Asset Management Plan
Underground Cables

Part of the Energy Queensland Group

Executive Summary

This Asset Management Plan (AMP) focuses on the management of underground cable and accessories.

Energy Queensland Limited (EQL) owns and maintains approximately 28,000km of underground cable throughout Queensland at distribution, sub-transmission, and transmission voltages. Approximately 19,000km (67%) of these assets are contained within the South East Region.

Underground cable 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. Failure of underground cable 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 underground cable types and sizes due to legacy organisation standards, changes in period contracts and advancement in cable technology. The majority of cable installed across all voltage designations within EQL use cross-linked polyethylene (XLPE) as the insulation medium (82%). Approximately 94% of underground cable assets are installed at distribution voltages less than or equal to 11kV. Using current asset quantities and replacement costs, underground cable assets have an undepreciated replacement value of the order of $8.13 billion, approximately 16% of the EQL total asset replacement value.

To meet the regulatory obligations of operating an electrically safe network, EQL has undertaken proactive replacement programs to remove high risk, aged underground cable assets including cast iron potheads, low voltage Concentric Neutral Solid Aluminium Conductor (CONSAC) and Hochstadter Screened Separately Lead Sheathed (HSL) cable. The regions of EQL are at different stages in these programs.

A considerable number of defects and in-service failures are attributed to low voltage underground pillars. Routine thermoscanning of underground pillars was trialled and subsequently introduced within the South East Region. It is proposed to introduce pillar thermoscanning to the Northern and Southern Regions to mitigate the risk of catastrophic failure within these areas.

EQL has experienced premature XLPE insulated cable failures that have been attributed to the presence of water trees in the cable dielectric. Due to the large population of XLPE cable, further monitoring, research and investigation into this failure mode have been proposed.

Ongoing tracking and post fault analysis of cable joint failure is required to enable continuous improvement in this area. Further investigation has been proposed to determine if a detailed cable pit inspection program to identify and mitigate the risk of distribution joint failure is warranted.

The effective management of underground assets requires specialist technical skills and workforce capability particularly for transmission, submarine and legacy cable types such as lead sheathed or pressure assisted cables. An audit and ongoing monitoring of these skills are warranted.

Underground cables due to their very nature are inherently challenging to access for maintenance or auditing. As such, verification of the data to ensure reliable asset population counts, age profiling and asset condition is difficult to accurately determine in situ. EQL is working to improve its data quality and actively investigating and pursuing advancements in underground cable condition assessment, cable diagnostics and insulation rejuvenation techniques that will further assist in the management of this asset class.

Revision History

Revision date	Version number	Description of change/revision
31/01/2019	1	AER Document Initial release

Document Approvals

Name	Position title	Date
Tim Hart	General Manager Asset Lifecycle Management	31/01/2019
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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 underground cable assets on the EQL network. The objectives of this plan are to:

1. Deliver customer outcomes to the required level of 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 (AMP) 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 1 contains references to other documents relevant to the management of the asset class covered in this plan.

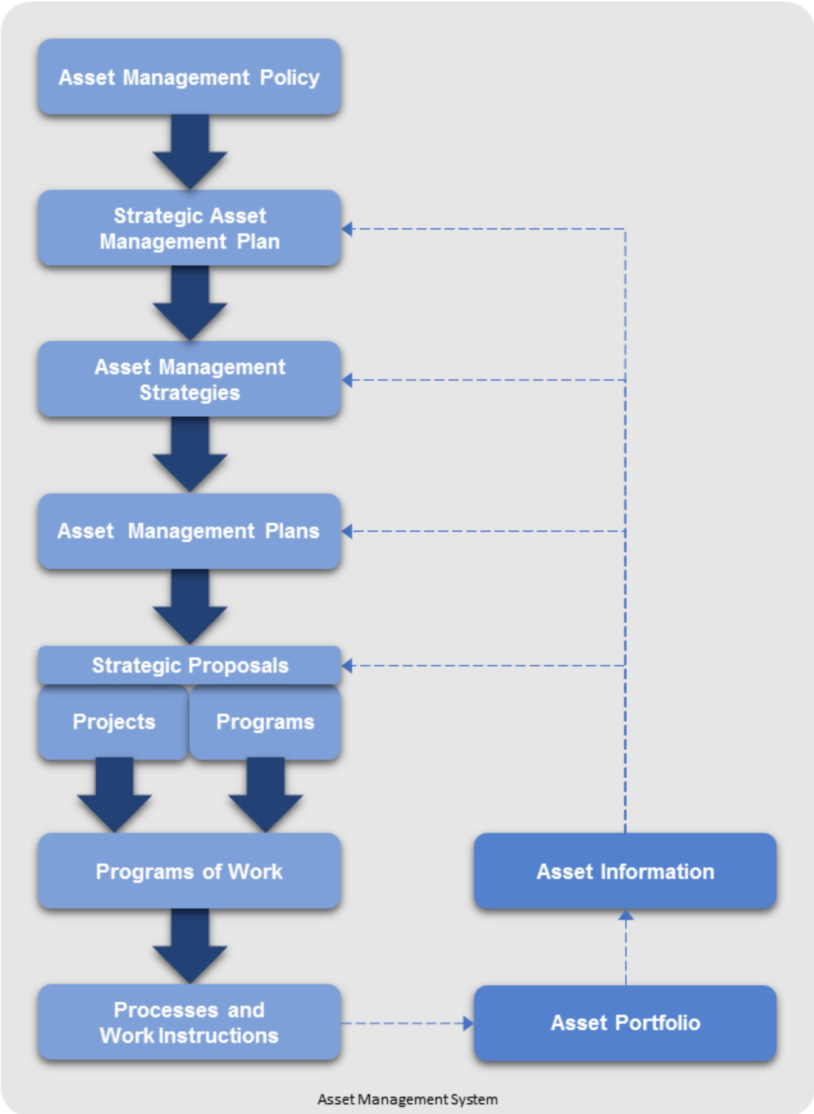

Figure 1: Energy Queensland Asset Management System

1.2 Scope

This plan covers the following assets:

