and environmental considerations
- asset criticality
- asset condition
- asset health
- maintenance requirements
- interaction with other assets.

These characteristics and the associated risks are discussed in the following subsections.

2.2.1 Safety and Environmental Considerations

We are committed to ensuring that safety and environmental risks are minimised at all times. These risks are considered early in the asset management planning process. The four most significant safety and environmental considerations for the tower and pole asset fleet are:

- pole and tower failure
- tower replacement versus painting
- pole and tower climbing
- step and touch and transferred potential.
Pole and tower failure

Safety and environmental considerations associated with tower and pole failures are specific to the local environment (road crossings, urban areas and rural zones), the proximity of population and whether there is a resulting conductor drop.

Failures of either towers or poles have the potential to cause significant outages and harm to people and property, particularly if the failure occurs in a built-up area. The possible consequences of a tower collapse include fire on public or private land, electrocution, physical damage to people and property and loss of power supply (which can impact safety indirectly). Risks associated with pole or tower failure are discussed further in subsection 2.3.4.

Tower replacement versus painting

Tower corrosion, which is driven by age together with the corrosiveness of the environment, can lead to tower failure. The two options to manage tower corrosion - full replacement or periodic tower painting - involve safety and environmental risks which need to be considered when selecting the preferred management strategy. In either case, delaying replacement or painting until severe corrosion has occurred increases the risk of tower failure, and hence the risk to both workers and public. See subsection 2.3.4 for more details on the safety risks involved with tower climbing.

Tower replacement requires multiple cranes to support the conductors and replace the tower. Alternatively, temporary structures can be erected to hold the conductors while the tower is replaced (generally by crane). Both options require large set-up areas and good site access. Considerable enabling works (site benching and upgrading access) with associated negative environmental impacts are required in most instances. These invariably require site remediation works after erection is complete. Tower replacement in some urban environments would be particularly difficult and expensive.

Painting equipment, by comparison, is relatively lightweight and can be accommodated at most sites. Abrasive blasting of towers is often required prior to painting depending on the condition of the tower. This has a detrimental environmental effect as zinc and steel are blasted off with the garnet. The poorer the tower condition, the more abrasive blasting is required prior to painting, resulting in a greater detrimental effect on the environment. These effects can be largely mitigated by the use of drop sheets in sensitive areas.

Although paint is applied by brush, paint drips can be carried by the wind. This can be an issue in urban environments if not managed appropriately.

Tower climbing

Painting towers and tower erection require working at height and with machinery. Both pose safety risks to workers. Since 2005, inspection and maintenance workers climbing the transmission towers have been required to be permanently attached while climbing the tower or working on the tower at height. Historically, the double lanyard method (which requires the repeated attachment of one lanyard and detachment of another) has been used. A number of international utilities are reducing the reliance on this method of climb by installing cable fall arrest systems. To enhance the safety of workers, a programme to install fall arrest systems on transmission towers began in 2010 and is still ongoing.
To deter members of the public from climbing transmission towers, we have erected barbed wire barriers (climb deterrents) and installed ‘do not climb’ signage on all towers and poles. This includes towers likely to be frequented by and readily accessible to the public. These towers are towers within 500m of rural and urban houses, in parks, or within 500m of any road beside which pedestrian traffic is likely.

**Step and touch and transferred potential**

The risk of electric shock to employees or members of the public from step and touch or transferred potential hazards from transmission line structures is a very low probability event. Yet the risk is significant because of the possible consequences.

We have a risk-based policy to identify and mitigate these hazards. The policy is in line with the industry standard EEA Guide to Power System Earthing Practice 2009.

Our risk management framework uses a location classification system that classifies individual sites based on the extent to which people may be nearby or may congregate in close proximity to the structure.

### 2.2.2 Asset Criticality

Our approach to asset management has been adapted to recognised the differing levels of asset criticality. This is discussed in more detail in Chapter 4. A framework has been created to classify assets in terms of criticality. The framework considers various aspects that would be impacted by a failure such as load carried, the level of reliability required by the customers, constraints that would be placed on the rest of the Grid and the level of redundancy. We are also developing a safety criticality framework. The asset criticality framework is relatively new, and will continue to be improved during RCP2.

The charts in Figure 5 set out the proportion of towers and poles in each criticality category. They show that more than half of the tower fleet are classified as medium or high with respect to network criticality. The performance and reliability of these assets need to be carefully managed.

![Figure 5: Towers and Poles Criticality as of June 2013](image)

Subsections 2.2.4 and 4.1.3 discuss how criticality is taken into account, in combination with asset health to determine prioritised replacement programmes.
2.2.3 Asset Condition

We carry out regular condition assessments on towers and poles. We began this programme in 1996, which now provides high-quality data allowing degradation rates to be better accurately modelled for the majority of lines assets.

The assessments produce a condition assessment (CA) score for various components on a scale from 100 (new) to 20 (replacement or decommissioning criteria) to 0 (where failure is likely under everyday conditions). New structures are first assessed just prior to the expiration of any defect liability period. Then, tower line assets are generally assessed every 8 years and pole lines every 6 years. When the Condition Assessment (CA) score of any component is less than 50, the assessment frequency is generally doubled, to take place every four years for towers and three years for poles. The aim is to ensure that no component is allowed to deteriorate by more than 50% between assessments (for example, from CA score 60 to CA score 30). Sites with very high criticality may be assessed more frequently. Full details of the condition assessments are contained in TP.SS 02.17.

Towers

Towers are made of galvanised steel where the zinc coating protects the steel from premature corrosion. New Zealand has a corrosive environment, with a prevailing salt-laden westerly wind flow, geothermal regions and high rainfall. Over time, these conditions erode the zinc coating and the steel then corrodes.

For steel towers, degradation of condition depends primarily on the corrosiveness of the local atmosphere but also on the quality and thickness of the original galvanising. In fact, while the atmosphere is the major factor, experience has shown that occasionally towers on two adjacent lines can degrade at different rates due to differences in the base metal composition and/or galvanising.

As discussed in subsection 2.1.3, we have allocated each tower structure to one of six corrosion zones. The classification was determined by analysis of existing tower ages and current condition. Table 5 shows the number of painted and unpainted towers in each corrosion zone as at June 2013.

<table>
<thead>
<tr>
<th>Corrosion Zone</th>
<th>Painted Towers</th>
<th>Unpainted Towers</th>
<th>% Painted In Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme</td>
<td>141</td>
<td>168</td>
<td>46%</td>
</tr>
<tr>
<td>Very Severe</td>
<td>1,051</td>
<td>812</td>
<td>56%</td>
</tr>
<tr>
<td>Severe</td>
<td>1,377</td>
<td>2,395</td>
<td>37%</td>
</tr>
<tr>
<td>Moderate</td>
<td>727</td>
<td>12,464</td>
<td>6%</td>
</tr>
<tr>
<td>Low</td>
<td>15</td>
<td>3,839</td>
<td>0.4%</td>
</tr>
<tr>
<td>Benign</td>
<td>2</td>
<td>1,658</td>
<td>0.1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,313</strong></td>
<td><strong>21,336</strong></td>
<td><strong>13%</strong></td>
</tr>
</tbody>
</table>

Table 5: Population of transmission towers by corrosion zone as of June 2013

Figure 6 shows the condition of our fleet of towers by corrosion zone. Corrosion has been modelled to estimate degradation since the CA data was collected.
While no towers are believed to be at imminent risk of failure due to poor condition, a significant number are degrading to the point where intervention by component replacement and/or painting is required to ensure the towers do not degrade to a point necessitating full replacement.

**Tower painting**

We began painting towers in the 1990s. The number of towers painted each year is shown in Figure 7. Until 2005, tower painting was constrained by financial allocation. After 2005, the quantity of towers being painting was constrained by resource availability – specifically the number of certified painters.

A significant proportion of the tower fleet has been painted to date. Table 5 shows the numbers of painted and unpainted towers as at June 2013.
Attachment points

An attachment point is the plate or swivel assembly on the tower onto which the insulator string or earthwire hardware is attached.

An increasing number of attachment points on towers are showing significant signs of corrosion and wear, particularly in more corrosive regions. Designs with large flat plates at the ends of crossarms have proven particularly susceptible to corrosion. The plates shield the attachment from rain washing, allowing a build-up of corrosive salts that, in turn, lead to accelerated corrosion rates. Manual washing of the attachment points would extend life a little, but the benefits would not be cost-effective. Other designs, using relatively thin plates and/or round on round fittings, are susceptible to rapid wear. Replacement with better designed attachment points is the best solution.

In addition, experience has shown that if the attachment point fasteners become too corroded then the entire crossarm has to be lowered to the ground to remove the fasteners. This is particularly expensive and requires longer outages than would have been required if the work had been completed earlier. Such fastener issues tend to occur at a CA score of 30.

Condition assessment samples for attachment points are lifted from 1 in 10 assessed structures. Samples are then measured for wear to give an indication for overall corrosion. Condition assessment scores of the towers’ attachment points are shown in the chart in Figure 8. The chart shows that just under 1,000 attachment points are below the CA 30 replacement criteria.

![Attachment Points - Condition Assessment](image)

Figure 8: Attachment Points - Condition Assessment as of June 2013

Poles

The steel and concrete pole fleet is generally in good condition, although some older-type concrete poles now have cracks, spalling and rusting reinforcement. Most poor condition poles in the fleet are old hardwood poles that tend to rot just below ground level, reducing section area to a point where the structure cannot reliably carry design loads. Significant above-ground defects also occur such as major splitting or pole top rot.
Figure 9 shows the current condition scores of the pole fleet. The majority of untreated hardwood poles are scored at less than CA 50, with a significant number of poles forecast to reach replacement criteria during RCP2.

**POLES - CONDITION**

- CONCRETE OCTAGONAL HOLLOW CAST
- HARDWOOD UNTREATED
- CONCRETE (OLD)
- HARDWOOD TREATED
- STEEL

![POLES - CONDITION](image)

**Figure 9: Poles - Condition Assessment as of June 2013**

### 2.2.4 Asset Health

The Asset Health Indices (AHI) reflects the forecast remaining life for any given asset – in effect, it is an assessment of current and future asset ‘fitness for purpose’. The AHI forecast of remaining useful life is based on modelling deterioration or risk that cannot be addressed by normal maintenance (where maintenance to address the deterioration or risk is not possible/practical, or is uneconomic). For transmission line structures, this is when the structure can no longer be relied upon to carry its design loads. At this point, major intervention is required, such as total replacement of the asset or refurbishment that significantly extends the original design life.

Asset health indicators provide a proxy for the probability of failure in asset risk management analysis.

AHI is calculated using:

- the current condition of the asset
- the age of the asset
- the typical degradation path of that type of asset
- any external factors that affect the rate of degradation, such as proximity to the coast affecting the rate of corrosion of steel towers.
Assessing asset health is particularly important, as it is used to understand the deterioration profile of asset fleets and to forecast and prioritise replacement and refurbishment activities. Asset health information and asset criticality data are used to assign an overall priority to each asset that then is used to optimise the level of investment in the fleet.

We are still at a relatively early stage in developing and applying asset health indicators. More details on our asset health methodology are set out in the document ‘Asset Risk Management – Asset Health Framework.’

**Towers**

The greatest asset management challenge for our ageing fleet of towers is from corrosion of the steel. As discussed in subsection 2.2.3, there are a number of towers that are degrading to the point where intervention by component replacement and/or painting is required to maintain the asset in perpetuity in a cost-effective manner.

Since 2010, we have continued to gain knowledge with regard to painting and corrosion rates. These lessons have been incorporated into the current AHI model. Below we note three examples.

- The number of corrosion zones has increased from 4 to 6 to better account for those towers located in extremely corrosive or benign environments. This allows more accurate prediction of degradation across the fleet, as the difference between each zone is now smaller.
- Actual degradation rates are continually monitored and towers re-assigned to other zones if the actual rates differ markedly from those predicted in the model.
- New, clearer CA criteria were introduced in 2012 – both for unpainted and painted steel. These will define the actual tower condition more clearly (rather than averaged findings). Quality CA data is vital if the model is to deliver accurate forward predictions of tower condition.

Degradation rate curves for tower steel have been derived for each corrosion zone, and are shown in the chart in Figure 10.
A tower is deemed to have reached end of life (or AHI of zero) when the average CA score of the major and minor tower steel reaches CA 20. At this point, major members will have lost 10% of their strength and minor members 20%. While the tower may still be in a workable condition, the risk of failure is deemed unacceptable and the tower must be replaced. At this point it is too late to paint the tower, as the steel cross section has been lost from numerous major members.

For unpainted towers, the time to reach CA 20 is calculated by taking the current condition score and corrosion zone to get a point on one of the respective curves, then using the curve to predict the time to degrade from that CA score to CA 20. For example, assume a tower in the severe zone was assessed as being CA 60 in 2010. This equates to an age of 26 years from the graph. CA 20 equates to approximately 45 years for that zone. End of life is therefore predicted to be ‘Date of Assessment’ + ‘The Total Time it takes to reach CA 20’ – ‘The Age value for the current CA value’ (e.g. 2010 + 45 - 26 = 2029).

The steel of a painted tower is assumed to have a CA score of 60 until the point where the paint coating fails, after which the steel degrades, following the Figure 10 curve from CA 60. Whenever a tower is painted, it is assumed that the underlying steel condition is raised to CA 60, as severely degraded members are replaced and zinc is applied to other corroded areas. (The underlying tower steel beneath the paint top coat will not be ‘as new’ because much of the galvanising will have gone. Yet removing the corrosion and applying zinc paint will improve the steel condition even if no top coat is applied). The underlying steel condition is assumed to remain at CA 60 for the assumed life of the paint; that is, when the paint coating fails and ceases to be an effective barrier coat. Assumed paint life ranges from 12 years in extreme zones to 20 years in benign (See Appendix B for more detail).

The chart in Figure 11 demonstrates the modelling approach for a new hypothetical tower in a severe corrosion zone. In this scenario, the tower is painted once but is not re-coated after the required re-coat period has elapsed.
There is limited direct correlation between asset health and structural performance. Asset health is not readily linked to the probability of failure until a condition score of CA 20 or below is recorded. Between CA 100 and CA 30, the failure risk changes very little. Below CA 30, there is a slight increase in the risk of failure. As CA reduces below 20, the risk of failure increases markedly.

Figure 12 shows the asset health profile of the tower fleet; that is, the remaining life, after which replacement is required.

**Tower attachment points**

As described in subsection 2.2.3, the condition of each attachment point is assessed during routine CA inspections. These existing CA scores have then been taken and reduced as for tower steel to predict when future replacement is likely to be required.

Asset health for attachment points is modelled in the same way as for towers using Figure 10 degradation curves, except replacement criteria is set at CA 30 (see subsection 4.4.3 for more detail). Figure 13 shows the asset health profile of the attachment point fleet; that is, the remaining life, after which replacement is required.
Poles

The health of the pole asset fleet is generally good, although a large number of older poles are in relatively poor condition, particularly non-treated hardwood poles.

End of life for a pole occurs when it has degraded to a point where it can no longer reliably carry its design loads. For poles, this equates to a CA score of 20. Detailed calculations are carried out for each pole to ensure appropriate CA scores are applied. Table 6 shows the remaining life expectancy of transmission pole assets based on their assessed condition score.

