Asset Management Plan
Overhead Conductor
2020-25

January 2019

Part of the Energy Queensland Group

Executive Summary

This Asset Management Plan (AMP) focuses on the management of overhead conductor and accessories.

Energy Queensland Limited (EQL) owns and maintains approximately 192,000km of overhead conductor throughout Queensland at distribution, sub-transmission and transmission voltages. Approximately 157,000km (82%) of these assets are contained within the Northern and Southern regions.

Overhead conductors are an asset of strategic importance to EQL as they provide the physical connection and electrical continuity to allow for the safe and reliable transmission and distribution of electrical power. Failure of overhead conductor assets to perform their function results in negative impacts to the EQL business objectives related to safety, customer and compliance.

EQL maintains a diverse population of bare and insulated overhead conductor types and sizes due to legacy organisations, the length of the assets operational life, changes in period supply contracts, and advancements in conductor technology. Galvanised steel is the predominant conductor type due to its prevalence on the rural network.

Approximately 48% of the EQL overhead conductor population is installed at distribution voltages less than or equal to 11kV. An additional 34% of the overhead conductor population is installed as part of the Single Wire Earth Return (SWER) distribution network. Using current asset quantities and replacement costs, overhead conductors have an undepreciated replacement value in the order of $10.33 Billion, approximately 21% of the EQL total asset replacement value.

Factors influencing the effective management of overhead conductor assets include the large, geographically dispersed asset population, the age, range and variability of conductor materials, and the diverse environmental and operational conditions.

To meet the regulatory obligations of operating an electrically safe network, EQL has commenced proactive conductor replacement programs to remove high risk, aged conductor from the network with particular focus on small diameter hard drawn bare copper (HDBC) due to poor performance. The legacy regions of EQL are at different stages in these programs, with significant quantities of HDBC remaining in the Northern and Southern Regions. The volume of aged, small diameter HDBC replaced per annum will need to increase to manage this risk. The addition of aging Galvanised Steel (SC/GZ) and Steel Reinforced Aluminium Conductor (ACSR) into these targeted programs is also proposed, prioritised by safety risk and the influence of coastal environments.

Alignment of conductor replacement program criteria across the regions of EQL, incorporating supporting assets such as poles and cross-arms for optimised delivery, efficiency, and maximum risk benefit has also been proposed.

Data quality, ongoing conformance with statutory conductor clearance requirements, and difficulty in obtaining in situ conductor condition information are key challenges for overhead conductor assets. EQL continues to improve the safety and cost-effective management of this asset class through use of the latest inspection and analysis techniques (Light Detection and Ranging (LiDAR), imagery and predictive analytics), optimal delivery models and techniques, and industry best practice management of conductor assets, through active participation in Energy Networks Australia (ENA) working groups.

EQL is working to improve its data quality and actively investigating and pursuing advancements in overhead inspection using emerging technologies that will further assist in the management of this asset class.

Document Tracking Details

Network and Non-Network Documents Hierarchy Reference Number	Regulatory Proposal Chapter Reference	Document	File Name
NET AMP – 009	7.035	Asset Management Plan - Overhead Conductor	EGX ERG 7.035 Asset Management Plan - Overhead conductors JAN19 PUBLIC

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1 Introduction

Energy Queensland Limited (EQL) was formed 1 July 2016 and holds Distribution Licences for the following regions:

- South East Region (Legacy organisation: Energex Limited); and
- Northern and Southern Regions (Legacy organisation: Ergon Energy Corporation Limited).

There are variations between EQL's operating regions in terms of asset base and management practice, as a result of geographic influences, market operation influences, and legacy organisation management practices. This Asset Management Plan (AMP) reflects the current practices and strategies for all assets managed by EQL, recognising the differences that have arisen due to legacy organisation management. These variations are expected to diminish over time with the integration of asset management practices.

1.1 Purpose

The purpose of this document is to demonstrate the responsible and sustainable management of overhead conductor and accessories on the EQL network. The objectives of this plan are to:

1. Deliver customer outcomes to the required level of safety and service.
2. Demonstrate alignment of asset management practices with EQL's Strategic Asset Management Plan and business objectives.
3. Demonstrate compliance with regulatory requirements.
4. Manage the risks associated with operating the assets over their lifespan.
5. Optimise the value EQL derives from this asset class.

This Asset Management Plan will be updated periodically to ensure it remains current and relevant to the organisation and its strategic objectives. Full revision of the plan will be completed every five years as a minimum.

This Asset Management Plan is guided by the following legislation, regulations, rules and codes:

- *National Electricity Rules (NER)*
- *Electricity Act 1994 (Qld)*
- *Electrical Safety Act 2002 (Qld)*
- *Electrical Safety Regulation 2013 (Qld)*
- *Queensland Electrical Safety Code of Practice 2010 – Works (ESCOP)*
- *Work Health & Safety Act 2014 (Qld)*
- *Work Health & Safety Regulation 2011 (Qld)*
- Ergon Energy Corporation Limited Distribution Authority No D01/99
- Energex Limited Distribution Authority No. D07/98

This Asset Management Plan forms part of EQL's strategic asset management documentation as shown in Figure 1. It is part of a suite of asset management plans, which collectively describe EQL's approach to the lifecycle management of the various assets which make up the network used to deliver electricity to its customers. Appendix 1contains references to other documents relevant to the management of the asset class covered in this plan.

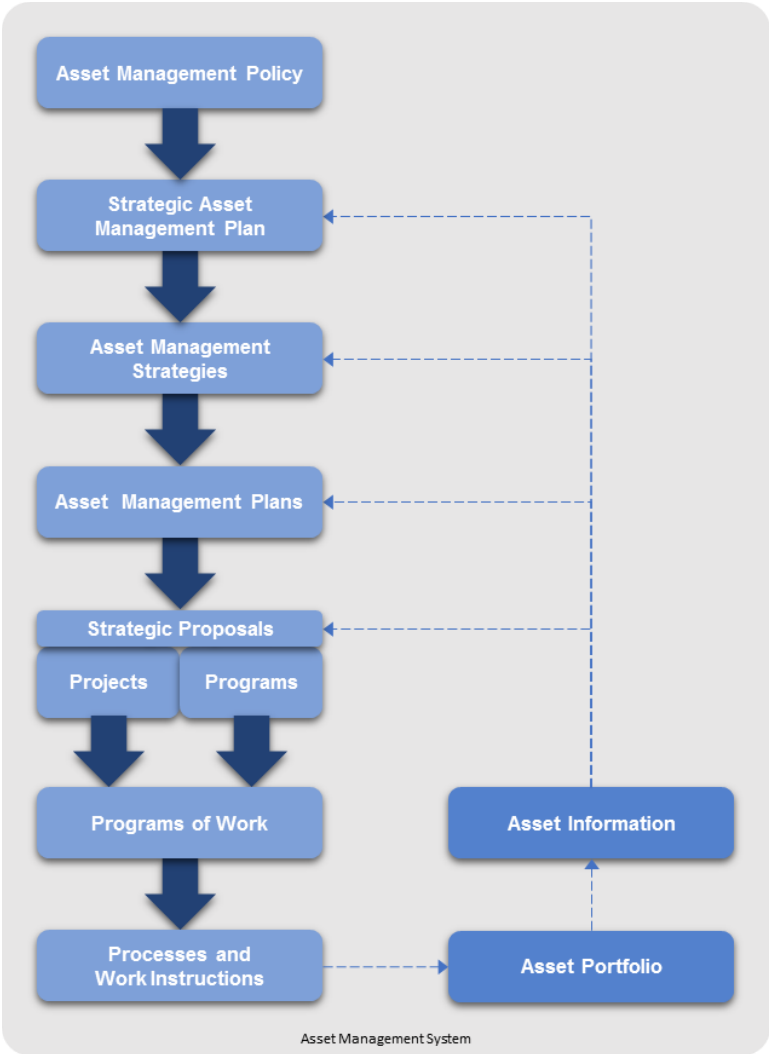


Figure 1: Energy Queensland Document Hierarchy

1.2 Scope

This plan covers the following assets:

- Bare conductor including all aluminium conductor (AAC), all aluminium alloy conductor (AAAC), aluminium conductor steel reinforced (ACSR), steel conductor galvanised (SC/GZ), steel conductor aluminium clad (SC/AC), and hard drawn bare copper (HDBC) conductors, and includes overhead earth wires (OHEW) and optical-fibre ground wire (OPGW).
- Covered conductor including low and high voltage aerial bundled cable (LV ABC and HV ABC), Hendrix type conductors, and other covered conductor types.
- Conductor accessories including and not limited to splices, connectors, and clamps.

EQL aims to provide a co-ordinated and optimised approach to the lifecycle management of all assets within the asset base. The scope of this Asset Management Plan has a strong linkage to other overhead assets including poles, lattice towers, and pole top structures. These plans should be considered together.

Many customers, typically those with high voltage connections, own and manage their own network assets including overhead conductors and ancillary equipment. EQL does not provide condition and maintenance services for third party assets, except as an unregulated and independent service. This AMP relates to EQL owned assets only and excludes any consideration of such commercial services.

1.3 Total Current Replacement Cost

Overhead conductors are a relatively low unit cost, high volume asset, and are second only behind poles in total replacement cost by asset type as depicted in Figure 2. Replacement of this asset can impact the design and construction of the supporting structures. Refer to the Asset Management Plans for Poles and Lattice Towers and Pole Top Structures. This relationship is excluded for the purposes of this section.

Using current asset quantities and replacement costs, EQL conductors have a replacement value of the order of $10.33 billion, this valuation is based on gross replacement costs of the assets using the cost of modern equivalents for superseded types on an average per metre basis, excluding savings that may be achieved through asset type optimisation.

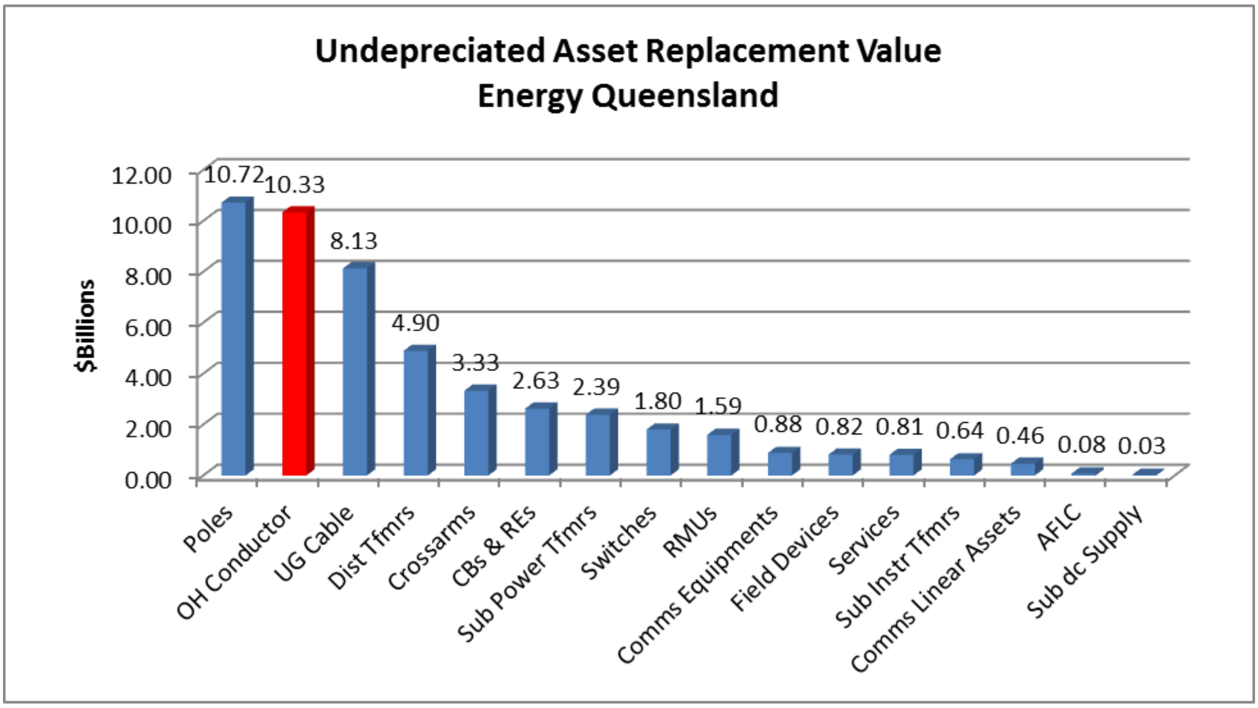


Figure 2: EQL – Total Current Asset Replacement Value

1.4 Asset Function and Strategic Alignment

Overhead conductor systems are designed and constructed to provide the physical connection and electrical continuity to allow for the safe and reliable transmission and distribution of electrical power between termination sites for the duration of asset operational life.

The failure of energised overhead conductor assets can pose a safety risk to EQL employees, contractors or the general public through electrical contact or secondary damage due to subsequent fire events.

Table 1 below details how overhead conductors contribute to EQL's corporate strategic asset management objectives.

Asset Management Objectives	Relationship of Asset to Asset Management Objectives
Ensure network safety for staff, contractors, and the community	Integrity and condition of overhead conductors is a key factor in managing safety and environmental hazards, and compliance to legislative and regulatory obligations.

Asset Management Objectives	Relationship of Asset to Asset Management Objectives
Meet customer and stakeholder expectations	The performance of overhead conductor assets supports the safe, cost effective, secure, and reliable supply of electricity to consumers.
Manage risk, performance standards, and asset investment to deliver balanced commercial outcomes	Performance of overhead conductor assets is integral to managing the hazard of exposure of workers and the general public to electrical safety risks and contributes directly to Network Performance MSS and STPIS reliability targets. Prudent management of overhead conductor assets assists in minimising capital and operational expenditure.
Develop Asset Management capability and align practices to the global ISO55000 standard	This AMP is consistent with ISO55000 objectives and drives asset management capability by promoting a continuous improvement environment.
Modernise the network and facilitate access to innovative energy technologies	This AMP promotes modernisation through increased asset utilisation, industry leading condition and health assessment, and replacement of assets at end of economic life as necessary to meet up to date standards and future requirements.

Table 1: Asset Function and Strategic Alignment

1.5 Owners and Stakeholders

The key roles and responsibilities for the management of this asset class are outlined in Table 2.

Role	Responsible Party
Asset Owner	Chief Financial Officer
Asset Operations Delivery	EGM Distribution
Asset Manager	EGM Asset Safety & Performance

Table 2: Stakeholders

2 Asset Class Information

The following sections provide a summary of the key functions and attributes of the assets covered in this AMP.

2.1 Asset Description

EQL owns and maintains approximately 192,000km of overhead conductor throughout Queensland at distribution, sub-transmission, and transmission voltages. Approximately 157,000km (82%) of these assets are contained within the Northern and Southern Regions.

The following sections provide a summary of the key functions and attributes of the assets covered in this management plan.

2.1.1 Bare Conductor

Bare conductor overhead systems are designed and constructed to conduct electrical energy, up to a rated voltage and current, safely and reliably between terminations.

Bare conductors are constructed from several strands of small diameter wire, concentrically laid up to form a single conductor with specific physical, mechanical and electrical performance properties.

