Action Plan

Treatment of prioritised asset risks subsequent to WSP's independent review of Aurora Energy's electricity distribution network.

30 September 2019

Document Control

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Revision Schedule

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1 Introduction

In 2018, Aurora Energy commissioned an independent review of the state of its electricity network. The main aims of the review were to confirm the state of our network and to determine the resulting risk to customers and the wider public.

The final report of the independent risk review by WSP was published in November 2018 and found most of Aurora Energy's assets pose a low risk to public safety, reliability or the environment. The final report is available on our website www.auroraenergy.co.nz together with summary information.

The review provided important insights and conclusions, including independent assurance that:

- most of our assets pose a low risk to public safety, reliability or the environment; and
- we are targeting our proposed investments in areas that need it most and will deliver the most safety, reliability and resilience benefits.

The review also highlighted the asset fleets (e.g., secondary systems, poles and cross arms) that have a portion of assets whose condition carry a higher public safety risk.

WSP's final report included a prioritised list of asset/process risks that needed to be addressed. The purpose of this Action Plan is to supplement our asset management plan by providing specific and detailed information on how assets deemed as having high-priority risk will be managed. This Action Plan will form the basis for ongoing delivery reports that will track our progress in addressing the issues raised in the WSP report.

2 Purpose

The purpose of this Action Plan is to demonstrate how the risks identified by WSP will be assessed, prioritised and treated.

We remain committed to open and transparent communication with our stakeholders on how the risks identified by WSP are addressed. We recognise that this Action Plan is a cornerstone of that commitment.

We expect that this Action Plan will ultimately document our approach to addressing all of the risks identified by WSP's report, not just those that are regarded as high-priority according to our risk management framework (albeit, that may be managed by referencing existing approaches documented within our asset management plan). In this way, we expect that, over time, the findings of the WSP can be objectively closed out.

3 Approach

The planning challenge in addressing the risks identified by WSP is complex, and the resources required to achieve a meaningful level of detail are not insignificant, as it requires strategic, planning and operations considerations to be brought together coherently. The challenge is heightened for asset categories where WSP's quantification of risk is based on statistical modelling and analysis. Establishing treatments for those asset categories will require considerably more effort and resource, in order to identify the specific assets that are actually at risk, and which require replacement or remediation.

3.1 Development of the Action Plan

We are an organisation that is working at full capacity, as we execute the largest works programme in the Company's recent history, and develop our customised price-quality path (CPP) application. This resource constrained environment imposes a limitation on how quickly this Action Plan can be developed while maintaining the preliminary work necessary for ensuring that workflows are both maintained and as efficient as reasonably practicable.

To manage our resource constraints, we have staged development of our Action Plan. Our approach has been to prioritise those risks that our risk management framework classifies as high-priority, over lesser-priority risks. Of the high-priority risks, we have had to further prioritise risks that are predominantly safety driven (high priority risks affecting the safety of the public and/or workers), over those that are predominantly reliability driven. Prioritising in this manner must not be construed as Aurora Energy considering reliability to be unimportant. It is simply that our values drive us to consider safety first in the decisions we make, and so prioritising safety over reliability is entirely consistent and appropriate.

Further discussion of our risk management framework is given in section 3.3, below.

Figure 1 - Aurora Energy's Values

Our prioritisation results in this action plan being developed in three distinct phases:

- **First edition:** addressing predominantly safety-driven high-priority risks, affecting the secondary systems (protection), zone substation circuit breakers, support structures, and conductor fleets, along with cast-iron potheads;
- **Second edition:** addressing remaining high-priority risks, affecting the power transformer, distribution transformer, and distribution switchgear fleets; and
- **Third edition:** addressing the remaining moderate risks identified by WSP.

We are taking an asset fleet-based approach, so it is natural that there will be some crossover in risk treatment (for example, the approach to addressing high priority risks identified with zone substation circuit breakers will be very similar to the treatment for moderate risks identified with that asset category, although the timing of treatment will differ).

3.2 Living Document

This Action Plan is a living document. It will be used internally to guide, document, and explain our approach to reducing or remediating the risks identified by WSP.

This Action Plan will be updated periodically (quarterly) to reflect operational changes as our understanding of the risk impact on specific assets and asset categories increases, and to include reporting on our progress. Over time, we expect that our understanding of specific assets will improve as new inspection and condition data becomes available. This enhanced knowledge will also drive better certainty over the timing of treatments and interventions. The timetable for further development of this Action Plan, over the 2019 calendar year, is given below.

	2019 (Jan–Dec)
Interim draft	4 April 2019
Action plan - first edition	30 April 2019
Action plan - second edition	30 May 2019
Action plan - third edition	31 July 2019
Action plan public disclosure	31 July 2019
Quarterly progress report	31 July 2019
Quarterly update and progress report	27 September 2019
Quarterly update and progress report	20 December 2019

Figure 2 - Action Plan Development and Reporting Timetable (2019)

3.3 Asset Management Plan and AMP Updates

This Action Plan stands as an adjunct to our 2018 asset management plan (AMP) and 2019 AMP Update. While the expenditure profiles in our 2019 AMP Update reflect the work needed to address the risks identified by WSP, this Action Plan provides the specific detail, not covered in the AMP Update, addressing how those risks will be dealt with.

This relationship will continue with future AMP publications until such time as actions relating to the WSP review can be objectively closed out.

4 Deliverability

Deliverability is a key factor in being able to successfully address the risks identified by WSP. Asset renewal and replacement is a key element of remediating the risks identified by WSP, along with increased inspections and maintenance interventions.

The negotiation of new contracts with Aurora Energy's principal contractors Delta, Connetics and Unison Contracting was started in August last year and, over the past year, all three contractors have been supporting us to deliver our major programme of work. Connetics and Unison, as new contractors, commenced under new contract arrangements on 1 April 2019.

While Delta, Connetics and Unison Contracting are our principal contractors for network work programmes, other contractors are available for customer-initiated work that would otherwise draw on principal resources. CIW contractors can also be drawn on for network work programmes as needed. The option of tendering specific work packages to the wider market exists; however, the work packages would generally need to be sufficiently large to make mobilisation/de-mobilisation economic.

We are confident that our expanded contracting pool will provide Aurora Energy with access to sufficient resources, at reasonably efficient cost, to execute the AMP and this Action Plan.

In addition to our field service capability, successful delivery of this Action Plan requires sufficient internal resource to develop new asset fleet strategies and plans, new systems and processes and project management and reporting capability. This Action Plan, including the tracking of our initiatives under each asset fleet section, provides an effective basis to monitor emerging internal and external resource constraints.

While the focus of this Action Plan is to address the high-level risks identified by WSP, we will also incorporate new feedback from the field and internal analysis that we consider presents a high-level risk to safety, or the performance of the assets more generally. For example, we have included the identification and replacement of steel conductor in high criticality areas.

4.1 Contingent Event Mitigation

While elevated levels of risk remain, and treatment plans are developed and implemented, there is a probability that a contingent event will occur. We can mitigate the impact of contingent events by preparing and implementing a range of business controls. For the asset fleets discussed in this Action Plan, we have the following controls and capabilities in place:

- Critical spares holdings across all asset fleets (and we have a critical spares review in progress);
- Mobile distribution substations (3);
- Mobile generators (3);
- 5MVA power transformer (on order);
- Mobile 66kV/33kV/11kV zone substation;
- Business continuity plans;
- Feeder and zone substation contingency plans.

Incident management and response planning is based on the Coordinated Incident Management System (CIMS), which is used by emergency services, civil defence emergency response organisations, and many utility operators in New Zealand.

5 Risk Framework

Our risk management framework is described in our Risk Control and Management standard (AE-HS02-S). We use a 5 x 5 likelihood-consequence matrix to establish a hierarchy of risk ratings, ranging from insignificant to extreme, and to designate a risk appetite boundary.

LIKELIHOOD	CONSEQUENCE				
	Insignificant	Minor	Moderate	Critical	Catastrophic
Almost Certain	L	M	H	E	E
Likely	L	L	M	H	E
Possible	I	L	M	H	H
Unlikely	I	I	L	M	H
Rare	I	I	L	M	M

Risk Rating	
E	Extreme
H	High
M	Medium
L	Low
I	Insignificant

Figure 3 - Aurora Energy Risk Matrix and Risk Appetite Boundary (AE-HS02-S, section 8, pp 27-29)

Risks that are above the risk appetite boundary (shown in purple in Figure 3) are considered to be high-priority risks and all reasonably practicable steps must be taken to mitigate, manage or reduce such risks.

Risks below the risk appetite boundary are generally only addressed to the extent that the benefit of treatment outweighs the cost of treatment. Typically, asset risks that exist below the risk appetite boundary would be managed in the normal course of asset lifecycle management.

5.1 WSP's Risk Prioritisation

As part of its review, WSP identified a prioritised list of risks in Appendix F to its report. In prioritising the identified risks, WSP used Aurora Energy's risk matrix to present its analysis. Figure 4, shows the risk priorities identified by WSP, mapped against Aurora Energy's risk matrix.

PROBABILITY	CONSEQUENCE				
		8	4	2	1
			7	3	2
			8	5	4
				7	5
				8	7

Figure 4 - Risk Prioritisation - WSP Report (Section F1, pp F1-F5)

Table 1, below, shows a summary of the prioritised risks identified by WSP that sit above Aurora Energy's risk appetite boundary. It is noted that one process risk is identified (inspection and testing of support structures – priority 3), all other prioritised risks are related to asset conditions or performance.

Priority	Risk Description	Locations	Quantity	Risk Driver
1	Nil			
2	Protection relays	12	504	Safety
	Protection coordination	1		Safety
	Instrument transformers	39		Safety
	Battery banks & chargers	39		Safety
	Zone substation circuit breakers	4	41	Safety & reliability
3	Cast-iron potheads		145	Safety
	Statter distribution switchgear		5	Safety & reliability
	Aged light Cu conductor		9.7km	Safety & reliability
	Malaysian hardwood crassarms		3601	Safety
	Support structure testing & inspection processes		Fleet	Safety
	High-risk crossarms		2142	Safety
	High-risk poles		1397	Safety
	Zone substation circuit breakers	4	60	Safety & reliability
	Zone substation transformers	1	1	Reliability
4	Zone substation circuit breakers	1	1	Safety & reliability
	Zone substation transformers	1	2	Reliability
5	Long & Crawford distribution switchgear		15	Safety & reliability
	GM distribution transformers		34	Reliability
	PM distribution transformers		25	Reliability
	Zone substation circuit breakers	1	3	Safety & reliability
	Zone substation transformers	4	5	Reliability

Table 1 - WSP High Priority Risks (Summary) – Above Aurora Energy's Risk Appetite

6 High-priority Risks by Fleet

Our risk management framework requires 'all reasonable practical steps' to be taken to address risks above the risk appetite boundary (see Figure 4). Table 2, below, categorises the high-priority risks identified by WSP according to asset fleet.

Risks by Fleet				
Secondary Assets Fleet				
Priority	**Risk Description**	**Locations**	**Quantity**	**Risk Driver**
2	Protection relays	12	504	Safety
	Protection coordination	1		Safety
	Instrument transformers	39		Safety
	Battery banks & chargers	39		Safety
Zone Substation Circuit Breakers				
Priority	**Risk Description**	**Locations**	**Quantity**	**Risk Driver**
2	Zone substation circuit breakers	4	41	Safety & reliability
3	Zone substation circuit breakers	4	60	Safety & reliability
4	Zone substation circuit breakers	1	1	Safety & reliability
5	Zone substation circuit breakers	1	3	Safety & reliability
Zone Substation Transformers				
Priority	**Risk Description**	**Locations**	**Quantity**	**Risk Driver**
3	Zone substation transformers	1	1	Reliability
4	Zone substation transformers	1	2	Reliability
5	Zone substation transformers	4	5	Reliability
Distribution Transformers				
Priority	**Risk Description**	**Locations**	**Quantity**	**Risk Driver**
5	GM distribution transformers		34	Reliability
	PM distribution transformers		25	Reliability
Cast Iron Potheads				
Priority	**Risk Description**	**Locations**	**Quantity**	**Risk Driver**
3	Cast-iron potheads		145	Safety
Distribution Switchgear				
Priority	**Risk Description**	**Locations**	**Quantity**	**Risk Driver**
3	Statter distribution switchgear		5	Safety & reliability
5	Long & Crawford distribution switchgear		15	Safety & reliability
Support Strucutres				
Priority	**Risk Description**	**Locations**	**Quantity**	**Risk Driver**
3	High-risk crossarms		2142	Safety
	High-risk poles		1397	Safety
	Support structure testing & inspection processes		3601	Safety
	Malaysian hardwood crassarms		Fleet	Safety
Conductors				
Priority	**Risk Description**	**Locations**	**Quantity**	**Risk Driver**
3	Aged light Cu conductor		9.7km	Safety & reliability

Table 2 - WSP High Priority Risks (Summary) – Asset Fleet View

7 Action Plan scope

This Action Plan addresses those assets and processes with a risk priority above Aurora Energy's risk appetite boundary (high-priority risks). These are outlined in Table 2 (above).