- Impregnated paper, solid dielectric and pressure assisted cable types at voltages up to 132kV
- Cable accessories including joints and terminations
- Underground accessories including link boxes, pits and pillars.

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

The customer's point of supply in the underground low voltage distribution network is the service fuse in the pit/pillar. The underground service (consumer's mains) from the service fuse to the customer's installation is owned and maintained by the customer and is therefore excluded from this document.

1.3 Total Current Replacement Cost

Underground cables are a low cost, high volume asset. As underground assets, a large component of their replacement cost is from civil works associated with installation.

Based upon asset quantities and replacement costs EQL underground cables have a replacement value in the order of $8.13 billion. This valuation is based on gross replacement costs of all the assets based on the cost of modern equivalents, without asset optimization. This is shown in Figure 2 below.

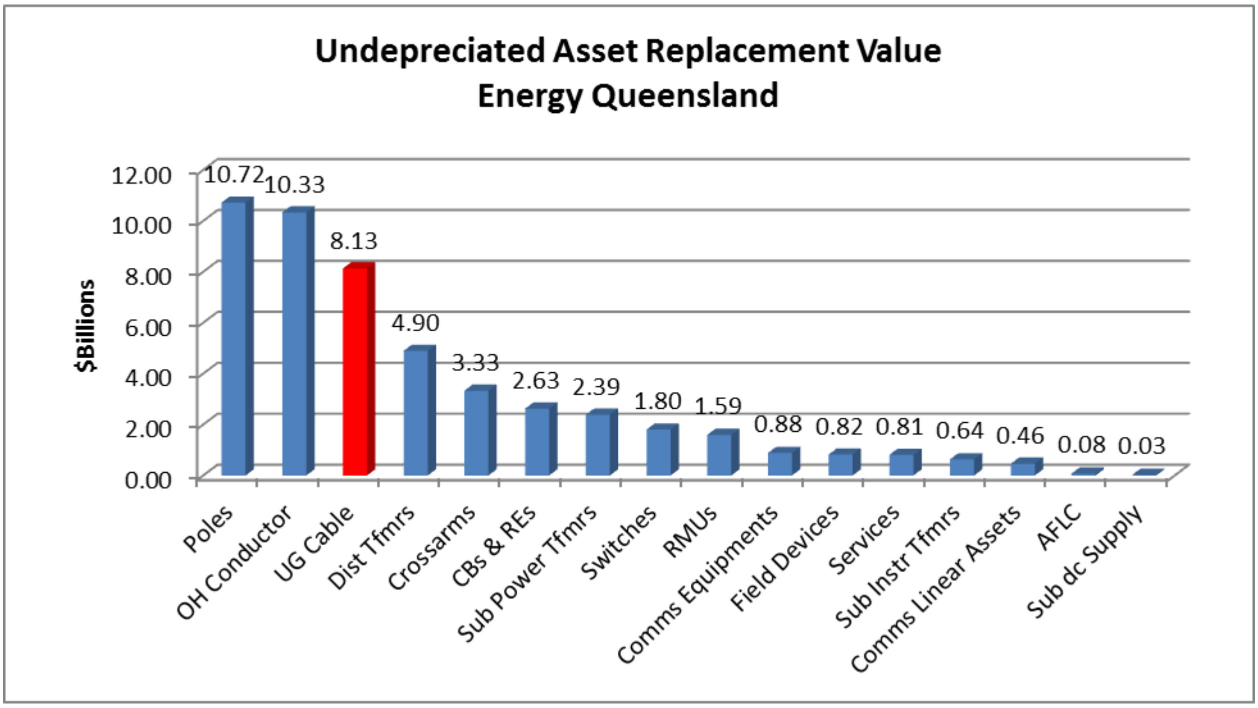

Figure 2: EQL – Total Current Asset Replacement Cost

1.4 Asset Function and Strategic Alignment

Underground cable 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 the assets operational life.

The consequences of failure of underground cable systems may include:

- Safety risks to the public and operational personnel
- Financial losses associated with cable system damage, repair and replacement
- Reduced network reliability and security
- Environmental risks associated with oil or gas cable systems.

Table 1 details how underground cables 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 underground cable assets is a key factor in managing safety or environmental hazards and compliance to legislative and regulatory obligations.
Meet customer and stakeholder expectations	The performance of underground cable 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 underground cable assets is integral in managing the exposure hazard of workers and the general public to electrical safety risks and contributes directly to Network Performance MSS and STPIS reliability targets. Prudent management of underground cable 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 innovation through increased asset utilisation, novel condition and health assessment and replacement of assets at end of economic life as necessary to suit modern standards and 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

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 28,000km of underground cable throughout Queensland at distribution, sub-transmission, and transmission voltages. Approximately 19,000km (67%) of these assets are contained within the South East Region.