EQL historically installed a range of hard drawn bare copper (HDBC) conductors on overhead distribution lines prior to 1960. Since 1960, the majority of overhead conductor types installed have been all aluminium conductor (AAC), all Aluminium alloy conductor (AAAC), and aluminium conductor steel reinforced (ACSR). Steel conductor galvanised (SC/GZ) and steel conductor aluminium clad (SC/AC) are used in large quantities on the rural network, particularly on Single Wire Earth Return (SWER) systems and some overhead earth wires (OHEWs) systems.

Smooth body conductor has also been used in limited quantities in the Northern and Southern Regions to reduce wind loading conditions.

The conductor types used to construct the overhead network have changed over time due to:

- Increases in electrical capacity requirements due to electricity demand growth;
- Improvements in overhead transmission and distribution line construction techniques;
- Improvements in economic viability and cost.

2.1.2 Overhead Earth Wire (OHEW) and Optical-fibre Ground Wire (OPGW)

Bare conductors may also be installed as overhead earth wire (OHEW), to shield phase conductors below from lightning strikes, and provide a return path for phase to ground fault currents.

OHEW is installed on all new overhead feeders at sub-transmission and transmission voltages, and at sections of distribution voltage feeders to protect key plant. On legacy 33kV and 66kV wood pole feeders, typically only the last 800m to 1000m section into the substation was shielded unless a requirement for increased reliability was justified.

Optical-fibre ground wire (OPGW) performs the same function as OHEW and additionally contains optical fibre that can be used for communications purposes.

2.1.3 Covered Conductor

Low voltage aerial bundled cable (LV ABC) is the current standard low voltage conductor installed on the EQL network. This conductor features four cores of all aluminium conductor (AAC) individually insulated in ultraviolet (UV) stabilized cross linked polyethylene (XLPE). The individual cores are laid up in a bundled cable. LV ABC fittings and clamps are designed to be intrinsically safe with insulation properties designed to remain intact during most failure modes.

At 11kV, covered conductor is sometimes used in areas with trees or heavy vegetation to minimise reliability problems associated with windblown branches, debris, or wildlife. High voltage covered conductors are single core, self-supporting, unscreened, insulated overhead conductors, installed in a similar manner to bare conductors. Covered conductor thick (CCT) has an XLPE layer proportional with the rated voltage. Prior to 2008 the conductor used in CCT was 1120 all aluminium alloy (AAAC). Current CCT is composed of 1350 all aluminium conductor (AAC).

Aerial bundled cable at 11kV (HV ABC) is used as an alternative where design constraints call for an increased level of insulation and functionality. This cable features three individually copper wire screened, XLPE insulated 1320 all aluminium conductor (AAC), laid up on a galvanised steel catenary (GZ) for mechanical support. The fully insulated screened HV ABC is considered “touch safe”. An alternative semi–conductive insulated and screened HV ABC is also available. This conductor has a smaller diameter and is supported by a 7/4.75 aluminium catenary wire. Semi–Conductive Screened HV ABC cannot be considered as “touch safe”, as the catenary wire may “float” above earth potential.

On the 33kV network, covered conductor solutions (Hendrix, Amokabel) have been investigated, however, these have not widely been adopted due to the high initial costs and lower current carrying capability compared to bare conductor constructions. This type of construction is limited to areas of heavy vegetation where vegetation management is impractical.

2.1.4 Conductor Accessories

Conductor fittings include the hardware installed ancillary to the conductor, that are required to attach the conductor to the supporting structure and/or carry the mechanical load, such as ties, clamps, connectors and terminations. Typical overhead conductor accessories include:

Sleeves and splices – used to extend or repair conductor lengths and can be of helical wrap or compression type :

- Armour rods – installed to improve conductor endurance at connection to insulator posts and strings.
- Top Ties and Suspension Clamps – installed to attach conductor to the insulator post or string.
- Vibration dampeners – installed to minimise fatigue related failures and include Stockbridge type dampers.
- Low voltage spreader rods – installed to improve reliability by preventing mid span conductor clashing during weather or through fault events.
- Transmission voltage spacers – installed on grouped conductors to prevent damage caused by clashing or twisting of conductors.
- Corona rings – installed at higher voltages to manage corona or Radio Interference Voltage (RIV).
- Overhead markers – improve visual sighting of conductor and include live line indicators, aerial markers, and wildlife protection.

Figure 3 shows an example of some of the conductor accessories as used in distribution networks.

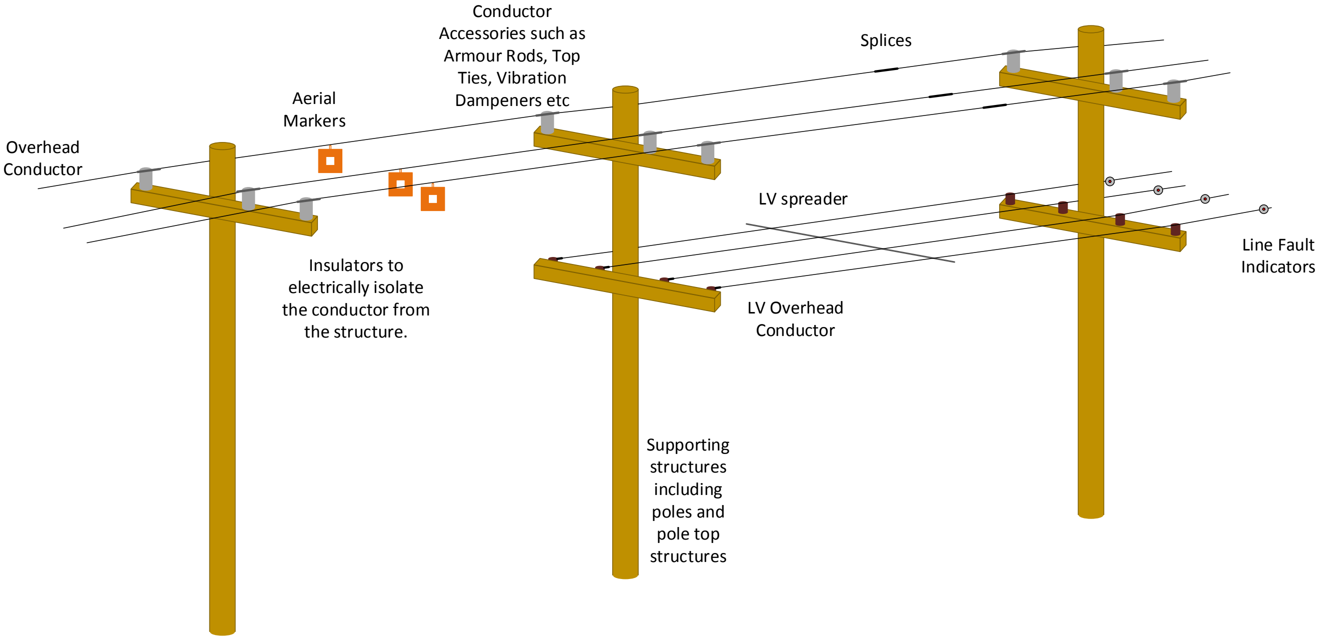


Figure 3: Example of Overhead Distribution Asset and Components

2.2 Asset Quantity and Physical Distribution

EQL operates at a wide variety of voltages including 132kV, 110kV, 66kV, 33kV, 22kV, 11kV and LV (<1kV). A breakdown of the EQL overhead conductor asset base by voltage designation is shown below in Table 3. Note that 66kV and 22kV voltage designations are present in the Northern and Southern regions only.

Overhead Conductor	Northern and Southern Regions	South East Region	Total
< = 1 kV	24,026	14,202	38,228
> 1 kV & < = 11 kV	36,594	17,613	54,207
> 11 kV & < = 22 kV ; SWER	65,788	40	65,828
> 11 kV & < = 22 kV ; Single-Ph	3,218	0	3,218
> 11 kV & < = 22 kV ; Multi-Ph	12,049	0	12,049
> 22 kV & < = 66 kV	12,528	2,125	14,653
> 66 kV & < = 132 kV	3,076	1,135	4,211
> 132 kV	0	0	0
Total Route Length (km)	157,279	35,115	192,394

Table 3: EQL Overhead Conductor Asset Population

Approximately 48% of overhead conductor assets are installed at distribution voltages less than or equal to 11kV. An additional 34% of the overhead conductor population is installed as part of the single wire earth return (SWER) distribution network.

2.3 Asset Age Distribution

EQL derives its conductor age based on the pole installation date, as the installation date of conductors has not historically been recorded. This has proven to be an accurate representation where the original poles remain in situ. Where pole replacement has occurred, the conductor age is derived by the oldest pole supporting that section of conductor. Refer to the Ergon and Energex Category Analysis Regulatory Information Notice (RIN) Basis of Preparation (BOP) documentation.

The age profiles for the overhead conductor asset base are shown in Figure 4 and Figure 5 below.

In the Northern and Southern Regions, pole year of manufacture (YOM) is stamped on pole discs and recorded at site asset inspection. The inspection process is cyclic, with a period of between 4 and 8 years assigned based upon maintenance zone, pole type and locational risk factors of the asset. Poles installed within recent years but not yet inspected may, therefore, any conductor associated with these poles may not be represented in Figure 4.

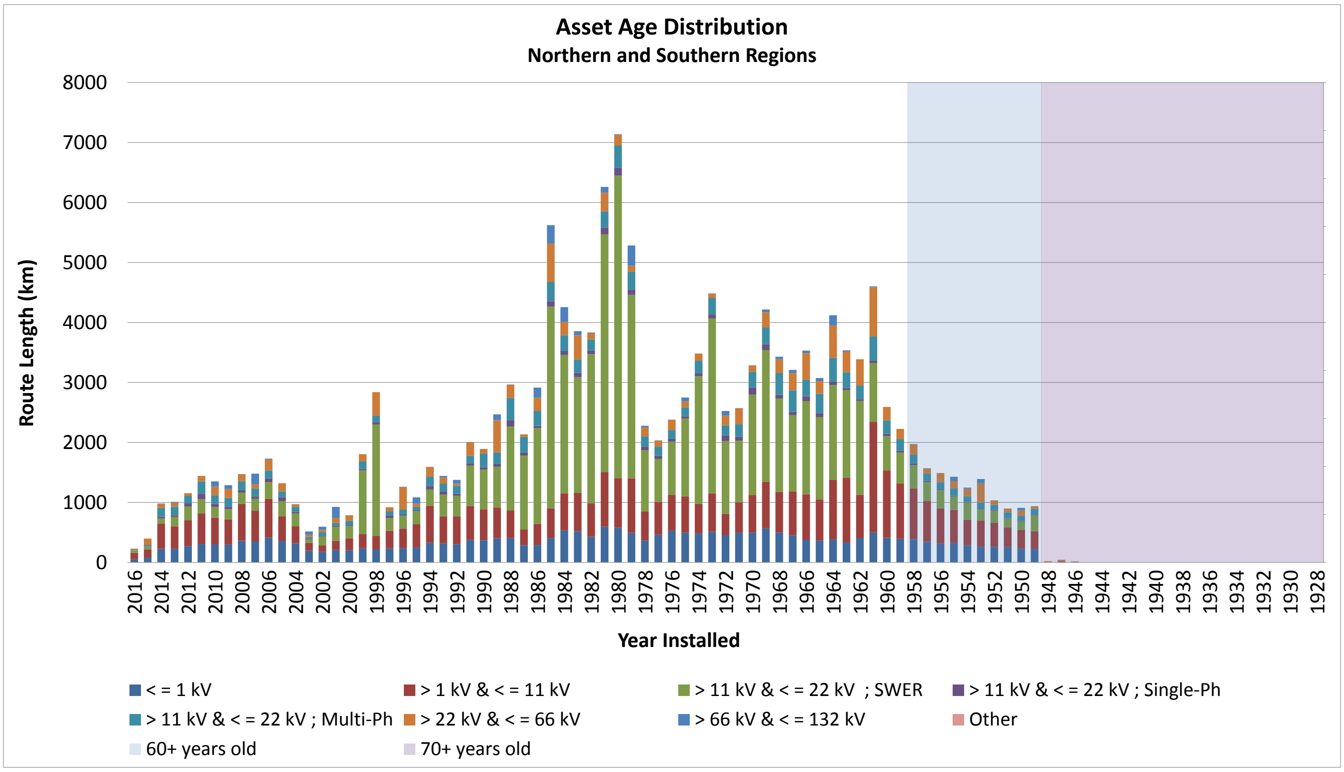


Figure 4: Northern and Southern Regions Conductor Age Profile by Voltage

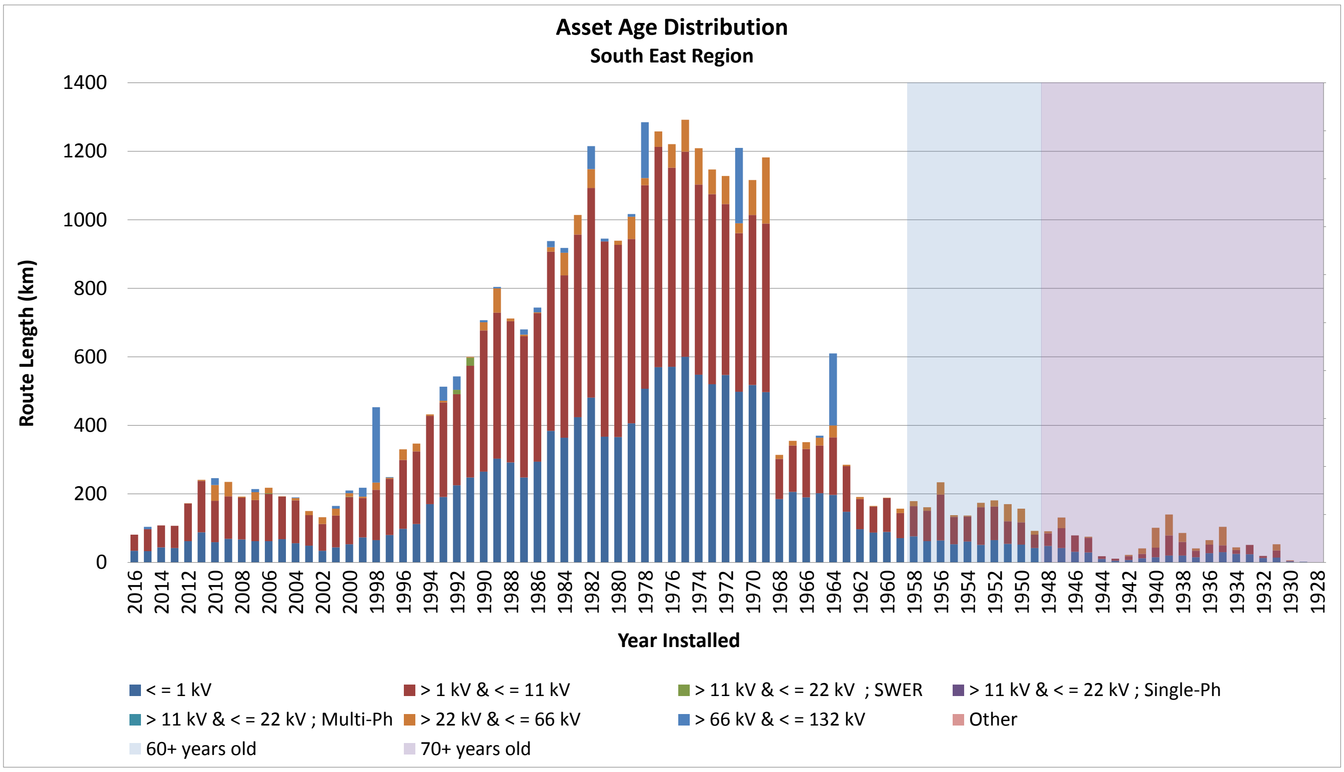


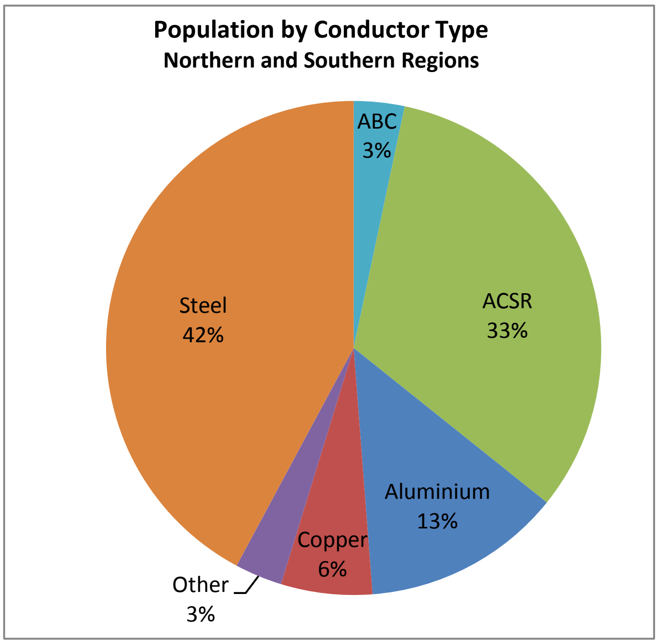
Figure 5: South East Region Conductor Age Profile by Voltage