For each asset fleet identified with high-priority risks, this Action Plan includes a section on:

- **Identified Risks:** including our high-level view on WSP's findings and any additional findings of our own. Where feasible we list the specific assets to be addressed by this Action Plan. This section also captures additional risks or information that helps to refine our Action Plan for each asset fleet.
- **Asset Management Approach**: to provide fleet-wide context on how our specific actions to address the WSP risks fit into our overall asset lifecycle management plan.
- **Planned Actions and Progress:** including; what we have planned, underway, completed to-date and what operational mitigations we have put in place to manage risk in the short-term while our medium-term Action Plan is implemented.

8 Progress Update

In this section, we document the incremental progress made since the previous edition of the Action Plan. Overall progress by asset category will be tracked in the tables given in each relevant fleet section.

Since the prior update of this plan, the following progress has been made:

8.1 Secondary Systems

- Protection design philosophy document completed to final draft stage;
- Revised protection design standard prepared an undergoing management review;
- Protection coordination review scope has been finalised;
- Protection relay replacements for St Kilda and Corstorphine one substations have been scoped, and procurement of detailed design is underway;

8.2 Zone Substation Circuit Breakers

- Development of 11kV standard switchgear specification completed and tender in progress;
- Zone substation high-level design criteria in development;
- Andersons Bay, Outram, Smith Street and Queenstown replacements in design phase.
- Operational safety measures developed for Alexandra zone substation and sites with non-arc fault contained indoor switchgear

8.3 Zone Substation Transformers

- Risk management / contingency plan for Zone Substation transformers under development;
- Critical spares review in progress;
- Cromwell transformer replacement detailed design completed, and procurement initiated;
- Andersons Bay transformer replacement in preliminary design;
- Green Island transformer replacement being scoped.

8.4 Support Structures

- Pole testing methodology review in progress;
- Separate asset register for crossarms in development;
- Wood pole forensic study in progress;
- Zone 1 (high criticality) wood pole remediation 82% completed;
- 80% of wood poles now within 5-year test/inspection cycle

8.5 Overhead Conductor

- Fleet strategy in development;
- Initial conductor testing completed and results being analysed;
- Trial of helicopter inspections undertaken and results reviewed;
- Short-term prioritised replacement plan established. RY20 replacement plan 20% complete;
- Queenstown/Glenorchy conductor review initiated.

8.6 Underground Cables (Cast-iron Potheads)

- Being progressed in accordance with the Asset Management Plan – refer section 14.

8.7 Distribution Transformers

- Being progressed in accordance with the Asset Management Plan – refer section 15.

8.8 Distribution Switchgear

- Being progressed in accordance with the Asset Management Plan – refer section 16.

9 Secondary Systems (Protection)

9.1 Identified Risks

As identified by WSP, safety is the main risk driver for secondary system assets. Protection failure can also lead to a reduction in reliability performance where network faults impact a wider group of customers than is necessary. The following table summarises the WSP identified secondary system risks and our initial view of those risks. In general, we agree with the risks that have been identified and provide additional commentary to support, clarify and interpret the findings.

<table>
<tr><th>WSP Report Findings</th><th>Aurora Energy's view of WSP findings</th></tr>
<tr><td>Protection Relays
There are 382 electromechanical relays (36% of the relay fleet) and 106 electronic relays (10% of the relay fleet) that are exceeding their expected life. This indicates an elevated risk of failure of these assets.
In a four-year period, 20 faults on the HV network were not cleared by the immediately up-stream protection asset.
Five types of electromechanical relays are now an obsolete technology and are consistently losing calibration between maintenance cycles. These relays are used for earth fault and over-current detection. The failure of these relays to operate as intended has resulted in live conductors on the ground not being detected and de-energised. Most observed instances where earth faults were not isolated were found to involve the identified relay types or older electromechanical relays more generally. This supports they are at the end of their serviceable lives. Protection system assets pose a significant safety risk and their remediation should be assigned a high priority.</td><td>We agree that we have an aging protection fleet that requires prioritised renewal.
Some of the 20 faults where protection did not operate were in situations where the fault was unlikely to be detected by protection regardless of age or condition of the protection system, e.g. low lines or lines down on the downstream side of a conductor break.
Notwithstanding the above, the electromechanical relays are due for replacement; we consider that some of the perceived drift in relay calibration is likely to be linked to inconsistencies in the testing approach and equipment. This needs to be addressed in the interim while we undertake a replacement programme.</td></tr>
<tr><td>Instrumentation Transformers
Historically current and voltage transformers have not been tested so there is no test data available for review. Historically instrument transformers have not been tested during maintenance. Testing was implemented this year for current transformers (2018) and a high rate of failure was found. Voltage transformers are still not tested as part of the inspection and maintenance procedures. The high failure rate and incomplete testing indicates an elevated level of risk on the network. The extent of the risk was not quantified as part of the WSP review as testing requires an outage of the associated protection system and substation.</td><td>We agree that instrumentation transformers pose a high risk to the successful operation of protection systems. We took immediate action and all Instrumentation transformers now have a test programme. Earlier in 2019, we found CTs at Green Island and Smith St had low insulation resistance due to an insulating washer breakdown. We have now replaced the insulating washers at both sites.</td></tr>
</table>

Battery Banks & Chargers • The majority of substations only have a single battery and charger configuration resulting in a single point of failure that could impact the protection systems should they fail. Approximately half of these do not have an alarm via SCADA to alert the control room to a charger failure. WSP's view is that there does not appear to be a standard battery system design for the network and a number of different battery types were found during site inspections. • Most sites have battery banks that are in a serviceable condition except East Taieri, North East Valley, North City.	• We agree that we need to consider whether a single battery bank and rectifier approach is appropriate for our zone substations. We have implemented a DC upgrade programme to offer dual battery bank and rectifier DC systems at high criticality sites, where practicable. Where not practicable we are reviewing the options to reduce risk, including reducing the replacement life of the battery bank system. • We have reviewed the DC system SCADA alarms and confirm that all but two (small) zone substation sites have at least a basic DC system alarm. Our current practice at new and refurbished sites is to provide a more comprehensive approach to DC System alarms as battery/converter replacements occur.
Protection Coordination • Alexandra, Smith St and Cromwell were mentioned as potentially having protection coordination risks.	• We agree that there is potential for protection coordination errors at these sites. We note that both Cromwell and Smith St have major work beginning soon which will necessitate a protection review • We also consider that there are other locations on the network where the protection systems are complex and protection coordination has not been reviewed recently

9.1.1 Specific Assets Identified by WSP

The following table lists the secondary systems assets requiring risk mitigation.

Location	Asset Type	Quantity
Alexandra ZS	'Other' electromechanical relays	19
Andersons Bay ZS	AKA, PBO, FGL and 'other' electromechanical relays	58
Corstorphine ZS	TCD5 and 'other' electromechanical relays	54
Green Island ZS	AKA, PBO, FGL and 'other' electromechanical relays	55
Halfway Bush GXP	'Other' electromechanical relays	7
North City ZS	'Other' electromechanical relays	29
Queenstown ZS	'Other' electromechanical relays	23
Smith Street ZS	TCD5 and 'other' electromechanical relays	59
South City ZS	TCD5 and 'other' electromechanical relays	68
St Kilda ZS	TCD5, TJM10 and 'other' electromechanical relays	52
Ward Street ZS	'Other' electromechanical relays	25
Willowbank ZS	AKA, PBO, FGL and 'other' electromechanical relays	55

WSP also identified issues with 64 x AKA, PBO, FGL and 'other' electromechanical relays at Neville Street; however, that substation was fully decommissioned on 21 December 2018, thereby eliminating that risk.

We note that the WSP findings incorrectly report 29 electromechanical relays at North City substation. All of the incomer, feeder and bus protection relays have been replaced with SEL 351 relays. The only remaining older relays are the transformer Buchholz, winding temperature and cooler control.

9.1.2 Additional Findings Since the WSP Review

The introduction of instrumentation transformer testing found deterioration of paxolin insulating washers on the Green Island and Smith Street instrument transformers, compromising performance. These washers have been replaced.

9.2 Asset Management Approach

At a high level, there are three main factors to consider when managing risks for the secondary systems fleet:

I. **Strategic Approach** – including equipment choice, scheme design and settings;

II. **Investment Planning** – timely, prudent replacement to ensure assets deliver reliable operation; and

III. **Operations and Maintenance** – what inspection, maintenance and additional operational measures will be required to achieve reliable operation.

When developing our Action Plan for secondary systems, we considered each of the above three categories. For example, like-for-like replacement of secondary system assets would be a lost opportunity if we did not explore greater protection performance options and upgrades to achieve safer functionality. WSP has identified risks in protection coordination capability, but most risks are associated with the condition/health of the secondary systems assets.

Given the relatively high number of sites and protection relays with heightened risk, we are not able to address all risks immediately and, therefore, we need to consider how we can best manage the risks, taking account of criticality to prioritise our asset interventions.

Work at Halfway Bush is underway, and detailed design for Smith St and Andersons Bay is underway, which creates a forward workload for our contractors and time to consider how we prioritise the remainder of our protection risks. Our prioritisation process considers the following aspects:

Safety

The safety of the general public, our customers and our people is paramount. When building the protection replacement plan, safety holds the top consideration. The safety criticality aspects we consider are:

> Asset Type: Given that overhead line circuits present a higher safety risk than cable circuits, the protection systems for predominantly overhead circuits are prioritised for replacement over those protecting predominantly cabled circuits.
>
> Population Density: Population density is the next most important consideration, given that this will impact the likelihood of a poorly performing protection system causing a safety incident. For example, a live conductor on the ground in a highly populated area carries a higher risk than a conductor down in a remote rural setting. We use points of interest and transport volumes as a proxy for population density.

Environmental Factors

For protection systems, dry forested areas (as a high-priority example) present a higher environmental risk in a line-down situation than irrigated paddocks or road reserve (as counterfactual examples).

Reliability Performance

The impact on reliability performance is dependent on the failure mode of the protection and requires careful consideration. For example, a false tripping on an N-security circuit results in an unnecessary power outage to customers. Conversely, a protection failure to operate on an N or N-1 system may lead to back-up systems operating and causing a widespread outage. In general, N security circuits carry a greater reliability risk.

Works Coordination

Coordinating protection replacement work with other replacement work, such as zone substation switchgear, creates project management and construction efficiencies. Given the number of sites that need to be addressed in the short-term, we do not expect to be able to do all protection replacement work in conjunction with other work, but we will seek to achieve works coordination where other priorities align and/or where risk can be managed in the short-term.

9.3 Planned Actions and Progress to-Date

As introduced above, our overall approach for secondary systems includes three main elements which have been summarised below. Our progress reporting has been split into two categories to show; how we are tracking with our strategic/process initiatives and our progress to address the specific high-priority risks.

Strategic Approach

We have begun a series of strategic initiatives to ensure that we prioritise our renewals effectively and to ensure that our protection replacement design and configuration meets the functionality and performance expectations of customers and wider stakeholders.

Investment Planning

We have committed to construction or detailed design for relay replacements at three of the high-priority risk sites. This ensures that we have work in the pipeline while we complete our prioritisation planning for the remaining high-priority risk sites. We expect to update / refine our prioritisation as we complete our strategic approach and new inspection and performance information becomes available..