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

2.1.1 Underground Cable

An underground cable system is designed and constructed so that it carries electrical energy, up to a rated voltage and current, safely and reliably between the terminations at each end of the underground circuit.

Cable design varies dependant on the application; however, the design generally consists of a conductor to carry current and insulation to keep each conductor isolated from its environment and other conductors. Insulation thickness increases with voltage designation. Cables may include screening, a metal sheath to contain pressurised fluid or gas and to act as barrier to moisture ingress, or armouring to act as mechanical protection.

In general, underground cables are classified by their voltage rating and construction including:

- Number of cores
- Conductor material, stranding, shape and cross-sectional area
- Insulation material and thickness
- Screen/conductor sheath material
- Armouring if present and protective outer sheath/serving material.

EQL maintains a diverse population of underground cable types and sizes due to legacy organisations standards, changes in period contracts and advancements in cable technology.

2.1.1.1 132/110kV (Transmission Cables)

EQL has predominantly copper sheathed; cross-linked polyethylene (XLPE) insulated cables at this voltage designation. XLPE insulated lead alloy (LY) sheathed cable is also present. Due to the required current carrying capacity, copper conductor is preferred over aluminium.

A significant legacy population of pressure assisted, oil filled, paper insulated, aluminium sheathed cable (OFPA) remains installed in the South East Region of the network.

2.1.1.2 66kV and 33kV (Sub transmission Cables)

EQL has predominantly copper core, cross-linked polyethylene (XLPE) insulated lead alloy (LY) sheathed cable at this voltage designation.

At 33kV in the South East Region, a corrugated copper sheathed cable was introduced due to concerns over the ongoing use of lead. More recently, this cable has been phased out and replaced with an XLPE insulated, aluminium cored cable with a copper wire screen and laminated aluminium tape (LAT) moisture barrier.

The remaining asset population consists of pressure assisted oil filled, paper insulated, aluminium sheathed cable (OFPA), Hochstadter separately screened lead sheathed (HSL) and paper insulated lead alloy sheathed (PLY) cable types.

Due to the unavailability of spare parts for the gas cable network, all known gas filled cables have been decommissioned from the network.

2.1.1.3 22kV and 11kV (HV Distribution Cables)

Cross-linked polyethylene (XLPE) insulated, copper wire screened cable is predominantly installed at this voltage designation. The majority of cables at this voltage employ a copper conductor although the use of aluminium has increased due to the cost and handling benefits of this material. Cables installed since the late 2000s may contain an improved formulation of XLPE to protect against water tree propagation (TR-XLPE). In recent years, Triplex cable, which consists of three individual single core XLPE insulated, copper wire screened cables laid up and twisted together to form a single cable has been adopted. There remains a significant population of legacy paper insulated, lead alloy sheathed/covered (PLY, PILC) cable at this voltage designation.

There are several submarine feeders installed on the network servicing island communities. These cables are typically paper insulated, lead alloy sheathed construction with a double brass tape water seal (PLYDBT) although some XLPE insulated submarine cable is also present.

2.1.1.4 <1kV (LV Distribution Cables)

The majority of cables in this voltage designation use cross-linked polyethylene (XLPE) as the insulating medium. The conductor may be copper or aluminium. Small populations of legacy polyvinyl chloride (PVC), paper insulated, lead alloy sheathed (PLY) and concentric neutral, solid aluminium conductor (CONSAC) cable also remain installed.

2.1.2 Cable Joints, Terminations, and Ancillary Equipment

Sections of underground cable are extended and/or repaired through the use of cable joints. At transmission and sub-transmission voltages, cable joints are ‘straight through’ and used to connect two sections of cable only. Terminations are used to connect sections of cable to plant such as transformers or switchgear or to transition to the overhead system on a hybrid overhead / underground feeder.

Transmission and sub-transmission joints are installed in a concrete jointing pit, which is typically backfilled with the appropriate thermal materials. Link boxes are installed below ground beside the joint bays where required to facilitate cross bonding or other earthing configurations. These pits have lids that allow for access for testing. Sheath Voltage limiters (SVL) are installed at link boxes or on the termination structure where required and can either be in weather resistant boxes or exposed.

At distribution voltages, underground pits are installed to facilitate pulling cables and jointing during installation. Distribution cable pits are fitted with removable covers and not backfilled. In addition to straight through joints, ‘branch’, ‘tee’, or ‘trouser’ joints may also be used to tee sections of cable and provide flexibility in reticulation. Live end seals are also used at distribution voltages for the safe termination of live cables in the ground or to facilitate future extension of feeders. At voltages below 1kV, terminations may take place in above ground enclosures, link or service pillars. These enclosures may contain protective devices and provide a safe, weatherproof environment for low voltage service distribution.

2.2 Asset Quantity and Physical Distribution

EQL operates at a wide variety of voltages including 132kV, 110kV, 66kV, 33kV, 22kV, 11kV, and low voltage (LV) (<1kV). A breakdown of the EQL underground cable asset base by voltage designation is shown in Table 3.

Note: 66kV and 22kV are present in the Northern and Southern Regions only.