2.4 Population Trends

EQL maintains a diverse asset population of overhead conductor types and sizes due to legacy organisations, the length of asset operational life, changes in period supply contracts, and advancement in conductor technology. Early lines employed hard drawn copper conductors, however, aluminium has become the preferred material due to its economic and weight advantages. Steel reinforced aluminium conductor is used for long spans due to its superior mechanical strength over aluminium or aluminium alloys.

Galvanised steel has historically been used for single wire rural electrification, as its low cost and high tensile strength allows for longer spans and use of fewer poles and pole-top hardware. Due to the geographically dispersed nature of rural communities, galvanised steel is the predominant conductor type currently installed on the network.

Figure 6 includes an approximate breakdown of overhead conductor types installed on the EQL network.



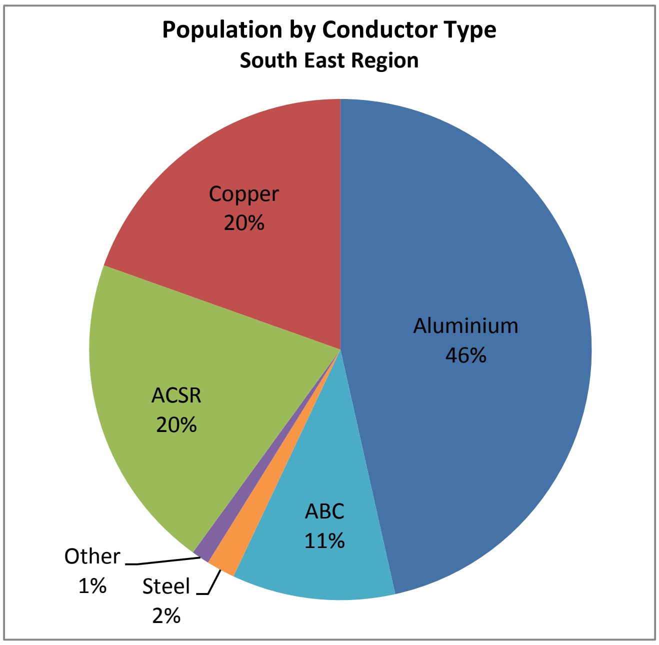


Figure 6: EQL Installed Overhead Conductor Population by Type

2.5 Asset Life Limiting Factors

The following table describes the key factors that influence the life of overhead conductor assets, and as a result, have a significant bearing on the programs of work implemented to manage the lifecycle.

Factor	Influence	Impact
Corrosion	Conductors are subject to deterioration in the presence of oxygen, dissimilar metals, and electrolytes. This is a significant issue at coastal locations.	Corrosion may result in a loss of material and increased resistance, which affects the mechanical and electrical characteristics of the conductor. The reduction in conductivity and strength has an effect on the life of the conductor. Increased safety risk of fallen conductors, including shock or electrocution of public or personnel, fire or damage to third party plant, equipment or loss of livestock.
Fatigue	Cyclic stress at a localized point on the conductor weakens the material. Wind induced oscillations (gallop, Aeolian vibration, wake-induced) can introduce fatigue at conductor attachment points.	Uncontrolled vibrations can lead to broken conductor strands leading to a reduction in strength and effective diameter of the conductor. On ACSR, broken strands can lead to overheating and failure of the steel core. Increased safety risk and third party damage as above.

Factor	Influence	Impact
Annealing	Conductors operated at high temperatures due to overloading or fault currents, and the accumulation of these effects over time leads to a permanent loss of tensile strength of the conductor.	Annealing leads to a reduction in tensile strength and ultimate failure of the conductor. Increased safety risk and third party damage as above.
Creep	Creep is the non-elastic strain placed upon the conductor under tension, causing an increase in conductor length with time.	Conductor sag may increase and encroach on statutory clearance limitations
Insulation damage	UV degradation, fire, vermin attack, or other mechanical damage of the insulation.	Exposed live conductor; increased risk to public and personnel. Increased risk of corrosion and arcing, causing fallen conductors in bundled cable installations.
Lightning and clashing	Direct and indirect lightning strikes can fuse or damage conductor strands and introduce over voltages that may stress line components.	Mechanical damage to bare conductor, accessories or the insulation of covered conductor.
Vegetation	Falling branches or trees may cause clashing and bring down live conductors. Vegetation may impact lines causing outages or damage.	Mechanical damage to bare conductor or the insulation of covered conductor.
Animals	Animals such as birds, bats, or possums may initiate arcing faults which may damage and bring down conductors.	Mechanical damage to bare conductor or the insulation of covered conductor

Table 4: Overhead Conductor Life Limiting Factors

3 Current and Desired Levels of Service

The following sections define the level of performance required from the asset class, measures used to determine the effectiveness of delivering corporate objectives, and any known or likely future changes in requirements.

3.1 Desired Levels of Service

This asset class will be managed, consistent with corporate asset management policy, to achieve all legislated obligations in the most cost-effective manner, along with any specifically defined corporate key performance indicators, and will support all associated key result areas as reported in the Statement of Corporate Intent (SCI).

Safety risks associated with this asset class will be eliminated so far as is reasonably practicable (SFAIRP), and if not able to be eliminated, will be mitigated SFAIRP. All other risks associated with this asset class will be managed to as low as reasonably practicable (ALARP).

This asset class consists of a functionally alike population, differing in age, brand, technology, material, construction design, technical performance, purchase price, and maintenance requirements. The asset population will be managed consistently based upon common performance outcomes, with an implicit aim to achieve the intended and optimised life cycle costs contemplated for the asset class and application.

All inspection and maintenance activities will be performed consistent with manufacturers' advice, good engineering operating practice, and historical performance, with the intent to achieve the longest practical asset life overall.

Life extension techniques will be applied where practical, consistent with overall legislative, risk, financial, and reliability expectations. Problematic assets such as very high maintenance or high safety risk assets in the population will be considered for early retirement.

Assets of this class will be managed by population trends, inspected regularly and allowed to operate as close as practical to end of life before replacement. End of asset life will be determined by reference to the benchmark standards defined in the Defect Classification Manuals and or Maintenance Acceptability Criteria. Replacement work practices will be optimised to achieve bulk replacement to maximise efficiency and minimise overall replacement cost and customer impact.

3.2 Legislative Requirements

EQL has a Duty to comply with all current legislative requirements and regulatory obligations including and not limited to those listed in Section 1.1.

The *Electrical Safety Act 2002 (Qld)* s29 places an obligation on an electricity entity to ensure that its works are electrically safe and operated in a way that is electrically safe. This includes the requirement that the electricity entity inspects, tests, and maintains the works.

Under the *Electricity Regulation 2006 (QLD)* an electricity entity must, in accordance with recognised practice in the electricity industry, periodically inspect and maintain its works to ensure the works remain in good working order and condition.

Division 4, part 9 of the *Electricity Safety Regulations 2013 (Qld)* contains general obligations related to safety of works of an electrical entity with regards to this asset class, specifically obligations regarding clearances to ground and nearby structures, including vegetation clearing and management. Schedules 2 and 4 of the Regulations specify the distances required for exclusion zones and clearances.

Good industry practice, including degradation mechanisms and holistic lifecycle management of overhead lines, is described in AS/NZS7000 Overhead Line Design Standard and previous versions of C (b) 1 – Guidelines for the Design and Maintenance of Distribution and Transmission Lines.

EQL, under the *Electrical Safety Regulation 2013 (Qld)*, are required to notify the Electrical Safety Office in the occurrence of any Serious Electrical Incident (SEI) or Dangerous Electrical Event (DEE).

3.3 Performance Requirements

EQL has a strategic objective to ensure a safe, cost effective and reliable network for the community. Performance targets associated with these asset classes, therefore, aim to reduce in-service failures to levels which deliver a safety risk outcome which is considered SFAIRP and as a minimum, maintains current reliability performance standards.

The Electrical Safety Code of Practice 2010 Risk Management discusses the need to identify and rectify obvious, concealed, developing, and transient risks on the network. The Code recommends that the most simple and effective way to do this is regular visual inspection and observation. EQL has developed a suite of maintenance programs to identify, prioritise and remediate overhead conductor assets defects. Defects identified via inspection programs are classified and prioritised according to the EQL Lines Defect Classification Manual (LDCM). The P1 and P2 defect categories relate to priority of repair, which effectively dictates whether normal planning processes are employed (P2), or more urgent repair works are initiated (P1). Additionally, classification of C3 aims to gather information to inform or create a "watching brief" on possible problematic asset conditions.

Asset failures occur where the programs in place to manage the assets do not identify and rectify an issue prior to it failing in service. Failures typically result in or expose the organisation to risk and represent the point at which asset related risk changes from being proactively managed to retrospectively mitigated.

While there are no specific serious electrical incidents (SEI) or dangerous electrical events (DEE) targets, EQL is committed to reduce these indicators in compliance with our electrical safety obligations under the regulations.

The frequency and duration of outages are also tracked and analysed to ensure ongoing compliance with minimum service standards set forth under the Electricity Industry Code. Under the Service Target Performance Incentive Scheme (STPIS), EQL is provided with financial incentive to maintain and improve reliability performance.

3.4 Current Levels of Service

The historical overhead conductor annual failures for each region are shown below in Figure 7 and Figure 8.

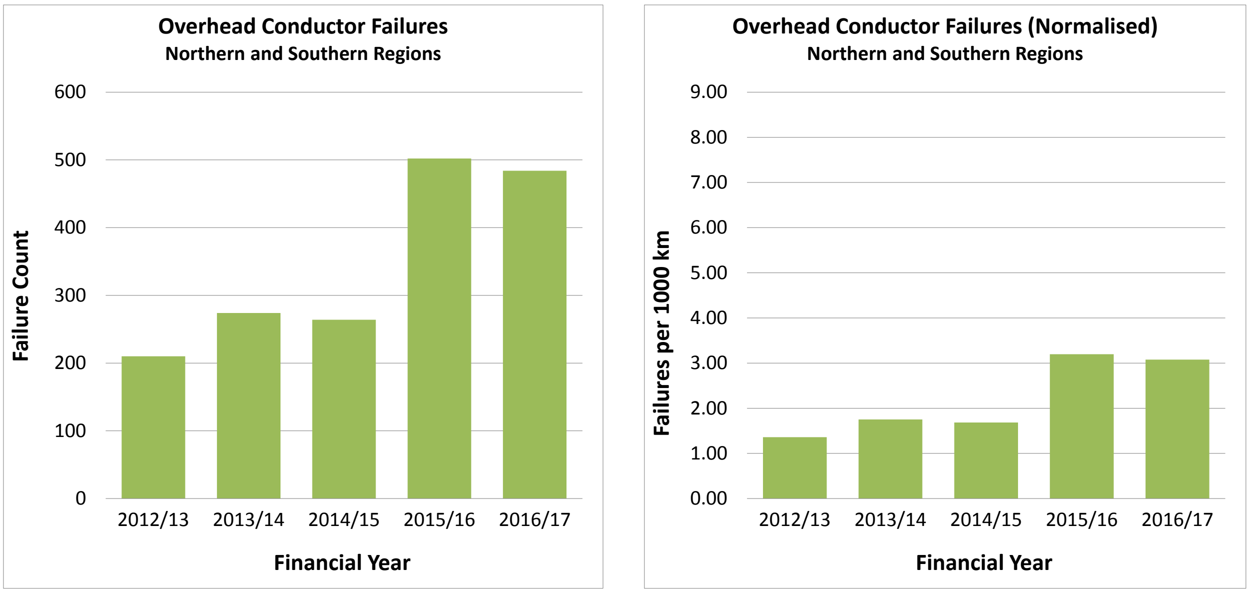


Figure 7: Historical Overhead Conductor Failures – Northern and Southern Regions

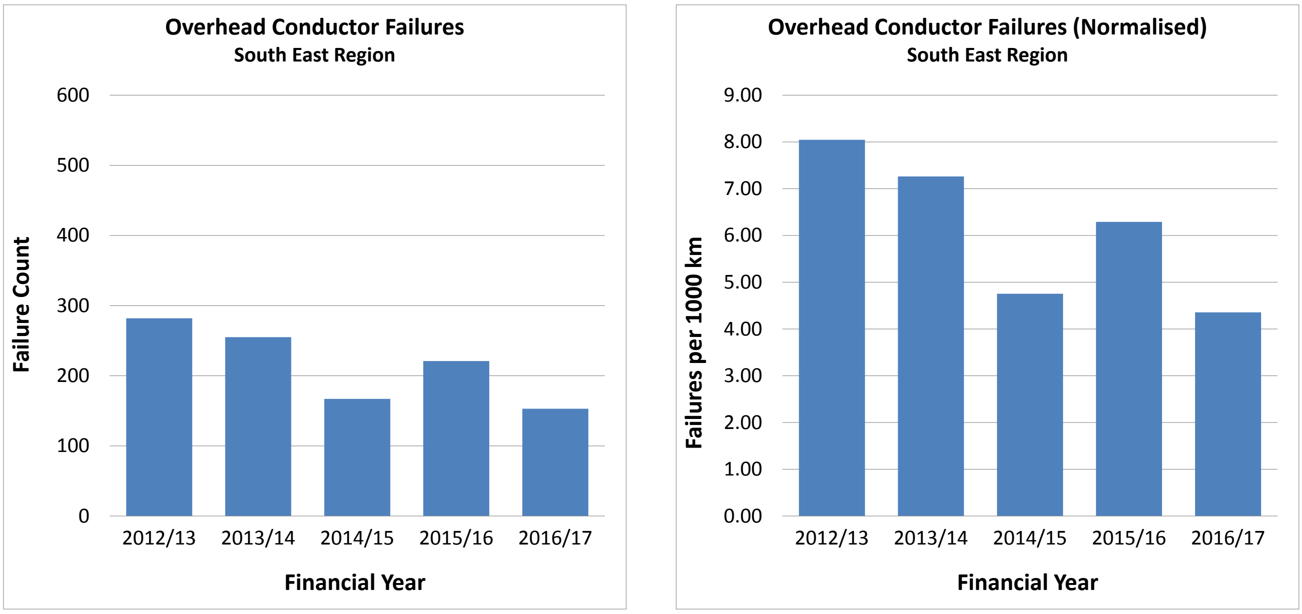


Figure 8: Historical Overhead Conductor Failures – South East Region

The disparity between the reported failures of the EQL legacy organisations is due to differences in source data and calculation methodology. EQL is working towards alignment of methodologies to ensure a common approach moving forward. EQL is required to report to the AER annually on asset failure for the given RIN asset classes as part of template 2.2.1. The AER definition of an asset failure is the failure of an asset to perform its intended function safely and in compliance with jurisdictional regulations. It excludes external impacts such as external weather event, third party interference, and planned interruptions.