Given the backlog of protection relay replacements, we have considered temporary arrangements; for example, the installation of reclosers outside zone substations to provide assurance of protection operation in the short term. However, this will divert key resources from our main replacement programme, and we consider the short-term risk to be manageable by prioritising our plan and taking other operations and maintenance actions. We will revisit this decision if protection performance deteriorates at any particular site and we are not able to respond quickly with full replacement.

Operations and Maintenance

We will make a number of operational changes to reduce risk to as low as reasonably practicable, until high-risk assets can be removed from the network. We are reviewing our maintenance approach, with a particular focus on identifying short term changes to address aging protection assets.

9.3.1 Improvement Initiatives

The table below sets out the status of Improvement Initiatives that support de-risking our Secondary Systems Fleet

Improvement Initiative	Initiated	In progress	Complete	Status	Comments
Strategic Approach					
Develop a protection design philosophy					See note 1
Develop a protection design standard			Mgmt. Review		See note 2
Protection coordination review					See note 3
Investment Planning					
Develop replacement prioritisation plan					See note 4
Identify settings and coordination gaps					To follow coordination review
Identify gaps against standard					To follow design standard
Operations and Maintenance					
Review maintenance procedures					See note 5
Provide contractor training	Proposed				See note 5
Review maintenance timing					See note 5
Address contractor resource constraints	Monitored				See note 5

Note 1	We engaged Ergo Consulting to assist with developing a protection design philosophy. The philosophy documents the key matters that are to be considered when designing a protection system and is intended to align our protection approach with industry best practice. This approach will allow our engineers and engineering consultants to quickly assess the substation or line protection needs and develop a solution. It will also pave the way for development of standard design elements, which will assist the end-to-end delivery of our protection replacements, with a particular emphasis on design time reduction. Note that our philosophy for DC systems is also included.
Note 2	Following completion of the protection design philosophy, we are underway with the development of a protection design standard. We have prepared a standard R&I template and setting guidelines.
Note 3	We are finalising the scope of the protection coordination review, based on highest risk of lost protection coordination. We have created a two-pronged approach with some areas of protection coordination being reviewed and addressed during renewal projects and other areas being specifically targeted through a protection coordination review.
Note 4	RY20/21 priorities have been established. Protection replacement for Corstorphine, Green Island and South City zone substations are likely to be high priority sites

Note 5	We have completed a review of our maintenance practices/procedures, leading to revised procedures and a reduced inspection cycle of 2 years for solid state and electromechanical relays to address the risk of inter-inspection setting drift or failure. Contractor training is to be developed to ensure adherence to the new procedures. Contractor resource/capability is being monitored and will be addressed if constraints emerge.

9.3.2 Work Programme

The table below sets out the status of the work programme. Note that, at this stage, the timing is as per our 2019 AMP Update and is likely to change as we complete our prioritisation work described above.

Asset / Site	Prioritisation	Scoping / Design	Construction	Complete	Timing	Comments
Alexandra ZS	TBD				RY22	
Andersons Bay ZS	Priority 2	Design in progress			RY23	To be bought forward
Cromwell ZS	Growth driver				RY20	
Corstorphine ZS	Priority 3	Scoped			RY20/21	
Green Island ZS	TBD				RY22	
Halfway Bush GXP	Priority 1	Complete	In progress		RY20/21	See note 1
North City ZS	TBD				TBD	See note 2
Queenstown ZS	Priority 2	Design tendered	TBC		RY21	See note 3
Smith Street ZS	Priority 1	Design in progress	RY20/21		RY21	
South City ZS	Priority 3				RY20/21	
St Kilda ZS	TBD	Scoped			TBD	
Ward Street ZS	TBD				TBD	
Willowbank ZS	TBD				RY22	
Additional works						
Instrument transformers			In progress			See note 4
Cromwell coordination		To be instigated			RY20	See note 5
Clyde to Alexandra Subtransmission		Complete	RY19/20			See note 6
Outram ZS		Design in progress	RY20/21			See note 7

Neville St ZS				Complete		See note 8
Cardrona ZS				Complete		See note 9
Roaring Meg	Growth driver	Design in progress			RY20	See note 10

Note 1	HWB GXP protection upgrade site works are underway. While the principal driver for this project is coordination with Transpower's ODID project, the work being undertaken removes a small number (7) of the high risk relays identified by WSP
Note 2	Aurora has been served with Notice of Desire, given under s18 of the Public Works Act 1981, to acquire the land on which the North City substation resides. The Notice has been issued by the Minister of Land Information, on behalf of the Ministry of Health, in relation to the redevelopment of the Dunedin Hospital. This has created some immediate uncertainty as to priority of treatment.
Note 3	An upgrade of Queenstown zone substation upgrade is in the detailed design phase. This project includes replacement of aging protection systems and will align to the new protection philosophy and standard
Note 4	Instrumentation transformer insulating washer replacements have been completed at Green Island and Smith Street zone substations
Note 5	The Cromwell transformer replacement and protection upgrade is scheduled for 2020/21. A protection coordination review will be undertaken as part of this project
Note 6	Clyde to Alexandra subtransmission protection is being replaced in 2019/20 to address intermittent performance of aged communication and Combiflex relays.
Note 7	Although not identified as a high risk protection site, an upgrade of Outram substation is scheduled for 2020/21 for other reasons and will include replacement of aging protection systems and will align to the new protection philosophy and standard.
Note 8	Decommissioning of Neville Street zone substation has removed 64 high risk protection assets from the network.
Note 9	Changes to Cardrona zone substation protection settings have been made in accordance with a recommendation from Tesla, and as a part of the protection coordination review.
Note 10	The 33/6.6kV Roaring Meg generation feeder protection has protection on the generation end only. This connection is being redesigned with 33kV recloser breaker with OC/EF protection under Cromwell transformer upgrade project.

10 Zone Substation Circuit Breakers

10.1 Identified Risks

The zone substation circuit breaker fleet is comprised of indoor and outdoor circuit breakers that use oil, vacuum and gas (SF6) interruption technologies.

As identified by WSP, there are both safety and reliability risks associated with zone substation circuit breakers. The following table summarises the WSP identified zone substation circuit breaker risks and our initial view of those risks. In general, we agree with the risks that have been identified and provide additional commentary to support, clarify and interpret the findings.

WSP Report Findings	Aurora Energy's view of findings
• The asset data available from Aurora's systems and augmented by our field inspections was suitable for the purpose of this review. We note that the data is not complete and improvements to consistency of the data recorded can be made. Incomplete asset data presents a risk to effective asset management.	• We agree that while zone substation circuit breaker data is of a relatively good quality, there is an opportunity to improve the collection and storage of attribute and condition data.
• There are 129 circuit breakers (31%) have exceed their expected lives.	• We agree that the identified circuit breakers require an end of life remediation plan.
• The inspection, testing and maintenance of ZSS circuit breakers is incomplete with 25 circuit breakers not been maintained within the required maintenance schedule. In addition, the internal mechanisms of HLC and HKK type circuit breakers have not been maintained. This elevates the probability of these assets failing.	• We agree that greater emphasis is required to ensure that CBs are maintained at regular intervals. Discussion held with original equipment manufacturer (OEM) on the HLC and HKK CBs concludes that they are no longer supported, and replacement is suggested.
• Some oil insulated zone substation circuit breakers were found to present an elevated risk to the network with respect to network reliability and the safety of field crews due to their potential failure mode through arc fault and fire. • Some of the specific types of circuit breaker in-service on the Aurora network have been identified in the electricity industry as having an elevated risk of failure, in particular the HLC, HKK and LMT models. • The switchboards are not rated to contain an arc fault and, hence, pose an elevated risk to field crews. • The VWVE type switchgear was modified at installation which has enabled moisture ingress and deterioration of the assets.	• We agree that these CBs are an elevated risk and require prioritised replacement. In the short term safe operating procedures are in place including remote operation. • Dunedin LMT switchgear is 11 kV rated and we operate all except one LMT switchboard (East Taieri) at 6.6 kV, causing less stress on the insulation and clearances.
• A number of indoor circuit breakers have been installed in custom built outdoor enclosures which, upon site inspection, did not appear to be fully sealed from the environment. This is likely to result in an increased rate of deterioration and an increased probability of failure.	• We agree and we are determining the priority of this switchgear replacement relative to the other priorities above.

10.1.1 Specific Assets Identified by WSP

Zone Substation	Number	DESCRIPTION
Alexandra ZSS	14	HKK and HLC circuit breakers. Not maintained internally. This includes High and Very High asset risks.
Arrowtown ZSS	2	HKK circuit breakers. Not maintained internally. This includes High and Very High asset risks.
Green Island ZSS	15	61 year old Cooke and Ferguson oil circuit breakers exceeding the expected life of 50 years. Have not been maintained within the maintenance schedule. This includes High and Very High asset risks.
Outram ZSS	10	57 year old circuit breakers are exceeding the expected life of 50 years, including 2 VWVE type which have an elevated risk due to modifications when installed. This includes High and Very High asset risks.
Andersons Bay ZSS	14	57 year old Brush bulk oil circuit breakers exceeding their expected life. High risk due to age, type and untested associated current transformers.
Halfway Bush ZSS	16	57 year old Cooke & Ferguson bulk oil circuit breakers exceeding their expected life. High risk due to age, type and untested associated current transformers.
Smith Street ZSS	15	61 year old Cooke & Ferguson bulk oil circuit breakers exceeding their expected life. High risk due to age, type and untested associated current transformers.
Willowbank ZSS	15	56 year old Brush bulk oil circuit breakers exceeding their expected life. High risk due to age, type and untested associated current transformers.
Omakau ZSS	1	HKK circuit breakers. Not maintained internally. This is a high risk.
Wanaka ZSS	3	VWVE type circuit breakers with issues due to modification when installed. This is a high risk.

10.2 Asset Management Approach

At a high level, there are three main factors considered when managing risks for the zone substation circuit breakers:

I. **Strategic Approach** – including future planning needs, equipment specification and approach to procurement.

II. **Investment Planning** – timely replacement to ensure assets deliver reliable operation.

III. **Operations and Maintenance** – what inspection, maintenance and additional operational measures will be required to achieve reliable operation.

Given the relatively high number of sites with heightened risk, we are not able to address all risks immediately and therefore we need to consider how we prioritise the de-risking of zone substation circuit breakers. Detailed design for Smith St and Andersons Bay is almost complete which creates a forward workload for our contractors and time to consider how we prioritise the remainder of our circuit breaker risks. Our prioritisation process considers the following:

Safety Factors

Worker safety is a material driver for the replacement of high-risk circuit breakers.

Environmental Factors

Environmental factors are not considered to be material at this time.

Reliability and Resilience

Reliability and resilience are material drivers for the replacement of high-risk circuit breakers, given the generally large number of ICPs connected to each circuit and the time required to off-load to adjacent circuits (where that facility is available). As per the WSP review, the risk and priority of replacement is high for sites without an 11kV or 6.6kV back-up.

Direct Costs

At this stage we do not expect the ongoing repair and maintenance costs to vary greatly between sites and therefore direct costs are not expected to drive prioritisation. If relevant, direct cost commentary and prioritisation will be added to future revisions of this Action Plan.

Works Coordination

Coordinating the Zone Substation Circuit Breaker replacement work with other replacement work such as zone substation Transformer and Protection upgrades creates project management and construction efficiencies.

In general, we expect that switchgear replacement will occur at the same time as protection replacement. There will be some sites where protection replacement will be accelerated in advance of switchgear due to higher protection risks and the need to manage our switchgear replacement programme within the deliverability capability of our contractors and the internal engineering and project management teams.

10.3 Planned Actions and Progress to-Date

As introduced above, our overall approach for zone substation circuit breakers includes three main elements which have been summarised below. Our progress reporting has been split into two categories to show how we are tracking with our strategic/process initiatives and also our progress to address the specific high-priority risks.

Strategic Approach

We have instigated strategic initiatives to ensure that we prioritise our renewals effectively and to ensure that the specification, configuration and procurement of our zone substation switchgear meets the functionality and performance expectations of customers and wider stakeholders.

Investment Planning

We have instigated a number of projects (Smith St, Andersons Bay and Queenstown) to replace aging zone substation circuit breakers. This ensures that we have work in the pipeline while we complete our prioritisation planning for the remaining high-priority risk sites. We expect to update / refine our prioritisation as we complete our strategic approach and mature our approach to achieving works coordination.