<table>
<thead>
<tr>
<th>Pole type</th>
<th>Condition score</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>60</th>
<th>80</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardwood</td>
<td>Untreated</td>
<td>0</td>
<td>4</td>
<td>10</td>
<td>25</td>
<td>40</td>
<td>50 years</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td>0</td>
<td>4</td>
<td>10</td>
<td>25</td>
<td>40</td>
<td>50 years</td>
</tr>
<tr>
<td>Concrete</td>
<td>Old concrete</td>
<td>0</td>
<td>4</td>
<td>10</td>
<td>25</td>
<td>50</td>
<td>70 years</td>
</tr>
<tr>
<td></td>
<td>Octagonal hollow cast</td>
<td>0</td>
<td>4</td>
<td>10</td>
<td>30</td>
<td>60</td>
<td>80 years</td>
</tr>
</tbody>
</table>

Table 6: Transmission pole life expectancy by pole type and condition score

The required replacement date for each pole is estimated by taking the latest CA score and date of inspection for each, and applying the condition scores in Table 6 to calculate remaining life. Figure 14 shows the Asset Health of the pole fleet; that is, the remaining life, after which replacement is required.

As a minimum, all poles identified as ‘Now Due’ are replaced in the year following their identification.
2.2.5 Maintenance Requirements

This subsection describes the maintenance activities undertaken on the towers and pole asset fleet which informs the maintenance strategies (see section 4.4). The most common types of maintenance carried out on these assets are:

- preventive maintenance, including
  - line patrols and condition assessments
  - servicing
- corrective maintenance, including
  - fault response
  - repairs
- maintenance projects.

The Maintenance Lifecycle Strategy provides further details on the above maintenance works.

Preventive maintenance

**Line patrols and condition assessment**

Line patrols are generally performed once a year on every transmission line asset. The primary purpose of the patrols is to identify defects that may affect security of supply or safety. Sites with very high criticality may be patrolled more frequently. A ground-based patrol visits each structure/span and will walk the conductor line, if possible, to identify any defects. A patrol report identifies defects required to be rectified. As discussed in subsection 2.2.3, condition assessments are carried out at every structure on a cyclic basis and include a detailed inspection of the complete structure.

**Servicing**

No scheduled servicing is currently carried out on the tower and pole fleets. Rather, work is planned based on condition.

Corrective maintenance

**Fault response**

The most common fault response is patrolling lines by following a fault to try to establish the cause and rectify the problem.

**Repairs**

The most common repairs to towers are:

- straightening and/or replacement of members due to damage from vehicles
- straightening and/or replacement of members due to damage from livestock
- straightening and/or replacement of members due to severe corrosion
- replacing attachment points
- tightening bolts
installing and maintaining climbing deterrents and bird deterrents
replacing signage.

The most common repairs carried out on poles are:
straightening poles
replacing the guy and deadman
replacing signage
installing and maintaining bird deterrents
installing and maintaining earthing down leads.

Maintenance projects

Maintenance projects typically consist of relatively high-value planned repairs or replacements of components of larger assets. Maintenance projects would not be expected to increase the original design life of the larger assets. Maintenance jobs are typically run as a project where there are operational and financial efficiencies from doing so. The drivers for maintenance projects include asset condition, mitigating safety and environmental risks, and to improve performance. Examples of past maintenance projects are set out below. Future maintenance projects are discussed in section 4.4.

Attachment point replacements

As stated in subsection 2.2.3, an increasing number of insulator attachment points on towers are showing significant signs of corrosion and wear. Annual maintenance projects have been carried out recently to replace attachment points. These will continue through RCP2 and constitute a significant strategy.

Steel and bolt replacement

Condition assessment has shown that numerous towers have some bolts and members that are severely corroded, while the majority on the tower are in reasonable condition. Targeted replacement of only those members and bolts that are severely corroded can ensure that structural integrity is maintained, and can delay (more costly) painting of the tower for several years.

Bird deterrents

Bird ‘streamers’ can cause insulation to flashover resulting in circuit trips. The flashovers occur when large birds perch above an insulator and then defecate as they take off. The incidence of such flashovers has increased in recent years and appears to be related to the increase in dairy conversions and irrigation use. The installation of bird deterrents or shrouds above insulators has proved to be an effective method of improving circuit performance. To date, some 3,300 pole structures and 2,400 tower structures have deterrents fitted.

Signage and climbing deterrents

Fit for purpose signage and climbing deterrents are required to deter members of the public from climbing transmission line towers and poles. Some 9,600 tower structures are currently fitted with climbing deterrents. Maintenance works have ensured that these climbing
deterrents remain effective and are installed on recently identified at-risk structures as noted in subsection 2.2.1.

**Fall arrests**

Fall arrests are progressively being installed on towers to provide a safer working environment for staff and contractors who need to scale these structures. The programme is risk-based, and focuses on towers that have particularly large spacings between members, and those that are forecast to require frequent climbing in the foreseeable future.

**Historic spend – maintenance projects**

Table 7 provides an overview of historic maintenance project expenditure on preventive maintenance, repairs and fault response. Future maintenance projects are discussed in section 4.4.

<table>
<thead>
<tr>
<th>Activity</th>
<th>2009/10</th>
<th>2010/11</th>
<th>2011/12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attachment point replacements</td>
<td>$2,000,000</td>
<td>$2,600,000</td>
<td>$1,900,000</td>
</tr>
<tr>
<td>Bird deterrents</td>
<td>$416,000</td>
<td>$751,000</td>
<td>$147,000</td>
</tr>
<tr>
<td>Signage and climb deterrents</td>
<td>$131,000</td>
<td>$252,000</td>
<td>$123,000</td>
</tr>
<tr>
<td>Steel and bolt replacements</td>
<td>$2,200,000</td>
<td>$3,000,000</td>
<td>$2,500,000</td>
</tr>
<tr>
<td>Various</td>
<td>$1,400,000</td>
<td>$1,700,000</td>
<td>$520,000</td>
</tr>
</tbody>
</table>

Table 7: Historic Expenditure on Maintenance Projects

### 2.2.6 Interaction with Other Assets

Programmes of work for tower and pole assets are closely aligned with conductor, insulator, and foundations work, as any of these asset fleets will interact with tower and pole assets.

Projects involving enhancement of existing lines generally include several of the following actions:

- detailed structural design and capacity checking
- tower strengthening
- tower replacement
- tower raising
- pole replacements.

Lines are uprated by installing larger conductors or by raising the maximum operating temperature of the line.

Raising the operating temperature increases conductor sag. If existing clearances to ground are already at statutory limits, structures must be raised to enable the increased temperature. Alternatively, conductor tension could be increased.

Larger conductors and/or higher tensions increase loads on structures. Detailed checks are carried out to ensure the structures comply with the requirements of current loading and design standards. Towers often require strengthening to ensure appropriate levels of reliability are maintained. In extreme cases, strengthening is not practical or cost-effective. In these instances, a new stronger tower will be constructed. Poles are never strengthened,
as it is always more cost-effective to simply replace them with stronger structures if required. Pole replacements that are required to support increased conductor loading are included as part of the overall project for re-conductoring a line.

An integrated works planning (IWP) process allows for coordination to minimise disruption and reduce costs.

2.3 Asset Performance
This section describes the historic reliability and safety and environmental performance of towers and poles together with any associated risks and issues.

2.3.1 Reliability
Achieving an appropriate level of reliability for our asset fleets is a key objective for us, as it directly affects the services received by our customers. Reliability is measured primarily by the frequency and length of outages.

The main tower and pole asset risks that impact on reliability are major structural failures. These have the potential to result in conductor drops that can cause significant outages and pose serious safety hazards. Other network reliability issues include bird interference leading to circuit tripplings.

Towers
With established modern design practices and a good history of performance, the probability of tower collapse is low. The number of tower failures recorded since 1963 is 53 (as at 30 June 2012). Of these, 12 are classified as foundation failures resulting from inadequate foundations and another 4 due to river encroachment and flooding. The balance can be classified as tower failures caused by structural failure of tower members. In the last 10 years, 11 towers have failed in 7 separate events. The latest, in 2012, was due to a tree falling onto a line near Taupo during a storm. Fourteen tower failures, all on the HVDC transmission line, are generally attributable to exceptional wind conditions.

Poles
Failure history indicates that the probability of pole structure failure is low. Although there are approximately 15,600 installed pole structures, only 28 pole or crossarm failures have occurred in the last 20 years, with 12 occurring in the last 10 years. It should be noted that a number of these are attributable to extreme weather events leading to conditions in excess of current design loads.

A significant number of degraded hardwood poles were replaced in the mid- to late-1990s as they had reached replacement criteria. The replacement of wooden structures with concrete poles (with steel arms) has dramatically reduced the incidence of pole top fires.

2.3.2 Safety and Environmental Performance
As discussed in subsection 2.3.1, a number of tower and pole failures have resulted in conductor drops.
2.3.3 Performance Benchmarking

International Transmission Operations & Maintenance Study (ITOMS) involves performance comparisons (including reliability) between 27 utilities. ITOMS considers overall transmission line performance rather than on an asset-type basis such as tower and pole structures. This overall performance is considered in the Conductors and Insulators fleet strategy.

2.3.4 Risks and Issues

This subsection briefly discusses identified risks and issues relating to the characteristics, condition, performance and management of the tower and pole asset fleets.

Strategies to address these risks and issues are set out in chapter 4.

Long-term management of tower asset health

The current painting programme is constrained by the available resources, and the volumes painted each year are currently less than the volumes that our model indicates are economically optimal. The model shows that a significant increase in the annual volumes of tower painting is required, to keep pace with the degradation of galvanised surfaces and to avoid the build-up of a large backlog of overdue work.

A further factor affecting the long-term maintenance of asset health is that an increasing proportion of the annual tower painting effort will be re-coating towers rather than applying a first coat. So the number of towers protected by their first application of paint does not increase linearly with the painting effort over time.

However, the long-term forecasts of painting volumes required in the RCP3 and RCP4 periods are sensitive to the steel degradation model. Small deviations between the modelled and actual rate of degradation can significantly change the required volumes of towers requiring an initial paint. The forecasts are also sensitive to small inconsistencies in the assessment of condition.

These factors inevitably lead to some uncertainty in the longer-range forecast, and the optimum future annual volumes may prove to be less than currently indicated by our existing model. Work will continue during RCP2 to improve the asset health model and long-range degradation forecasts, as outlined in subsection 4.6.1.

The risk of long-term deterioration in the overall asset health of towers and an increasing backlog of work and associated future costs are mitigated by the preferred tower painting approach set out in the strategies in chapter 4.

Tower insulator attachment points

The structural strength and condition of attachment points must be maintained at a suitable level to avoid the risks of attachment point and insulator failures leading to conductor drop.

Experience has shown that if attachment point fasteners become too corroded, the entire crossarms have to be lowered to ground level to remove the fasteners, with consequential effects on the time and costs for replacement, and the planned outages required to undertake replacements.

There is a substantial ongoing programme of work in replacing deteriorated insulator attachment points. The strategies set out in chapter 4 mitigate the risks of failures caused by
attachment points and avoid the build-up of an increasing backlog of work and associated future costs.

**Tower failure**

Towers are designed to withstand severe climatic loading and, as a result, the probability of structural failure under most environmental conditions is very low. There is a good history of reliable performance.

Yet the consequences from a tower failing can be significant. The severity of the consequences can depend on:

- the specific local environment (such as road crossings, urban areas and rural zones)
- the power system (such as the number of circuits and power transfer requirements)
- whether advanced knowledge of the impending failure is possible (such as if a tower is known to be at risk of failing, the system can be reconfigured to minimise any interruption to supply, and the local environment can be cordoned off).

The criticality framework will be further developed (as outlined in subsection 4.6.1) to provide improved prioritisation of asset management activities for towers so that we can respond to the potential consequences of failure at each location.

**Pole failure**

Failure history indicates that the probability of a pole structure failure is low. The high reliability is due to our condition assessment process, regular review and identification of at-risk poles, and our ongoing pole replacement programme.

The consequence of a pole structure failing is specific to:

- the local environment
- the power system (such as the number of circuits and power transfer requirements)
- whether the failure is able to be planned for in any way (such as if a pole structure is known to be at risk of failing, the system can be reconfigured to minimise any power outage, and the local environment can be cordoned off).

Possible consequences include fire on public or private land, electrocution, physical damage to people and property and loss of power supply.

Pole replacement strategies are set out in subsection 4.1.2.

**Tower data/information**

Insufficient and/or inaccurate tower data/information can lead to poor asset monitoring and subsequent unexpected degradation of the asset fleet. Collecting and maintaining quality asset data is critical to inform good asset management decisions.

Steel condition scores in the tower data have been recognised as lacking some detail. This issue has been identified and, as discussed in subsection 2.2.4, clearer criteria were introduced in 2012 that will provide greater score visibility than the current averaged score.
Underbuild and land use near structures

We are somewhat unusual compared to similar overseas utilities, in that very few of our lines have easements. As such, we have limited control over land use beneath or beside our transmission line structures. Many buildings have been constructed immediately adjacent to transmission structures. Inappropriately sized trees are planted beneath or very close to structures, even in commercial forests. These issues all increase risk to the public, property and to the Grid.

Considerable ongoing effort is required to engage with stakeholders and manage the clearance distances around structures to avoid vegetation/human-related influences resulting in flashover, and to maintain appropriate access to the structure for maintenance.

Birds

Bird streamers and nests can cause line faults. The increase in dairy farming has seen an increase in bird-related faults. Bird deterrents are being installed on structures where birds are a particular problem.

Climbing

Since 2005, inspection and maintenance workers climbing the transmission towers have been required to be permanently attached. In the absence of a fall arrest system, the double lanyard method is used. This method is based on the ‘attach before detach’ principle.

Where structures do not have appropriate attachment positions for double lanyard climbing due to widely spaced steelwork, fall arrest systems are being progressively installed. A number of international utilities are eliminating the double lanyard method of climb by installing cable fall arrest systems.

We are fitting fall arrest systems to new lines, and have commenced a programme of work to retrofit fall arrest systems to structures on a risk basis, and focusing on those requiring frequent access. Our strategy is further outlined in subsection 4.4.3.

Safety of tower painting

Working at height painting towers requires careful management of safety hazards. There is also increased risk to painting crews when a tower is severely corroded due to the increased time the workers are required to abrasive blast. A number of injuries have occurred in the past while blasting our towers, including one fatality. Improvements to work practices and equipment have helped to mitigate the risk.

Step and touch and transferred potential

We have an ongoing programme of risk assessment for existing sites. For sites assessed as high risk under the EEA Guide to Power System Earthing Practice 2009, we investigate further and plan the implementation of risk mitigation measures. These measures typically include installing fences or vegetation around structures to reduce the likelihood of people touching the transmission line structures, and/or installing an insulating layer of asphalt around the structure.

Our strategy for assessment and mitigation of risks associated with step and touch and transferred potential is further outlined in subsection 4.4.3.
Diversity

Diversity within the tower fleet is a significant consideration for asset management, particularly in terms of recovery from failure. The risk arising from the wide range of tower structures and components in service is mitigated by the availability of temporary towers. These temporary structures provide an interim solution to allow the time required to undertake permanent repairs or replacements that take into account the often unique tower configurations at individual locations.

In regard to the pole asset fleet, diversity is not a major issue because poles of different types are largely interchangeable as long as appropriate crossarms are used.
3 OBJECTIVES

Chapter 3 sets out asset management related objectives for the tower and pole asset fleets. As described in section 1.4, these objectives have been aligned with our corporate management objectives, and higher-level asset management objectives and targets as set out in the Asset Management Strategy.