The declining observed number of failures per year in the South East Region can be attributed to the proactive, risk based replacement of aged, legacy conductor types, in particular, small diameter copper conductor. Conversely, significant volumes of legacy, aged conductor remain installed in the

Northern and Southern Regions. Proactive conductor replacement programs are ongoing across all regions of EQL to manage the residual risk on the network.

A significant portion of the rural network features a single wire as opposed to the traditional three or four wire construction present in urban network. Conductor in this part of the network is not subject to many of the failure modes that affect the performance of conductors in an urban environment (for example coastal corrosion, high loading, high fault currents, or conductor clashing). These factors account for the comparatively low failure rate observed in the Northern and Southern regions when normalised over the entire installed population.

Figure 9 details the historical trend of defect replacement/refurbishment works that have been conducted on these assets. The P0, P1, and P2 references relate to priority of work required, which effectively dictates whether normal planning processes are employed (P2), or more urgent repair works are initiated (P1 and P0). A normalised view of defects by installed population is shown in Figure 10.

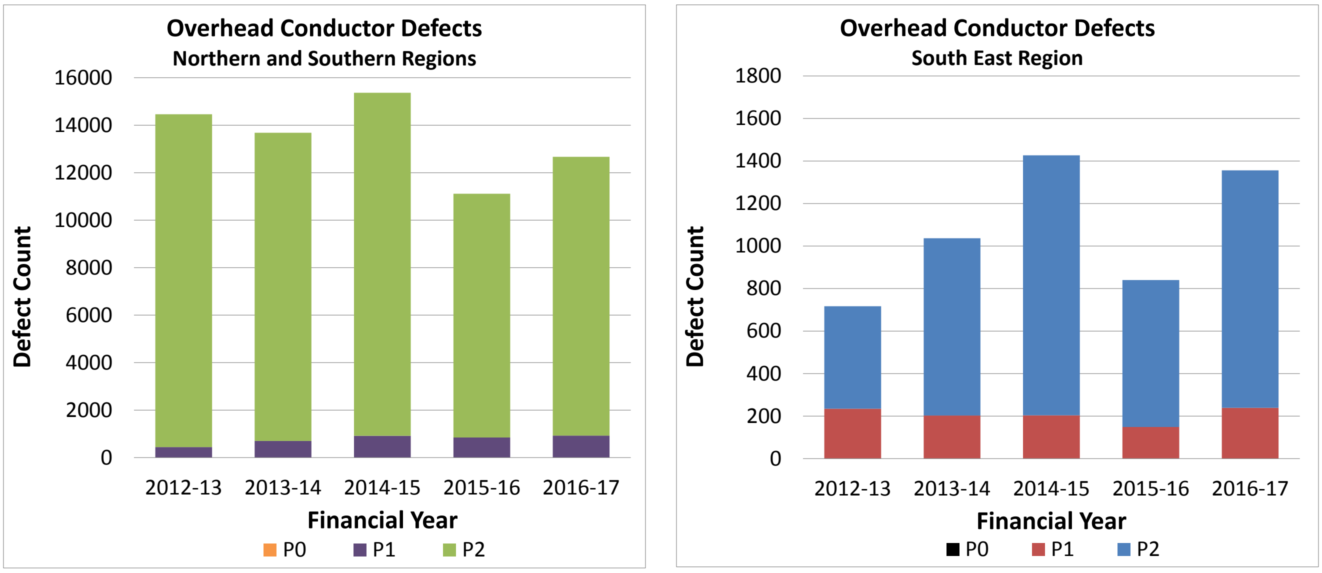


Figure 9: EQL Overhead Conductor Defects by Region

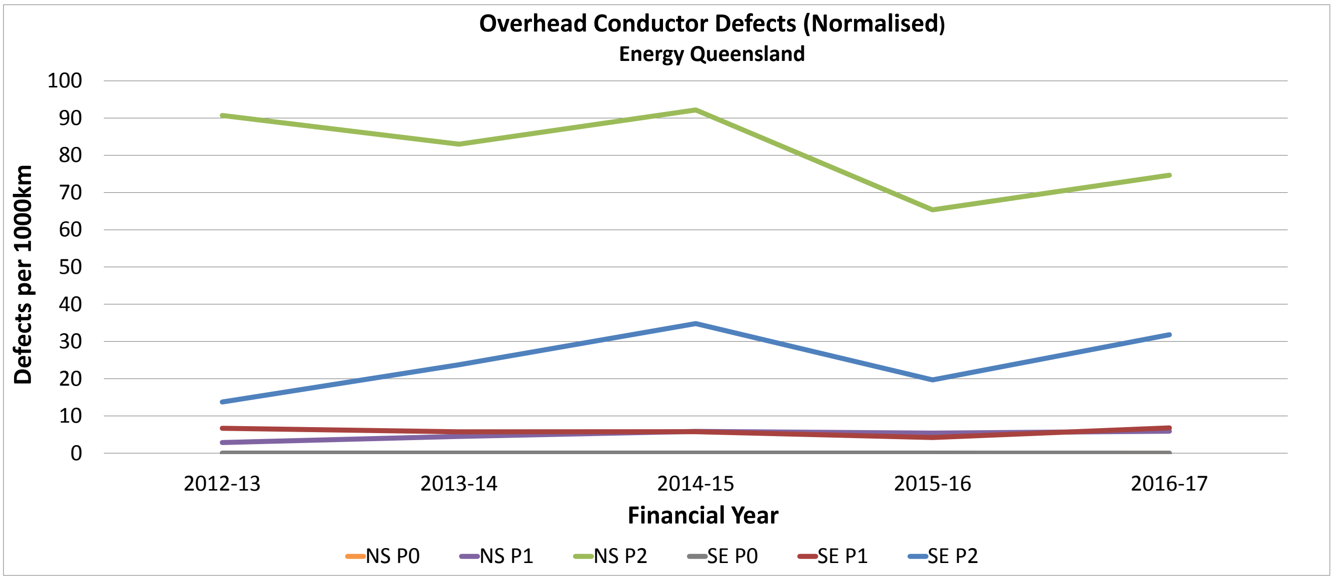


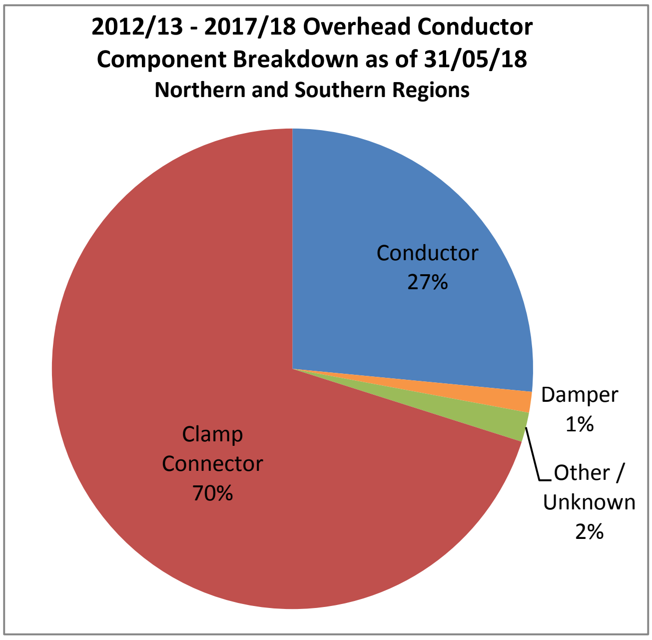
Figure 10: EQL Overhead Conductor Defects Normalised by Asset Population

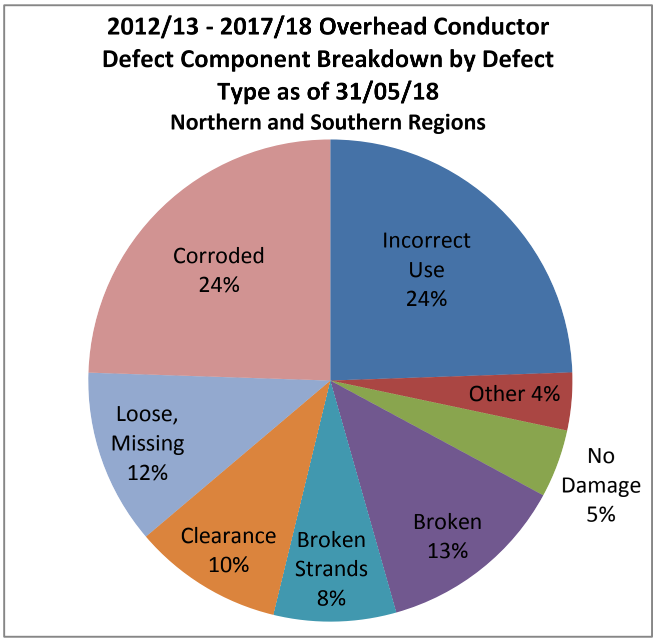
Ergon Energy developed and implemented a record system for all failures, incorporating a requirement to record the asset component (object) that failed, the damage found, and the cause of the failure. EQL has adopted this approach, and the system was introduced to the South East region for corrective maintenance work only, starting in the 2017/18 financial year.

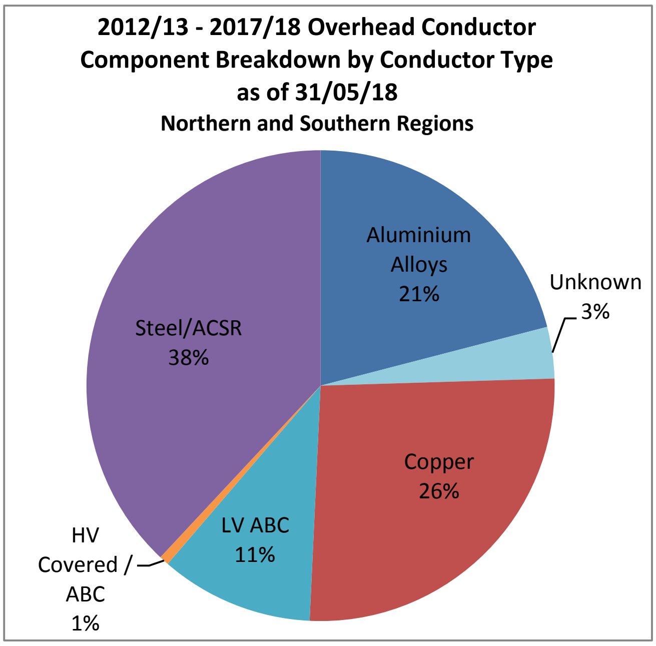
This Maintenance Strategy Support System (MSSS) record history is building over time and starting to provide the information necessary to support improvements in inspection and maintenance practices. There is an expectation that this will also support and influence standard design and procurement decisions. Alignment of failure and defect data capture across regions is required to take full advantage of the larger dataset available across the state.

Historical MSSS data collected over the period 2012/13 - 2017/18 for the Northern and Southern Regions is shown in Figure 11. Analysis shows that accessories such as clamps and connectors have historically been driving the defects in the Northern and Southern Regions. Where conductor defects have been recorded, corrosion and fatigue related issues have been reported. When normalised by population, HDBC is contributing significantly to the number of defects in this region. Low voltage aerial bundled cable is also showing signs of increased defects per installed population.

The South East Region MSSS data recorded since the introduction of the system in 2017/18 has been included in Figure 12. Analysis of this data indicates that the majority of corrective maintenance work is being performed at lower voltages. This is expected due to the size of this population. Most of the corrective work has been attributed to the conductor itself rather than the associated accessories. Vegetation is a significant factor in the maintenance attributed to this asset class. When normalised by population, HDBC and galvanised steel require more attention than other conductor types. This can be attributed to the age of the bare copper assets and the performance of galvanised steel in coastal environments.