Given the backlog of switchgear replacements, we have considered temporary arrangements; for example, the installation of reclosers outside zone substations to provide assurance of switchgear and protection operation in the short term. However, this will divert key resources from our main replacement programme, and we consider the short-term risk to be manageable by prioritising our plan and taking other operations and maintenance actions. We will revisit this decision if protection performance deteriorates at any particular site and we are not able to respond quickly with full replacement.

Operations and Maintenance

We have made a number of operational changes to reduce risk to as low as reasonably practicable, until high-risk assets can be removed from the network.

10.3.1 Improvement Initiatives

The table below sets out the status of Improvement Initiatives that support de-risking our Zone Substation Circuit Breaker Fleet.

Improvement Initiative	Initiated	In progress	Complete	Status	Comments
Strategic Approach					
Develop ZS 11kV CB specification					See note 1
Tender for supply of 11kV CB					See note 1
Develop configuration criteria					See note 2
Investment Planning					
Develop replacement prioritisation plan		Refining			See note 3

Improvement Initiative	Initiated	In progress	Complete	Status	Comments
Operations and Maintenance					
Review maintenance procedures			Complete		See note 4
Review maintenance practices and test results					See note 5
Operational changes			Complete		See note 6

Note 1	Given the quantity of 11kV switchgear requiring replacement over the next 5 years, we will seek to specify and standardise our 11kV zone substation switchgear. The intention is to tender for a 3+2 year (or similar) switchgear supply contract enabling standardisation and efficiency gains. This is progressing slightly slower than anticipated but still on track to support our major replacement projects in the immediate pipeline.
Note 2	With the relatively wide range of zone substation sizes, with different levels of network back-up, we are developing configuration criteria, including number of feeders, bus coupler requirements and firewalls etc. Jacobs is assisting with this work.
Note 3	Design is underway for Smith St, Andersons Bay and Queenstown, and further work is now required to ensure that we prioritise the highest risk sites while coordinating with other asset risks, including protection replacement
Note 4	Improved maintenance procedures and forms have been completed to ensure that contractors are given the correct instructions and appropriate data collected. This is an ongoing improvement and the procedures and forms will evolve as we learn from the implementation of new electronic applications. Examples of improvements include insulation testing of CTs, removal of pressure test across a vacuum bottle, capture of cleanliness information before megger testing bushings etc.
Note 5	Review maintenance practices and test results. This will help determine an improved understanding of asset health, including constancy in maintenance practice which may lead to field service contractor training. Abnormal results are reported by the contractor to aid quick resolution.
Note 6	Standard safe operating practices are applied, and appropriate PPE worn. High-risk circuit breakers are almost exclusively opened remotely with the switch room evacuated.

10.3.2Work Programme

The table below sets out the status of the work programme. Note that, at this stage, the timing is as per our 2019 AMP Update and is likely to change as we complete our prioritisation work described above.

Asset / Site	Prioritisation	Scoping / Design	Construction	Complete	Timing	Comments
Neville St Decommission					RY19	See note 1
Alexandra	TBD	Investigation phase			RY22	
Andersons Bay	Priority 1	Design phase			RY23	See note 2
Arrowtown	TBD	Investigation phase			TBD	
Green Island	Priority 1	Investigation phase			RY22	
Halfway Bush	TBD				RY23	
Omakau	TBD				TBD	
Outram	Priority 1	Design phase			RY20	See note 3
Smith St	Priority 1	Design phase			RY20/21	See note 3

Asset / Site	Prioritisation	Scoping / Design	Construction	Complete	Timing	Comments
Queenstown	Priority 2	Design phase			RY21	See note 3
Wanaka	TBD	Design/Tender			TBD	
Willowbank	TBD				RY22	

Note 1	The de-commissioning of Neville St has removed 31at risk Circuit Breakers from our network.
Note 2	Detailed design complete but requires a review to ensure it meets our emerging switchgear specifications and configuration standards
Note 3	Detailed design underway in conjunction with substantial refurbishment of Outram and Smith Street substations

11 Zone Substation Transformers

11.1 Identified Risks

The zone substation transformer fleet is comprised of power transformers and their associated tap changers and bushings. WSP stated that most zone substation transformers are in good condition and they are inspected regularly and appear to be appropriately managed.

As identified by WSP, and in terms of 'high' risks, zone substation transformers pose a reliability risk only. The following table summarises the WSP identified zone substation transformer risks and our initial view of those risks. Many of the risks below are not considered high risk, but in some cases the risks identified (e.g. data deficiencies) could lead to longer-term high risks if not addressed. For this reason we have included a response in this Action Plan. In general, we agree with the risks that have been identified, and provide additional commentary to support, clarify and interpret the findings.

WSP Report Findings	Aurora Energy's view of findings
• The asset data available from Aurora's systems and augmented by our field inspections was suitable for the purpose of this review. We note that the data on tap changers and bushings is not complete and improvements to consistency of the data recorded can be made. Incomplete asset data presents a risk to effective asset management.	• We agree that, in general, we have adequate data for determining and managing the lifecycle of our power transformer assets. • We agree that there is an opportunity to improve data collection on bushings and tap changers, and we will consider this in our asset management system improvements.
• External deterioration that has resulted in minor oil leaks was identified on three transformers (4.7%).	• Oil leaks are captured in our inspection data, which forms part of our asset health scoring.
• Internal condition is assessed by analysis of the oil which is common industry practice. This shows the transformers to be in serviceable condition. However, we note that the oil has been filtered and there has not been a physical sample taken from inside the transformers to provide a baseline for the oil tests. This presents a risk that the oil test results may indicate a better than actual internal condition.	• Aurora has historically used online streamline oil filtering, on a rotational basis, to keep transformers dry. This may lead to lower than expected levels of dissolved gas and furans. However, industry experience shows that any material internal defects or degraded paper would still be visible in oil test results. We believe that, overall, our transformer active part (core and windings) health is good, as transformers have not been highly loaded. We will seek to introduce better records of when transformer oil is filtered to assist in oil analysis.

WSP Report Findings	Aurora Energy’s view of findings
• Test reports showed that the tap changer fleet was in acceptable condition, except for five tap changers (7.9%). There have also been three tap changer failures during the past year indicating an elevated level of risk from this transformer component. There are 24 tap changers that are overdue for maintenance by between 1 and 7 years.	• After investigation, Aurora believes that the data used for this assessment was incorrect. Three tap changers were found to be overdue for maintenance; one of these has now been maintained. The other transformers are N security sites (Clyde/Earnscleugh and Omakau) with insufficient 6.6 kV and 11 kV ties to enable a full offload. We plan to remedy the long term issue at Clyde/Earnscleugh by conversion from 6.6 kV to 11 kV, and in the meantime we will plan a shutdown to undertake this maintenance. Further investigation is required for Omakau. • Tap changer history, consideration of sister unit failures, and industry expertise are key factors in considering replacement of power transformers.
• Bunding around each transformer to contain oil leaks was established at all but 6 substations. The main risk related to a lack of bunding was at Omakau, which is located adjacent a small waterway. The environmental risk was classified as Moderate.	• Although this is not considered high risk, we have undertaken a review of these sites. Remediation options will be considered in due course, and in accordance with priority across other network assets. We believe remediation cost will not be justified on a risk basis at many sites until the transformer is decommissioned or replaced. • For growth reasons, Omakau substation may be relocated and we will consider whether oil bunding remediation is appropriate in the short term.
• Aurora has a mobile substation with connection points at most of the single transformer substations to provide support in case of a transformer failure.	• The mobile substation is a key risk control measure for our smaller single transformer zone substation sites.
• East Taieri was the only zone substation identified to pose a safety risk, classified as Moderate. It is located adjacent to a petrol station but does not have any physical protection in place to protect the petrol station in case of a serious failure and/or fire	• The transformers are relatively young and in good condition and hence we agree with the Moderate risk level, at most. • Following remediation of our high priority risks we will consider the options to address this risk, including modern pressure relief systems, Buchholz, differential protection and/or firewalls.
• The transformers at two zone substations are in poor condition, although we note that one is currently in the process of being decommissioned. Additionally, transformer tap changers are showing signs of deterioration and some are behind their maintenance schedule, increasing risk of an outage on the associated transformers.	• As noted above, the number of tap changers behind schedule is less than determined by WSP (only two transformers are behind schedule). We have a zone substation maintenance plan to monitor this going forward. • We will prepare and prioritise our transformer renewal programme accordingly.

WSP Report Findings	Aurora Energy's view of findings
• There were 8 transformers (12.7%) identified as high risk to reliability, predominately due to the transformer internal condition and tap changers.	• We are prioritising the replacement of these transformers. Aged tap changer issues are the highest risk to our transformer fleet reliability.

11.1.1Specific Assets Identified by WSP

ASSET	NUMBER	DESCRIPTION	AURORA COMMENT
Green Island T1and T2	1	Transformer condition modelled to be poor. Tap changer has not been maintained within the required schedule resulting in high risk.	These transformers are within maintenance cycle. Replacement of these transformers is planned within the next three years (in preliminary design phase).
Cromwell T1 and T2	2	Tap changer has not been maintained within the required schedule. Demand is exceeding substation N-1 capacity. This is a high risk.	These transformers are within maintenance cycle. Replacement of these transformers is underway (in design phase).
Andersons Bay T1 and T2	2	Transformer condition modelled to have elevated probability of failure. This is a high risk.	These transformers are within maintenance cycle. Replacement of these transformers is planned within the next five years (in design phase).
North East Valley T1	1	Tap changer has not been maintained within the required schedule resulting in elevated risk. This is a high risk.	This transformer is within maintenance cycle.
Wanaka T2	1	Tap changer has not been maintained within the required schedule resulting in elevated risk. This is a high risk.	This transformer is within maintenance cycle.
Arrowtown T1 and T2	2	Low probability of failure but high consequence. Demand is exceeding substation N-1 capacity. This is a moderate risk.	A third transformer has been added to Arrowtown to increase the N-1 capacity.

ASSET	NUMBER	DESCRIPTION	AURORA COMMENT
Port Chalmers T1 and T2	2	Transformer condition modelled to be poor. Tap changer on T2 has not been maintained within the required schedule resulting in elevated risk. No DGA results, so no internal condition data. This is a moderate risk.	The transformers are within maintenance cycle. 2019 furans tests results indicate these units have one of the highest paper degradation levels in our fleet; however not at a level to justify immediate action. 2019 DGA results show some gassing but, again, not at levels that would justify action. The gasses present may simply be from tap changer action, depending on the tap changer sealing arrangement. These units will form part of our prioritised replacement plan.

ASSET	NUMBER	DESCRIPTION	AURORA COMMENT
Tap changer maintenance	12	Elevated risk of 12 transformers due to tap changers not being maintained according to schedule and recent tap changer failures on network indicating elevated risk. The risk ranges from low to moderate depending on the transformer.	After investigation, Aurora believes that the data used for this assessment was incorrect. Three tap changers were found to be overdue for maintenance; one of these has now been maintained. The other transformers are N security sites (Clyde/Earnscleugh and Omakau) with insufficient 6.6 kV and 11 kV ties to enable a full offload. We plan to remedy the long term issue at Clyde/Earnscleugh by conversion from 6.6 kV to 11 kV, and in the meantime we will plan a shutdown to undertake this maintenance. Further investigation is required for Omakau. As noted prior, the number of tap changers behind schedule is less than determined by WSP. We now have a zone substation maintenance plan which will address maintenance that is behind schedule.
East Taieri	2	Located adjacent to a petrol station without firewalls/protection. This is a Medium risk.	The transformers are relatively young and in good condition and hence we agree with the Moderate risk level at most. Following remediation of our high priority risks, we will consider the options to address this risk, including modern pressure relief systems, Buchholz, differential protection and/or firewalls.

ASSET	NUMBER	DESCRIPTION	AURORA COMMENT
Omakau	1	No bunding and located adjacent to a waterway. This is a Medium risk.	For growth reasons, Omakau substation may be relocated and we will consider whether oil bunding remediation is appropriate in the short term.

11.1.2Additional Findings since the WSP Review

Our additional findings have been reported against the relevant WSP conclusions above.