Underground Cable	Northern and Southern Regions	South East Region	Total
<= 1 kV	6,628	11,726	18,354
> 1 kV & <= 11 kV	1,767	5,921	7,688
> 11 kV & <= 22 kV	697	0	697
> 22 kV & <= 33 kV	56	828	884
> 33 kV & <= 66 kV	20	0	20
> 66 kV & <= 132 kV	11	162	173
> 132 kV	0	0	0
Total Route Length (km)	9,179	18,637	27,816

Table 3: EQL Underground Cable Population

Approximately 94% of underground cable assets are installed at distribution voltages less than or equal to 11kV.

2.3 Asset Age Distribution

The age profile for the underground cable asset base in the Northern and Southern and South East Regions are shown in Figure 3 and Figure 4.

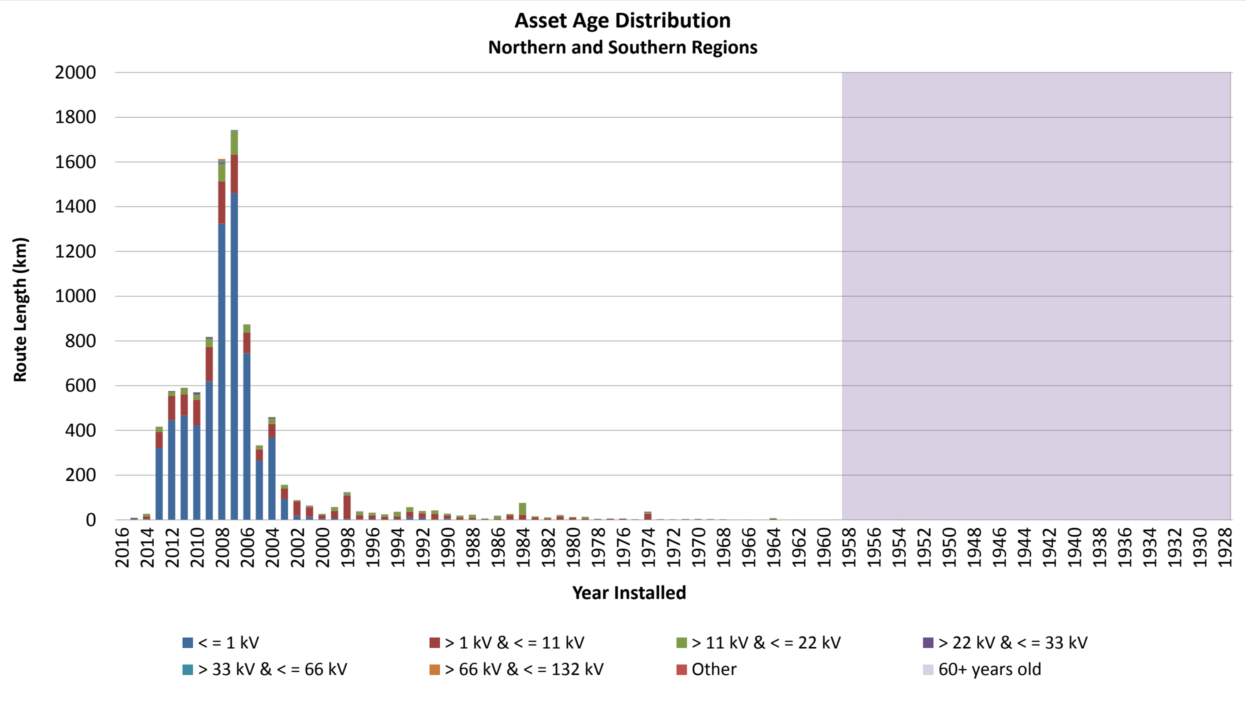

Figure 3: Northern and Southern Regions Underground Cable Age Profile by Voltage

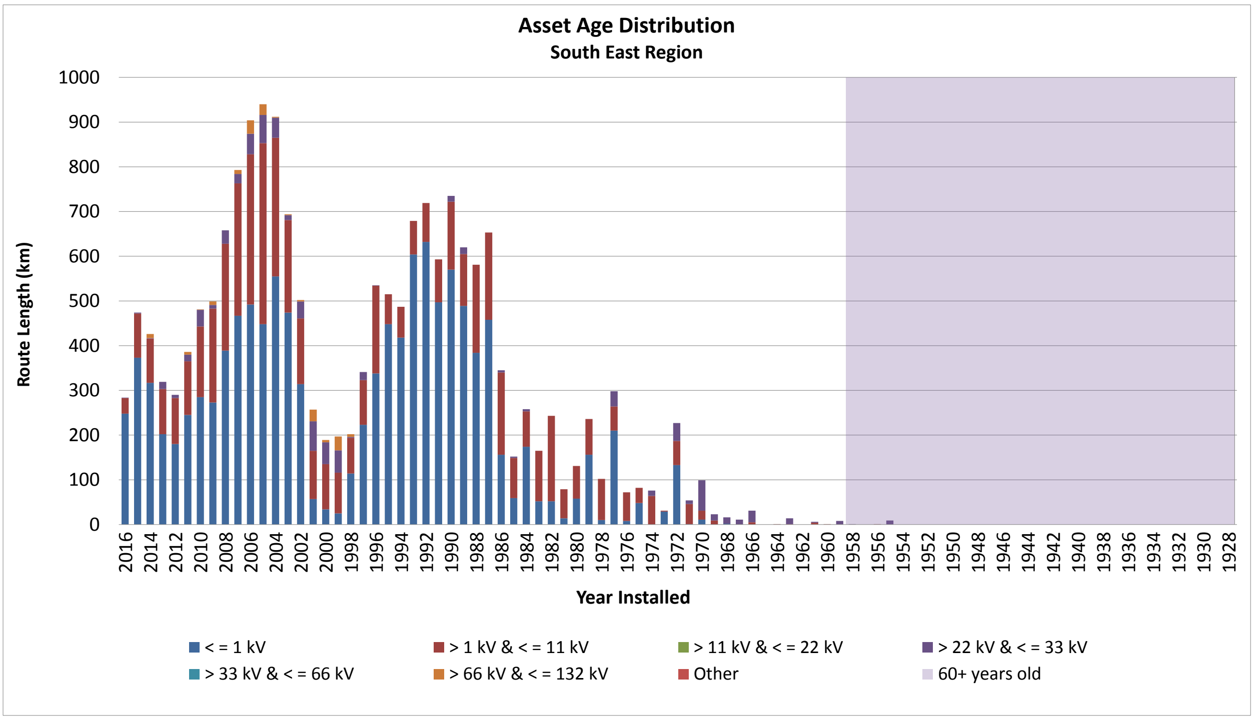

Figure 4: South East Region Underground Cable Age Profile by Voltage

2.4 Population Trends

The majority of cable installed across all voltage designations within EQL uses cross-linked polyethylene (XLPE) as the insulation medium. XLPE has significant advantages over legacy cable technologies with regards to cost, maintenance and environmental risk. Globally, the electricity industry has moved to XLPE as the preferred insulation material for all underground cable systems.