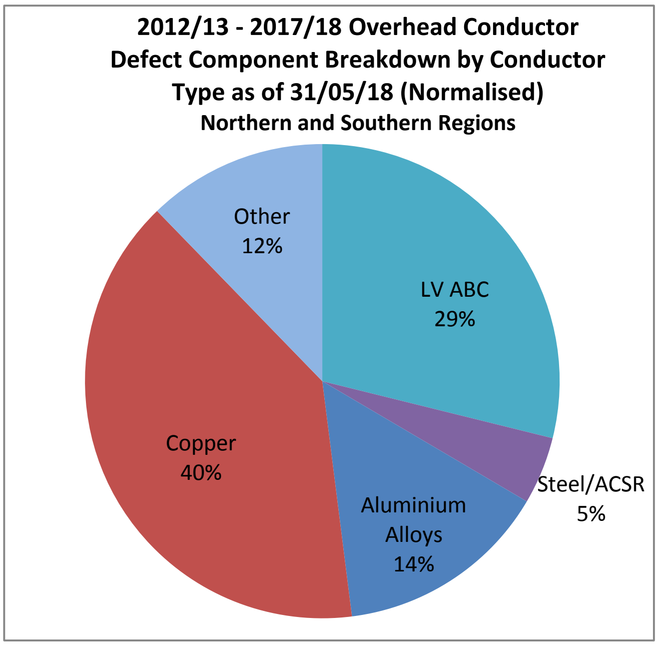
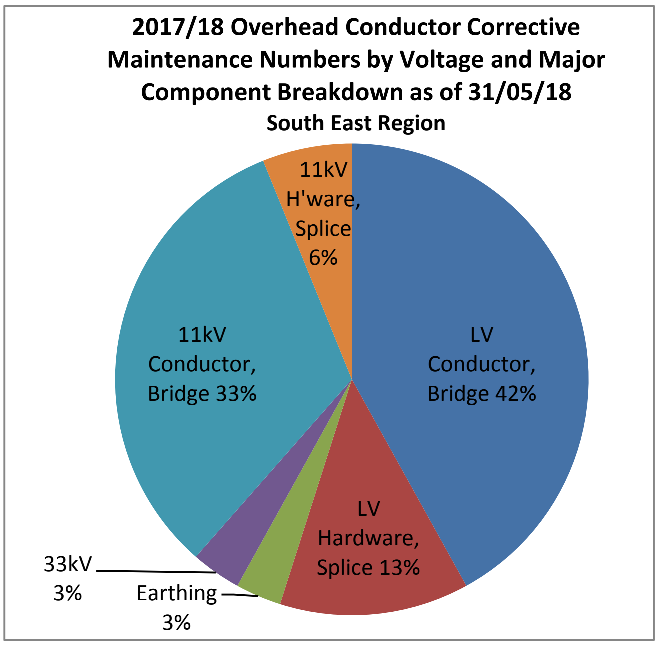
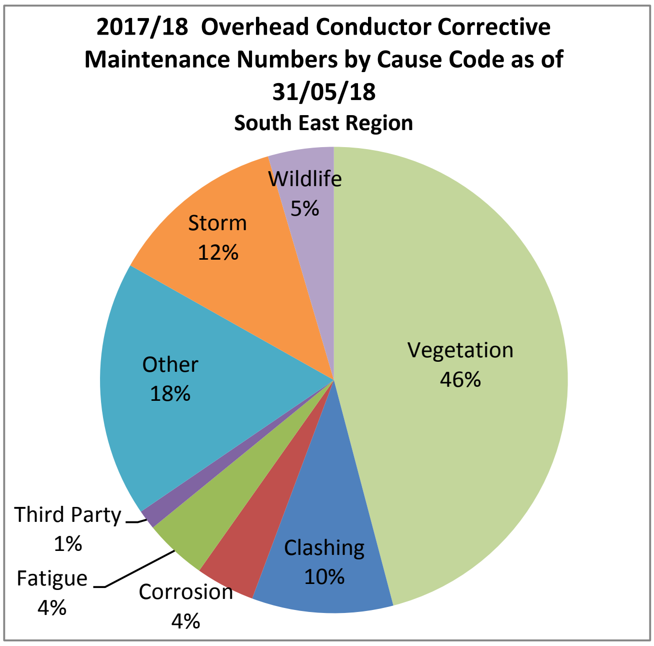
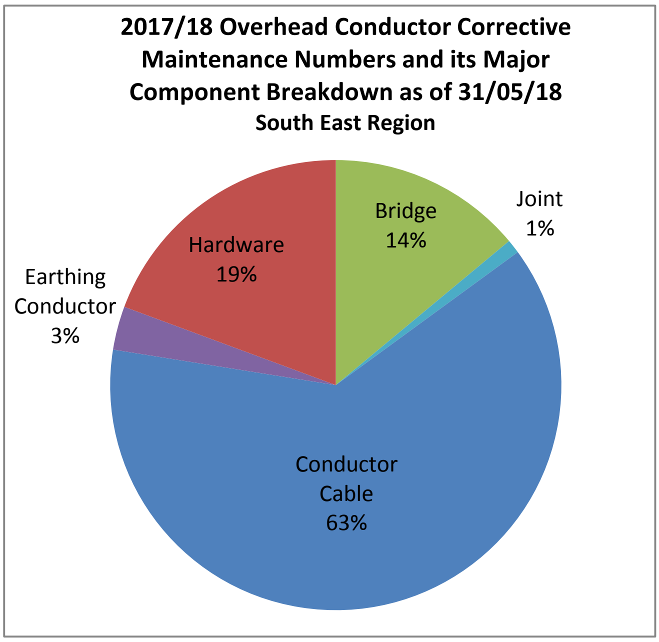


Figure 11: Northern and Southern Regions 2012/13 - 2017/18 YTD MSSS Analysis







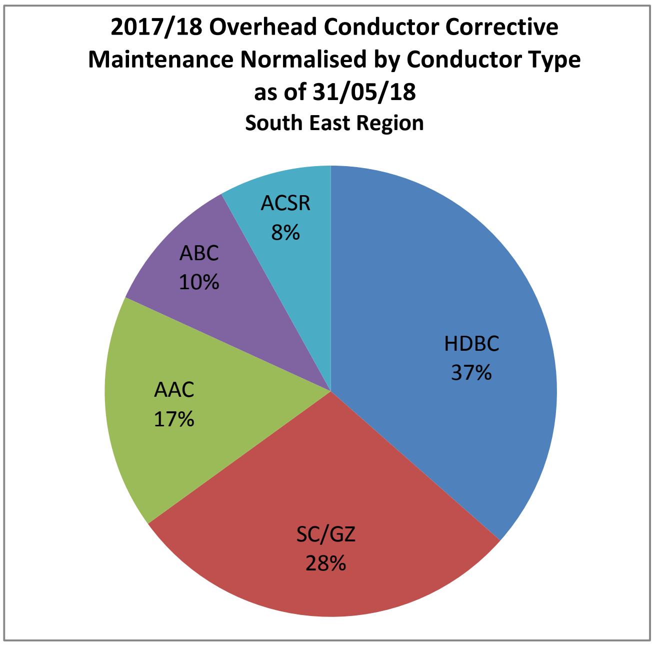
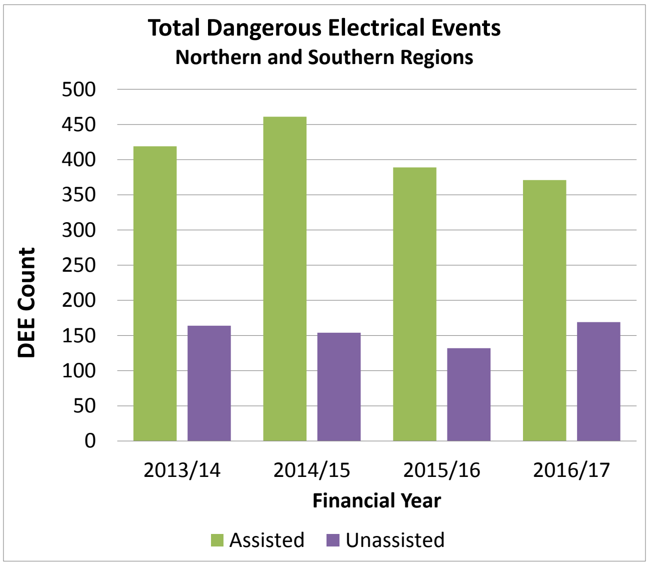


Figure 12: South East Region 2017/18 YTD MSSS Analysis

Dangerous electrical events (DEEs) are defined in Section 12 of the *Electrical Safety Act 1994 (Qld)*. DEEs are typically circumstances involving a high voltage asset, where a person would not have been electrically safe had they been exposed to the event. EQL assigns DEES into two the following two categories:

- Unassisted DEEs - incidents where the root cause may have been preventable via a maintenance program (e.g. corrosion).
- Assisted DEEs - incidents where the root cause of failure occurs outside the control of any maintenance program (e.g. lightning strike).

The total number of asset related dangerous electrical events (DEEs) is shown in Figure 13. The total number of DEEs normalised by population is shown in Figure 14.



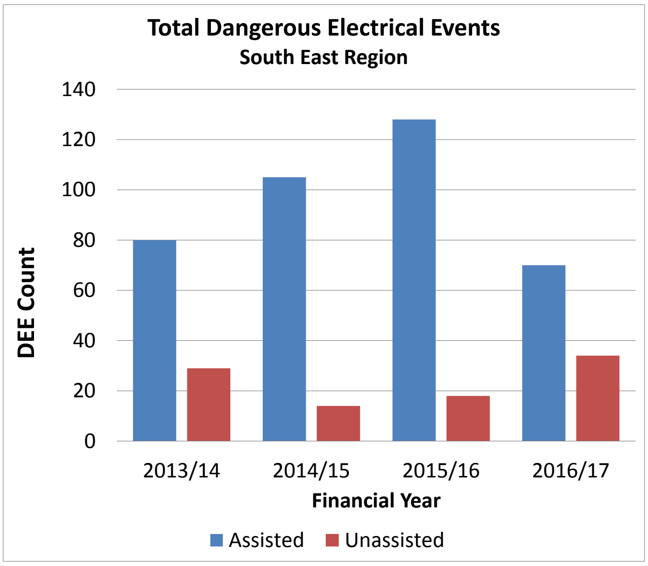


Figure 13: Dangerous Electrical Events (DEE) - Overhead Conductors by Region

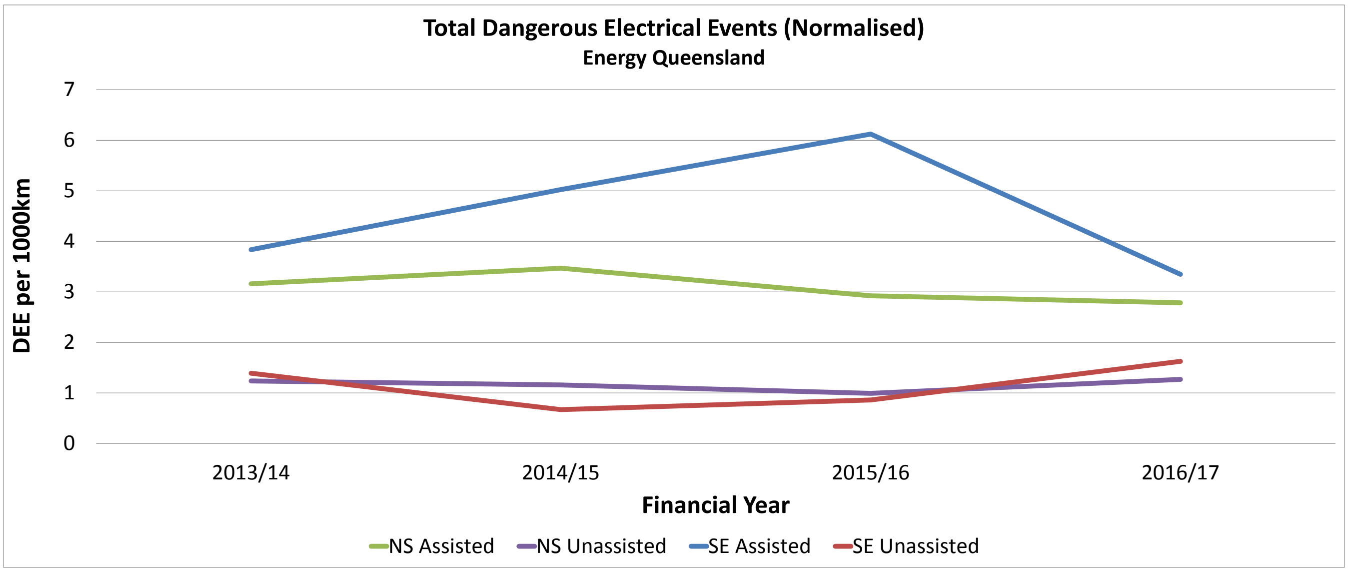
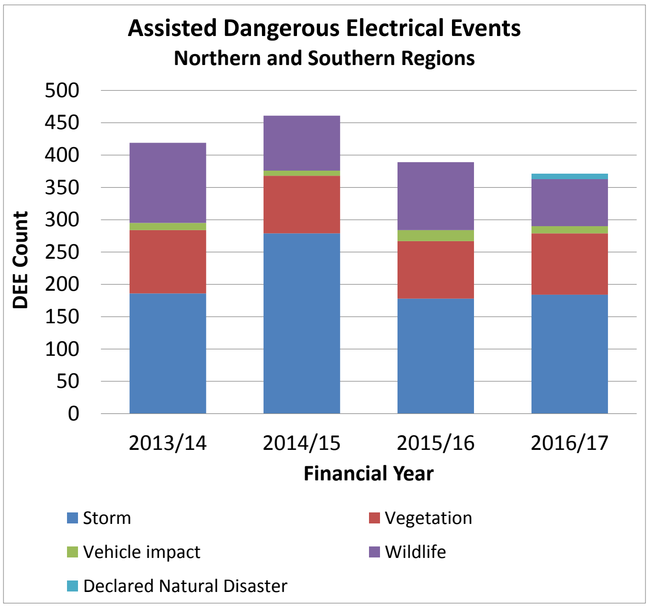
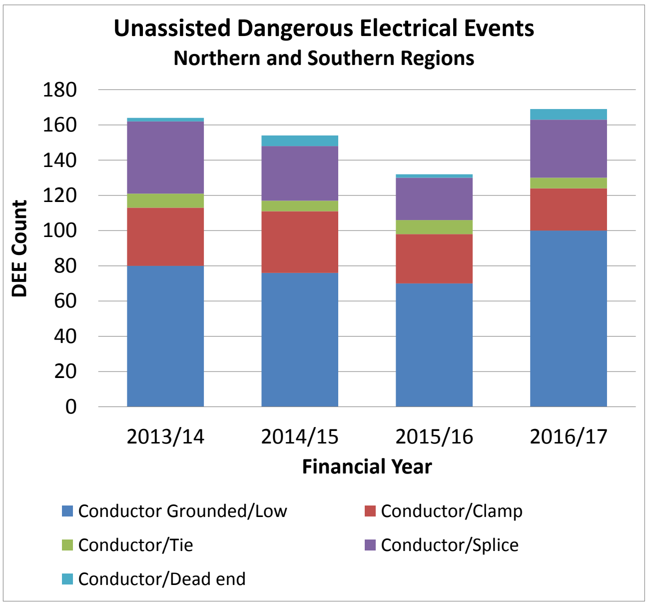
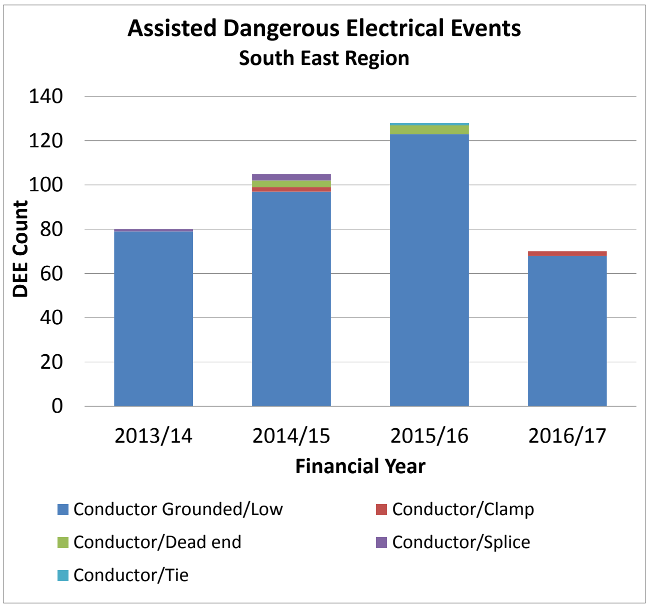