11.2 Planned Actions and Progress to Date – Zone Substation Transformers

At a high level, there are three main factors to consider when managing risks for the zone substation transformers:

I. **Strategic Approach** – including future planning needs, equipment specification and approach to procurement.

II. **Investment Planning** – timely replacement to ensure assets deliver safe and reliable operation.

III. **Operations and Maintenance** – what inspection, maintenance and additional operational measures will be required to achieve reliable operation.

Our prioritisation process considers the following:

Safety Factors

Zone substation transformers are located in either a secure site or remote from highly populated areas, meaning that safety is not a major factor when creating our investment plan. However, we note the moderate risk posed by the East Taieri transformers being located next to a service station and plan to analyse and consider mitigations to this risk.

Environmental Factors

Environmental factors are not a major driver for replacement because these can be mitigated or managed through interventions such as oil containment or noise attenuation. Oil containment is a moderate risk and risk mitigations will be considered following mitigation of our high priority risks.

Reliability and Resilience

Reliability and resilience is a material driver for the replacement of zone substation transformers, given the generally large number of ICPs connected to each transformer and the time required to repair or replace or off-load to adjacent circuits (where that facility is available). We agree with WSP's view that the risk and priority for replacement is higher for transformers at sites without an 11kV or 6.6kV back-up.

Direct Costs

At this stage, we do not expect the ongoing repair and maintenance costs to vary greatly between sites and therefore direct costs are not expected to drive prioritisation. As our asset management approach matures, we will consider direct costs in more detail, including high impact, low probability catastrophic transformer failure causing fire and damaging multiple assets.

Works Coordination

There are relatively few sites with high risk transformers. Many of these sites also contain high risk zone substation circuit breakers and/or protection systems. There are efficiency benefits that can be achieved by coordinating the replacement of zone substation assets. Our Action Plan will schedule zone substation transformer replacement to coincide with switchgear replacement, where economically justified, and projects will be staged to take account of deliverability constraints.

11.3 Planned Actions and Progress to-Date

As introduced above, our overall approach for zone substation transformers includes three main elements, which have been summarised below. Our progress reporting has been split into two categories to show how we are tracking with our strategic/process initiatives and also our progress to address the specific high-priority risks.

Strategic Approach

We have instigated strategic initiatives to ensure that risks are managed efficiently. Deferred replacement can be achieved by implementing other risk controls such as the procurement of critical spares, the application of the mobile substation and increased network back-up.

Investment Planning

We have entered into supply contracts for a 5 MVA emergency spare and two new 24 MVA transformers for Cromwell. This ensures that we have work in the pipeline while we complete our prioritisation planning for the remaining high-priority risk sites. We expect to update / refine our prioritisation as we complete our strategic approach and mature our approach to achieving works coordination.

Green Island T1/T2 and Andersons Bay T1/T2 are part of substation rebuild projects, which are both in the preliminary design phase.

Operations and Maintenance

We have improved condition information gathering during transformer maintenance, including recording severity of corrosion and oil leaks. Work has been completed, or is underway, to improve our maintenance approach across all fleets.

11.3.1 Improvement Initiatives

The table, below, sets out the status of improvement initiatives that support de-risking our zone substation transformer fleet. Not all of the initiatives are directly related to addressing high priority risks, but have been included to provide context for our approach to managing our zone substation transformer fleet. This includes improving our condition information and implementing a range of risk mitigation measures.

Improvement Initiative	Initiated	In progress	Complete	Status	Comments
Strategic Approach					
Develop a ZS Transformer Risk Management Strategy and Plan					See note 1
Investment Planning					
Develop replacement prioritisation plan					See note 2
Operations and Maintenance					
Review maintenance procedures			Complete		See note 3
Review maintenance test results			Complete		See note 4
Ensure maintenance cycle met					See note 5
2019 DGA/TCA testing programme					See note 6
Review critical spares					See note 7

Note 1	Our strategic approach to managing zone substation transformer risks will include a mixture of transformer replacement, improved network back-up, the mobile substation and the provision of critical spares. Our risk management plan will identify what combination of our strategic initiatives will apply for each site. This plan will inform our replacement prioritisation plan.
Note 2	Multiple transformer projects are in different phases of design and construction. Upon completion of our Risk Management Strategy and Plan we will develop a longer term replacement plan that will continue to coordinate transformer replacement with other large zone substation work, including switchgear and protection replacement.
Note 3	Improvements have been made to gather better condition data on transformers, including details on corrosion and oil leaks.
Note 4	Maintenance and condition information, including DGA/TCA, has been reviewed as part of asset health model development.
Note 5	Tap changer maintenance at Clyde/Earnscleugh is currently outside the maintenance cycle, as is Omakau. Both are single transformer sites with only partial back-up during a shutdown. We are proposing to utilise the mobile zone substation to prevent a shutdown to the Clyde township. We also have 6.6kV to 11kV conversion projects in the Earnscleugh area which will prevent the need for a shutdown during future maintenance.
Note 6	2018/19 DGA/TCA testing shows continued satisfactory performance of power transformers, noting that Aurora has historically used online streamline oil filtering, on a rotational basis, to keep transformer oil dry. This may lead to lower than expected levels of dissolved gas and furans. However, experience shows that any material internal defects or degraded paper would still be visible in oil test results. We believe that, overall, our transformer active part (core and windings) health is good, as transformers have not been highly loaded. We will work to keep better records of when transformer oil is filtered to assist in oil analysis. We will continue to monitor the health of zone substation power transformers to industry standards and good practice.

Note 7	We have initiated a review of transformer component spares holdings, including bushings, and tap changer components. The first stage is to undertake an up to date stocktake.

11.3.2Work Programme

The table, below, sets out the status of the work programme. Note that, at this stage, the timing is as per our 2019 AMP Update and is likely to change as we complete our prioritisation work described above.

Asset / Site	Prioritisation	Scoping / Design	Construction	Complete	Timing	Comments
Clyde/Earnscleugh T1 tap changer maintenance		Planned	January		RY21	See note 1
Omakau tap changer maintenance		Planned			RY21	See note 2
Cromwell T1/T2 replacement			Procurement		RY21	
Green Island T1/T2 replacement		Scoping			RY22	
Andersons Bay T1/T2 replacement		Preliminary Design			RY23	
Port Chalmers T1/T2 replacement					TBD	

Note 1	Tap changer maintenance at Clyde/Earnscleugh is currently outside the maintenance cycle. It is a single transformer site with only partial back-up during a shutdown. It is proposed to utilise the mobile substation as temporary solution while we undertake maintenance. We also have 6.6kV to 11kV conversion projects in the area which in the future will provide a permanent back-up solution during maintenance.
Note 2	Following the completion of Clyde/Earnscleugh maintenance we will investigate options for finishing Omakau zone substation maintenance. Transformer insulation resistance and Buchholz/PRV testing is completed.

12 Support Structures

12.1 Identified Risks

The key components of support structures are poles, crossarms and insulators. Information on insulator defects and condition is not separately recorded but those components are generally replaced with the crossarm; hence, the review assessed insulators and crossarms together.

WSP concluded that support structures pose a moderate-to-high risk to network reliability, and specific assets pose a high risk to public safety due to their location in populated areas.

The following table summarises the WSP-identified support structure risks and our initial view of those risks. In general, we agree with the risks that have been identified and provide additional commentary to support, clarify and interpret WSP's findings.

WSP Report Findings	Aurora Energy's view of findings
• The asset data available from Aurora's systems and augmented by our field inspections was suitable for the purpose of this review. We note that the data is not complete and improvements to consistency of the data recorded can be made. Incomplete asset data presents a risk to effective asset management.	• We agree with the findings – we plan to collect more detailed information via our testing/inspection applications, including a standard information set on crossarms and insulators. Additional detail on poles will be collected to assist good asset management (e.g. which poles are in a two-pole structures, square vs round, etc.).
• There are 6,660 poles (12%) in service that exceed their expected life and there are 44,260 crossarms (47%) in service that are estimated to exceed their expected life based on the age of the pole they are installed on. Crossarm installation date information is not recorded by Aurora. The large number of support structures that exceed their expected lives indicates an elevated risk of failure of these assets. Further modelling was undertaken to refine the assessment of network risk and to identify quantities of high risk poles (2.6%) and crossarms (2.3%).	• We agree with the approximate quantities of end service life and high risk poles, noting that we have remediated a significant number of high risk poles since the WSP report was published. • We are starting condition assessment of crossarms and insulators as a separate asset fleet. As per poles, it will be a five-yearly testing cycle with priority given to testing areas of highest risk, leading to identification and replacement of highest risk crossarms first. • We are implementing an interim solution to record the installation date of crossarms while we investigate the long term asset management system solution.
• A rising trend in supply outages from failed poles prior to 2016 has been arrested in 2017-2018, likely because of the accelerated pole programme.	• We agree and note that the number of 'unassisted' pole failures has continued to decline as we undertake further pole replacements and reinforcements
• The pole inspection program has recently been improved but has not identified all poles that are in poor condition as it has not yet covered the whole network.	• We agree. Given the backlog of pole testing we have focussed our pole testing on the wooden poles which present the greatest risk. The inspection programme is currently achieving ~200 tests per week. We have completed inspection of the 'zone 1' highest criticality poles and we have begun to inspect lower criticality areas where we know that poles are approaching end of life.

WSP Report Findings	Aurora Energy's view of findings
• Crossarms are not inspected adequately and many are in poor condition. Some are categorised as high risk due to their location relative to population and the probability of failure. Probability of failure was based on results from our field inspections.	• A separate crossarm inspection programme has been implemented in parallel with the five-yearly pole inspection programme, as discussed above. • Remote cameras on fibreglass poles are being utilised. We will review the effectiveness of this approach as soon as we have a useful size data set.

12.1.1 Specific Assets Identified by WSP

item	Number	Description
Remediation of poles	1,397	Expected number of high risk poles on the network. These are predominately termination and Tee-Off poles in high population areas. Individual assets to be identified through normal inspection process.
Remediation of crossarms	2,142	Modelled volume of high risk crossarms based on drone inspections. Individual assets to be identified through normal inspection process.
Malaysian hardwood crossarms	~3,600	Hazard posed by Malaysian hardwood cross arms. Estimated volume based on interviews and available data. Individual assets to be identified through normal inspection process.
Improvement to testing and inspection processes	Fleet wide	Assessment of pole strength, particularly concrete poles, to enable improved condition assessment accuracy.

12.2 Asset Management Approach

At a high level there, are three main factors to consider when managing risks for support structures:

I. **Strategic Approach** – including continued research, testing methodology assessment, criticality framework implementation, remediation options, outage mitigation and across-fleet optimisation.

II. **Investment Planning** – timely remediation/replacement to ensure assets deliver reliable operation

III. **Operations and Maintenance** – what inspection, maintenance and additional operational measures will be required to achieve reliable operation

Given the high number of poles, crossarms and insulators on the network it is important that we develop a pragmatic approach to the management of support structures. Our testing regime must be well-founded and produce credible results, but also needs to be cost-effective.

We have made significant progress on de-risking the pole fleet since the publication of the WSP report, but a small backlog of end-of-life poles still remains on the network. It is important that we continue with our risk-based approach while the backlog is addressed. The status of our risk-based approach is described by the following prioritisation factors:

Safety Factors

Public safety is currently the main driver for remediation of support structures. We have developed a five-zone criticality framework, with zone 1 carrying the highest public safety risk. Our criticality framework utilises 'points of interest' to determine likely population density (e.g., proximity to schools) and transport volumes to classify public roads into criticality zones.

Environmental Factors

We are identifying areas of high fire risk, with the intention that these could be added to our zone 1 high criticality areas. We made some progress with this approach during the high-risk fire season this summer, but need to formalise this into our criticality framework.

Reliability and Resilience

At the current time, safety is the main driver for prioritising our pole testing and remediation. However, as we address the backlog of end-of-life poles on the network, we will consider whether we include critical sub transmission and highly loaded feeders into our criticality framework.

Direct Costs

Pole defects are given a severity grade of D1 to D6. Poles with multiple or severe defects can be uneconomic to repair, and are prioritised for replacement based on the level of risk.

Works Coordination

Often, poles cannot be replaced without an outage to customers, so there is significant benefit in combining multiple pole replacements into one outage and/or combining pole work with other replacement or maintenance work; e.g., pothead replacement or RMU maintenance. As we complete testing and remediation of high-risk poles, we plan to transition to an area-based testing regime, which enables all assets in an 'outage zone' to be tested and a remediation plan developed that fully addresses the area.