Our overarching vision for the towers and poles fleet is to maintain the integrity and reliability of the structures and the conductors they support. Specific objectives have been defined in the following five areas:

- Safety
- Service performance
- Cost performance
- New Zealand communities
- Asset management capability.

These objectives are set out below, while the strategies to achieve them are discussed in chapter 4.

3.1 Safety

We are committed to becoming a leader in safety by achieving injury-free workplaces for our employees and to mitigating risks to the general public. Safety is a fundamental organisational value and we consider that all incidents are preventable.

**Safety Objectives for Towers and Poles**

- Zero injuries caused by tower or pole failures.
- No falls from heights involving towers or poles.
- Zero injuries requiring medical treatment for workers who climb or work on towers and poles.
- No unauthorised tower climbing.
- The risk of injury to members of the public from step and touch potential is as low as reasonably practical.

Recognising the reduced level of control we have in relation to public safety, we will take all practicable steps to ensure transmission line assets do not present a risk of serious harm to any member of the public or significant damage to property.
3.2 Service Performance

Ensuring appropriate levels of service performance is a key underlying objective. The overall service performance objectives for the Grid in terms of Grid Performance (reliability) and Asset Performance (availability) are set out in our Asset Management Strategy.

Grid performance objectives state that a set of measures are to be met for Grid Exit Points (GXP) based on the criticality of the connected load. In addition, asset performance objectives linked to system availability have been defined. These high-level objectives are supported by a number of fleet specific objectives, and we will work towards these being formally linked in the future.

**Service Performance Objectives for Towers and Poles**

- Tower failure rate of one failure per annum or less.
- Pole or crossarm failures of one or less each year, excluding those events that exceed the current design loads. Currently this is 1.4 each year over last 20 years.
- Maximise availability by using live line techniques where it is practical, safe, and cost-effective to do so.

3.3 Cost Performance

Effective asset management requires optimising lifecycle asset costs while managing risks and maintaining performance. We are committed to implementing systems and decision-making processes that allow us to effectively manage the lifecycle costs of our assets.

**Cost Performance Objectives for Towers and Poles**

- Achieve improved efficiency through extension of the planning horizon.
- Design, construct, and maintain towers and poles to minimise lifecycle costs, while meeting required levels of performance.
- Minimise cost of capital and maintenance projects through long-term, third-party resource planning.
- Minimise cost of works by packaging work into blocks of consecutive structures wherever possible.
3.4 New Zealand Communities

Asset management activities associated with the towers and poles fleets have the potential to impact on both the environment and on the day-to-day lives of various stakeholders. Relationships with landowners and communities are of great importance to us and we are committed to using asset management approaches that protect the natural environment.

### Environmental Objectives for Towers and Poles

- No significant environmental damage due to tower and pole works such as tower painting.
- Recycle redundant materials (including tower steel and poles) wherever possible.
- As a minimum, comply with the environmental requirements associated with any resource consent.
- No damage to third party property due to tower or pole failures.
- Minimise stakeholder disruption by packaging work into blocks of consecutive structures wherever possible.
- Maintain effective relationship with stakeholders affected by tower and pole works, including rectification of any damage caused by tower and pole works.

3.5 Asset Management Capability

We aim to be recognised as a leading asset management company. To achieve this, we have set out a number of maturity and capability related objectives. These objectives have been grouped under a number of processes and disciplines that include:

- Risk Management
- Asset Knowledge
- Training and Competency
- Continual Improvement and Innovation.

The rest of this section discusses objectives in these areas relevant to the towers and poles fleets.

3.5.1 Risk Management

Understanding and managing asset-related risk is essential to successful asset management. We currently use asset criticality and asset health as proxies for a fully modelled asset risk approach.
Asset criticality is a key element of many asset management systems. We are currently at an early stage of developing and implementing the framework as we work towards formal and consistent integration of asset criticality into the asset management system. We have commenced this by prioritising fleet replacement expenditure programmes, based on the model outputs.

### Risk Management Objectives for Towers and Poles

- Finalise and implement consistent and systematic safety and network criticality framework for tower and pole applications.
- Continuously improve the asset health modelling of towers and poles.
- Continue and improve the asset management approach that is differentiated by criticality.
- Develop a risk-based model for assessing the trade-offs between different work methods (such as live line techniques), including the risk-weighted cost of circuit unavailability (the cost of outage or increased chance of outage due to reduced redundancy).

#### 3.5.2 Asset Knowledge

We are committed to ensuring that our asset knowledge standards are well defined to ensure good asset management decisions. Relevant asset knowledge comes from a variety of sources including experience from assets on the Grid and information from the manufacturers. This asset knowledge must be captured and recorded in such a way that it can be conveniently accessed.

### Asset Knowledge Objectives for Towers and Poles

- Complete first round of improved condition assessment data collection for tower steel and bolts (covering all structures by the end of RCP2).
- Enhance the failure and incident records system to improve consistency and usefulness of data, including root cause analysis.
- Continued improvement of condition assessment consistency through enhanced guidelines (such as photographic examples, including components).

#### 3.5.3 Training and Competency

We are committed to developing and retaining the right mix of talented, competent and motivated staff to improve our asset management capability.

### Training and Competency Objectives for Towers and Poles

- All tower and pole works to be carried out by service providers who are suitably qualified and competent for the specific tasks required.
- Sufficient quantity of trained personnel available to implement the planned works.
- Increase tower painting service provider resources by at least 20% over RCP2.
3.5.4 Continual Improvement and Innovation

Continuous improvement and innovation are important aspects of asset management. A large source of continual improvement initiatives will be ongoing learning from our asset management experience.

**Continuous Improvement and Innovation Objectives for Towers and Poles**

- Monitor and explore international trends and knowledge in tower painting products and techniques.
- Monitor international developments with regard to the use of composite materials in pole structures and crossarms.
4 STRATEGIES

Chapter 4 sets out the fleet specific strategies used to manage tower and pole assets. These strategies are designed to support the achievement of the objectives in chapter 3. They reflect the characteristics, issues and risks identified in chapter 2 and provide medium-term to long-term guidance and direction for our asset management decisions.

The strategies are aligned with the lifecycle strategies below and the chapter has been drafted to be read in conjunction with them.

- Planning Lifecycle Strategy
- Delivery Lifecycle Strategy
- Operations Lifecycle Strategy
- Maintenance Lifecycle Strategy
- Disposal Lifecycle Strategy

This chapter also discusses personnel and service provider capability related strategies which cover asset knowledge, training and competence.

Scope of strategies

The strategies focus on expenditure that is planned to occur over the RCP2 period (2015–2020), but also include expenditure from 1 July 2013 to the start of the RCP2 period and some expenditure after the RCP2 period (where relevant). Capex planned for the RCP2 period is covered by the strategies in sections 4.1 and 4.2, and opex is covered by the strategies in sections 4.3 to 4.6. The majority of the capex consists of asset replacements, as described in subsection 4.1.3.

4.1 Planning

This section describes our strategies for the planning lifecycle for the tower and pole asset fleets.

Planning activities

Planning activities are primarily concerned with identifying the need to make capital investments in the asset fleet. The main types of investment considered for this fleet are enhancement and development, replacement and refurbishment.

We support these activities through a number of processes, including:

- Integrated Works Planning (IWP)
- cost estimation.

The planning lifecycle strategies for the towers and poles fleets are described in the subsections below.
Capex investment drivers

Categories of capital investment generally have specific drivers or triggers that are derived from the state of the overall system or of individual assets. These drivers include demand growth, compliance with Grid reliability standards, safety and failure risk (indicated by asset criticality and health measures).

Specific examples that drive capital investment in tower and pole assets include:

- new line developments or uprating of existing circuits, driven by demand
- tower painting, driven by asset condition
- structure replacement, driven by failure risk.

The first step in the planning phase is identifying the asset investment required to meet our asset management objectives and policy. The generalised process for planning tower and pole works, as shown in Figure 15, summarises the approach used to identify required investment. The process is mainly driven by asset condition and development plans such as those contained in our Annual Planning Report. These drivers are discussed further in the following subsections.

**Figure 15: Process map for planning work on towers**
4.1.1 Enhancement and Development

This subsection describes enhancement and development investments for the tower and poles fleets. A key driver for new tower or pole investments is the requirement for new or strengthened structures to support new conductors required in growth or reliability driven projects. These enhancement and development projects mainly include new greenfield transmission projects and the uprating of lines, which may require stronger structures.

Modification of existing towers for upgrade projects

Modify existing towers, including strengthening, raising and relocating to enable larger conductor or thermal upgrades.

Towers supporting a line undergoing re-conductoring may require strengthening or raising due to:

- heavier conductors or higher tensions being used
- the need to maintain clearance standards and other regulatory requirements.

Over the RCP2 period, we will install a number of new tower and pole structures and modify a number of towers as part of enhancement projects. The cost for this work will be included in the relevant conductor projects, and any ongoing asset management costs following their installation will be managed through the relevant portfolios. For further details on these works, see the fleet strategy for conductors.

4.1.2 Replacement and Refurbishment

Replacement is expenditure to replace substantially all of an asset. Refurbishment is expenditure on an asset that creates a material extension to the end of life of the asset. It does not improve its attributes. This is distinct from maintenance work, which is carried out to ensure that an asset is able to perform its designated function for its normal life expectancy.

Condition-driven projects

Replacement and refurbishment of tower and pole assets are primarily triggered by asset health data which forecasts remaining life and reflecting asset condition. Specific interventions have been defined for tower and pole assets based on their condition and informed by their relative criticality. As discussed in subsection 2.2.3, the condition scores are on a scale from 0 to 100 where 100 is new. When a score of 20 is reached, it is generally considered necessary to replace or refurbish the asset.

Our approach is consistent with those used by peer utilities. The investment criteria have been defined to support the objectives discussed in chapter 3 and have been selected to achieve the optimum time to refurbish or replace the structure. An example of the type of modelling used is provided in Appendix B, which shows the optimisation of tower painting interventions.

Towers

The most significant challenge in maintaining an ageing fleet of steel towers is managing corrosion. As discussed in subsection 2.2.3, a significant number of towers are degrading to
the point where intervention is required to cost-effectively mitigate the risk of failure. Four options for intervention are:

1. protecting the tower’s steelwork with a protective paint layer prior to the state where replacement is required
2. allowing the tower to corrode to a state where replacement is required
3. decommissioning the line
4. replacing the tower with an improved tower.

For the purposes of this subsection, only the first two options are considered further.

**Tower painting**

Paint towers prior to significant rusting based on CA scores and re-paint prior to paint failure.

The Tower Painting Strategy (TP.TL 01.01) published in late 2010 incorporated the first formal model of the long-term effect of corrosion on the tower fleet. The investigation considered options for cost, safety and environmental impacts and concluded that:

- painting has lower lifecycle costs than replacement
- the optimum time to paint is dependent on the corrosiveness of the environment (that is, the corrosion zone)
- a significant increase in the number of towers painted each year needed to occur to minimise lifecycle costs across the fleet.

**Lifecycle cost model**

We have further developed this analysis and updated the lifecycle cost model to establish the optimum time to apply the paint. Our analysis is summarised in Appendix B. The model now includes six corrosion zones (four used previously) and updated costing data.

Generally the strategy remains unchanged from 2010. Future improvements to paint technology may increase coating life which would further reduce the lifecycle cost of the painting strategy. Four key aspects of the strategy are:

- tower painting continues to have lower lifecycle cost than replacement
- by managing the impact of corrosion through painting, the life of towers can be extended indefinitely, provided they are re-painted prior to significant paint failure occurring
- newer, better condition towers should be left to age, allowing them to reach the optimum condition for painting
- towers should be painted before the condition goes significantly beyond the economically optimum point, to avoid excessive future costs for maintaining overall asset health.

Table 8 lists the optimum condition codes at which to paint, for each corrosion zone as derived from the model.
Corrosion Zone | Condition | Typical age at first paint (years)
--- | --- | ---
Extreme | CA 50 | 13
Very Severe | CA 40 | 20
Severe | CA 40 | 35
Moderate | CA 30 | 56
Low | CA 30 | 78
Benign | CA 30 | 111

Table 8: Optimum condition for first paint application

Long-term forecast of painting requirements

If the most recent condition scores for all towers in the fleet are adjusted for the expected deterioration since the date of their last assessment, then the model indicates that about 1,300 towers are already past the optimal point for painting. These towers will be targeted as a priority for painting because costs escalate rapidly as condition falls below this point (see Table 9).

The tower painting forecast model indicates that, with no constraints applied, the optimum annual average tower painting requirement is 780 towers each year, for the period up to 2029/30. The model forecast is shown in Figure 16. The chart also shows the demand for tower painting increasing rapidly as the fleet ages and painted towers become due for re-coats.

![Figure 16: Long-term Unconstrained Tower Painting Plan](image)

Figure 16 shows the unconstrained tower painting plan, where towers identified as 'Now Due' are painted as soon as possible and all other towers are painted in the optimal year. The estimated average annual cost of an unconstrained plan is approximately $63m each year for the period 2013/14 to 2029/30. This estimate is based on an initial paint of about 7,300 towers at an average cost of $95,000, and re-coating of about 5,800 towers at an average cost of $65,000.
Long-term consequences of alternative painting plans

Appendix C presents an analysis of the long-term consequences of different painting plans on the likelihood of structural failure of towers. Tower painting modelling assumes re-coats occur on time according to the re-coat periods defined for each corrosion zone in Appendix B, therefore no paint coat failure is currently modelled. Below are our four main conclusions from this analysis.

- Minimum present cost of painting (excluding direct and indirect cost of tower failure) occurs when painting about 300 towers each year. However, this level of painting, if sustained, results in a significant proportion of the fleet (about 85%) being at high likelihood of long-term structural failure.

- If a long-term target of 0 tower failures each year is desired, the optimal (unconstrained) paint quantity of approximately 780 each year through to 2029/30 results in the minimum present cost. This result is expected, as the optimal paint plan involves optimising the lifecycle painting cost for individual towers.

- The overall long-term trend for a painting plan averaging less than about 500 towers each year is a steep increase in the proportion of towers with a high likelihood of structural failure. The rate of increase slows after approximately 2040, as a large percentage of the fleet becomes painted.

- Tower painting plans averaging above 500 towers each year result in a lower long-term increase in the proportion of towers with a high likelihood of structural failure.

Ensuring deliverability

The ‘unconstrained’ painting plan shown in Figure 16 is not deliverable because of the current lack of sufficient certified tower painters. In the year 2011/12, only 283 towers were painted. As a result, towers are being painted later than ideal, at increased lifecycle cost. In particular, there is a significant shortfall of painters available in the lower North Island, which has a large number of towers located in severe and very severe environments.

We have put considerable effort into developing the available painting resource in recent years. Safety performance is a primary consideration, with the engagement and performance monitoring of contractors. Where safety performance issues have been identified, works have been suspended until these issues are resolved. This has impacted on the volumes completed in the past 2 years.

Subsection 4.2.2 provides more information on the procurement strategy for tower painting.

Developing the nominal painting plan – with constraints

Figure 17 shows the proposed annual expenditure on tower painting presented in real 2012/13 dollars, taking into account the constraint on the availability of tower painters. The forecast increase in expenditure is directly proportional to the predicted sustainable growth in available painting resource. There are currently 110 fully competent painters, and this is

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2 There is limited direct correlation between asset health and structural performance. Asset health is not readily linked to the probability of failure until a condition score of CA 20 or below is recorded, and is currently only applicable to unpainted towers.
forecast to increase to 140 by 2015. We will need a further increase of 35% to 190 fully competent painters by 2020, to deliver the submitted plan.