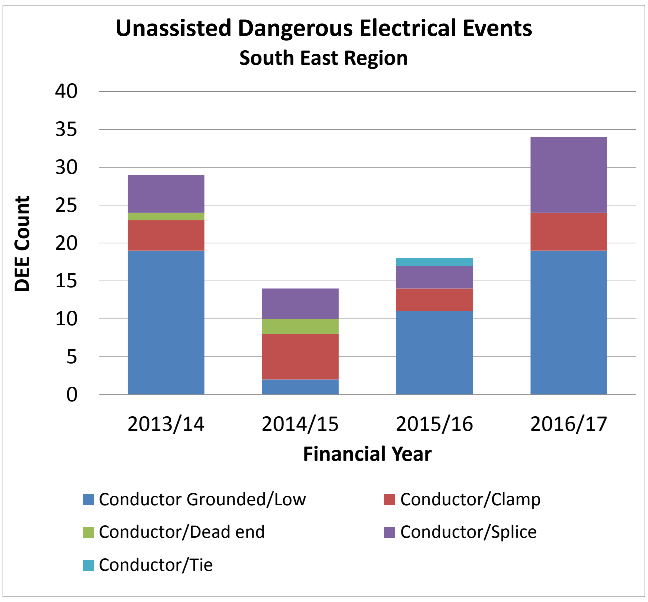
Figure 14: EQL Dangerous Electrical Event (DEE) Types Normalised by Asset Population





Northern and Southern Regions



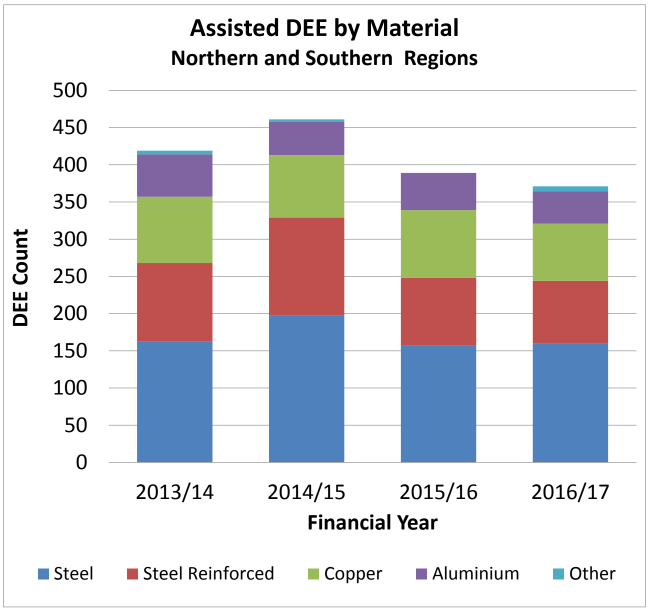


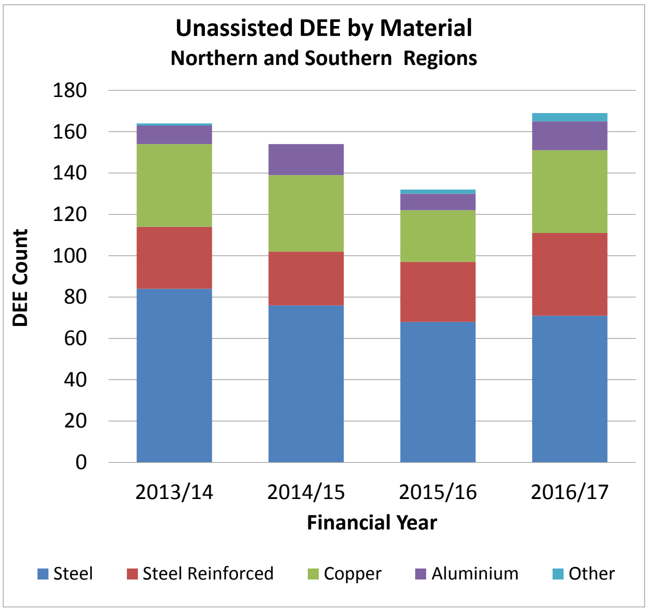
South East Region

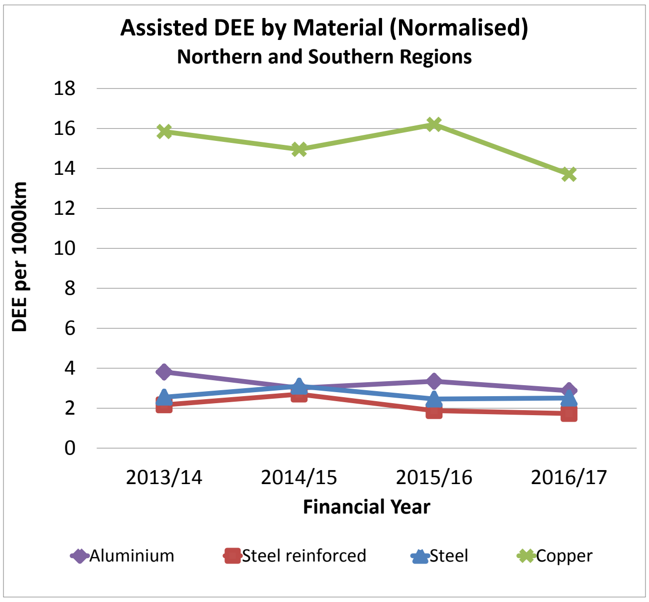
Figure 15: Dangerous Electrical Events (DEE) – Assisted / Unassisted Breakdown by Region

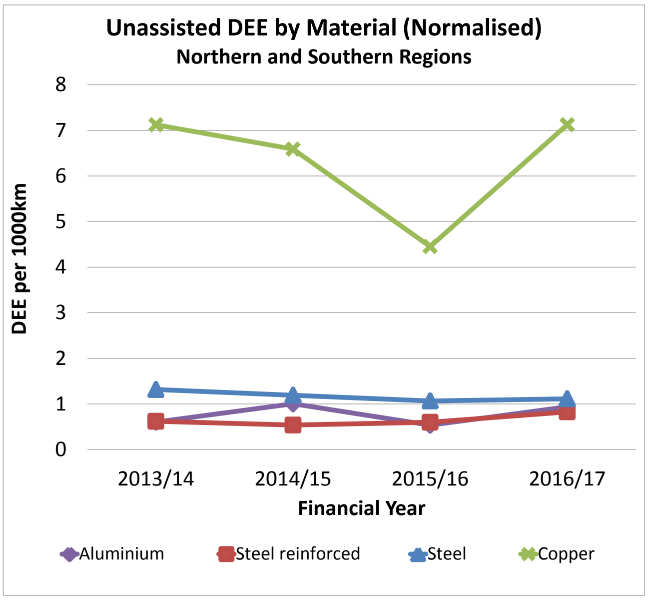
Figure 15 highlights that storms and vegetation (mostly from outside clearance zones) are the main cause of assisted, conductor related dangerous electrical events on the overhead network. EQL currently mitigates this risk through summer preparedness and vegetation management programs. Clearance to ground and clearance to structure programs also assist in identifying and mitigating vegetation hazards.

Unassisted failures have predominantly been attributed to conductor failure, although a considerable amount of hardware driven events are also present. Normailised breakdown of the conductor failures shown in Figure 16 indicates that significantly more events occur on bare copper per kilometre of installed conductor. Breakdown of dangerous electrical events by conductor material is not currently available in the South East Region.









Note:

- DEE data excludes LV conductor.
- DEE conductor material is not available in the South East Region.
- Conductor breakdown only available for 16/17, assumed for previous years.

Figure 16: Dangerous Electrical Events (DEE) – Assisted / Unassisted Breakdown by Conductor Type

4 Asset Related Corporate Risk

As outlined in Section 3.2, EQL has a duty to ensure its assets are electrically safe. This safety duty requires EQL to take action so far as is reasonably Practicable (SFAIRP) to eliminate safety related risks, and where it is not possible to eliminate these risks, to mitigate them SFAIRP. Risks in all other categories are managed to levels as low as reasonably practicable (ALARP).

EQL undertakes a number of actions such as inspections and maintenance to eliminate or mitigate the risks to SFAIRP/ALARP EQL's safety duty result in most inspection, maintenance and replacement works and expenditure related to overhead conductor being entirely focused upon preventing and mitigating failure.

The following sections detail the ongoing asset management journey necessary to continue to achieve high performance standards into the future. Action items have been raised in the following sections where relevant, detailing the specific actions that EQL will undertake as part of program delivery of this Asset Management Plan.

Figure 17 displays a threat-barrier diagram for the failure of overhead conductor assets.

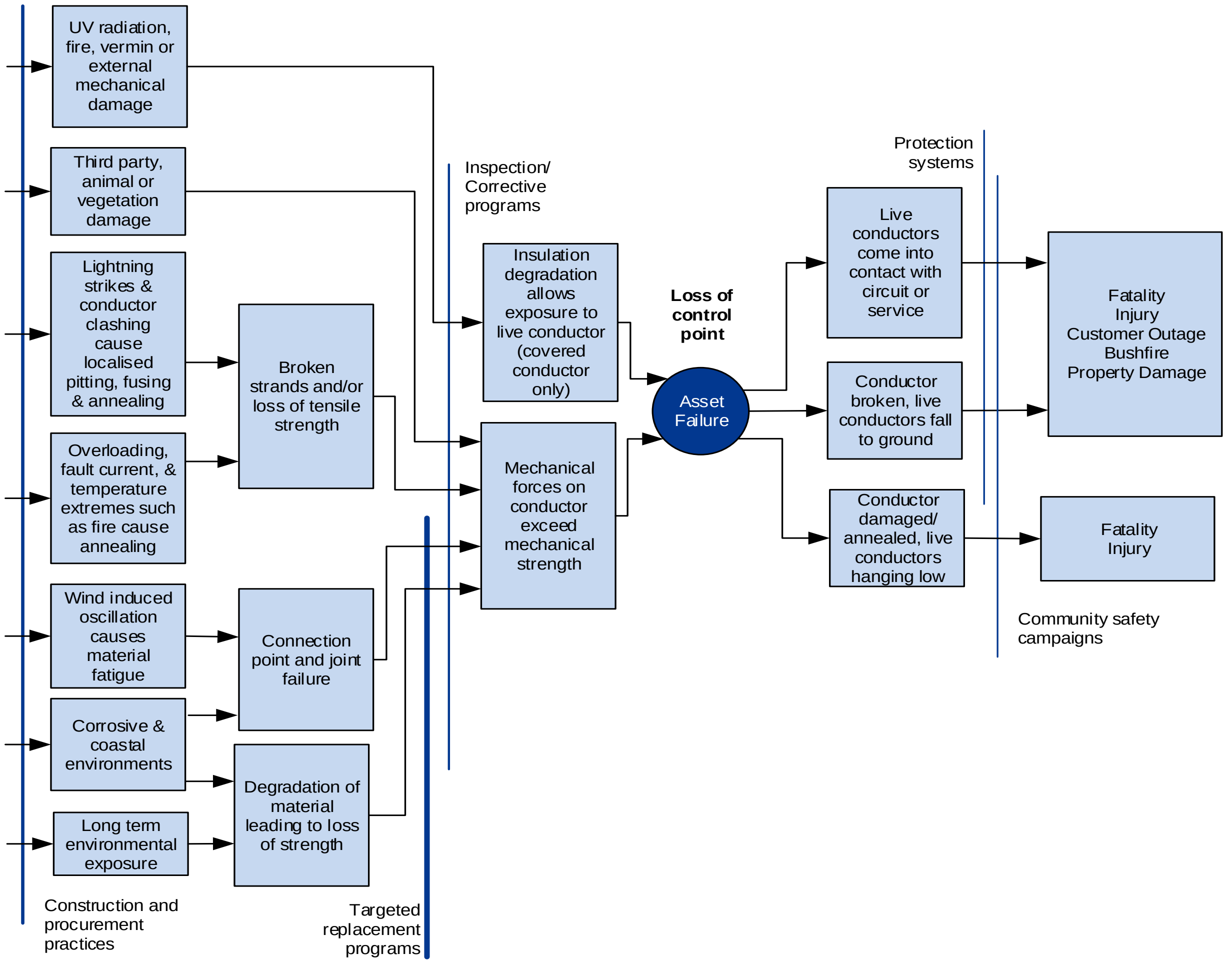


Figure 17: Overhead Conductor Threat Barrier Diagram

5 Health, Safety & Environment

EQL has adopted a policy of prudent avoidance for the design, construction and operation of its facilities with regards to Electromagnetic fields (EMF). Based on current industry guidelines and best practice, overhead conductors are configured and constructed with specific clearances to minimise occupational and general public exposure.

6 Current Issues

The following sections outline current issues that have been identified as having the potential to impact EQL's ability to meet corporate objectives.

6.1 Accessory Defects - Northern and Southern Regions

Overhead conductor accessories are the largest source of defects reported on the network in the Northern and Southern regions of EQL (see Figure 11).

Overhead accessory degradation, particularly corrosion, can be difficult to assess from the ground, which can lead to conservative defect classification by the asset inspectors. Several Defect Point of Reference Guides (DPORGs) has been issued to assist asset inspectors in identifying and assigning the correct priority to defects in the field.

Changes in defect identification and management managed through the deployment of DPORG's are then incorporated in the next revision of the Lines Defect Classification Manual (LDCM) to ensure ongoing continuous improvement of the defect management process.

EQL is actively investigating and pursuing advancements in overhead inspection using emerging technologies that will further assist in the management of these assets.

Action 6.1-1: Monitor failures and defect classification of overhead conductor accessories in the Northern and Southern regions to drive performance improvement and mitigate risk within this asset class.

6.2 Conductor Clearance to Ground and Clearance to Structure Programs

Non-conformance with statutory conductor clearance requirements was traditionally identified manually through ground-based inspection and rectified using the P1/P2 defect process under routine maintenance programs.

The introduction of light detection and ranging (LiDAR) technology and three-dimensional network/environment modelling, initially for vegetation management has provided EQL with the ability to efficiently identify statutory clearance impingement across the network with greater accuracy and in shorter timeframes than traditional inspection methods. This has resulted in a significant increase in the number of potential clearance non-conformances that require rectification to ensure ongoing compliance with regulatory obligations.