Substantial populations of paper insulated and oil filled, pressure assisted cables are also present.

LV Concentric Neutral Solid Aluminium Conductor (CONSAC) cable and 33kV HSL cable types are legacy cable types that remain in service in limited quantities. Due to safety and reliability concerns, proactive replacement of these cables types has been initiated.

Small quantities of submarine cable are also installed on the network.

A breakdown of cable types installed on the EQL underground network by voltage class is shown in Figure 5.

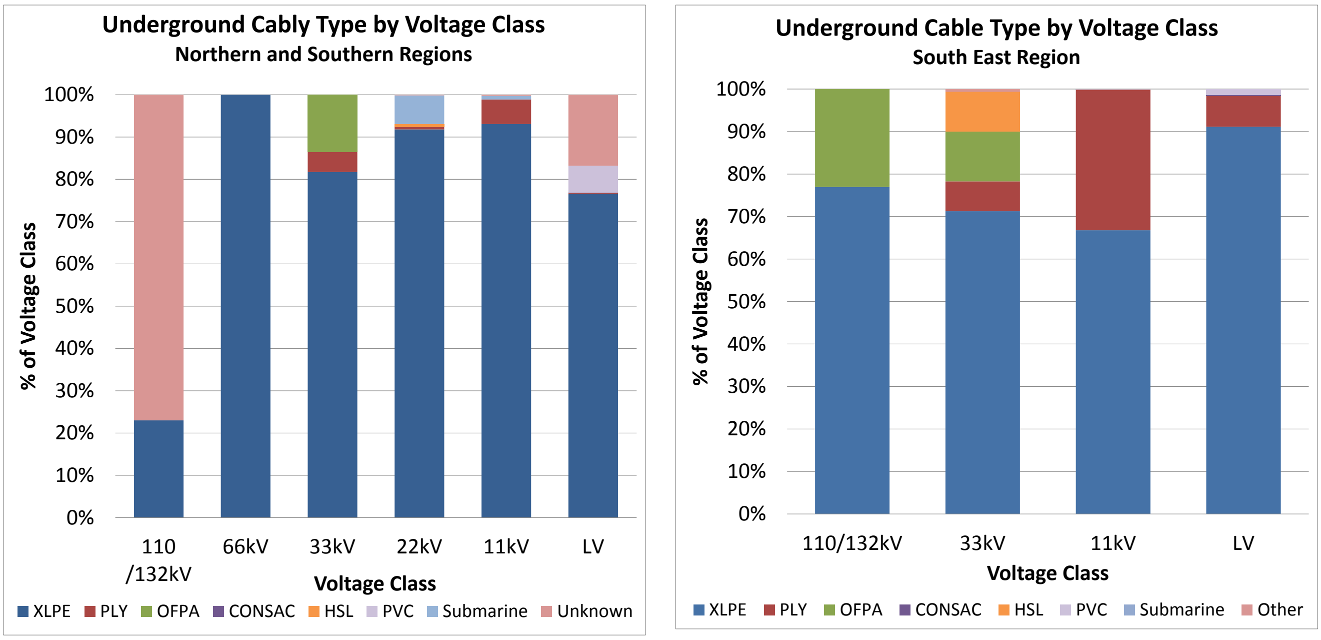

Figure 5: EQL Breakdown of Cable Type by Voltage Class

In the South East Region, network reliability, security, and community standards have increased demand for underground reticulation at all voltage classes. Public safety and joint initiatives with Councils, Main Roads, and other government agencies have also influenced the asset population however the undergrounding of existing and established overhead networks are cost prohibitive and limited to high risk, critical, environmentally sensitive, or heritage areas. In general, the vast majority of new subdivisions are underground and undergrounding is requested of developers by local Councils as part of the Development Approval Process.

Refer to Energex BMS 03364 Powerline Undergrounding and RE-Engineering Programs.