Given the constrained resource (and so expenditure), the planned number of towers to be painted each year is shown in Figure 18.

The nominal plan produced by the tower painting forecast model involves painting about 2,700 towers over the next 7 years (409 each year on average over RCP2), comprising about 1,500 first paints and 1,200 re-coats. This is significantly below the unconstrained plan requirement of 780 each year over the period to 2029/30. Costs are discussed further below.

Below we note four key assumptions used to determine the constrained and unconstrained plans.
• If previously unpainted, tower steel is returned to condition CA 60 upon painting. For painted towers, the surface preparation, including removal of corrosion and sandblasting, returns the tower steel to condition CA 60.

• Re-coating towers in the specified re-coat year carries the highest priority, as late re-coating incurs significantly higher costs and is environmentally damaging as large quantities of old paint are blasted off (see Appendix B for assumed re-coat periods).

• If a painted tower is not re-coated by the specified re-coat date, then the tower steel degrades from CA 60 at a rate consistent with the degradation rate of an unpainted tower in the same corrosion zone.

• Painting prioritisation is based on the tower painting priority matrix in Figure 19, which balances remaining life (if tower is at or below optimal painting condition) and criticality. Due to heightened risk of failure, towers identified as ‘Now Due’ carry a higher priority than a high-criticality tower just reaching optimal paint condition.

Figure 19: Tower Painting Priority Matrix

Painting costs

Painting costs have risen significantly in recent years, due mainly to increased preparation requirements. Previous approaches to tower painting assumed that zinc corrosion product could be painted over without adversely affecting the paint life. However, premature coating failures resulted, requiring the full removal of the old paint system prior to re-painting.

To ensure adequate paint system life, all zinc corrosion product is now removed, along with any rust, by abrasive blasting to meet paint manufacturers application specification. To date, coatings on towers prepared in this manner are performing very well.

The average out-turn painting cost for each tower varies depending on three factors:

1. whether the tower is being re-coated or being painted for the first time
2. the steel condition for unpainted towers or paint condition for painted towers
3. tower size.

The extent of preparation work and associated cost to paint a tower increases as the tower condition deteriorates. Towers in ‘as new’ condition, or painted towers with good paint condition simply require a wash prior to painting. As towers deteriorate, the amount of full abrasive blasting and sweep blasting increases. When a tower is rated at CA 40, a few bolts

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3 Overseas utilities typically paint towers before corrosion product is noticeable, but the age and condition of our fleet requires painting after corrosion has formed, significantly increasing the cost.
may require replacement (bolts tend to rust before steel members due to their thinner galvanising coating). At CA 30, approximately $25,000 of bolts and minor steelwork may require replacement prior to painting. Below CA 30, it is likely that all bolts, numerous minor members and some major members will require replacement.

Table 9 lists the tower painting costs (for each tower) at various condition codes used to derive the optimum painting plan. These have been derived from average out-turn costs of numerous completed projects on the tower fleet. The table shows the increase in costs for preparing and painting a tower as the tower deteriorates.

The table lists the values used for modelling tower painting costs.

<table>
<thead>
<tr>
<th>Description</th>
<th>220 kV Single Circuit</th>
<th>220 kV Double Circuit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Re-paint</td>
<td>52,000</td>
<td>72,000</td>
</tr>
<tr>
<td>Paint CA 100</td>
<td>40,000</td>
<td>55,000</td>
</tr>
<tr>
<td>Paint CA 90</td>
<td>42,000</td>
<td>58,000</td>
</tr>
<tr>
<td>Paint CA 80</td>
<td>44,000</td>
<td>61,000</td>
</tr>
<tr>
<td>Paint CA 70</td>
<td>47,000</td>
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<tr>
<td>Paint CA 20</td>
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<td>165,000</td>
</tr>
<tr>
<td>Replace</td>
<td>250,000</td>
<td>300,000</td>
</tr>
<tr>
<td>Replace Inc. Foundation</td>
<td>300,000</td>
<td>350,000</td>
</tr>
</tbody>
</table>

Table 9: Tower Painting Costs

Cost estimation for tower painting works is an example of volumetric forecasting (see subsection 4.1.4). Like other volumetric estimates, tower painting costs are estimated using the Transpower Enterprise Estimation System (TEES) (US Cost) system. The assumptions made in using the average out-turn cost include:

- the completed costs from previous works
- the impact of historic project risks for tower painting are captured by out-turn costs
- the proportion of sites in typical environment (those not requiring specific environmental compliance actions) remains constant
- the proportion of sites located within regional zones not requiring full-time accommodation or excessive daily travel remains constant
- the proportion of cost incurred due to access and site topography remains constant.

Comparing the nominal and actual plans

The nominal plan for tower painting is derived from our tower painting forecast model.
As outlined above, the model shows that there is a significant backlog\(^4\) of painting. Our programme of tower painting is constrained by limited availability of competent service providers.

The model determines the priority of towers to be painted and allocates the available resources to the highest priority towers (where priority is based on asset health and criticality).

The model uses standard costings for painting based on the parameters of a single or double circuit structure type, and its forecast condition. The costings used in the model are based on our actual experience to date, but are an average across the population of tower types. In addition to this, the re-paint cost used in the model only varies due to tower size and does not take into account the condition of the paint at time of re-painting.

The model has a single focus of identifying specific towers based on limited selection criteria, excluding issues such as creating blocks of work, landowner entry approvals, seasonality and regional resource availability. This leads to a simplistic modelling assumption that individual towers can be painted in a strict order of priority irrespective of their location in New Zealand.

Our proposed plan for tower painting takes the prioritised outputs from the tower painting forecast model, and adjusts the plan to allow for aggregation of work (reducing mobilisation costs and satisfying landowner requirements of ‘one entry only’), and the effects of regional constraints (resource availability, seasonal weather variation and accessibility). The consequence of aggregation of work is that some towers in the work packages are painted slightly earlier than the theoretical model forecasts, yet overall lifecycle costs are maintained if not reduced by the benefits of aggregation. The towers have a similar lifecycle cost to paint, because of reduced costs in preparing and optimising mobilisation and demobilisation costs. Further, the proposed plan is based on the actual experience of the costs of tower painting where aggregation has led to efficiencies.

The nominal plan produced by the model forecasts that 409 towers each year can be painted for an average annual expenditure of $37.4m through the RCP2 period. However, the proposed RCP2 plan is that an average of 530 towers can be painted for the same budget given the efficiencies of aggregating work and the use of a wider family of building block cost estimates that are reflective of the work that must be undertaken for each project.

Our expenditure and volume forecasts for RCP2 are based on the proposed plan.

At present, our tower painting forecast model does not have the capability to include regional resource constraints, or the opportunities for efficiency in aggregating work. We will continue to develop the model during the rest of RCP1, including considering regional resource constraints and the opportunities for efficiency in aggregation of work. Other improvements will include refining the costing inputs, including allowing for modelling of re-paint cost based on the condition of the existing paint coating.

\(^4\) The term ‘backlog’ refers to the quantity of towers that the modelling process shows are past the time of least lifecycle cost for painting.
Summary of tower painting forecast costs and volumes

We plan to spend $187.2m on tower painting over RCP2. This is based on painting an average of 530 towers each year.

Asset health forecasts

The tower painting programme effectively introduces a new asset (tower paint) to the portfolio. So describing the effect of the tower painting programme on the tower steel asset health alone is not sufficient. An asset health forecast is also required for the applied protective coating. Separate asset health forecasts for the tower steel and the tower paint are given below.

The modelled effect of the proposed (constrained) painting plan on tower steel asset health/remaining life is shown in the charts in Figure 20. This contrasts with the effect on asset health of not performing any painting work, and allowing the remaining unpainted towers to degrade.

The estimated effect of the painting plan on tower paint remaining life is shown in the charts in Figure 21. For unpainted towers, ‘paint remaining life’ represents the number of years until painting is required. For painted towers, it represents the number of years until a repaint is required.

Conclusions

The above figures demonstrate that the proposed painting plan will not fully eliminate towers identified as ‘Now Due’ by 2020. To do so would require significantly more towers to be painted each year, which is not feasible with the current painting resource.
Towers in poor condition will be painted as soon as possible when the additional painting resource becomes available. Improvements in painting efficiency and paint products must also be sought at every opportunity. It may be more cost-effective to replace smaller towers with poles than to paint them and refurbish their grillage foundations. See the separate strategy under ‘Poles’ below.

Painting as many towers as we can (up to the optimal quantity) is necessary if we are to achieve the service performance objective of limiting tower failure to one failure each year or less. See Appendix C for an overview of the long-term effect of various tower painting plans on the likelihood of tower failure.

Planned divestments will lead to a reduction in the number of older towers in the fleet. Assets that are likely to be divested are treated as a lower priority for painting.

**Predictive corrosion/painting model**

Continually update the model used to predict future tower condition, remediation options and costs.

As discussed in subsection 2.2.4, we have continued to gain knowledge with regard to painting and corrosion rates. We have incorporated these rates into the current painting model. For example:

- the number of corrosion zones has been increased from 4 to 6 to better account for those towers located in extremely corrosive or benign environments
- actual degradation rates are continually monitored and towers re-assigned to other zones if the actual rates differ markedly from those predicted in the model
- new, clearer condition assessment criteria were introduced in 2012, for unpainted and painted steel (these will define the actual tower condition more clearly, rather than averaging the findings)
- increased costs associated with secondary preparation requirements have been incorporated into the current model.

While there is some uncertainty around the conservatism of the model’s outputs in relation to degradation, this will not affect the plan in the short term because significantly fewer towers can be painted annually than the model requires. With time and experience, the model’s predictions in relation to condition and painting costs should increase in accuracy. Furthermore, significant effort will continue to be placed on ensuring data is collected in a consistent and accurate manner.

As outlined above, we will continue to develop the model during the remainder of RCP1, including consideration of regional resource constraints and the opportunities for efficiency in aggregation of work. Other improvements will include refining the costing inputs and modelling of paint coating failure.

It should be noted that currently, and in the foreseeable future, towers are only ever painted based on actual condition, not on a modelled prediction. Modelling is used to determine the likely resource requirements and to quantify the long-term benefits in terms of fleet condition.
**Tower replacement**

Replace towers at risk of failure due to unstable ground or slips, or when they have failed.

Every year we closely monitor several towers identified as being at risk of failure due to unstable ground or slips. In some instances the ground can be stabilised by earthworks, while in others the better option is to relocate the structure. The existing structure can often be relocated onto new foundations, provided it has sufficient capacity and height.

In rare instances, a tower will collapse and require replacement. For example, in 2012 a tree fell onto a conductor on the BPE-WRK A line in a planted forest. The tower was damaged beyond repair and was replaced.

The strategy supports our safety and service performance objectives.

On the basis of condition assessment information, we have identified the need to replace 10 towers during RCP2, at a total cost of $2.2m ($440,000 each year).

**Tower works prioritisation**

Prioritise the painting of towers, taking into account existing health, asset criticality and degradation rate.

We have developed an integrated risk based prioritisation approach for tower works. The following factors will be used to prioritise tower works: AHI, and asset criticality.

This approach ensures that the risks associated with tower works are appropriately factored into prioritisation decisions. As detailed above, painting prioritisation balances remaining life (if tower is at or below optimal painting condition) and criticality. Due to heightened risk of failure, towers identified as ‘Now Due’ carry a higher priority than a high criticality tower that is just reaching optimal paint condition.

**Pole strategies**

**Pole replacements**

Replace poles just before they have degraded to a point where they can no longer support their design loads, or where it is prudent to do so due to ground instability.

Poles and associated components are subject to annual inspections and condition assessments. The steel and concrete poles in the fleet are generally in good condition, but a significant number of older hardwood poles are reaching replacement criteria. Accurate calculations of remaining wooden pole strength are made using measurements of below-ground pole diameter. Poles are scheduled for replacement just before being unable to support their design load. We note that this criteria still preserves a factor of safety.

Replacing degraded poles reduces the risk of pole failure, significantly contributing to our safety and system performance objectives. It is also a regulatory requirement - the Electricity Regulations require that any pole found to be unable to support its design loads must be replaced within 12 months.
A significant number of degraded hardwood poles were replaced in the mid- to late-1990s as they had reached replacement criteria. Since then, pole replacement work due to condition has fallen somewhat and remained reasonably constant at around 250 structures annually. Future replacement work is forecast based on replacement of poles that reach end of life at CA 20 for lines where work can readily be carried out de-energised and CA 25 where live line replacement is preferred due to system constraints. It is not safe to climb a pole rated at less than CA 25.

The chart in Figure 22 summarises the forecast replacement schedule. This was developed based on the remaining life rationale presented in subsection 2.2.4.

![POLE REPLACEMENT- ANNUAL QUANTITY](image)

**Figure 22: Forecast Pole Structure Replacements**

The effect of the pole replacement plan on the health of the pole fleet is shown below in Figure 23.

![POLES - ASSET HEALTH (19/20 - PLAN)](image)

**Figure 23: Forecast Pole Asset Health 2019/20**

All poles identified as ‘Now Due’ as at June 2013 will be scheduled for replacement in 2013/14. As shown in Figure 24, this equates to an average annual cost of $5.1m through RCP2 ($27,000 for PI pole and $22,000 for single pole).
Cost and scope estimation for pole replacement works are an example of volumetric forecasting. Our approach to cost estimation is discussed further in subsection 4.1.6.

Like other volumetric estimates, the costs are estimated using the TEES (US Cost) system using formal ‘building blocks’ based on historic cost out-turns from completed, equivalent works in the portfolio.

**Conversion of small towers to poles**

Replace small towers with poles in preference to painting the tower (and refurbishing the grillage), where practicable and cost-effective.

A number of older 110 kV lines have numerous relatively small towers. In many instances, these could be replaced quite readily with standard concrete poles or special steel poles. Not only would replacing them remove or defer the need for painting, it would invariably remove the need for a grillage encasement/refurbishment. This supports our cost performance objective. In addition, landowners often prefer poles to towers because of their reduced (environmental) footprint.

Lines with small towers that are programmed for painting before 2020 will be assessed by mid-2015 to establish if a pole replacement is practical. Site-specific designs will be completed for the new poles. Towers identified for pole replacement can then be left to degrade further (beyond the optimum painting time) before being replaced with the pole.

Assuming the proposed tower painting strategy is followed and the modelling is valid, it is unlikely that any towers will justify replacement with poles in the RCP2 period. If there is an economically justifiable case for replacing a tower with a pole, the cost will be met from the painting and grillage refurbishment budgets.

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5 Details for grillage encasement/refurbishment work are in the Foundations fleet strategy.
**Pole material type**

Use pre-stressed concrete poles wherever practical.

We will use pre-stressed concrete poles wherever practical, given they provide the lowest lifecycle cost solution. The cost of hardwood, steel and concrete are similar, but concrete poles are maintenance-free and last longer than steel or hardwood. Further, quality hardwood poles are becoming increasingly difficult and expensive to source. The recently identified problems with fungus in Peruvian hardwood sleepers used in other New Zealand industries also highlights the risks involved with hardwood assets.

In inaccessible locations where transporting a concrete pole is impractical, a hardwood or steel pole may be used. Likewise, a hardwood pole may be installed in locations to mitigate earth potential rise (EPR) risk. This strategy supports our cost performance and service performance objectives.