12.3 Planned Actions and Progress to-Date

As introduced above, our overall approach for support structures includes three main elements which have been summarised below. Our progress reporting has been split into two categories to show how we are tracking with our strategic/process initiatives, and also our progress to address the specific high-priority risks.

Strategic Approach

We have instigated strategic initiatives to ensure that we get the best value from our inspection and testing methods, so that our repairs and renewals can be prioritised accordingly. We consider that our approach to managing poles is relatively advanced, with testing that compares pole strength to pole load, use of criticality zones, and the use of pole reinforcement as a cost effective risk remediation measure. Our strategic initiatives are designed to either validate or further advance the management of our support structures. In particular, we are reviewing pole testing methodologies, potentially including destructive testing, to assess the accuracy of various technologies and introducing new inspection processes and data capture to better manage crossarms and insulators.

Investment Planning

Our prioritisation approach to pole remediation has been focussed on de-risking wooden poles in high criticality zones. We are now transitioning to an area-based approach, which creates the opportunity for greater efficiency and better management of planned outages for customers. Given the backlog of crossarms requiring renewal, we will introduce a risk-based approach utilising the same criticality zones as poles. Our prioritisation process will continue to flex as we transition from risk reduction to increased efficiency through works coordination.

Operations and Maintenance

We have made a number of operational changes to reduce risk to as low as reasonably practicable until high-risk assets can be removed from the network. In particular, the introduction of an app-based defects identification process and our rapid response process enables critical condition poles to be addressed in a timely manner. The key priority now is the review of our new inspection method for assessing crossarms.

12.3.1 Improvement Initiatives

The table below sets out the status of Improvement Initiatives that support de-risking our Support Structures fleet.

Improvement Initiative	Initiated	In progress	Complete	Status	Comments
Strategic Approach					
Refine and document our fleet strategy/plan					See note 1
Wood Pole testing review/trial					See note 2
Concrete pole strength determination					See note 3
Develop a pole design standard					See note 4
Review triggers for pole replacement					See note 5
Develop an asset register for crossarms					See note 6
Develop an asset register for insulators					See note 6
Wood pole forensic analysis					See note 7
Wooden crossarm forensic study					See note 8
Investment Planning					
Develop three month rolling plan.			On-going		See note 9
Review of pole remediation process					See note 10
Works coordination					See note 11
Adapt plan to new fleet strategy/plan					
Operations and Maintenance					
Development of risk based pole testing			Complete		See note 12
Implement Rapid Response programme			On-going		See note 13
Pole reinforcement/nailing programme			On-going		See note 14
Red & orange pole testing methodology			On-going		See note 15
Deuar pole test training			On-going		See note 16
Pole safety awareness			On-going		See note 17

Improvement Initiative	Initiated	In progress	Complete	Status	Comments
Development of defects mobile app			Complete		See note 18
New Field Service Agreements			Complete		See note 19
Implement crossarm inspection programme					See note 20

Note 1	The refinement and documentation of our strategy and plan will consider how our approach will change over time as support structures are de-risked and we seek to efficiently manage risk to acceptable levels. It is envisaged that we will transition from criticality-based prioritisation to criticality-focussed management; e.g., reduced inspection intervals and/or greater safety margins on pole assessments in areas of high criticality.
Note 2	This will include a desktop review of available pole testing methodologies, including results of previous destructive testing trials, field observations and potentially new destructive testing. This will enable us to determine the accuracy and practicalities of a number of testing regimes and decide on a preferred long-term testing approach, which may include a combination of testing technologies.
Note 3	We consider it important to base our pole replacement decisions on pole strength and condition, as opposed to pure condition-based replacement. This work will investigate the design strength of concrete poles and utilise destructive pole testing to validate where required.
Note 4	A pole design standard has been created to ensure consistency of approach and enable an outsourced design model.
Note 5	New poles are designed to AS/NZS 7000 and our current pole testing methodologies assess existing poles to the same standard (or similar). It is feasible that a healthy condition pole is proposed for replacement because it falls marginally short of the new design standard. This review will consider whether existing poles can be assessed against a lower standard, especially where poles are in areas of wind and ice loading that is known to be lower than that applied through AS/NZS 7000.
Note 6	The introduction of an asset register for crossarms will enable us to better track asset attributes, age and condition. This is an intermediate step, while we implement a longer-term asset or enterprise management system.
Note 7	Anecdotally, it has been observed that poles are vulnerable to different types of rot, depending on their location. This initiative will utilise wood scientist expertise to help us understand what conditions create the different types of pole decay/rot. This may lead to specific lifecycle management practices for poles in specific areas.
Note 8	We plan to carry out forensics on crossarms to identify different wood species, such as Malaysian hardwoods, and their deterioration profiles, and identify other valuable condition information which can help inform our replacement strategy
Note 9	Continued improvement of the 3-month rolling plan, taking account of completing zone 1 criticality poles and moving to zone 2-5 poles, while considering our works coordination objectives
Note 10	The pole remediation process will be reviewed to ensure that we make optimal choices between pole replacement, reinforcement and repair of defects
Note 11	Creation of outage zones to enable more efficient work programming (currently feeder based); e.g., in conjunction with other safety/reliability risks, other pole-mounted equipment, remediation of low clearances, etc. Coordination with the conductor replacement programme will be required, as it is expected that this will replace some older or poor condition poles due to loading increases (subject to design).
Note 12	A pole testing programme that focusses on testing poles in high criticality areas (zone 1), first enabling identification of high risk poles for remediation
Note 13	The rapid response programme enables poles at immediate risk of failure to have accelerated replacement.
Note 14	Pole reinforcement is used predominantly as a prudent method of extending the life of a pole by 15 years (subject to defects on the upper half of the pole). Pole reinforcement is sometimes also used as a short-term risk management measure while medium-term plans are put in place.

Note 15	Our focus on zone 1 high criticality poles creates the risk that adjacent lower criticality poles in poor condition may be overlooked and present a safety risk for our contractors. We manage this risk by ensuring that when a test results in a red/orange tag, we keep testing poles in each direction until the work area is bounded by healthy poles.
Note 16	Two new teams have been trained in Deuar mechanical pole testing. To ensure consistency and quality of testing, existing inspection teams have had refresher training.
Note 17	We continually communicate with our contractors that the pre-climb test is still mandatory on every pole.
Note 18	A defects mobile application has been developed and deployed. This allows non-pole testers to report observations or defects for further analysis. This has helped identify at-risk poles more effectively
Note 19	New Field Service Agreements have been put in place with Connetics and Unison. This provides increased assurance of contractor availability and enhanced contracting arrangements, leading to improved quality assurance and competitive rates.
Note 20	A new pole-top testing programme has been introduced to inspect crossarms and other pole-top hardware. The separation of this testing programme from the pole testing programme will enable us to better target at-risk crossarms and ensure that the speed of the pole testing programme is not put at risk by the additional pole top inspections. We will review the technical effectiveness and cost efficiency of this approach when we have a data set of sufficient size to draw conclusions.

12.3.2-Work Programme

The table below sets out the status of de-risking our support structures fleet. Note: the outcome of our inspection and testing reviews (discussed above) will have some impact on the work programme outlined below, but we consider this programme to be representative of what can be achieved over the next 2-3 years. We note that although it will take 2-3 years to clear the pole backlog, poor condition poles in high criticality locations (i.e. high-risk) will be addressed this year. The crossarm testing and remediation plan is likely to flex as we learn from our inspections and how crossarm renewals can be integrated with other renewals work for poles and conductor.

Asset Group / Site	% Complete	Target Completion	Status	Comments
High criticality (Zone 1) wood pole testing	100%	June 2019		See note 1
Zone 1 wood pole remediation	80%	Sep 2019		See note 2
All wood poles within 5yr test cycle	82%	June 2020		See note 3
All poles within 5yr test cycle	50% +	March 2021		See note 4
Pole programme backlog addressed	60%	RY22		See note 5
Zone 1 crossarm inspection programme	Underway	RY21		See note 6
Zone 1 crossarm remediation programme	Underway	RY22		See note 7

Note 1	The testing of poles outside the 5-year testing cycle in high criticality zone 1 areas was completed in June. There were some exceptions that need to be addressed such as poles within NZTA restriction areas beside certain types of highways, although this is also largely complete.
Note 2	The current backlog of zone 1 poles for remediation is very low as our contractors are now able to keep up with the discovery rate of zone 1 red-tagged poles. More generally, our pole remediation backlog has been significantly reduced and we anticipate that very soon all red-tagged poles will be remediated within 90 days of being tested. With the completion of zone 1 pole testing in June, we forecast completion of zone 1 pole remediation by September 2019.
Note 3	On track for completion in RY20 with an average of 200 wood poles being tested every week.

Note 4	Following the completion of wood pole testing and the concrete pole strength determination project, we will reintroduce concrete pole testing. We estimate that ramping up (from 10,000) to testing 15,000 per annum will address the backlog of poles outside the 5 year testing cycle by March 2021. At that time, testing could be reduced down to steady state levels of 11,000 poles per annum.
Note 5	As a consequence of addressing the 5-year testing backlog by March 2021, we anticipate that the backlog of end-of-life poles will be addressed early in RY22. Since we ramped up our pole programme in 2017 we have replaced or reinforced approximately 60% of the backlog required before reaching steady state.
Note 6	From an inspection perspective, the number of zone 1 crossarms is relatively low and can be inspected relatively quickly.
Note 7	The crossarm remediation programme will run in parallel to the crossarm testing programme. Once the actual condition of the zone 1 crossarms is established we will be able to determine whether crossarms need to be replaced immediately or whether they can be coordinated with other works over the next 1-2 years.

13 Overhead Conductor – Subtransmission & Distribution

13.1 Identified Risks

WSP has reported the subtransmission and distribution overhead line risk separately. We note that the only high-risk overhead lines identified by WSP were those involving aged, light copper, conductor. However, we consider that some aged steel conductor is also located in areas of high criticality and needs to be prioritised. We have therefore provided a more comprehensive overview of our conductor asset management plans than would be indicated by the prioritisation approach described in section 3.1, above.

13.1.1 Identified Risks – Subtransmission

The key components of overhead subtransmission lines are conductors and connectors. They operate predominantly at 33kV, with two circuits operating at 66kV. WSP concluded that, overall, the subtransmission network is performing well. Several issues are identified, but they are not yet adversely affecting network performance and pose a low risk to network reliability and safety.

The following table summarises the WSP-identified subtransmission overhead line risks, and our initial view of those risks. In general, we agree with the risks that have been identified and provide additional commentary to support, clarify and interpret the findings.

WSP Report Findings	Aurora Energy's view of findings
• The asset data available from Aurora's systems and augmented by our field inspections was suitable for the purpose of this review. Only performance data was found to be incomplete, i.e. sub transmission line availability is not recorded	• Sub Transmission line availability is being reported but unfortunately was not readily available in time for the WSP review. We are now more readily tracking this.
• On average, one sub transmission line per year causes either a safety incident by falling to the ground or is reported in the public hazard register. This indicates that, although these assets can pose a risk to public safety, the events are infrequent and the information available indicates that the protection operated for the incidents where the conductor made contact with the ground.	• We agree
• The A, B and C sub transmission lines in Dunedin are in poor condition and there is a higher probability of failure on some sections (the A and B Lines that are in closer proximity to the coast and 111 years old). However, the consequence of failure is low due to the redundancy in the network and because the sub transmission lines are located away from highly populated areas	• We agree and note that the quantity of end-of-life poles associated with these circuits means that a complete rebuild of the lines provides the most efficient solution. Pole and conductor replacement is scheduled from RY21 to RY23.

WSP Report Findings	Aurora Energy's view of findings
• The Cromwell to Wanaka lines have a number of issues including vertical separation between the 11kV and 66kV circuits of 1.8 m compared to the requirement for separation of 2m. In addition, there are a number of issues relating to its construction.	• Reduced separation between circuits can be facilitated under ECP34 SecT6.3.2 ref Table 8 where a detailed engineering study is undertaken. At the time of designing the conversion from 33kV to 66kV an engineering assessment was undertaken to ensure that the maximum possible over-voltages and conductor motion would not cause adverse effects. • In general the remaining issues raised by WSP are related to the support structures rather than the conductor – see the support structure section for risk management of poles and crossarms
• It is likely there are spans of the sub transmission lines that do not comply with the minimum height requirements. This was not quantified as part of this review but is indicated by the asset data.	• Aurora Energy will review this as a part of scheduled inspections.