2.5 Asset Life Limiting Factors

Table 4 describes the key factors that influence the life of underground cable assets, and as a result, have a significant bearing on the programs of work implemented to manage the lifecycle.

Factor	Influence	Impact
Aging	Cable insulation and serving materials lose mechanical and electrical strength through natural aging and thermal cycling under normal operation.	Cable material degradation and ultimate failure of the asset.
Overloading	The expected service life of underground cables can be significantly reduced if cables are loaded to operate at temperatures that exceed their design criteria.	Accelerated aging and poor electrical performance due to insulation damage.
Environmental Overheating	Excessive heating due to nearby cables, other heat sources, or cables buried in materials with high thermal resistivity leading to thermal runaway.	Insulation damage and premature failure of all affected underground cables in the vicinity.
Sheath Corrosion	Concentric neutral wires in the presence of moisture or direct contact with the soil are susceptible to corrosion.	Increased ground circuit impedance may affect protection clearing times and result in fault or unbalanced neutral current flowing in alternate paths. This may decrease the safety of workers and the public due to increased step and touch potentials.
Oil Leaks	The solid concentric aluminium sheath of oil filled cables serves to maintain pressure on the oil impregnated paper within the cable. Mechanical damage, corrosion, fatigue or other age-based deterioration to the aluminium sheath can lead to oil leakage and directly affect electrical performance of the insulation.	Reduced electrical performance of the insulation. Environmental impacts of oil leaks such as soil or waterway contamination.
Environmental/ Mechanical damage	UV degradation of above ground cable tails, mechanical damage to the cable during installation or third-party damage during life.	Damage to the outer serving that allows moisture to enter the cable. Damage to the insulation leading to reduced electrical performance.
Water Trees	Moisture ingress in the presence of electrical stress promotes the growth of tree like defects through the extruded cable insulation (i.e. XLPE).	Reduced electrical performance of the insulation leading to premature failure.
Electrical Trees	As above, however, formed in the absence of water due to contaminants, voids or impurities in the insulation.	Reduced electrical performance of the insulation leading to premature failure.
Vermin	Termites, rodents and other vermin can attack the outer sheath and insulation of cables leading to premature cable failure.	Damage to cable materials leading to reduced electrical and mechanical performance.
Workmanship	Poor workmanship or materials can lead to the premature failure of joints and terminations.	Poor electrical stress control, increased mechanical stresses, thermal damage due to high impedance connections and moisture ingress leading to reduced asset life.

Table 4: Underground Cable 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 and any specifically defined corporate key performance indicators, and to 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, 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 population will be managed consistently based upon generic 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 intent to achieve the longest practical asset life overall.

Life extension techniques will be applied where practical, consistent with overall legislative, risk, reliability and financial 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 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 but not limited to those listed in Section 1.1.

The E*lectrical 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.

Section 86 of the *Harbours Act 1955 (Qld)* (tidal lands and waterways), *Transport Infrastructure Act 1994 (Qld)* and the *Marine Parks Act 1982 (Cth)* (Moreton Bay areas) require EQL obtain approval for all tidal water and tidal lands (salt flats inundated at high tide) crossings.

Under “Part 2A” of the *Great Barrier Reef Marine Park Regulations 1983 (Cth)*, if EQL wishes to install additional submarine cables in the Great Barrier Reef Marine Park, it must apply to the Great Barrier Reef Marine Park Authority (GBRMPA). The GBRMPA will consider the potential impacts on the environment and on the social, cultural and heritage values on the Marine Park before granting the permit to install new Submarine cables. In order to assess the application, the GBRMPA may ask EQL to provide additional information on the existing submarine cables. Therefore, EQL will need to keep records on asset information and the maintenance requirements for the currently installed submarine cables.

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 (Qld) 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 underground cable asset defects where visual inspection is achievable. 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 Incident (SEI) or Dangerous Electrical Event (DEE) targets, EQL is committed to reducing 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

Figure 6 shows the historical five-year annual asset failure numbers per 1000km of installed underground cable.