**Pole hardware replacement coinciding with pole replacements**

Combine the replacement of poles with related hardware where they meet certain criteria.

When replacing a pole, the incremental cost to replace insulators and other hardware is relatively small. Items to be considered for replacement include crossarms, insulators, conductor clamps, other hardware and dampers. While it would be inefficient to replace items in near new condition, we have determined that items with less than half their remaining life should be replaced at the same time as the pole is replaced. This broadly equates to a CA score of 60 for these items. The following criteria are used to assess the scope of work for replacing associated items.

- When replacing a pole within a PI structure (2 pole H-shaped structure), replace the other pole at the same time if its CA is less than 60. We note that, in the vast majority of cases, both poles of a PI structure are in a similar condition.
- When replacing any pole, replace crossarms, hardware and insulators if their CA is less than 60.
- Always replace guy deadmen and anchor bolts when replacing a pole structure unless they are under 5 years old.

This strategy reduces lifecycle cost and landowner disruption, improves resource efficiency and minimises outage needs. This strategy supports our cost performance and service performance objectives.

**4.1.3 Integrated Works Planning**

Our capital governance process – IWP – includes the creation of business cases that track capital projects through three approval gates, with the scope and cost estimates becoming more accurate as the project becomes more refined.

The IWP process integrates capex across a moving window of up to 10 years in the future. This optimisation approach seeks to ensure that works are deliverable and undertaken in an efficient and timely manner. Planning of all the work on towers and poles takes into
consideration relevant site strategies, minimise required outages and resources, and any potential synergies with other projects.

The specific strategies below describe how capital works on towers and poles will be optimised through the IWP process.

**Pole structure replacement aligned to re-conductoring**

Have a remaining Asset Health of 10 years for pole structures as a minimum requirement after a line is re-conductored. Structures should be replaced before re-conductoring if this requirement is not met.

We estimate that it is most cost efficient to replace poles if they have an estimated remaining life of 10 years or less when re-conductoring is carried out. Replacing poles at the same time as re-conductoring achieves economies of scale and minimises landowner disruption.

This fleet strategy supports our cost performance objectives.

**Painting to follow other tower works**

Schedule refurbishment/replacement works for completion before painting towers where practicable.

Planned replacement and refurbishment work such as re-insulation, attachment point replacements or damper replacements should be completed before tower painting. Freshly painted structures can be more slippery to climb when wet, and climbing can damage paintwork.

This fleet strategy supports our objectives pertaining to safety and cost performance.

### 4.1.4 Cost Estimation

Cost estimation is a key stage of the capital investment process and forms a critical input into projects at various stages in the planning process. Historically, cost estimates for foundation works were developed using proprietary systems. This has now transitioned to a central cost estimation team, which uses the cost estimation tool (TEES). Further details on our cost estimation approach are in the Planning Lifecycle Strategy document.

**Ensure volumetric works are scoped to achieve P50**

Ensure volumetric works are scoped to achieve P50. P50 is an estimate of the project cost based on a 50% probability that the cost will not be exceeded.

Most tower and pole works are repetitive with similar scopes. They are categorised as volumetric works for estimation purposes. Cost estimates for volumetric capital projects are developed on the basis of tailored ‘building blocks’ informed by actual cost of completed, equivalent historic projects. This feedback-based process is used to derive average unit costs for future works. See subsection 4.1.2 for further details on how this is applied to replacement projects.
The P50 cost value is an estimate of the project cost based on a 50% probability that the cost will not be exceeded; that is, the P50 estimate is based upon an equal chance of project overruns or under-runs up to the finalisation of the project scope. In a general sense, the expected cost of a programme of similar projects is of more interest than the costs of projects that are estimated separately. Assumptions made in using a volumetric costs methodology to achieve P50 include:

- the sample size of historic works is sufficiently large to provide a symmetric distribution for the cost
- a large number of equivalent projects will be undertaken in future
- cost building blocks based on historic out-turn costs capture the impact of past risks
- volumetric estimates are determined using the TEES (US Cost) system
- scope is reasonably well defined and reflects a predetermined list of ‘standard building blocks applied to all estimates.

4.2 Delivery

Once the planning activities are completed, capex projects move into the Delivery Lifecycle. Delivery activities are described in detail in the Delivery Lifecycle Strategy. The following discussion focuses on delivery issues that are specific to the tower and pole fleets.

4.2.1 Design

The design process aims to ensure safety, optimise the use of materials, standardise structure designs as far as practicable, and ensure the structures are appropriately resilient to high loading events.

Safety by Design

Ensure that safety is explicitly built into all stages of the delivery process, including design, procurement and construction.

An example of adherence to Safety by Design principles would be designing new towers with sufficiently long crossarms to ensure that a lineman can reasonably climb around the tower without violating the minimum electrical approach distance to the live conductors. We intend to design a family of single circuit towers before 2016 that will incorporate appropriate clearances.

This quality assurance step supports high-quality design and implementation to meet our safety objectives.

Load assessments on towers and poles

Ensure all structures undergoing re-conductoring have sufficient capacity to carry full design loads calculated in line with current standards. Strengthen or replace structures when necessary.

Re-conductoring will often change the load on towers and poles due to more or fewer conductors, and the use of different materials, that may involve different weights or
tensions. It is essential for safety and system reliability that towers and poles are of sufficient strength, which can only be achieved if their required strength is calculated when re-conductoring is planned.

Design standards have changed with time, as greater understanding of weather-induced loads, material performance and the like have been incorporated. In some locations, such as atop steep hills, design loads have increased significantly.

We will ensure that all affected structures on the line comply with the capacity requirements of its current design standards following a re-conductoring project. This applies in all instances, even when the new conductor is the same as the old.

The design check must also ensure structures can safely carry any extra loading that may be applied during the re-conductoring works.

This strategy supports our service performance and safety objectives.

**Design for live line techniques**

Design structures to enable works to be carried out using live line techniques wherever practical.

Increasing the amount of work carried out using live line techniques will reduce the number of outages required for maintenance, so improving system performance and reliability.

This strategy directly supports our service performance objective to use live line techniques wherever practical, to minimise disruption to customers. There is little extra cost in procuring towers and poles that have been designed to enable live line techniques.

While we provide for live line work when building new lines, it is not always possible to achieve the increased clearances required when replacing existing structures. The requirements of the Resource Management Act 1991 and the National Policy Statement on Electricity Transmission of April 2008, and the Electricity Act 1992 provisions for injurious affection constrain our ability to make significant changes to the spacing and configuration of existing lines.

**Fleet design diversity**

Minimise, as far as practical, the design diversity of pole and tower structure types and fittings used in new and replacement construction. Standardise design for new towers and poles.

This strategy directly links to our objective to reduce fleet diversity through prioritised replacement of legacy technologies with standardised modern asset types. As outlined in subsection 2.3.2, reducing fleet diversity supports our cost performance objectives by reducing the risk and cost of maintenance because of the large variety of specifications and procedures.

**4.2.2 Procurement**

For details of our general approach to procurement, see the Sourcing, Supply & Contracts Approach (2011) and the Delivery Lifecycle Strategy.
Procurement strategies relevant to the tower and pole fleet are set out below.

**Service provider contracting**

Award contractor work by geographic locations on a sole source ‘yours to lose’ basis.

Tower and pole work is mostly of a volumetric nature. Our preferred procurement method is sole source ‘yours to lose’; our second preference is selected tender. Awarding contractor work by geographic locations recognises that locally based contractors often have geographic knowledge of the area that makes them more suitable to work in rugged terrain.

This strategy aligns with our objective to control costs by minimising supplier diversity. Performance-based contracting will be used to provide incentives to contractors to align their objectives with ours.

**Tower painting resources**

Increase the available pool of approved painting contractor resource to enable towers to be painted at the optimum time.

Due to a lack of competent painting contractors, we are unable to achieve the work volume required to paint towers at the optimum time (see subsection 4.1.2). A considerable increase is required in the number of competent tower painters.

The Procurement Strategy for Tower Painting (TP.TL 01.02 Feb 2011) was introduced in 2011/12. That strategy involves an agreed schedule of rates/open book method as opposed to lump sum arrangements. This process has resulted in greater visibility of costs and the ability for us to work with contractors to drive efficiency. It has also brought the painting contracts into line with the other transmission line maintenance contracts.

Currently we have about 110 painters from six businesses working on our towers. Of the six businesses, only two have been painting our assets for more than four years. The newer players (54 painters) have taken longer to come up to speed than expected, and often demonstrate significantly lower productivity rates than the two more established companies. Maintaining a reliable, suitably skilled and reliable workforce has proven challenging for some. An adjustment to agreed rates may be required in some regions to maintain business viability. This is currently being investigated. All companies are being encouraged to grow continuously throughout RCP1 and RCP2, as it is estimated that between 160 and 170 painters will be required by 2020 to enable the plan to be delivered. Most of the growth is required in the lower North Island where many of the worst condition towers are located and where the painting ‘window’ can be limited significantly by weather.

The costs associated with Tower Painting are discussed in subsection 4.1.2.

**4.2.3 Delivery Planning**

The plan for delivering new towers and poles for new transmission lines and upgraded transmission lines are managed under our IWP process as set out in subsection 4.1.3. This subsection sets out how IWP is applied to tower and pole project delivery.
Project deliverability

Ensure planned projects are deliverable within available financial, labour and material constraints.

Our IWP processes deliver on this strategy. In particular, ensuring deliverability of projects planned in line with the IWP processes is essential to support our objectives of controlling costs and achieving the desired asset management outcomes.

Work packaging

Package work into blocks of consecutive structures/spans wherever possible to maximise efficiency and minimise outages.

Where practicable, work is packaged to maximise efficiency and ensure that any system outages are minimised. Under the IWP processes, an integrated programme view is taken rather than evaluating the sum of the individual works. This strategy aligns with our objectives in relation to service performance.

4.3 Operations

The Operations Lifecycle phase for asset management relates to planning and real-time functions. Operational activities undertaken are described in detail in the Operations Lifecycle Strategy.

The following discussions focus on operational issues that are specific to the tower and pole fleets. The most important aspect of the Operation Lifecycle phase in relation to towers and poles is the contingency planning for pole or tower failure.

4.3.1 Outage Planning

Power system outages for preventive maintenance, corrective maintenance, and replacements must be planned to minimise disruption to customers. A number of procedures carried out on towers and poles for preventive maintenance, corrective maintenance and replacements cannot be carried out as live line work. This means that an outage must be planned and managed in a way that creates a safe environment for employees and contractors to undertake the work, while minimising the disruption for customers. Grid Operations identify requirements for outages (including reclose blocks) and manages the planning of outages and reclose blocks.

Tower and pole works outage planning

Minimise disruption to customers by meticulously planning outages required for tower and pole works.

We coordinate with key stakeholders to ensure that any unavoidable system disruptions and outages are notified well in advance so that affected parties can prepare. This strategy aligns with our service performance objectives.
4.3.2 Contingency Planning

With approximately 41,000 structures on the network, located in many different conditions, it is inevitable that towers and poles will occasionally fail during extreme events such as high winds, earthquakes, volcanic eruptions, and landslides. Planning for such events is essential so that, in the event of an operational failure overhead transmission lines can be restored relatively readily.

To ensure rapid restoration times, we will employ the following contingency strategies.

**Contingency situation resources**

Ensure there are sufficient plans, skilled manpower and emergency spares to enable rapid restoration of transmission service following single or multiple structure failure(s) or conductor drop(s).

Resources must be sufficient to manage contingencies using a tiered response where local contractors rectify failures of one or two structures, but may call upon others for assistance following multiple structure failures. We will use two teams to ensure asset specific emergency plans are developed for critical assets.

- **Emergency Restoration Team and spares:** Maintain the readiness of the Emergency Restoration Team and structures with the ability to temporarily restore a localised failure (up to 5 towers or 2 km) of any one line (double or single circuit) within 10 days where physical Grid redundancy is not available.

- **Emergency Management Team:** Maintain the readiness of the Emergency Management Team with communications routes to Civil Defence and to site works contractors. Yearly drill for significant outage communications and process. Continue the business continuity plan, including emergency restoration structures.

This delivers on our objectives in relation to service performance.

**Emergency (temporary) towers**

Keep one emergency tower for every 800 towers in service, located strategically throughout the country.

This strategy addresses our high-level risk management objective that requires restoration of security at a site within one calendar week of a major failure of a tower. We believe that the current stock of one emergency towers for every 800 towers in service provides the optimal balance between maintaining an appropriate level of service while controlling costs.

We note that a review of the emergency tower fleet is underway following completion of the 400 kV Brownhill to Whakamaru line to ensure appropriate structures can be constructed to replace towers on that line.

Additionally, spare poles are kept throughout the country to support our service performance objectives by providing field contractors with the resources to quickly restore power in the case of a pole, or sometimes tower, failure. While 30 poles is considered a minimum number for spares, generally far more are available throughout the country due to orders for maintenance and project works.
**Spare poles**

Keep 30 spare poles, located strategically throughout the country, including a small number of hardwood or steel poles for sites with difficult access.

Keeping a sufficient number of spare poles throughout the country supports our reliability objectives by providing field contractors with the resources to quickly restore power in the case of a pole, or sometimes tower, failure. While 30 poles are considered a minimum number for spares, generally far more are available throughout the country due to orders for maintenance and project works.

**Emergency tower and pole hardware**

Keep an appropriate stock of tower and pole hardware at various locations around the country.

Keeping a sufficient number and range of spare tower and pole hardware throughout the country supports our system performance and reliability objectives by providing field contractors with the resources to quickly restore power in the case of a failure of a tower or pole component. Without spares available, we would find it difficult to meet the high-level risk management objective that requires restoration of security at a site within two days of a major failure of a tower or pole hardware component.

4.3.3 **Corridor Management**

We engage closely with stakeholders in relation to corridor management. Material provided to landowners and occupiers of land impacted by line corridors includes brochures\(^6\) and advisories on our activities. The brochures and regular maintenance visits help in identifying asset-related and third party risks. This is considered the most cost-effective means of ensuring that developers are aware of safety requirements before committing to detailed design.

The public education process also includes liaising with local authorities and building and rural contractors, and improving relationships with landowner/occupiers.

It is anticipated that these actions will reduce the number of disputes with landowners and occupiers when negotiating access for conductor and insulator-related works.

**Council-regulated buffer distances**

Seek provisions in council plans to ensure that appropriate buffer distances are provided from existing transmission assets for third-party activities.

When council district plans are reviewed, we will seek to ensure Councils give effect to Policies 10 and 11 of the National Policy Statement on Electricity Transmission. This is to provide buffer corridors for sensitive activities and to ensure the ability to maintain and

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\(^6\) These brochures include a General Corridor Management Brochure, a Corridor Management Activity Lists Brochure, a Development Guide, and Tree Management brochures.
upgrade the Grid is not compromised. As at September 2013, provisions have been made in 9 out of 70 Council plans.

This work will continue during RCP2 and is included in departmental opex.

4.4 Maintenance

We and our service providers carry out ongoing works to maintain assets in an appropriate condition and to ensure that they operate as required. Our approach to Maintenance and the activities it undertakes are described in detail in the Maintenance Lifecycle Strategy. We classify maintenance tasks into the following categories:

- preventive maintenance
  - condition assessments
  - servicing
- corrective maintenance
  - fault response
  - repairs
- maintenance projects.