13.1.2Identified Risks – Distribution

The key components of overhead distribution lines are conductors and connectors. They operate at 6.6kV and 11kV. WSP concludes that distribution overhead lines pose a moderate risk to network reliability and safety, mostly due to their relatively high failure rate, but low consequence to public safety when they fail. There are some conductors located in Dunedin with a higher consequence due to their location in densely populated areas. WSP found:

WSP Report Findings	Aurora Energy's view of findings
• The asset data available from Aurora's systems and augmented by our field inspections was suitable for the purpose of this review and the assessment approach undertaken. We note that the data is not complete as inspections are not undertaken consistently and outage data does not capture specific conductor material types. Incomplete asset data presents a risk to effective asset management.	• We agree that our conductor inspection and condition data could be improved • We also agree that the capture of conductor fault related information could be improved and we are developing new processes/systems for better collection of all types of fault related data
• There are 10 to 25 public safety incidents per year related to distribution overhead line conductors. This asset class also contributes the largest impact to network performance, with an annual average of 33% of the outages from 2013 to 2017. The outage data indicates an increasing trend in the number of outages caused by this asset class.	• Agree and a conductor replacement programme is underway.

WSP Report Findings	Aurora Energy's view of findings
• The HV network consists of mainly ACSR conductor while the LV network consists mainly of copper conductor. There are 309 km (12%) of copper conductor, 162 km (11%) of ACSR conductors and 35 km (15%) of steel conductor that are currently exceeding their expected life.	• Agree – Re assessment of maximum practical life of our conductors and a replacement programme based on age and public safety/criticality is underway.
• A common failure mode for this asset class is failure of the conductor by way of corrosion or fatigue, both of which are related to age. Aurora does not have a dedicated inspection and testing program for overhead conductors but undertakes visual inspection on an opportunistic basis when inspecting other assets as part of other maintenance tasks. The evidence examined suggests that ACSR and copper conductor with a cross sectional area of less than 100 mm2 have the highest failure rates.	• Our first focus is on the replacement of small steel and copper conductor beyond its useful life • We agree that improved conductor inspection and data and analytics is required to inform the maximum useful life and thereby enable us to plan and forecast the next type and location of conductor replacement.
• Aurora has recorded 225 instances where conductors did not meet the minimum safe heights above ground outlined in NZECP 34:2001.	• We agree and we have a work programme underway to remedy low conductor clearance risks.

13.1.3Specific Assets Identified by WSP

Subtransmission

Circuit/Item	Quantity	Risk Driver	Notes
Address risk posed by Waipori A, B, C Line	93km	Reliability	The section of line owned by Aurora from Halfway Bush GXP to Berwick zone substation. This was categorised by WSP as a low risk.
Vertical separation and construction issues on Cromwell – Wanaka No 1 and No 2 Lines	101km	Regulatory	The complete No. 1 and No. 2 lines have identified issues with vertical separation and construction. The level of risk was not quantified by WSP as part of its review.
Height above ground of sub transmission lines	N/A	Regulatory/Safety	It is likely there are spans of the sub transmission lines that do not comply with the minimum height requirements. The level of risk was not quantified by WSP as part of its review.

13.2 Asset Management Approach

At a high level, there are three main factors to consider when managing risks for overhead lines:

I. **Strategic Approach** – including continued research, risk or criticality framework implementation, remediation options including outage mitigation and across-fleet optimisation.

II. **Investment Planning** – timely remediation/replacement to ensure assets deliver reliable operation

III. **Operations and Maintenance** – what inspection, maintenance and additional operational measures will be required to achieve reliable operation.

WSP has identified a proportion of the small copper conductor fleet to be high risk. We consider that some steel conductor is also a high risk when taking account of the potential for fire risk. We already have a programme underway to address small copper and steel conductor. Our focus at present is on refining the priority order of these replacements to ensure that the highest risk sites are addressed first. This will be followed by identifying emerging risk of other conductor types.

Given the consequence of line failure and pole failure being very similar, our risk-based approach to overhead lines is very similar to support structures. The status of our risk-based approach is described by the following prioritisation factors:

Safety Factors

Public safety is currently the main driver for remediation of overhead lines. We have developed a five-zone criticality framework, with zone 1 carrying the highest public safety risk. Our criticality framework utilises 'points of interest' to determine likely population density (e.g., proximity to schools) and transport volumes to classify public roads into criticality zones. Given that a proportion of the conductor fleet is beyond its maximum practical life, our risk based approach needs to account for both the public safety criticality and probability of failure.

Environmental Factors

We are identifying areas of high fire risk, with the intention that these could be added to our zone 1 high criticality areas. We made some progress with this approach during the high-risk fire season this summer, but need to formalise this into our criticality framework.

Reliability and Resilience

At the current time, safety is the main driver for prioritising our conductor replacement. However, as we mitigate the high-risk safety areas, we will consider whether we include critical subtransmission and highly loaded feeders into our criticality framework.

Direct Costs

The costs to repair failed conductors is not material enough in any particular location to drive prioritisation on the basis of direct costs.

Works Coordination

Coordinating conductor replacement work with other replacement work such as poles, crossarms and insulator replacement projects, where practical, will create project management and construction efficiencies.

13.3 Planned Actions and Progress to-Date

As introduced above, our overall approach for overhead lines includes three main elements, which have been summarised below. Our progress reporting has been split into two categories to show how we are tracking with our strategic/process initiatives, and also our progress to address the specific high-priority risks.

Strategic Approach

Our immediate focus is on addressing end-of-life conductor in areas of high criticality. To better predict end-of-life conductors, we have instigated strategic initiatives to ensure that we get the best value from our inspection and testing methods. In particular, we are undertaking forensic testing of conductor samples and we have joined the EEA Conductor working group.

The complexity of our risk-based approach will increase as we better understand the life expectancy of conductor in different locations, taking account of local wind, ice and corrosion effects.

Investment Planning

There is a significant opportunity to align conductor replacement with crossarm and pole replacement work. Our prioritisation process will continue to flex as we transition from risk reduction to increased efficiency through works coordination.

Operations and Maintenance

The key priority is the introduction of a new inspection and testing method for assessing conductor. To limit the possibility of starting a fire due to conductor failure, etc we turn off auto-reclose functionality during the fire risk season.

13.3.1 Improvement Initiatives

The table below sets out the status of improvement initiatives that support de-risking of our overhead lines fleet.

Improvement Initiative	Initiated	In progress	Complete	Status	Comments
Strategic Approach					
Refine and document our fleet strategy/plan					See note 1
Conductor forensic testing and analysis			Analysis		See note 2
Research and trial aerial inspection technologies					See note 3
Develop a procedure for conductor inspections					See note 4
Refine our fault data capture process					See note 5
Confirm engineering validation of the Wanaka lines			Complete		See note 6
Investment Planning					
Develop short term replacement prioritisation plan			Complete		See note 7
Improve replacement project scoping and tracking					See note 8
Adapt plan to new fleet strategy/plan					
Operations and Maintenance					
Implement our conductor inspection programme		Trials only			
Summer – auto-reclose blocking			On-going		See note 9
Queenstown & Glenorchy conductor review					See note 10

Note 1	We will continue to further develop our risk-based approach to the management of the overhead Lines fleet taking account of our research into new inspection options and further development of our criticality framework.
Note 2	Conductor samples have been sent to PLP Ltd for forensic analysis. This will help us determine maximum practical life of our conductors.
Note 3	We have received two proposals for helicopter-based inspections of conductor and pole top hardware. We are assessing the results of a recent trial to ascertain the technical suitability and economic efficiency of helicopter-based inspections. We will also consider other options such as drones and ground based technologies.
Note 4	Following the research and trials above, the development of a more comprehensive conductor inspection programme will become important, as we make progress to address the identified high risks, and we begin planning to remediate the second-tier risks. Forensic testing and analysis will also help to inform prioritisation of our routine inspections.

Note 5	As part of our Reliability Management Plan (RMP) workstream, we are reviewing our end-to-end process for capturing fault related 'root cause' data. This is particularly important to allow trends to be identified in not only conductor type performance but also conductor hardware performance, such as bindings, terminations and clamps etc.
Note 6	Reduced separation between 66kV and 11kV circuits can be facilitated under ECP34 Sec 6.3.2 (ref Table 8), where a detailed engineering study is undertaken. At the time of designing the conversion from 33kV to 66kV, an engineering assessment was undertaken to ensure that the maximum possible over-voltages and conductor motion would not cause adverse effects.
Note 7	RY20 conductor replacement programme is underway with 16 projects planned for completion.
Note 8	We have applied a new conductor replacement scoping template to recent projects to ensure that conductor work is properly specified, including coordination with other works such as crossarms, poles, and other pole hardware. We are developing new processes and supporting systems to track projects through to completion.
Note 9	Auto-reclose function has been disabled in summer months to mitigate the fire risk associated with conductor down events, etc.
Note 10	A recommendation from the 17 September 2018 Snowstorm Major Event Day Review report highlighted some areas in Queenstown and Glenorchy that are at risk due to conductor stretching during the snow storm. We are assessing the conductor for damage and/or signs of end-of-life. Remediation work will be scheduled as required.

13.3.2Work Programme

The table below sets out the status of our work programme to address high risks. Note that the only high risk overhead lines identified by WSP were those with aged, light copper, conductor. However, we consider that some steel conductor is also located in areas of high criticality and needs to be prioritised. The reporting metrics will be updated in future versions of this Action Plan, when we have finalised our risk-based approach, including fire criticality, and we have completed our analytics to determine the quantities of high-risk conductor; i.e., end-of-life in high criticality areas.

Asset Group / Site	% Complete	Target Completion	Status	Comments
RY20 conductor replacement programme	20%	RY20		See note 1
High risk light Cu conductor replacement	Reporting to be developed	TBD		
High risk steel conductor replacement	Reporting to be developed	TBD		
End of life Cu conductor replacement	Reporting to be developed	TBD		
End of life steel conductor replacement	Reporting to be developed	TBD		

Note 1	16 conductor replacement projects are at various stages of completion, from scoping to design and construction.

14 Underground Cables – (Cast-iron Potheads Only)

While the WSP review identifies moderate risks associated with the underground cable fleet, cast-iron potheads are identified by WSP as a high risk impacting public safety. This edition of the Action Plan addresses only the cast-iron pothead subcomponents of the underground cable fleet.

14.1 Identified Risks

The distribution underground cables fleet is comprised of largely XLPE and PILC type cables. Overall, the underground cable fleet is performing well but there are some condition issues that have emerged during the past few years. Overall, WSP found:

WSP Report Findings	Aurora Energy's view of findings
• HV distribution cables asset class causes 11% of the network outages, the fourth highest contribution out of the asset classes. Most outages in this asset class are recorded as being caused by asset deterioration.	• Agree. To be addressed as with other moderate risks.
• Approximately 10% of PILC cables and the entire section of HV submarine cables exceed their expected life and, therefore, represent an elevated risk of failure for this asset type.	• Agree. To be addressed as with other moderate risks.
• Cast iron potheads were identified to present a public safety risk because they are installed on poles and is it possible for their failure mode to affect public safety. Aurora has a program in place to remove these from the network.	• We plan to remove all cast-iron potheads by 2028, with zone 1 assets removed by 2021.
• The dominant risk posed by distribution cables is related to network reliability. However, each cable generally supplies a small number of customers so the impact of each individual cable failure is low.	• Started 11/6.6 kV testing in conjunction with ring-main unit maintenance and testing.

14.1.1 Specific Assets Identified by WSP

item	Number	Description
Cast iron potheads	455	455 cast iron potheads are installed on the Dunedin network. These have an elevated risk to safety, ranging from low to high dependant on their location.

14.2 Planned Actions and Progress to-Date

The safety issues present by cast-iron potheads is recognised and well understood. We have been actively replacing cast-iron potheads since 2014.

Renewals

At this time, our replacement objective for cast-iron potheads remains consistent with our 2018 AMP. We plan to have all cast-iron potheads removed from the network by 2028. With the exception noted below, the majority of replacements will be carried out opportunistically when these are de-energised for other work such as pole, conductor and cable replacements.