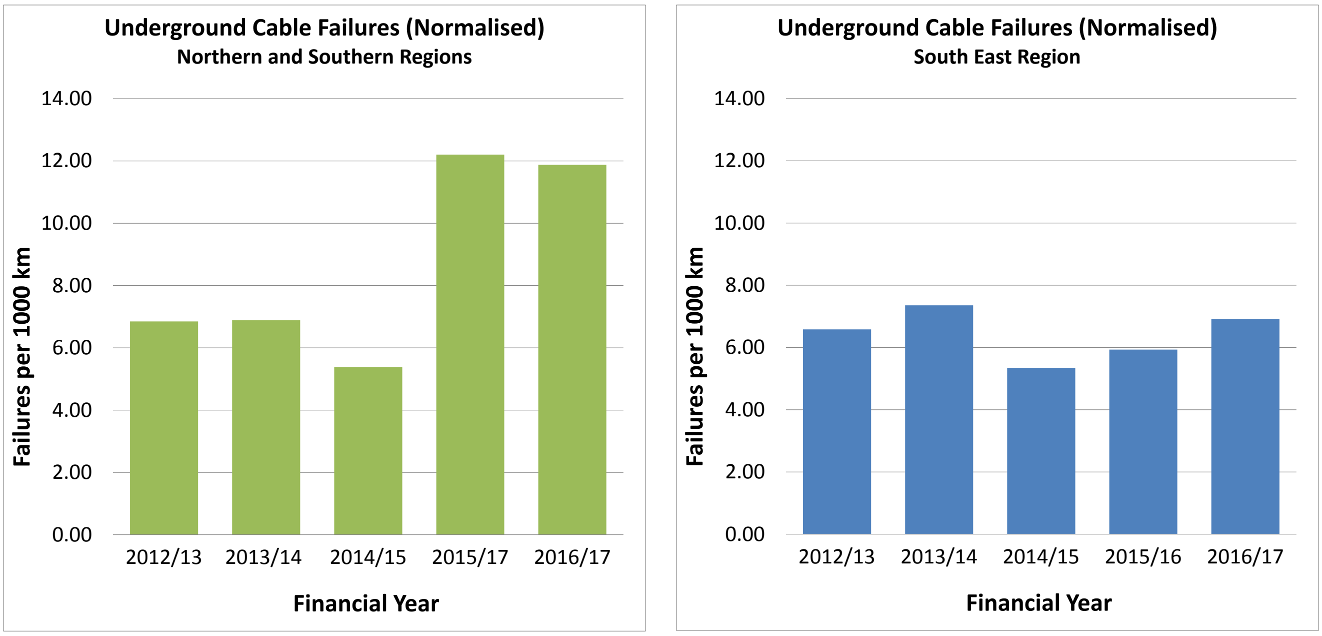

Figure 6: Historical Underground Cable Failures by Region (Normalised)

The disparity between the reported failures of the EQL legacy organisations reported failures 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 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.

Figure 7 details the historical trend of defect replacement and 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 8.