The following discussion focuses on maintenance activities and associated strategies that are specific to the tower and pole fleets, including specific maintenance projects planned for RCP2.

4.4.1 Preventive Maintenance

Preventive maintenance is work undertaken on a scheduled basis to ensure the continued safety and integrity of assets and to compile condition information for subsequent analysis and planning. Preventive maintenance is generally our most regular asset intervention, so it is important in terms of providing feedback of information into the overall asset management system. Being the most common physical interaction with assets, it is also a potential source of safety incidents and human error. The main activities undertaken are listed below.

- **Inspections**: non-intrusive checks to confirm safety and integrity of assets, assess fitness for service, and identify follow up work.
- **Condition Assessments**: activities performed to monitor asset condition or predict the remaining life of the asset.
- **Servicing**: routine tasks performed on the asset to ensure asset condition is maintained at an acceptable level.

For the towers and poles fleets, the largest component of preventive maintenance is condition assessment, as little servicing is required, mostly because there are no moving parts. Condition assessments are very important because of their role in planning replacement and refurbishment to prevent structural failures.

We intend to implement the following preventive maintenance on the towers and poles fleets in support of our objectives stated in chapter 3.
Regular patrols

Carry out regular patrols to allow the planning of work required to mitigate or avoid any failure risks.

Line patrols are generally performed once a year on every transmission line asset. The frequency of patrols will be determined based on site or corridor safety criticality. A ground-based patrol visits each structure to identify any defects that could pose risk to the structure integrity. These include:

- severely distorted tower members
- leaning poles
- undue cracking in poles
- loose or broken wires in climb deterrents
- missing or eligible signage
- any other obvious sign of distress in the structure that, left unchecked, could cause failure.

When significant defects are identified, a maintenance job is raised to rectify the issue.

This strategy delivers on our service performance objectives for towers and poles.

Tower and pole condition assessments

Carry out regular detailed condition assessments of towers and poles.

The condition assessment programme monitors and records the condition of transmission line structures, foundations, conductors and hardware. The programme provides a basis upon which to investigate replacement or maintenance options, and enables planning to take into account the impact of varying environmental ageing factors. It also allows extrapolation of the assessed condition into the future.

Condition assessment is carried out in line with TP.SS 02.17B Transmission line condition assessment Part B: Structures.

As discussed in subsection 2.2.3, condition assessments are carried out on a cyclic basis and entail a detailed inspection of the structure and span. The assessment produces a CA score for various components and a defect list. New assets will first be assessed 8 years after commissioning. After the first assessment, tower line assets will generally be assessed every 8 years. If the CA score is less than 50, the assessment frequency will be reduced to 4 years. Pole lines will generally be assessed every 6 years, reducing to 3 years when the CA score is less than 50. Sites with unusually rapid degradation or those with higher criticality will be assessed more often.

We will continue to develop and refine the existing CA process to ensure relevant, nationally consistent, high-quality data is collected to inform asset planning and decision making.
4.4.2 Corrective Maintenance

Corrective maintenance includes unforeseen activities to restore an asset to service, make it safe or secure, prevent imminent failure and address defects. It includes the required follow-up action, even if this is scheduled some time after the initial need for action is identified. These jobs are identified as a result of a fault or in the course of preventive work such as inspections. Corrective works may be urgent and if not completed for a prolonged period, reduced network reliability may result.

Corrective maintenance has historically been categorised as repairs and fault (response) activities. Repairs include the correction of defects identified during preventive maintenance and other additional predictive works driven by known model type issues and investigations. Timely repairs reduce the risk of failure, improve redundancy and remove system constraints by maximising the availability of assets. Activities include:

- **Fault restoration**: unscheduled work in response to repair a fault in equipment that has safety, environmental or operational implications, including urgent dispatch to collect more information
- **Repairs**: unforeseen tasks necessary to repair damage, prevent failure or rapid degradation of equipment
- **Reactive inspections**: patrols or inspections used to check for public safety risks or conditions not directly related to the fault in the event of failure

**Fault response**

Fault response is required to restore the function of assets as quickly as possible to maintain supply to customers.

**Tower and pole failure response**

Respond to all failures in a timely manner, as determined by the criticality of the asset.

We have established a framework for asset criticality based on the criticality of the line being supported. This will be used to prioritise fault response and determine how quickly personnel are required to respond in order to most efficiently maintain the performance of the network.

This strategy supports our key objectives of service performance and safety. There have been 14 recorded fault responses during the last 10 years.

**Repairs**

We will make repairs to towers, poles and associated hardware where a defect has been identified that could potentially result in a failure, or when a failure has occurred.

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7 Where the number of potential repairs is deemed sufficiently high a Maintenance Project will be instigated to undertake the repairs works.
**Tower signage and climbing deterrents**

Maintain signs in a fit for purpose condition in line with TP.SS 02.14 and install and maintain climb deterrents on towers in high-risk areas as described in TP.SS 02.14.

Appropriate signage on each structure is essential to ensure the public are informed of the risks posed by the overhead live wires. Signs showing the line name and structure number are also imperative as they allow structure identification, particularly following a fault. Signs that show the relative circuit and phase locations are also required to ensure work can be carried out safely on the line.

Climb deterrents occasionally come loose, or wires break. These must be repaired in a timely manner to mitigate risk. Changing land use may require us to install climb deterrents on some additional towers.

### 4.4.3 Maintenance Projects

As discussed in subsection 2.2.5, maintenance projects typically consist of relatively high-value planned repairs or replacements of components of larger assets. Maintenance projects would not be expected to increase the original design life of the larger assets. Maintenance jobs are typically run as a project where there are operational and financial efficiencies from doing so. The drivers for maintenance projects include asset condition, mitigating safety and environmental risks, and to improve performance.

Over the RCP2 period we intend to implement the following maintenance projects on the tower and pole asset fleets.

**Fall arrest systems installation**

Install fall arrest systems on existing towers at an average rate of 90 each year in the period 2013 to 2020.

To enhance the safety of line workers, a programme commenced in 2010/11 to install fall arrest systems on the transmission towers.

Towers will be prioritised for fall arrest system installation as follows:

- towers with large panels that have few secondary members (such towers are particularly unsafe to climb using double lanyard because there are insufficient members for attachment)
- towers where multiple climbs are expected as part of a larger project such as painting, re-insulation and so on, and that can be installed before or as part of the project preparation
- towers that will be subject to a minimum of three climbs within 18 months of system installation
- structures that are not easily accessed using elevated work platforms.

We will periodically review the number of fall arrest systems installed, and experiences in the field with their use, to assess plans for further rollout. Based on out-turn rates to date,
we estimate that 90 fall arrest systems will be installed each year during RCP2, at a yearly cost of $407,000.

The implementation of this strategy will improve the safety of employees and service providers working on and inspecting transmission towers, and so directly support our safety objectives.

**Tower steel and bolt replacements**

Replace severely corroded steel and bolts before significant loss of the section.

Significantly corroded tower members and bolts require replacement to ensure that the integrity of the tower structure is maintained. Condition assessment has shown that numerous towers have some bolts and members that are severely corroded, while the majority on the tower are in a reasonable condition. Generally it is the smaller members that corrode first because galvanising thickness is proportional to member thickness. Replacing minor members is relatively straightforward.

Major steel members on a tower, such as main leg steel members, require alternative structural support during replacement. This involves removing conductors from the tower or transferring alternative support to enable the steel member replacement. This work is titled ‘Major Structural Steel’ replacement and is distinct from major tower steel and bolt replacement works.

When major load-carrying members require replacement, detailed engineering analysis and temporary bracing systems are generally required.

By replacing only the corroded items, structural integrity can be maintained, and painting of the tower can usually be postponed for several years.

The amount and complexity of work can vary widely at any given tower. For cost estimation purposes, we have assigned works in this fleet strategy to one of four categories:

- steel and bolt major
- steel and bolt minor
- tower crossarms
- major structural steel.

In RCP2, we plan to carry out steel and bolt replacements on 2,095 towers, comprising 1,670 major steel and bolt works at about $7,800 each, 425 minor steel and bolt works at about $3,100 each. We also plan to carry out 470 tower crossarm works at approximately $6,200 each, and 80 major structural steel works at about $25,000 each. The total cost of the maintenance project will be approximately $19.2m ($3.8m each year).

This strategy supports our cost performance objectives.

**Replacement of corroding attachment points**

Replace insulator attachment points at the onset of section loss and before the fastener threads seize up.
As with other ageing tower components, attachment points (such as swivels, hanger brackets and strain plates) are subject to wear and corrosion. While attachment points are a minor component of the larger tower structure (and as such their replacement is considered a maintenance project activity), they are a critical tower component as their failure will result in a conductor drop.

As discussed in subsection 2.3.4, if attachment point fasteners become too corroded the crossarms must be lowered to ground level to enable their removal. This impacts transmission line availability and significantly increases cost. Whenever practicable, the preferred approach is to replace fasteners and corroded or worn plates before the crossarms need to be removed for attachment point replacements. This equates to a CA score of 30.

The complexity of the work is dependent on the model of tower. On some towers, removal and replacement of the attachments and supporting plates (which also wear out) is straightforward. On other towers, where the support is welded to a large plate at the end of the crossarm, removal is particularly difficult.

The optimum time to replace is when the attachment reaches a CA score of 20, or the fasteners reach a CA score of 30 (before threads seize up). Existing attachment point and fastener condition scores have been taken and degraded as for tower steel degradation to predict when replacement is likely to be required.

**Costs and volume forecasts**

As outlined in subsection 2.2.3, there are just under 1,000 attachment points below CA 30 replacement criteria. Replacement of attachment points identified as ‘Now Due’ will be spread over RCP2, with the objective of replacing all ‘Now Due’ attachment points by the end of the period.

The number of attachments to be replaced each year is shown in Figure 25. This chart was developed based on the remaining life rationale presented in subsection 2.2.4.

![Figure 25: Attachment Point Replacement Quantity](image)
Impact of works

Figure 26 shows the effect of the replacement plan on the asset health of attachment points.

All attachment points identified as ‘Now Due’ as at June 2013 will be scheduled for replacement before 2019/20. Attachment point repairs beyond RCP2 are forecast to continue at similar volumes, at around 500 circuit sets each year for the following 10 years.

Cost estimates

The cost of the attachment replacement plan is shown in Figure 27.

For cost estimation purposes, we have assigned each replacement to one of three categories: simple, typical and complex. In RCP2, we plan to carry out attachment point replacements on about 2,610 towers, 405 simple replacements at about $2,025 each, 1,642 typical replacements at about $7,000 each and 560 complex replacements at about $15,000 each. The total cost over RCP2 will be about $21m ($4.2m each year). This strategy supports the objectives pertaining to safety, service and cost performance.
Step and touch; and transferred potential

Identify situations where there are high risks from step and touch and transferred potential, and take action to reduce those risks.

By 2023 we plan to have identified, assessed and mitigated EPR risk at all existing structures, in line with our risk based policy.

Typically, mitigation measures will include installing fences or vegetation around structures to reduce the likelihood of people touching the transmission line structures, and/or installing an insulating layer of asphalt around the structure. Insulators or isolation sections installed in conductive fences will mitigate the risk of transferred hazardous voltages.

Expenditure of $1m each year is forecast for each year of RCP2 to allow for investigation, design and installation of risk mitigations. This estimate is based on installing mitigations at about 130 sites each year, at an average cost of $7,700 for each site. This strategy supports our safety objectives.

Install bird deterrents or guards

Install bird deterrents or guards on structures where evidence suggests electrical performance is being, or is likely to be, compromised by bird activity.

As discussed in subsection 2.2.5, bird ‘streamers’ can cause insulation to flashover that result in circuit trips. The installation of bird deterrents or shrouds above insulators has proved to be a cost-effective method of improving circuit performance. Avoiding trippings in a cost-effective manner supports our objectives involving cost performance and service performance.

We plan to install bird deterrents on structures where bird specific performance issues have been identified. These works are to be completed as part of the routine repair works.

Tower and pole minor repairs

Complete minor repairs to towers and poles that do not warrant full replacement or extensive refurbishment.

The main purpose of this strategy is to carry out minor repair work to towers or poles that have either sustained minor damage, require some remedial work (such as tightening some bolts) or require simple, relatively low-value components to be replaced. Where the issue is widespread along the line, the repair works would generally be bundled together and a maintenance project raised.

Expenditure of $690,000 over RCP2 has been allowed to repair pole structures. This estimate is based on repairing 340 structures at an average cost of $2,000 for each structure. This strategy supports our safety objectives.

Other minor tower and pole repairs are to be completed as part of routine repair works.
4.5 Disposal and Divestment

The disposal and divestment lifecycle phase includes the process from when planning of disposal of an asset begins through to the point where we no longer own the asset.

Asset disposal includes the decommissioning of the asset after which it may be sold as a functioning asset, sold as scrap, disposed of to a waste management facility, or re-used elsewhere as an in-service asset or as a spare. The approach is set out in detail in the Disposal Lifecycle document. This subsection describes the strategies for disposal of assets within the tower and pole fleets.

4.5.1 Disposal

The disposal lifecycle eventuates when towers or poles are no longer needed or when a tower has corroded to an extent where it is uneconomic to paint. Towers and poles may be replaced with new ones, but there are important requirements for the disposal phase.

In the case of a failure, we carry out diagnostic inspection and testing to investigate the cause of the failure. This information is fed into the management of the entire tower and pole asset fleet.

Redeployment of assets

Where appropriate, redeploy assets such as poles and towers that are no longer needed.

Redeploying redundant assets and so avoiding disposal meets environmental and cost performance objectives. Recovery for re-use of a tower or pole should be considered in the following situations:

- where a clear need for similar tower or pole can be identified
- where the existing tower to be decommissioned is in good condition, and can be recovered in a fit state
- if there is a suitable and economic process to recondition a tower’s steelwork
- where an economic comparison with a new, standard design structure shows clear value in the re-use.

Spare towers

Review and rationalise the holdings of spare towers and tower components.

Spare towers and parts of towers occupy significant amounts of storage space, and yet are seldom required. Further, the condition of spare towers deteriorates over time. Our holdings of emergency towers enable a prompt response to structure failures or impending failures.

We will review the nationwide holdings of spare towers and components over the period 2014 to 2016, to identify opportunities for rationalisation and disposal of tower spares that are no longer required.
Decommissioning process

Maintain and follow an appropriate decommissioning process as part of projects where re-use is not appropriate.

Where re-use is not appropriate, we will maintain and follow appropriate decommissioning processes as part of projects.

Requirements for tower demolition, recovery and recycling/disposal work include appropriate site reinstatement processes.

Requirements for recovery and recycling/disposal work include safe work and site management processes and appropriate probity and environmental responsibility of scrap disposal processes. Tower steel is scrapped for recycling, and hardwood poles are either scrapped (not on sold for structural purposes) or, for above-ground treated pole sections, re-assessed for use as buried anchor blocks.

4.5.2 Divestment

Implementation of divestment is primarily the change of ownership, although we must also remain aware of any safety and environmental issues and technical impacts on the Grid such as a change in constraints and flexibility of Grid operation.

Tower and pole divestment

Divest towers and poles as part of transmission line divestments to customers.

We are continuing to transfer a number of assets at the fringes of the existing Grid to our distribution business customers. This process and its justification are described in the Disposal and Divestment Lifecycle Strategy.

Table 10 shows the number of towers and poles likely to be transferred to customers between 2013/14 and 2019/20. This includes all divestments that we believe have a 50% or greater likelihood of occurring during the timeframe.