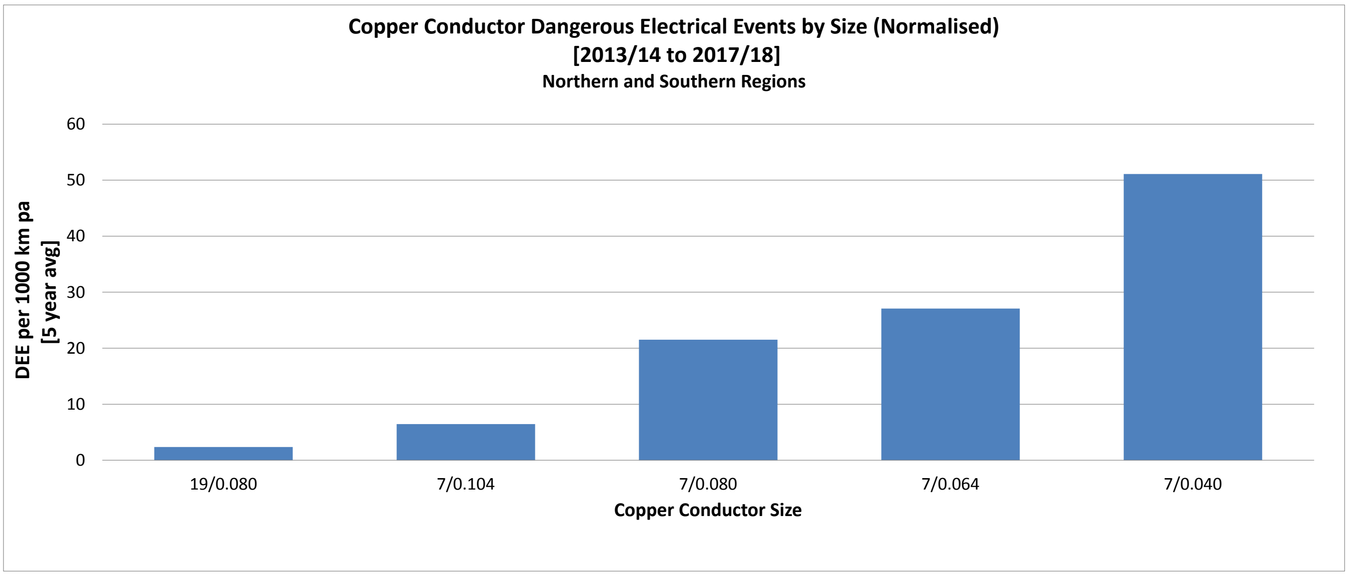
EQL has risk assessed and prioritised the identified non-conformances and established a program to address and rectify regulatory compliance issues. Clearance defects may be influenced by third party land use in the vicinity of assets. EQL may opt to move/augment these assets or place responsibility on the customer to rectify the situation, whichever is appropriate.

Remediation works to address the initial volume of clearance to ground and clearance to structure defects identified under LiDAR based inspection is targeted for completion in late 2019. EQL is continuing to engage with concerned parties (land and property owners, business operators, government agencies and building approval bodies) to increase awareness, obligations and mitigation strategies.

6.3 Copper Replacement Programs

Legacy line assets installed prior to the 1960s were constructed using HDBC conductor. To meet the regulatory obligations of operating an electrically safe network, EQL commenced proactive conductor replacement programs to remove high risk, small diameter HDBC conductor from the network. The legacy regions of EQL are at different stages in these programs with significant populations of at risk HDBC conductor remaining in the Northern and Southern Regions.

HDBC contributes significantly to the dangerous electrical events reported in the Northern and Southern Regions when normalised by installed population as shown in Figure 16.



Note: DEE failures only, excludes LV population

Figure 18: Copper Conductor DEE by Conductor Size (Northern and Southern Regions)

HDBC conductor with diameters of 7/0.104 and smaller have been identified as susceptible to mechanical failure due to fault current exposure (annealing) or loss of material (corrosion/scaling). Figure 18 shows that the average number of dangerous electrical events (DEE) per annum over the period 2013/14 to 2017/18 is inversely proportional to the size of the HDBC conductor when normalised by the installed population.

The replacement of 7/0.064 and smaller HDBC conductor and 7/0.080 backbone has been completed in the South East region. The remaining small diameter HDBC in the South East region is being managed through an age/population based planning approach, which aims to manage the mean life of the overhead conductor asset population as a whole.

An 'LV Risk Mitigation' program to remove low voltage HDBC, which is mostly sized 7/0.064 and smaller, from the Northern and Southern regions is anticipated to be completed by 2021. Targeted replacement of high voltage 7/0.64 in the Northern and Southern regions will follow and be ongoing through the 2020-25 AER period.

It is expected that the volume of copper conductor replacement required to be delivered per annum will significantly ramp up in future regulatory periods in order to manage the risk of aged HDBC sized 7/0.104 and smaller in the Northern and Southern Regions of the EQL network.

Action 6.3-1: Continue hard drawn bare copper (HDBC) conductor replacement programs to mitigate the risk associated with this population. Accelerate the replacement of small diameter (<7/.104) HDBC conductor in the Northern and Southern Regions, prioritized by geographical risk.

6.4 Bushfire Mitigation Strategies

In addition to aged conductor replacement, EQL has adopted several best practice overhead conductor asset management strategies to minimise the risk of bushfires and to minimise the associated risk to its assets and customer supply reliability during times of bushfire. Refer to the EQL Bushfire Risk Management Plan.

7 Emerging Issues and Actions

The following sections outline emerging issues which have been identified as having the potential to impact on EQL’s ability to meet corporate objectives in the future.

7.1 3/12 (3/2.75mm) Galvanised Steel

Galvanised Steel (SC/GZ) is the predominant conductor material installed on the EQL network with an asset population of approximately 61,000 km (34% of the total asset base). The relatively high tensile strength of steel allows for long spans and has therefore proven an economic material for use in lightly loaded single and multi-wire rural electrification. It has also historically been used as a low-cost material for overhead earth wire.

SC/GZ exhibits poor performance in coastal and polluted environments. To address this failure mode, EQL has modified its design standards to install aluminium clad steel (SC/AC) conductor on new steel lines installed in proximity to the coast. Steel conductor has also been targeted for removal in urban centres due to thermal limitations under high fault currents. There remains a significant population of SC/GZ installed in coastal areas across the Northern and Southern Regions.

The majority of this conductor type is installed in the rural single wire network servicing remote customers in the Northern and Southern Regions of EQL. Conductor in this part of the network is typically installed in non-corrosive environments, is lightly loaded, and is not subject to high fault currents, conductor clashing, or other factors that may significantly affect the performance of conductors in an urban environment. In the South East Region, corrosion of SC/GZ conductor and subsequent elevated risk of failure have been observed at approximately 55 years, though it is anticipated that most rural galvanised steel conductor will perform well beyond this age.

Action 7.1-1: Incorporate the management of the aging galvanised steel (SC/GZ) population into the priority of targeted line replacement programs across all regions, including consideration of geographical location to ensure appropriate management of safety risk and the influence of coastal environments.

7.2 Aluminium Conductor, Steel Reinforced (ACSR) Conductor

EQL has a significant population of aluminium conductor, steel reinforced (ACSR) installed on the network. This conductor typically has a galvanised steel core and is used most frequently at sub-transmission, transmission and on long spans in rural networks.

The steel core of ACSR conductor is susceptible to mechanical failure due to both environmental and galvanic corrosion once the galvanizing layer is lost. Grease is now commonly applied during manufacture to retard galvanic corrosion due to the dissimilar metal construction of steel core and aluminium strands; however, it may not be present in all ACSR conductors in the population. Inconsistent application of grease by the manufacturer or break down over time can lead to localized corrosion, directly affecting the mechanical strength.

Action 7.2-1: Incorporate the management of the aging aluminium conductor, steel reinforced (ACSR) population into the priority of targeted line replacement programs across all regions, including consideration of geographical location to ensure appropriate management of safety risk and the influence of coastal environments.

7.3 Smooth Body ACSR Conductor

Smooth body ACSR conductor has been installed in limited quantities in the Northern and Southern regions of EQL. This type of conductor is not common globally, is constructed to a Canadian standard, and has a specific application (to reduce wind loading) which limits its widespread use.

This type of conductor, especially in the smaller diameters, is seeing higher than average failure rates when normalised by installed population. These rates are at least three times the average for other ACSR type conductors, although the majority of these failures are assisted.

The availability of replacement conductor and accessories has been identified as a risk to the network although with only limited quantities installed further investigation is required to determine if a replacement strategy is warranted.

Action 7.3-1: Review the spares holdings for the small population of 'smooth body' ACSR to ensure the supply risk for this unique conductor type is adequately managed. Determine if a replacement strategy is required for this population.

7.4 Low Voltage Aerial Bundled Cable (LV ABC)

Low voltage aerial bundled cable (LV ABC) defects have been increasing in the Northern and Southern regions. The majority of the defects have been attributed to the deterioration of the insulation due to bird or UV damage. Further investigation is underway to determine if an inspection and/or age-based replacement program is required for this conductor type.

Action 7.4-1: Determine if an inspection and age-based replacement program is required for low voltage aerial bundled cable (LV ABC) due to the increase in insulation based defects.

8 Improvements and Innovation

The following sections outline any improvements or innovations to asset management strategies relevant to this asset class, being investigated by EQL.

8.1 Conductor Condition Assessment

EQL uses Condition Based Risk Management (CBRM) to forecast the retirement of many assets on the network. Overhead conductor assets are not currently modelled in CBRM, as conductor condition is difficult to assess in situ. At present, conductor age, type, construction, and environment are used as proxy for condition based on analysis of performance.

Current visual inspection methodologies can only identify surface defects if present. A conductor may appear visibly sound, yet the structural integrity of the material can be compromised beneath the outer layers of the conductor, or fittings applied such as joints and amour rods. Conductor sampling and testing by a materials laboratory can give an indication of the remaining strength. This approach is costly in terms of labour and network outages and can produce misleading results as material degradation may not be uniform for the entire route length.

Action 8.1-1: Further develop inspection techniques and diagnostic tests methodologies to accurately assess conductor condition to inform an overhead conductor CBRM model.

8.2 ENA Overhead Conductor Condition Monitoring

Energy Networks Australia (ENA) is the peak national body representing gas distribution and electricity transmission and distribution businesses throughout Australia.

ENA has acknowledged that conductor populations are ageing globally, and despite technology advancements, there has been little change in cost effective methods for monitoring the condition of conductor assets.

ENA are investigating reliable and cost-effective methods to assess the likelihood of a conductor failure.

Action 8.2-1: Develop industry best practice overhead conductor condition monitoring standards through active participation in Energy Networks Australia (ENA) working groups.

8.3 Dynamic Ratings

Dynamic conductor ratings are being explored on specific feeders to enable better utilization of conductor assets. In addition to the operational advantages, the introduction of dynamic ratings would also allow for real time awareness of statutory clearance requirements, and improved modelling of condition-based failure modes on critical feeders.

Action 8.3-1: Continue the development of the dynamic ratings in project business cases and use the systems to improve measurement techniques for clearance to ground and structure measurements.

8.4 ACSR Corrosion Detection

Due to the concentric construction of ACSR, corrosion of the steel core is difficult to assess by visual inspection.

Commercial, non-destructive devices are available that can estimate the remaining thickness of the zinc or aluminium coating on the steel core wire of ACSR conductors, and therefore provide an indication of remaining life. As this technology is still in its infancy, there are also concerns over the accuracy of the results.

Action 8.4-1: Investigate the use of commercially available, non-destructive technologies for the condition assessment of steel reinforced aluminium conductor (ACSR).

8.5 Future Technologies to Deliver Inspection Capability

Emerging technologies such as image recognition and defect classification may provide an efficient, effective and economic solution for condition monitoring of overhead conductor assets. Technologies in this field are continuing to evolve to deliver greater quality while the cost of implementation reducing. Energy Queensland continually monitors advancements in this field through the market in order to evaluate the potential to provide efficiencies in program delivery and risk reduction.

It is recommended that Energy Queensland continue to investigate technology-based techniques to monitor condition of overhead conductors to deliver greater risk reductions at lower cost.

Action 8.5-1: Investigate the use of technological advancements in pole top asset condition assessment such as LiDAR, 3D modelling and ultra-high resolution imaging, and post processing technology, combined with EQL's existing defect classification manual to identify conductors in need of replacement. Partner with external providers of this technology to support development and feedback EQL's requirements to technology developers and service providers.

8.6 Future Technologies as an Alternative to Replacement

Technology advancement in areas which present an alternative to traditional network is currently increasing at an unprecedented rate. Technologies such as distributed generation, batteries and isolated grids may present a viable alternative to like-for-like replacement in order to mitigate risk; particularly in rural areas.

It is recommended that Energy Queensland continue to investigate technology-based techniques to provide an alternative to like-for-like replacement to deliver greater risk reductions at lower cost.

Action 8.6-1: Investigate the use of technology-based solutions such as distributed generation, batteries, and isolated grids as an alternative like-for-like replacement in overhead distribution networks.

9 Lifecycle Strategies

The following sections outline the approach of EQL to the lifecycle asset management of this asset class.

9.1 Philosophy of Approach

The breaking load of new overhead conductor is given by the manufacture and is a measure of the material's rated tensile strength. This parameter is directly related to the strength of the individual component strands and may reduce over years of service, due to the life limiting factors outlined in Table 4. Ultimate failure occurs when the applied external forces (working tension or mechanical impact) exceed the strength remaining in the conductor.

Based on the prudency of CAPEX spend, risk reduction, and contribution to business outcomes (safety and network performance), EQL has adopted a risk-based approach in determining the end of life of conductor assets.

9.2 Supporting Data Requirements

Historical data migration and consolidation from siloed, legacy corporate systems including the manual conversion of paper-based records, has resulted in data quality issues. EQL is working to improve its data quality.

To support the forecasting of replacement quantities for business planning purposes, specific information such as the conductor type, age, location, and environment in which assets fail, needs to be recorded and managed. This will enable the application of probabilistic reliability engineering techniques such as Weibull analysis. Reliability engineering will allow EQL to predict replacement quantities for regulatory determinations and resource planning.

Due to inconsistent data capturing practices in EQL, the actual historical failure data cannot be obtained without comprehensive manual assessment.

Action 9.2-1: Incorporate asset data structure changes in the new Enterprise Asset Management system being proposed for EQL, to capture overhead conductor as equipment rather than a component. This will improve asset data and cost capture, and failure and condition monitoring capability, to support the asset management objectives.

Action 9.2-2: Align and improve defect, failure, and dangerous electrical event data capture processes and reporting methodologies to ensure consistency across EQL.

9.3 Acquisition and Procurement

EQL's procurement policy and practices are detailed in policy P011 – sustainable procurement policy. Overhead conductors and ancillary equipment are specified in line with relevant Australian Standards, industry best practice, and in consultation with stakeholders and subject matter experts. These assets are procured on period contracts awarded through technical and commercial evaluation in line with Queensland Government's QTenders process.

Overhead networks associated with connection assets such as large customer or subdivision connections may also be designed, procured, and constructed by approved service providers to EQL standards, under the contestable works process. The connection assets are "gifted" to EQL following final product audit and acceptance of the installation. EQL takes responsibility to own, operate, maintain and replace these assets from the date of acceptance.

9.4 Operation and Maintenance

Operation and maintenance includes planned and corrective maintenance. Operation and maintenance procedures are supported by a suite of documentation which describes in detail the levels of maintenance applicable, the activities to be undertaken, the frequency of each activity, and the defect and assessment criteria to which the condition and testing are compared to determine required actions. The relevant documents are included in Appendix 1 for reference.

EQL has an obligation under the Electricity Act and Regulations to maintain a safe and reliable electrical supply network. This obligation is in turn reflected by the need to achieve and demonstrate compliance with the applicable EQL maintenance policies and standards.

A significant contributor to the safe and reliable operation of an overhead network is the effective management of vegetation in the vicinity of this network. EQL is required, under section 216 of the Electrical Safety Regulation 2013, to maintain a safe and reliable network by maintaining safe clearances between vegetation and power lines:

An electricity entity must ensure that trees and other vegetation are trimmed and other measures taken, to prevent contact with an overhead electric line forming part of its works that is likely to cause injury from electric shock to any person or damage to property.

EQL maintains this level of safety, as well as ensuring a level of asset and power supply reliability, through an effective vegetation management program according to its Vegetation Management Strategy (G001).