102 cast-iron potheads, however, are located in zone 1 and represent an elevated risk. These zone 1 assets require a more immediate intervention, and we plan to have these removed from the network by the end of RY21. These will be carried out through a combination of:

- specific work packages where the condition and strength of the support structure to allow the replacement to be performed safely; and
- in conjunction with pole replacements in all other cases.

Operational Considerations

Cast-iron potheads are known to present and elevated risk of failure (explosive hazard) when re-energising. We are managing this risk by ensuring that public are not in the vicinity of the pothead when re-energising the circuit.

15 Distribution Transformers

WSP identified, on a statistical basis, high risk associated with 59 transformers (0.8% of fleet), and moderate risk associated with 328 distribution transformers (4.7% of fleet). Individual units requiring intervention need to be identified through Aurora Energy's normal inspection programme.

15.1 Identified Risks

The distribution transformer fleet was segmented by WSP based on being pole or ground mounted, and having a capacity of less than or greater than 50kVA.

WSP noted that its analysis focussed on a whole of fleet basis and identified expected quantities, rather than individual at-risk assets.

Overall, WSP found:

WSP Report Findings	Aurora Energy's view of findings
• There are 727 distribution transformers (10%) that have exceeded their expected life and, therefore, pose an elevated risk to the network.	• We agree.
• About 10 distribution transformers (0.1%) fail in-service each year. There is a gradual increasing trend of transformer failures, which indicates these assets pose an increasing risk to network reliability and safety.	• We agree.
• With some exceptions, distribution transformers are a run to failure asset and present small risks to safety, reliability or the environment.	• We agree.
• There are 57 distribution transformers in the Dunedin network considered to have a high safety risk due to their age (as a proxy for condition), capacity and proximity to the public. In the Central network, two distribution transformers are considered a high risk to safety. There are no transformers in either the Dunedin or Central networks that are a high risk to reliability.	• We note that these are expected quantities. Individual assets will continue to be identified through Aurora's normal inspection programme, as noted/recommended by WSP.
• There are 328 distribution transformers (4.7%) with a moderate level of risk.	• We note that these are expected quantities. Individual assets will continue to be identified through Aurora's normal inspection programme, as noted/recommended by WSP.

WSP concludes that distribution transformers pose a low to moderate risk to network reliability and safety, except for a few aged transformers in the Dunedin network that pose a high risk.

15.1.1 Specific Assets Identified by WSP

item	Number	Description
Ground mounted distribution transformers	34	Distribution transformers with high safety risk. Modelled volume based on historical data to develop survivor curve. Individual assets to be identified through normal inspection process.
Pole mounted distribution transformers	25	Distribution transformers with high safety risk. Modelled volume based on historical data to develop survivor curve. Individual assets to be identified through normal inspection process.
Ground mounted distribution transformers	168	Distribution transformers with medium safety risk. Modelled volume based on historical data to develop survivor curve. Individual assets to be identified through normal inspection process.
Pole mounted distribution transformers	160	Distribution transformers with medium safety risk. Modelled volume based on historical data to develop survivor curve. Individual assets to be identified through normal inspection process.

15.2 Planned Actions and Progress to-Date

15.2.1 Preliminary

We note that WSP has categorised the risk type for distribution transformers as safety, which is inconsistent with the risk type assigned in Appendix F of their report (reliability). We note WSP's comments that:

- for ground-mounted transformers, the common failure mode is usually insulation failure or external factors e.g. falling debris, ground subsidence or damaged foundation;
- for pole-mounted transformers, the common failure mode is usually insulation failure or external factors e.g. vehicle collision into the pole, ground subsidence or damaged pole foundations, and;
- distribution transformers are not expected to explode and internal faults are typically contained within the transformer tank.

15.2.2 Fleet Management

Given the above considerations, our view is that the risks posed by the distribution transformer fleet are of a lesser order than other high priority fleet risks described in this plan. We also note that WSP's analysis is statistically based rather than identifying specific at-risk assets, which will rely on continuing Aurora Energy's normal inspection programme to identify and target specific assets for intervention.

Accordingly, we consider that the fleet objectives and strategies (refer Table 3, below) outlined in our 2018 AMP remain fit-for-purpose and generally aligned with the WSP review findings, noting that in our 2019 AMP update, we advised of increased expenditure to manage the higher risk ground-mounted transformers identified by WSP.

Fleet Objectives:
• Reduce public safety risks arising from unauthorised access to electrical enclosures, contact with live metal, step and touch potential, leaking oil and excessive noise; • Where economic, transition from age-based to condition-based forecasting and replacement; • Achieve asset lifecycle efficiency by seeking out opportunities to minimise replacement costs and associated customer outage impacts.
Fleet Strategies:
• Replace pole mounted transformers reactively when 100 kVA or less; • Replace pole mounted transformers based on condition when larger than 100 kVA; • Replace transformers during pole replacements when remaining life is less than 15 years; • Replace ground mounted transformers based on condition; • Reduce earthquake exposure and operational safety risks by converting larger pole mounted transformers to ground mounted units as they become due for renewal; • Develop an inspection and condition assessment methodology for pole mounted transformers to identify defects for repair and capture information for asset health reporting; • Refine the transformer condition assessment collection and process to align with our asset health classification categories.

Table 3 - Distribution Transformer Fleet Objectives and Strategies

15.2.3Underground Distribution Transformers

While, following assessments by Calibre Consulting and AECOM, underground distribution transformers are considered to be in reasonable condition or better, and not at risk of failure in the near future, we prefer that these are decommissioned over time to remove the field risk of working in a confined space. Accordingly, we intend to continue replacement/relocation of underground distribution transformers located in the Dunedin CBD; however, completion of this initiative will be undertaken over the medium term.

16 Distribution Switchgear

16.1 Identified Risks

The key assets in the distribution switchgear fleet are pole mounted air break switches (ABS), pole mounted auto reclosers, ground-mounted switchgear (including RMUs) and LV enclosures. We note that many of the risks are not high priority risks but, in general, we agree with the risks that have been identified and provide additional commentary to support, clarify and interpret WSP's findings.

This edition of the Action Plan addresses only the high priority distribution switchgear risk (Statter and Long and Crawford), with other switchgear to be covered in future editions.

WSP Report Findings	Aurora Energy's view of findings
• The asset data available from Aurora's systems and augmented by our field inspections was suitable for the purpose of this review. We note that the data is not complete and improvements to consistency of the data recorded can be made. Incomplete asset data presents a risk to effective asset management.	• Noted and an inspection was carried out in late 2018 to collect asset data on the RMU fleet. This is being analysed to inform our replacement plan. • We are also gathering ABS and LV enclosure asset information. • Aurora Energy is comfortable with the recloser information it has available
• The distribution switchgear fleet has 1,678 units (21%) exceeding their expected life. This indicates that there is an elevated probability of failure of these assets and provides an indication of the magnitude of risk on the network. Further modelling was undertaken to refine the assessment of network risk and to identify quantities of high risk assets.	• We agree that a significant proportion of the RMU fleet will require replacement over the next 10 years. While age is a relatively good indicator of RMU health, we are improving our asset health scoring based on inspection data. Tank condition is a major driver for replacement, but most of the Dunedin fleet is installed in housings and Central Otago is a more benign weather area, so we are seeing longer than normal tank life.
• Distribution switchgear has only contributed 8% to the average number of outages on the network between 2013 and 2017 but is displaying an increasing trend.	• We agree that increased renewal and/or maintenance will be required to reverse this trend.
• A significant number of distribution switchgear units are defective and inhibit normal operation of the network, which can lengthen outages experienced by customers or expand the number of customers affected as an upstream switch must be operated instead. This can impact the reliability performance of the network.	• We have been actively maintaining DNO RMUs and have started a campaign to correct leaning RMUs, which is the basis for most DNOs. • We are also going to replace or maintain all ABS's identified as DNO.
• A significant portion of the RMU type switchgear inspected (40%) have oil leaks, indicating a deteriorated condition.	• Most oil leaks come from ABB SD units tilting forward. We have a tilt correction programme in place which will remedy most of these issues. A few units have failed welds which will result in RMU replacement.

WSP Report Findings	Aurora Energy's view of findings
• The L&C type switchgear are at or approaching their end of life and are found to have a high probability of failure. They have been found to have an explosive failure mode and, hence, can pose a risk to safety. There are a number of industry safety advice notices related to this asset type. The Statter type switchgear has a similar construction to the L&C type switchgear of oil filled fuse units with cast iron lids/casing. It is also of a similar age to the L&C units so are found to have the same risk profile. A significant portion of the RMU type switchgear inspected (40%) have oil leaks, indicating a deteriorated condition.	• WSPs findings are the result of commentary on an L&C unit failure in Perth. However, the final report was never made available to industry. In 2018, the UK-based Long Controls Limited (LCL) came to Aurora to finalise arrangements for the supply of parts and specialised training in the maintenance of L&C T4GF3 RMUs. LCL assured us of a positive response in the UK to their maintenance regimes and their ability to supply spare parts from OEMs. LCL commented on how the covered nature of Aurora's RMUs has led to better condition than similar units in the UK – with their maintenance giving the RMU up to 24 years further service. Other utilities in NZ are also keeping L&C RMUs in service longer, where in covered installations. • We will document our risk assessment including our risk control measures to ensure that the life of L&C RMUs can be safely extended.
• There are three types of fuses: HV HRC fuses, and LV JW Wedge and Lucy fuses, that have identified type issues, but pose a low risk to reliability and safety. The need to de-energise the LV fuses prior to operation is a risk to reliability, however, as LV fuses only impact a small number of people the risk is low.	• We agree with these findings and note the relatively low risk. • JW type fuses are being replaced with priority in areas where we need to undertake regular operation.
• 77% of fuse failures are caused by DDO type fuses, indicating a possible type failure. However, the impact of reliability and safety is immaterial	• We note the low risk associated with this. • We are identifying (during pole inspection) and replacing glass type fuses which are the most likely type to fail.
• Batteries in circuit reclosers do not have a regular replacement scheme. This poses risk that the reclosers may not operate when required.	• We have updated our maintenance plan to include recloser testing and our recloser batteries will be replaced on a periodic basis (in a similar way but shorter time frame than substation batteries)

16.1.1 Specific Assets Identified by WSP

The following specific safety and reliability risks were identified by WSP as being high priority risks.

item	Number	Description
Statter distribution switchgear	5	Statter switchgear units with high risk.
Long & Crawford distribution switchgear	15	Long and Crawford switchgear with high risk.

16.2 Planned Actions and Progress to-Date

16.2.1Statter Switchgear

Four of the Statter switchgear units are installed at Willowbank zone substation, and used to connect the substations 6.6.kV ripple injection plant and local service. It is intended that these units are monitored, and not removed from service until the zone substation's circuit breakers are replaced (currently scheduled for RY22). At that time, the 6.6kV ripple injection plant will be decommissioned and the switchgear removed from service (ripple signalling will be maintained by the 33kV injection plant installed at Halfway Bush GXP).

The remaining unit is a single switch that will be replaced in RY21

16.2.2Long and Crawford Switchgear

In 2018, UK-based Long Controls Limited (LCL) came to Aurora to finalise arrangements for the supply of parts and specialised training in the maintenance of L&C T4GF3 RMUs. LCL assured us of a positive response in the UK to their maintenance regimes, and their ability to supply spare parts from OEMs.

We have commenced a formal risk assessment of Long & Crawford switchgear, to assure ourselves that LCL's proposal that risk be managed through a combination of increased maintenance and operational control measures.

16.2.3Other, Lower-priority Switchgear

The RY20 Distribution Switchgear plan primarily focuses on:

- Replacing the poorest condition RMUs of all types, based on inspection data recently gathered;
- Removing orphan models from the network which have no manufacturer support, spare parts, and/or lack of field staff familiar with this equipment;
- Maintaining RMUs and remediating 'do not operate' (DNO) tilt issues;
- Replacing and/or maintaining DNO ABSs;
- Inspecting other ABSs;
- Continuing to inspect the LV enclosure fleet and remediating installations that present a public safety hazard.

Our intention with switchgear subject to DNO orders is to clear the backlog during RY20, to the extent that any new DNO orders raised are resolved within 90 days.