<table>
<thead>
<tr>
<th>Period</th>
<th>Towers</th>
<th>Poles</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCP1‡</td>
<td>737</td>
<td>1,236</td>
</tr>
<tr>
<td>RCP2</td>
<td>269</td>
<td>157</td>
</tr>
<tr>
<td>Total</td>
<td>1,006</td>
<td>1,393</td>
</tr>
</tbody>
</table>

Table 10: Tower and Pole Divestments

4.6 Asset Management Capability

We require our national Grid assets and equipment to be managed, maintained, tested and operated to high standards of skill, professionalism and safety supported by high-quality

---

‡ This excludes historical divestments (it only includes divestments to be carried out in 2013/14 and 2014/15).
Asset knowledge and risk management tools. This will ensure satisfactory and safe functioning of the network while minimising whole-of-life costs. Work is to be carried out only by individuals with competencies that are appropriate and current (see TP.SS 06.20 Minimum Competencies for Line Maintenance and TP.SS 06.25 Minimum Requirements for Transpower field Work). This helps to ensure the prevention of injury to workers and damage to assets, and the protection of the public and their property from harm.

This section describes the specific strategies for obtaining and maintaining capability in managing and handling the tower and pole fleets.

The capability strategies are described under the following three headings:

- Asset Knowledge
- Risk Management
- Training and Competence.

### 4.6.1 Asset Knowledge

Robust asset knowledge is critical to good decision making for asset management. Asset knowledge comes from a variety of sources, including overseas experiences, experience from assets on our network, theoretical modelling, and information from the manufacturers. This asset knowledge must be captured and recorded in such a way that it can be conveniently accessed when future asset management decisions are made. A key part of improving our asset knowledge is the commissioning of the new Asset Management Information System (AMIS).

**Maintenance of asset records**

Maintain up-to-date records of all towers and poles.

Comprehensive records that cover the original installation of a tower or pole structure and any subsequent modifications are vital to enable quality asset management decisions. Data must include details of exactly what is installed, tower and pole capacities and type test reports, design reports, condition data and investigation reports.

While good asset attribute and condition data is available for most sites, some fields are currently incomplete. Data quality and completeness will continually be reviewed and amended as required to ensure a high quality dataset is maintained. The current project to transition to the MAXIMO-based asset management information system will include a review and cleansing of data.

We plan to enhance the failure and incidence records system to improve consistency and usefulness of the data, including root cause analysis.

To improve condition assessment consistency guidelines will be developed, including more photographic examples where relevant.

**Fleet strategy development**

Maintain and develop strategies for towers and poles fleet.
We will continue to develop and refine models for tower painting, steel degradation, attachment points and pole replacements. We will further enhance the degradation curves used as the basis for corrosion and the geographic zones in which structures are located.

We will revise building blocks on an ongoing basis using costs from completed works and forecast innovations and improvements. We will use these costs in the economic modelling along with degradation rates and asset health indices to define least life cycle cost options for programmes of work.

4.6.2 Risk Management

Our approach to risk management is central to our decision making as we seek to achieve our overall asset management objectives and optimise the timing of major investments.

Knowledge of tower and pole condition is crucial to the assessment of options for tower and pole replacement and refurbishment. As outlined in subsection 2.2.3, we apply an adaptive condition assessment approach, where the frequency and extent of condition assessment interventions is determined based on the most recent condition assessment and the predicted current state.

Understanding and modelling uncertainty then becomes an increasingly important element in risk management decision making, particularly given the consequences of the failure of towers and poles on transmission line performance. In recognition of this we are developing asset health and criticality frameworks to improve and integrate our risk-based asset management. The strategies below discuss how we plan to progress this in regards to the towers and poles fleet.

**Risk-based options evaluation framework**

Develop a risk-based framework and associated tools for evaluating tower and pole investments.

We will develop an improved risk management framework and tools that can be used across the towers and poles fleet to evaluate investment options. The key parts of this will be tools for making quantitative estimates of the likely impacts of tower and pole failures on service performance and safety on a span-by-span basis. The risk model will specifically consider uncertainty in the inputs to risk-based decision making.

We will also ensure more robust and detailed development of scope for major replacements, to improve the accuracy of cost estimates and the validity of the economic analysis of options. Risk management processes will be made more robust and systematic, and will allow risk assessments to be more readily communicated to internal and external stakeholders.

4.6.3 Training and Competence

Our overarching strategy for maintaining and/or improving worker competence can be summarised as follows:

- all persons (our employees, service providers and sub-contractors) working on our assets must be properly trained and currently competent for the tasks they undertake
all maintenance service providers must comply with the competency criteria set out in the relevant Service Specification

employers must manage the currency of competencies of their workers for the work they undertake to the appropriate requirements of the relevant Service Specification.

We have two service specifications that define the competency requirements for working with our towers and poles:

- TP.SS 06.20 Minimum competencies for lines maintenance
- TP.SS 06.25 Minimum requirements for Transpower field work.

**Competency requirements for tower and pole service providers and employees**

Adhere to the following service specifications: TP.SS 06.20 (Minimum competencies for lines maintenance) and TP.SS 06.25 (Minimum requirements for Transpower field work).

We maintain a minimum baseline of retained skilled workforce: engineers and site works operators who understand the physical assets. All workers must hold appropriate competencies to work on our assets in line with the service specifications.

Since 2011, we have provided much of the training to service providers at no cost (other than the service providers’ time). This has resulted in a considerable increase in service provider training. We will continue with this training approach in RCP2.

**Asset management competency**

Increase and then maintain the in-house skill base with regard to Asset Management.

To ensure better long-term asset management outcomes, we plan to increase the emphasis on training in Asset Management principles and application across all relevant parts of the business.

### 4.7 Summary of RCP2 Fleet Strategies

Our asset management plans for the fleet of tower and pole assets is summarised below for each lifecycle stage.

<table>
<thead>
<tr>
<th>Enhancement and Development</th>
<th>Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modify existing towers, including strengthening, raising and relocating to enable larger conductor or thermal upgrades.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Replacement and Refurbishment</th>
<th>Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paint towers prior to significant rusting based on CA scores and re-paint prior to paint failure.</td>
<td></td>
</tr>
<tr>
<td>Continually update the model used to predict future tower condition, remediation options and costs.</td>
<td></td>
</tr>
<tr>
<td>Replace towers at risk of failure due to unstable ground or slips, or when they have failed.</td>
<td></td>
</tr>
<tr>
<td>Prioritise the painting of towers, taking into account existing health, asset criticality and degradation rate.</td>
<td></td>
</tr>
<tr>
<td>Replace poles just before they have degraded to a point where they can no longer support their design loads, or where it is prudent to do so due to ground instability.</td>
<td></td>
</tr>
</tbody>
</table>
Towers and Poles Fleet Strategy
TP.FL 01.01
Issue 1
November 2013

<table>
<thead>
<tr>
<th>Integrated Works Planning</th>
<th>Replace small towers with poles in preference to painting the tower (and refurbishing the grillage), where practicable and cost-effective.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Use pre-stressed concrete poles wherever practical.</td>
</tr>
<tr>
<td></td>
<td>Combine the replacement of poles with related hardware where they meet certain criteria.</td>
</tr>
<tr>
<td></td>
<td>Have a remaining Asset Health of 10 years for pole structures as a minimum requirement after a line is re-conductedored. Structures should be replaced before re-conductoring if this requirement is not met.</td>
</tr>
<tr>
<td></td>
<td>Schedule refurbishment/replacement works for completion before painting towers where practicable.</td>
</tr>
<tr>
<td>Cost Estimation</td>
<td>Ensure volumetric works are scoped to achieve P50. P50 is an estimate of the project cost based on a 50% probability that the cost will not be exceeded.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Delivery

<table>
<thead>
<tr>
<th>Design</th>
<th>Ensure that safety is explicitly built into all stages of the delivery process, including design, procurement and construction.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ensure all structures undergoing re-conductoring have sufficient capacity to carry full design loads calculated in line with current standards. Strengthen or replace structures when necessary.</td>
</tr>
<tr>
<td></td>
<td>Design structures to enable works to be carried out using live line techniques wherever practical.</td>
</tr>
<tr>
<td></td>
<td>Minimise, as far as practical, the design diversity of pole and tower structure types and fittings used in new and replacement construction. Standardise design for new towers and poles.</td>
</tr>
<tr>
<td>Procurement</td>
<td>Award contractor work by geographic locations on a sole source ‘yours to lose’ basis.</td>
</tr>
<tr>
<td></td>
<td>Increase the available pool of approved painting contractor resource to enable towers to be painted at the optimum time.</td>
</tr>
<tr>
<td>Delivery Planning</td>
<td>Ensure planned projects are deliverable within available financial, labour and material constraints.</td>
</tr>
<tr>
<td></td>
<td>Package work into blocks of consecutive structures/spans wherever possible to maximise efficiency and minimise outages.</td>
</tr>
</tbody>
</table>

### Operations

<table>
<thead>
<tr>
<th>Outage Planning</th>
<th>Minimise disruption to customers by meticulously planning outages required for tower and pole works.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ensure there are sufficient plans, skilled manpower and emergency spares to enable rapid restoration of transmission service following single or multiple structure failure(s) or conductor drop(s).</td>
</tr>
<tr>
<td>Contingency Planning</td>
<td>Keep 1 emergency tower per 800 towers in service, located strategically throughout the country.</td>
</tr>
<tr>
<td></td>
<td>Keep 30 spare poles, located strategically throughout the country, including a small number of hardwood or steel poles for sites with difficult access.</td>
</tr>
<tr>
<td>Corridor Management</td>
<td>Seek provisions in council plans to ensure that appropriate buffer distances are provided from existing transmission assets for third party activities.</td>
</tr>
</tbody>
</table>

### Maintenance

| Preventive Maintenance     | Carry out regular patrols to allow the planning of work required to mitigate or avoid any failure risks.                             |
| Corrective Maintenance     | Carry out regular detailed condition assessments of towers and poles.                                                            |
|                            | Respond to all failures in a timely manner, as determined by the criticality of the asset.                                      |
|                            | Maintain signs in a fit for purpose condition in line with TP.SS 02.14 and install and maintain climb deterrents on towers in high-risk areas as described in TP.SS 02.14. |
| Maintenance Projects       | Install fall arrest systems on existing towers at an average rate of 90 each year in the period 2013 to 2020.                    |
|                            | Replace severely corroded steel and bolts before significant loss of the section.                                                 |
|                            | Replace insulator attachment points at the onset of section loss and before the fastener threads seize up.                        |
|                            | Identify situations where there are high risks from step and touch and transferred potential, and take action to reduce those risks. |
Install bird deterrents or guards on structures where evidence suggests electrical performance is being, or is likely to be, compromised by bird activity.

Complete minor repairs to towers and poles that do not warrant full replacement or extensive refurbishment.

### Disposal and Divestment

<table>
<thead>
<tr>
<th>Disposal</th>
<th>Where appropriate, redeploy assets such as poles and towers that are no longer needed.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review and rationalise the holdings of spare towers and tower components.</td>
<td></td>
</tr>
<tr>
<td>Maintain and follow an appropriate decommissioning process as part of projects where re-use is not appropriate.</td>
<td></td>
</tr>
<tr>
<td>Divestment</td>
<td>Divest towers and poles as part of transmission line divestments to customers.</td>
</tr>
</tbody>
</table>

### Capability

<table>
<thead>
<tr>
<th>Asset Knowledge</th>
<th>Maintain up-to-date records of all towers and poles.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintain and develop strategies for towers and poles fleet.</td>
<td></td>
</tr>
<tr>
<td>Risk Management</td>
<td>Develop a risk-based framework and associated tools for evaluating tower and pole investments.</td>
</tr>
<tr>
<td>Training and Competence</td>
<td>Adhere to the following service specifications: TP.SS 06.20 (Minimum competencies for lines maintenance) and TP.SS 06.25 (Minimum requirements for Transpower field work).</td>
</tr>
<tr>
<td>Increase and then maintain the in-house skill base with regard to Asset Management.</td>
<td></td>
</tr>
</tbody>
</table>
Appendices
A  CORROSION ZONE MAP

The map in Figure 28 shows the geographical location of transmission towers by corrosion zone. Extreme corrosion zones are restricted to small areas near Bluff, Oteranga Bay, New Plymouth and some geothermal areas on the Volcanic Plateau. Most towers rated as very severe are located on the Kapiti and Taranaki Coasts. At the other end of the scale, most of Central Otago is classified as benign.

Figure 28: Corrosion zones
B TOWER PAINTING OPTIMISATION ANALYSIS

The following three options are considered for extending the life of transmission towers.

- Replace the entire tower when a material number of members reach CA 20.
- Protect the steelwork with a protective paint layer, selecting the optimal time for initial painting and re-coating.
- Decommission the line, and replace with an enhanced asset.

Line decommissioning and replacement with enhanced assets are not considered further in the optimisation analysis.

Tower painting background

Since 2010, we have continued to gain knowledge with regard to painting and corrosion rates. These lessons have been incorporated into the current AHI model. For example:

- the number of corrosion zones has been increased from 4 to 6 to better account for those towers located in extremely corrosive or benign environments
- actual degradation rates are continually monitored and towers re-assigned to other zones if the actual rates differ markedly from those predicted in the model
- few, clearer CA criteria for unpainted and painted steel were introduced in 2012 (quality CA data is vital if the model is to deliver accurate forward predictions of tower condition)
- increased costs associated with secondary preparation requirements have been incorporated into the current model.

Similarly, this work is integrated with other work on lines (such as grillage, conductor replacement, general maintenance, and site works) at the work planning phase.

Economic analysis details

Two options to consider in this economic analysis are:

- replace steelwork at the end of its life (CA 20), or
- protect the steelwork with paint.

Subsection 2.2.1 considers the environmental impact of the options.

A Net Present Value (NPV) analysis calculates a comparison of various painting options against the replacement option at CA 20.

Key inputs to the analysis are:

- cost to prepare and paint a tower in various CA conditions
- forecast degradation rates based on corrosion zone
- periodic re-paint cycle, with reduced cost to re-coat compared to initial paint, and there-paint period changes depending on corrosion zone being:
  - Extreme: 12 years
  - Very Severe: 12 years
- Severe: 15 years
- Moderate: 15 years
- Low: 18 years
- Benign: 20 years

- cost of replacing on site when tower reaches CA 20.
- NPV discount rate of 7%.
- 120 years modelled.

**Tower painting cost**

The extent of preparation work and related cost to paint a tower increases as the tower deteriorates, as shown in Figure 29. Two important assumptions in the cost figures are noted below.

- If the tower is in very poor condition, numerous steel members and all bolts need to be replaced before paint can be applied.
- Two replacement costs are shown, the first using the existing tower foundation and the second including a new foundation. The analysis of painting versus replacement is concerned with like-for-like replacement only.

**TOWER PAINTING - COST INPUTS**

- 220 KV SINGLE CIRCUIT TOWER 230M2
- 220 KV DOUBLE CIRCUIT TOWER 430M2

![Figure 29: Tower Painting/Replacement Cost](image-url)

The NPV cost for each zone covers:

- cost of the first-time painting for the tower
- cost of re-painting at the set re-paint intervals.
The summary of the analysis is shown in the charts in Figures 30 and 31 and in Table 11. In the charts, the minimum point on each curve is the most economic time to paint a tower.
From the charts above, we can identify the absolute cost minima for each corrosion zone. These are the **absolute** least cost options for each zone. Other factors need to be considered as part of the option selection, as detailed in Table 11.