Vegetation growth within clearance spaces may impact the safe and effective operational performance of the overhead network with failure modes including:

- Vegetation occurring within arcing distance of a conductor, transferring electrical current to the ground and/or to persons in close proximity to vegetation
- Vegetation facilitating access, through climbing, to a bare electrical conductor
- Vegetation in contact with the network, causing abrasion or other damage to the network, resulting in mechanical failure of the conductor
- Vegetation impacting on the network through whole tree or branch failure, resulting in network damage or unsafe conditions

EQL continues to improve the safety and cost-effective performance of its vegetation management program through use of the latest inspection and analysis techniques (LiDAR, imagery, predictive analytics), optimal delivery models/techniques, and active participation through Energy Networks Australia (ENA) working groups.

9.4.1 Preventive Maintenance

Preventive maintenance is comprised of scheduled inspection and maintenance activities required to ensure network assets remain serviceable and fit for purpose throughout their asset life cycle.

Ground and aerial inspections are performed to provide an integrated approach to condition assessment of overhead conductor and ancillary assets. Defects including and not limited to statutory clearance impingement, corrosion, broken strands, loose connections, and wear/corrosion of mechanical fittings can be identified and rectified prior to ultimate failure or incident. Known augmentation and replacement plans are considered prior to carrying out defect repairs.

In addition to routine ground and aerial inspections, an annual, high-level preventative 'Summer Preparedness Patrol' is also undertaken on critical feeders to mitigate the risk of storm/bushfire damage, and to identify obvious line components that have failed or are at imminent risk of failure prior to the storm/bushfire season.

Overhead conductor maintenance task and frequency rates are contained in the following maintenance standard documents:

- EX STD01121 / EE STNW1139 Maintenance Standard for Overhead Tower Lines
- EX STD01117 / EE STNW1140 Maintenance Standard for Overhead Pole Lines

9.4.2 Corrective Maintenance

Corrective maintenance is generated from preventive maintenance programs, ad-hoc inspections, public reports, and in-service failures. Non-urgent actions to address issues identified through customer notification or ad-hoc inspections are scheduled for a later time through corrective maintenance.

For corrective maintenance, overhead conductor networks are repaired or replaced to the current standard where cost effective and technically feasible.

Emergency maintenance may be required at any time of the day or night due to failure or third-party damage. This requires experienced and skilled staff, a range of tools and equipment well maintained records and instructions, and adequate stocks of conductor and accessories.

9.4.3 Spares

EQL maintains an inventory of strategic spares where deemed appropriate by Subject Matter Experts (SMEs). Spares holdings are periodically reviewed to ensure the minimum holding quantity is appropriate for the installed population.

It is impractical to carry spares for all conductor types and accessories. Critical or obsolete conductor types require special attention to provide adequate coverage for emergency situations.

9.5 Refurbishment and Replacement

The following sections outline the practices used to either extend the life of the asset through refurbishment or to replace the asset at the end of its serviceable life.

9.5.1 Refurbishment

On identification of defects or improvements through regular inspection and testing, EQL undertakes refurbishment of overhead conductor assets to ensure they remain safe and fit for purpose. The mechanical properties of the conductor itself cannot be restored once lost. Inspection driven refurbishment is therefore typically limited to statutory clearances and items ancillary to the conductor such as connectors, clamps and fittings.

9.5.2 Replacement

Overhead conductor systems are designed and constructed to ensure that they are fit for purpose and will continue to perform and operate safely under system normal and contingency situations. When the asset can no longer safely perform its function, is uneconomic to refurbish, or presents an unacceptable risk to the business, it is considered to have reached end of life, and planned replacement is proposed.

In the South East region, conductors are flagged for replacement based on age and location, then field assessed by subject matter experts to validate the corporate data and assess the asset in service. The number of splices/joints identified in each span is used as an indicator of condition. The planning and delivery of the replacement is then targeted for replacement according to the priorities detailed in Figure 19.

While both legacy organisations employed a common set of standard processes and inspection defect benchmarks, the practical implementation of the work has been different. This has developed as a result of variations in approach to use of contractors for tasks, contractual obligations, asset environments (e.g. CBD vs long rural), routine travel distances and diversity of environments promoting a range of work practices, and corporate direction and policy.

With the establishment of EQL, there is intent to merge these practices, policies, and procedures where prudent, such as when contracts fall due and are renewed, and to actively pursue opportunities for common approach and service delivery where performance improvement opportunities arise.

Conductor Type:

- All 7/0.064 and smaller HDBC.
- 7/0.080 HDBC > 70 years with excessive splices
- SC/GZ > 55 years in coastal environments
- ACSR > 70 years
- OH conductor identified at risk of failure as per DCM

Location:

- Road, rail, and water crossings
- Located within 100m of the following:
  - School grounds
  - Children’s playgrounds
  - Public swimming pool areas
  - Popular beaches or water recreation areas
  - Very close proximity to residential housing (e.g. within a backyard)

• All other 7/0.080 HDBC > 70 years	
• All Conductor > 70 years	• Within 100m of areas frequented by the general public including and not limited to; schools, shopping centres, shopping precincts, major sporting and recreational grounds, and community centres.
	• All other locations

Figure 19: Overhead Conductor Replacement Priorities

Action 9.5-1: Review and align the maintenance and replacement strategy between regions where prudent, to ensure a common EQL approach and industry best practice management of overhead conductor assets is maintained.

Action 9.5-2: Establish a line refurbishment program in the Northern and Southern Regions incorporating targeted pole, cross-arm, and conductor replacements to drive efficiency, deliver customer outcomes, and mitigate risk.

9.6 Disposal

Recovered overhead conductor assets, which may include the copper or aluminium conductor together with other materials, are disposed of via scrap merchants, and reflective of prudent and responsible recycling outcomes.

10 Program Requirements and Delivery

The programs of maintenance, refurbishment and replacement required to outwork the strategies of this AMP are documented in Network Program Documents and reflected in corporate management systems. Programs are typically coordinated to address the requirements of multiple asset classes at a higher level such, as a substation site or feeder, to provide delivery efficiency and reduce travel costs and overheads. The Network Program Documents provide a description of works included in the respective programs as well as the forecast units.

Program budgets are approved in accordance with Corporate Financial Policy. The physical and financial performance of programs is monitored and reported on a monthly basis to manage variations in delivery and resulting network risk.

11 Summary of Actions

The following provides a summary of the specific actions noted throughout this AMP for ease of reference.

Action 6.1-1: Monitor failures and defect classification of overhead conductor accessories in the Northern and Southern regions to drive performance improvement and mitigate risk within this asset class.

Action 6.3-1: Continue hard drawn bare copper (HDBC) conductor replacement programs to mitigate the risk associated with this population. Accelerate the replacement of small diameter (<7/.104) HDBC conductor in the Northern and Southern Regions, prioritized by geographical risk.

Action 7.1-1: Incorporate the management of the aging galvanised steel (SC/GZ) population into the priority of targeted line replacement programs across all regions, including consideration of geographical location to ensure appropriate management of safety risk and the influence of coastal environments.

Action 7.2-1: Incorporate the management of the aging aluminium conductor, steel reinforced (ACSR) population into the priority of targeted line replacement programs across all regions, including consideration of geographical location to ensure appropriate management of safety risk and the influence of coastal environments.

Action 7.3-1: Review the spares holdings for the small population of 'smooth body' ACSR to ensure the supply risk for this unique conductor type is adequately managed. Determine if a replacement strategy is required for this population.

Action 7.4-1: Determine if an inspection and age-based replacement program is required for low voltage aerial bundled cable (LV ABC) due to the increase in insulation based defects.

Action 8.1-1: Further develop inspection techniques and diagnostic tests methodologies to accurately assess conductor condition to inform an overhead conductor CBRM model.

Action 8.2-1: Develop industry best practice overhead conductor condition monitoring standards through active participation in Energy Networks Australia (ENA) working groups.

Action 8.3-1: Continue the development of the dynamic ratings in project business cases and use the systems to improve measurement techniques for clearance to ground and structure measurements.

Action 8.4-1: Investigate the use of commercially available, non-destructive technologies for the condition assessment of steel reinforced aluminium conductor (ACSR).

Action 8.5-1: Investigate the use of technological advancements in pole top asset condition assessment such as LiDAR, 3D modelling and ultra-high resolution imaging, and post processing technology, combined with EQL's existing defect classification manual to identify conductors in need of replacement. Partner with external providers of this technology to support development and feedback EQL's requirements to technology developers and service providers.

Action 8.6-1: Investigate the use of technology-based solutions such as distributed generation, batteries, and isolated grids as an alternative like-for-like replacement in overhead distribution networks.

Action 9.2-1: Incorporate asset data structure changes in the new Enterprise Asset Management system being proposed for EQL, to capture overhead conductor as equipment rather than a component. This will improve asset data and cost capture, and failure and condition monitoring capability, to support the asset management objectives.

Action 9.2-2: Align and improve defect, failure, and dangerous electrical event data capture processes and reporting methodologies to ensure consistency across EQL.

Action 9.5-1: Review and align the maintenance and replacement strategy between regions where prudent, to ensure a common EQL approach and industry best practice management of overhead conductor assets is maintained.

Action 9.5-2: Establish a line refurbishment program in the Northern and Southern Regions incorporating targeted pole, cross-arm, and conductor replacements to drive efficiency, deliver customer outcomes, and mitigate risk.

Appendix 1. References

It takes several years to integrate all standards and documents after a merger between two large corporations. This table details all documents authorised/approved for use in either legacy organisation, and therefore authorised/approved for use by EQL, that supports this Management Plan.

Legacy Organisation	Document Number	Title	Type
Ergon Energy **Energex**	EPONW01 EX 03595	Network Asset Management Policy	Policy
Ergon Energy **Energex**	PRNF001 EX 03596	Protocol for Network Maintenance	Protocol
Ergon Energy **Energex**	PRNF003 EX 04080	Protocol for Refurbishment and Replacement	Protocol
Ergon Energy **Energex**	STNW0330 EX 03918	Standard for Network Assets Defect/Condition Prioritisation	Standard
Ergon Energy **Energex**	STNW1160 EX STD00299	Maintenance Acceptance Criteria	Manual
Ergon Energy **Energex**		Lines Defect Classification Manual	Manual
Energex	EX 00302	Overhead Design Manual	Manual
Ergon Energy **Energex**	EX 04920	Overhead Construction Manual	Manual
Ergon Energy	EP26	Risk Management Policy	Policy
Ergon Energy	EP51	Defect Management Policy	Policy
Ergon Energy	SGNW0004	Network Optimisation Asset Strategy	Strategy
Ergon Energy	SGNW0038	Poles and Towers Inspection Strategy	Strategy
Ergon Energy	STNW0717	Standard for Preventive Maintenance Programs for 2017-18	Standard
Energex	00569	Network Risk Assessment	Procedure
Energex	354	Overhead Network Condition Assessment Manual	Manual
Energex	502	Lines Defect Classification	Standard
Energex **Ergon**	EX STD01121 EE STNW1139	Maintenance Standard for Overhead Tower Lines	Standard
Energex **Ergon**	EX STD01117 EE STNW1140	Maintenance Standard for Overhead Pole Lines	Standard

Appendix 2. Definitions

Term	Definition
Condition Based Risk Management	A formal methodology used to define current condition of assets in terms of health indices and to model future condition of assets, network performance, and risk based on different maintenance, asset refurbishment, or asset replacement strategies.
Corrective maintenance	This type of maintenance involves planned repair, replacement, or restoration work that is carried out to repair an identified asset defect or failure occurrence, in order to bring the network to at least its minimum acceptable and safe operating condition. An annual estimate is provided for the PoW against the appropriate category and resource type.
Distribution	LV and up to 22kV networks, all SWER networks
Forced maintenance	This type of maintenance involves urgent, unplanned repair, replacement, or restoration work that is carried out as quickly as possible after the occurrence of an unexpected event or failure; in order to bring the network to at least its minimum acceptable and safe operating condition. Although unplanned, an annual estimate is provided for the PoW against the appropriate category and resource type.
Preventative maintenance	This type of maintenance involves routine planned/scheduled work, including systematic inspections, detection and correction of incipient failures, testing of the condition and routine parts replacement designed to keep the asset in an ongoing continued serviceable condition, capable of delivering its intended service.
Sub transmission	33kV and 66kV networks
Transmission	Above 66kV networks

Appendix 3. Acronyms and Abbreviations

The following abbreviations and acronyms may appear in this asset management plan.

Abbreviation or acronym	Definition
AAAC	All Aluminium Alloy Conductor
AAC	All Aluminium Conductor
ABC	Aerial Bundled Cable
ACSR	Aluminium Conductor Steel Reinforced
AIDM	Asset Inspection & Defect Management system
ALARP	As Low As Reasonably Practicable
AMP	Asset Management Plan
Augex	Augmentation Expenditure
BOP	Basis of Preparation
CBRM	Condition Based Risk Management
CB	Circuit Breaker
CCT	Covered Conductor Thick
CT	Current Transformer
CVT	Capacitor Voltage Transformer
DEE	Dangerous Electrical Event
DPORG	Defect Point of Reference Guide
DGA	Dissolved Gas Analysis
DLA	Dielectric Loss Angle
EMF	Electromagnetic Fields
ENA	Energy Networks Australia
EQL	Energy Queensland Limited
ESCOP	Electricity Safety Code of Practice
ESR	Queensland Electrical Safety Regulation (2013)
GZ	Galvanised Steel
HDBC	Hard Drawn Bare Conductor (copper)
HV	High Voltage
IoT	Internet of Things
ISCA	In-Service Condition Assessment
LiDAR	Light Detection and Ranging
LDCM	Lines Defect Classification Manual
LV	Low Voltage

Abbreviation or acronym	Definition
MSSS	Maintenance Strategy Support System
MU	Metering Unit
MVAr	Mega-VAr, unit of reactive power
NER	Neutral Earthing Resistor
NEX	Neutral Earthing Reactor
OH	Overhead
OHEW	Overhead Earth Wire
OLTC	On-load tap -changers
OPGW	Optical-fibre Ground Wire
OTI	Oil Temperature Indicators
PCB	Polychlorinated Biphenyls
POC	Point of Connection (between EQL assets and customer assets)
POEL	Privately owned Electric Line
PRD	Pressure Relief Device
PVC	Poly Vinyl Chloride
QLD	Queensland
RED	Repository of Energex Documents
REPEX	Renewal Expenditure
RIN	Regulatory Information Notice
RIV	Radio Interference Voltage
RMU	Ring Main Unit
SC/AC	Steel Conductor Aluminium Clad
SC/GZ	Steel Conductor Zinc Galvanised
SCAMS	Substation Contingency Asset Management System
SDCM	Substation Defect Classification Manual
SEI	Serious Electrical Incident
SFAIRP	So Far As Is Reasonably Practicable
STPIS	Service Target Performance Incentive Scheme
SHI	Security and Hazard Inspection
SM	Small
SME	Subject Matter Expert
SWER	Single Wire Earth Return
SVC	Static VAR Compensator
UV	Ultraviolet

Abbreviation or acronym	Definition
VT	Voltage Transformer
WCP	Water Content of Paper
WTI	Winding Temperature Indicators
WTP	Wet Transformer Profile
XLPE	Cross–linked Polyethylene