<table>
<thead>
<tr>
<th>Option</th>
<th>Economic costing (NPV 2012)</th>
<th>Absolute Cost Minima</th>
<th>Environmental preference</th>
<th>Safety preference</th>
<th>Final Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paint tower when new and repeat</td>
<td></td>
<td>Worst (all corrosive zones)</td>
<td>Best</td>
<td>Good – out of service Good – live line</td>
<td>Most costly paint option</td>
</tr>
<tr>
<td>Paint tower at CA 60 and repeat</td>
<td></td>
<td>Extreme: $37,025</td>
<td>Very Severe: $30,214</td>
<td>Moderate: $6,108</td>
<td>Low: $1,907</td>
</tr>
<tr>
<td></td>
<td>Very Severe: $12,870</td>
<td>Severe: $5,107</td>
<td>Low: $1,907</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paint tower at CA 50 and repeat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Paint tower at CA 40 and repeat</td>
<td>Extreme: $35,234</td>
<td>Very Severe: $26,880</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Very Severe: $10,096</td>
<td>Severe: $4,185</td>
<td>Moderate: $1,075</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low: $3,335</td>
<td></td>
<td>Benign: $160</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paint tower at CA 40 and repeat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extreme: $36,032</td>
<td>Moderate: $2,870</td>
<td>Low: $688</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Very Severe: $24,009</td>
<td>Low: $668</td>
<td>Benign: $85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paint tower at CA 30 and repeat</td>
<td></td>
<td>Moderate: $7,665</td>
<td>Low: $554</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seroxer: $5,291</td>
<td>Low: $477</td>
<td>Benign: $52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paint tower at CA 20 and repeat</td>
<td></td>
<td>Moderate: $8,649</td>
<td>Low: $594</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderate: $2,547</td>
<td></td>
<td>Low: $45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Replace tower at CA 20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extreme: $83,980</td>
<td></td>
<td>Relatively poor</td>
<td>Ok – out of service Ok – live line</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Very Severe: $45,121</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Severe: $10,708</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderate: $3,015</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low: $594</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Benign: $60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 11: Tower refurbishment option evaluation
In purely economic terms, the optimum condition score at which to paint extreme zone towers is CA 50, very severe at CA 40, severe zone towers at CA 30, and moderate, low, and benign zones at CA 20.

**Preferred CA score for tower painting**

For extreme and very severe zone towers, costs escalate rapidly as condition decreases below CA 40 and CA 30, respectively. It is imperative that towers in these zones do not degrade below the specified condition scores before they are painted.

For severe zone towers, the NPV cost difference between CA 40 and CA 30 is small. To align with towers in the very severe zone, the preference is to paint severe zone towers at CA 40.

For moderate, low, and benign zone towers, there is a significant risk of tower failure if they are allowed to degrade to CA 20. The NPV cost difference between CA 30 and CA 20 is small. For this reason, the preference is to paint towers in these zones at CA 30.

The final preferred condition scores for tower painting are:

- Extreme: CA 50
- Very Severe: CA 40
- Severe: CA 40
- Moderate: CA 30
- Low: CA 30
- Benign: CA 30
C TOWER PAINTING LONG-TERM ANALYSIS

Appendix C describes how we analyse the long-term effect of various tower painting plans on the likelihood of tower failure.

This analysis differs from the Tower Painting Optimisation Analysis discussed separately in this fleet strategy. The Optimisation Analysis focuses on selecting the optimal point at which to paint a tower, based on current painting costs and the steel degradation rate for each corrosion zone.

This Tower Painting Plan Analysis outlines the long-term effect of various tower painting scenarios on the long-term likelihood of tower failure.

Appendix C is structured in three sections: Introduction, Approach, and Findings.

- **Introduction**: introduces the key measures used to evaluate the tower painting plan and background.
- **Approach**: describes the assumptions and method used to quantify the effect of the tower painting plan and alternatives on the failure likelihood of the tower fleet.
- **Findings**: presents a summary of the analysis results and a statement on the long-term effects of the proposed tower painting plan.

**Background**

The Tower Painting Optimisation Analysis concludes that protecting the tower steelwork with paint provides for an optimal economic outcome, when whole-of-life costs for tower maintenance are considered.

The Towers and Poles Fleet Strategy discusses the challenges that we face in procuring enough resource to paint our fleet of towers. For the foreseeable future we will not be able to achieve the optimal level of tower painting required, because of restricted painting resource.

This analysis models the consequence of various painting scenarios:

- on an economic basis, by evaluating present cost for tower upkeep/maintenance
- on a risk basis, based on determining the likelihood of tower failure.

**C1 Introduction**

**Painting plan**

As discussed in the Towers and Poles fleet strategy, an optimal painting plan was derived based on the current condition of the tower fleet, the assumed degradation rate of tower steel, and the required time between re-coats. The optimal painting plan requires an average of 780 structures to be painted every year over the period 2013/14 to 2029/30.

The optimal painting plan represents the lowest Present cost option to completely eliminate the risk of tower failure due to conventional tower steel degradation.

All alternative painting plans are considered on an **average annual quantity** over the period 2013/14 to 2029/30. This is to ensure comparability with the optimal painting plan annual quantity.
Tower failure likelihood

As discussed in the Towers and Poles fleet strategy, tower steel condition is not linked to the likelihood of structural failure until a condition score of CA 20 or below is recorded. As CA reduces below 20, the risk of failure increases markedly.

For the purpose of this analysis, tower failure likelihood is a binary factor, and is defined as:

- High: tower condition below CA 20
- Low: tower condition at or above CA 20.

Present cost of painting plan

The whole-of-life present cost to maintain the entire tower fleet in perpetuity is calculated for each painting plan analysed.

This calculation allows us to balance the need to optimise costs while maximising asset performance (availability) and, by proxy, minimising the probability (likelihood) of tower failure.

C2 Approach

Present cost of painting plan

The whole-of-life present cost for each tower in our fleet is calculated based on the following four tower factors:

- tower type (single circuit/double circuit)
- paint status (painted/unpainted)
- corrosion zone
- when painting is planned, and the condition of the tower at the time it is painted.

The whole-of-life present cost is based on the following six key assumptions.

- An unplanned in-situ replacement will occur if a tower reaches CA0 before painting intervention. Cost for unplanned replacement of a single circuit tower is $300,000, while a double circuit tower is $350,000. Unplanned replacement cost assumptions are indicative. Future improvements to this model may include refinement of cost estimates to reflect the emergency nature of such a replacement.
- Re-paints are always ‘on-time’. This is consistent with the approach used for the health model.
- Towers will be replaced at time of painting, if the CA drops below replacement criteria.
- The tower population will remain static.
- All costs are in real 2012/13 dollars.
- Tower painting (first coats) are prioritised according to the risk prioritisation method discussed in the fleet strategy.

The whole-of-life present cost is based on the following five key inputs:

- discount rate of 7%
- 160 years modelled (minimum)
- paint cost based on tower type and CA code (see the Towers and Poles fleet strategy)
- in-situ replacement cost
- tower steel degradation rates.

The whole-of-life present cost is based on the following key limitation.

- The model does not account for the value of lost load and other associated costs and externalities that may arise from the unexpected failure of a tower.

**Painted tower present cost**

Table 12 lists the whole-of-life present cost for a painted tower that is re-coated in the current financial year. As stated above, the figures represent the present cost to maintain the tower in perpetuity.

<table>
<thead>
<tr>
<th></th>
<th>Extreme</th>
<th>Very Severe</th>
<th>Severe</th>
<th>Moderate</th>
<th>Low</th>
<th>Benign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Circuit Tower</td>
<td>93,526</td>
<td>93,526</td>
<td>81,561</td>
<td>81,561</td>
<td>73,848</td>
<td>70,120</td>
</tr>
<tr>
<td>Double Circuit Tower</td>
<td>129,498</td>
<td>129,498</td>
<td>112,930</td>
<td>112,930</td>
<td>102,251</td>
<td>97,089</td>
</tr>
</tbody>
</table>

*Table 12: Painted Tower Whole-of-Life Present Cost*
Unpainted tower present cost

Table 13 lists the whole-of-life present cost for an unpainted tower that is painted in the current financial year. As stated above, the figures represent the present cost to maintain the tower in perpetuity.

We note that this analysis assumes the tower will be replaced if a CA score less than CA 20 is recorded at time of painting.

<table>
<thead>
<tr>
<th>CA Score</th>
<th>Extreme</th>
<th>Very Severe</th>
<th>Severe</th>
<th>Moderate</th>
<th>Low</th>
<th>Benign</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>80,957</td>
<td>80,957</td>
<td>68,992</td>
<td>68,992</td>
<td>61,280</td>
<td>57,551</td>
</tr>
<tr>
<td>90</td>
<td>84,000</td>
<td>84,000</td>
<td>72,035</td>
<td>72,035</td>
<td>64,322</td>
<td>60,594</td>
</tr>
<tr>
<td>80</td>
<td>86,284</td>
<td>86,284</td>
<td>74,319</td>
<td>74,319</td>
<td>66,607</td>
<td>62,878</td>
</tr>
<tr>
<td>70</td>
<td>87,965</td>
<td>87,965</td>
<td>76,000</td>
<td>76,000</td>
<td>68,288</td>
<td>64,559</td>
</tr>
<tr>
<td>60</td>
<td>90,336</td>
<td>90,336</td>
<td>78,371</td>
<td>78,371</td>
<td>70,658</td>
<td>66,929</td>
</tr>
<tr>
<td>50</td>
<td>95,827</td>
<td>95,827</td>
<td>83,861</td>
<td>83,861</td>
<td>76,149</td>
<td>72,420</td>
</tr>
<tr>
<td>40</td>
<td>108,005</td>
<td>108,005</td>
<td>96,039</td>
<td>96,039</td>
<td>88,327</td>
<td>84,598</td>
</tr>
<tr>
<td>20</td>
<td>172,382</td>
<td>172,382</td>
<td>160,416</td>
<td>160,416</td>
<td>152,704</td>
<td>148,975</td>
</tr>
</tbody>
</table>

Table 13: Unpainted Tower Whole-of-Life Present Cost

Tower failure likelihood

The proportion of the tower fleet at high likelihood of immediate structural failure (due to tower steel degradation and under every-day loading conditions), is calculated based on proportion of fleet with a condition score less than CA 20.

C3 Findings

This section discusses the effect of different levels of tower painting on the likelihood of tower structure failure across the fleet.

Towers are prioritised according to the prioritisation matrix described in the Towers and Poles fleet strategy. The prioritisation matrix assigns priority according to asset risk using asset health (likelihood) and network criticality (consequence).

As discussed in chapter 4, demand for tower painting increases steeply as the tower fleet ages. As stated in the key assumptions above, current modelling assumes that re-painting is always ‘on-time’, which leaves the level of ‘new’ paint as the change variable.

Present cost and long-term failure likelihood

Figure 32 shows the effect of different levels of tower painting on the present cost, and the long-term failure likelihood of the tower fleet.
A tower with a high likelihood of failure over the long-term is one that is forecast to fall under CA 20 in the future.

**Present Cost and Failure Likelihood vs Paint Quantity**

Notable results include:

- the overall trend of the painting programme cost increases linearly with the average quantity painted.
- minimum present cost of painting occurs when painting approximately 300 towers each year from 2013/14 to 2029/30; yet this level of painting results in a significant proportion of the fleet (about 85%) being at high likelihood of structural failure in the long term.\(^9\)
- if a long-term target of 0 tower failures per year is desired, the optimal (unconstrained) paint quantity of approximately 780 each year through to 2029/30 results in the minimum present cost (an expected result as the optimal paint plan involves optimising the lifecycle painting cost for individual towers).

---

\(^9\) The stated quantity each year is for the period 2013/14 to 2029/30. The average quantity changes as the fleet ages and painting demand increases. See Table 15 for the average paint quantity modelled for specified periods.

\(^{10}\) A tower being at high likelihood of structural failure is a tower predicted to fall below condition score CA 20.
Paint quantity and failure likelihood

Figure 33 shows the effect of different levels of tower painting on the annual proportion of towers with a high likelihood of structural failure. Table 14 shows the average tower painting modelled quantity each year over a specified period.

![Figure 33: Tower Fleet Long-term Failure Risk](image)

Table 15: Tower Painting Modelled Quantity (average each year over specified period)

<table>
<thead>
<tr>
<th></th>
<th>2013/14 - 2029/30</th>
<th>2030/31 - 2039/40</th>
<th>2040/41 - 2049/50</th>
<th>2050/51 - 2059/60</th>
<th>2060/61 - 2069/70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan A</td>
<td>181</td>
<td>315</td>
<td>335</td>
<td>368</td>
<td>411</td>
</tr>
<tr>
<td>Plan B</td>
<td>299</td>
<td>567</td>
<td>715</td>
<td>763</td>
<td>770</td>
</tr>
<tr>
<td>Plan C</td>
<td>413</td>
<td>794</td>
<td>1,028</td>
<td>1,249</td>
<td>1,277</td>
</tr>
<tr>
<td>Plan D</td>
<td>527</td>
<td>1,014</td>
<td>1,282</td>
<td>1,558</td>
<td>1,589</td>
</tr>
<tr>
<td>Plan E</td>
<td>696</td>
<td>1,353</td>
<td>1,541</td>
<td>1,524</td>
<td>1,577</td>
</tr>
<tr>
<td>Plan F</td>
<td>1,157</td>
<td>1,565</td>
<td>1,548</td>
<td>1,547</td>
<td>1,622</td>
</tr>
<tr>
<td>Optimal</td>
<td>760</td>
<td>1,362</td>
<td>1,435</td>
<td>1,537</td>
<td>1,523</td>
</tr>
</tbody>
</table>

Below are three notable results.

- The overall long-term trend for a painting plan averaging less than about 500 towers each year through to 2029/30 is a steep increase in the proportion of towers with a high likelihood of structural failure. The rate of increase slows after approximately 2040, as a large percentage of the fleet will have been painted.

- Tower painting plans averaging above 500 towers each year from 2013/14 to 2029/30 result in a lower long-term increase in the proportion of towers with a high likelihood of structural failure.
In the medium term to long term, we need to significantly increase the number of towers being painted, to avoid the adverse outcomes demonstrated in this model. See the Towers and Poles fleet strategy for details on how we plan to address this need.

**Cost of deferred painting**

Figure 34 shows the effect of painting less, or, in the case of Plan F, more than the optimal unconstrained paint plan described in chapter 4.

‘Cumulative Benefit’ represents the near-term savings, in real 2012/13 dollars, that a less-than-optimal painting plan may deliver, when compared to the cumulative expenditure required to paint to the optimal unconstrained plan. As the fleet ages and the tower painting backlog grows, the rate of unplanned tower failures due to severely corrosion increases significantly, resulting in increasingly large expenditure on recovery from failure.

![Cumulative Benefit of Deferred Painting](image)

**Figure 34: Cumulative Benefit of Deferred Painting (see Table 15 for an explanation of the plans)**

Below are two notable results.

- All modelled painting plans, excepting Plan F, represent a lower-than-optimal near-term painting quantity. These plans deliver a positive financial benefit for the short term to medium term, but this benefit is quickly reversed if the rate of painting is not dramatically increased in the long term.

- The cumulative benefit trend for Plan F (which represents significant over-delivery of painting) shows that there is no tangible financial benefit in over-painting the tower fleet.