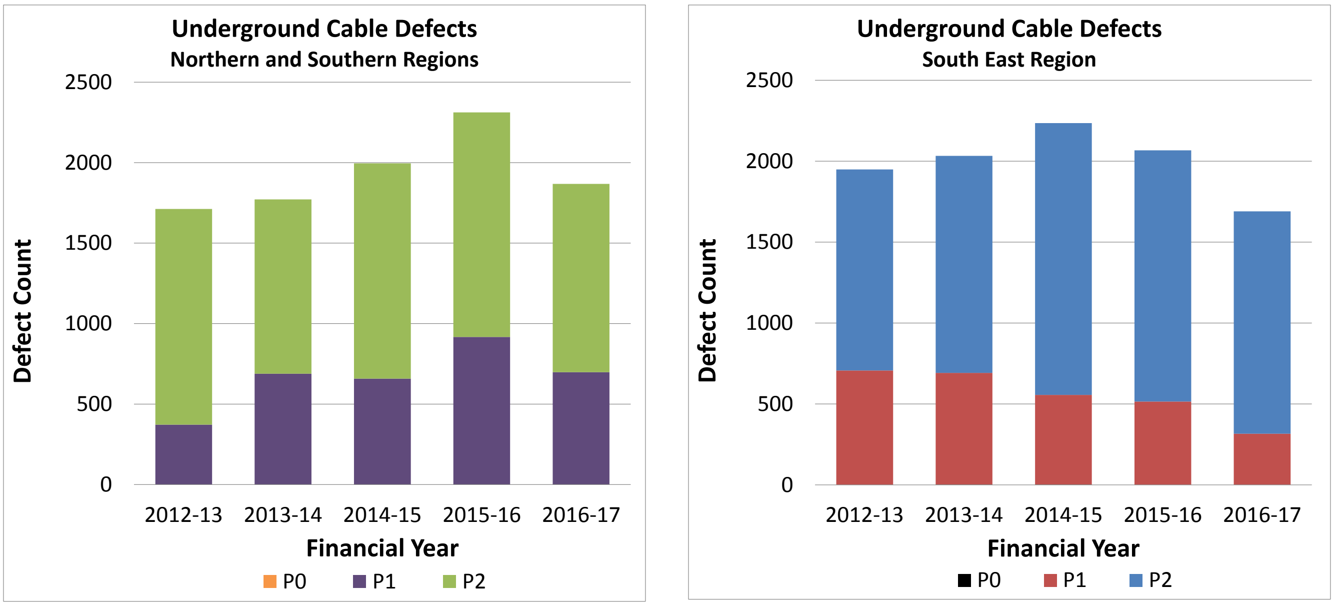

Figure 7: EQL Underground Defects by Region

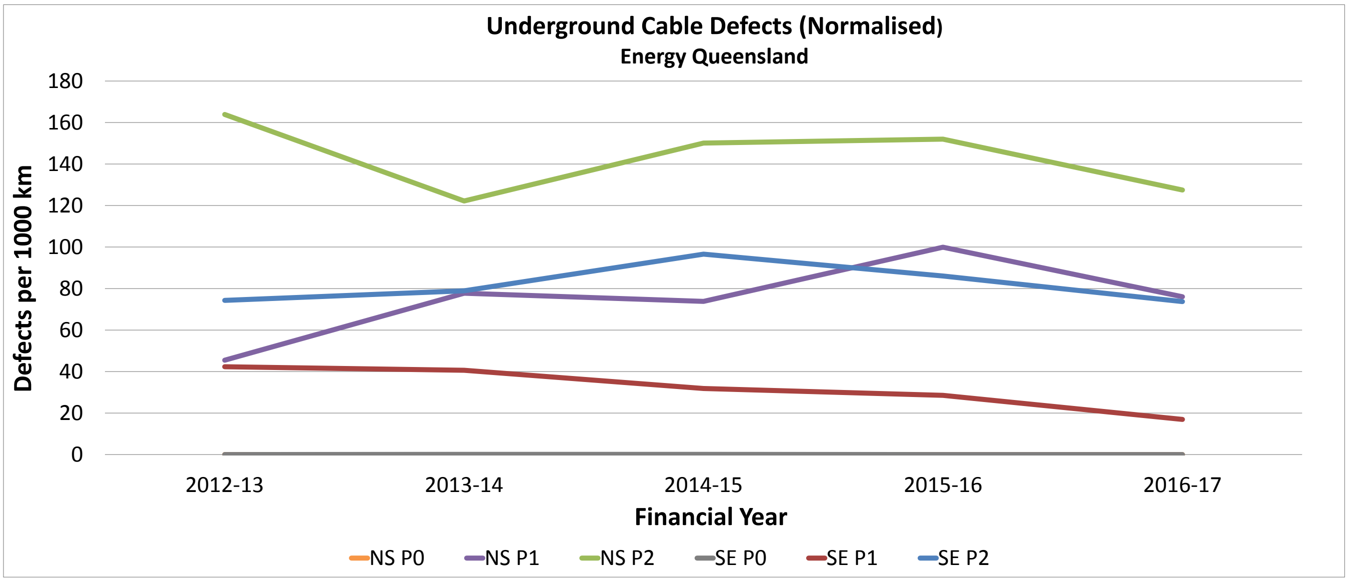

Figure 8: EQL Underground Defects Normalised by Population

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 set 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 9. Analysis shows that pillars and cable guards are a significant source of defects within this area. Further breakdown by voltage or cable type is currently unavailable within this region.

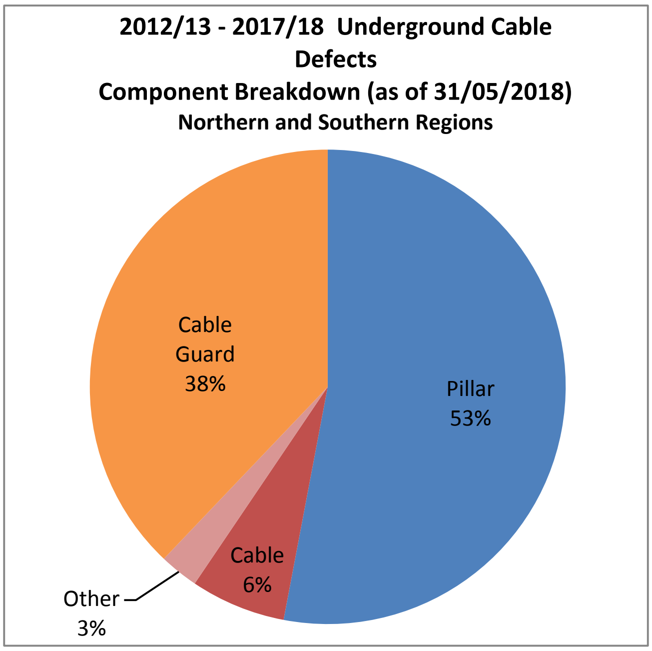

Figure 9: Northern and Southern Regions 2012/13 - 2017/18 YTD MSSS Analysis

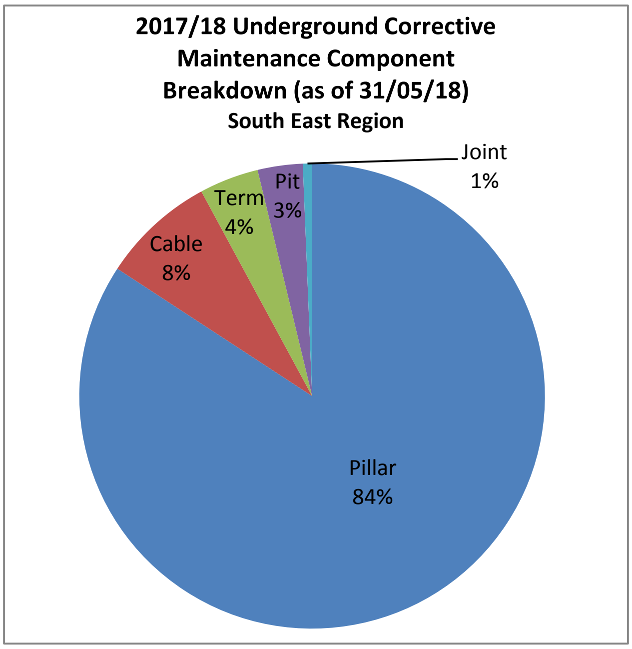

Figure 10: South East Region 2017/18 MSSS Analysis

The South East Region MSSS data recorded since the introduction of the system in 2017/18 has been included in Figure 10 and Figure 11.

Analysis of this data indicates that the majority of corrective work is being performed at distribution and lower voltages which can be expected due to the size of this asset population. Pillars are a significant source of corrective work in the South East Region. Further analysis shows that impact related causes prevalent on the underground network which is expected. Vehicular damage to pillars is common as they are installed above ground in the services corridor adjacent to driveways.

When normalised by population, corrective maintenance on obsolete cable types such as CONSAC and OFPA cable types are highlighted. This can be attributed to the age and relatively small populations of these cable types.

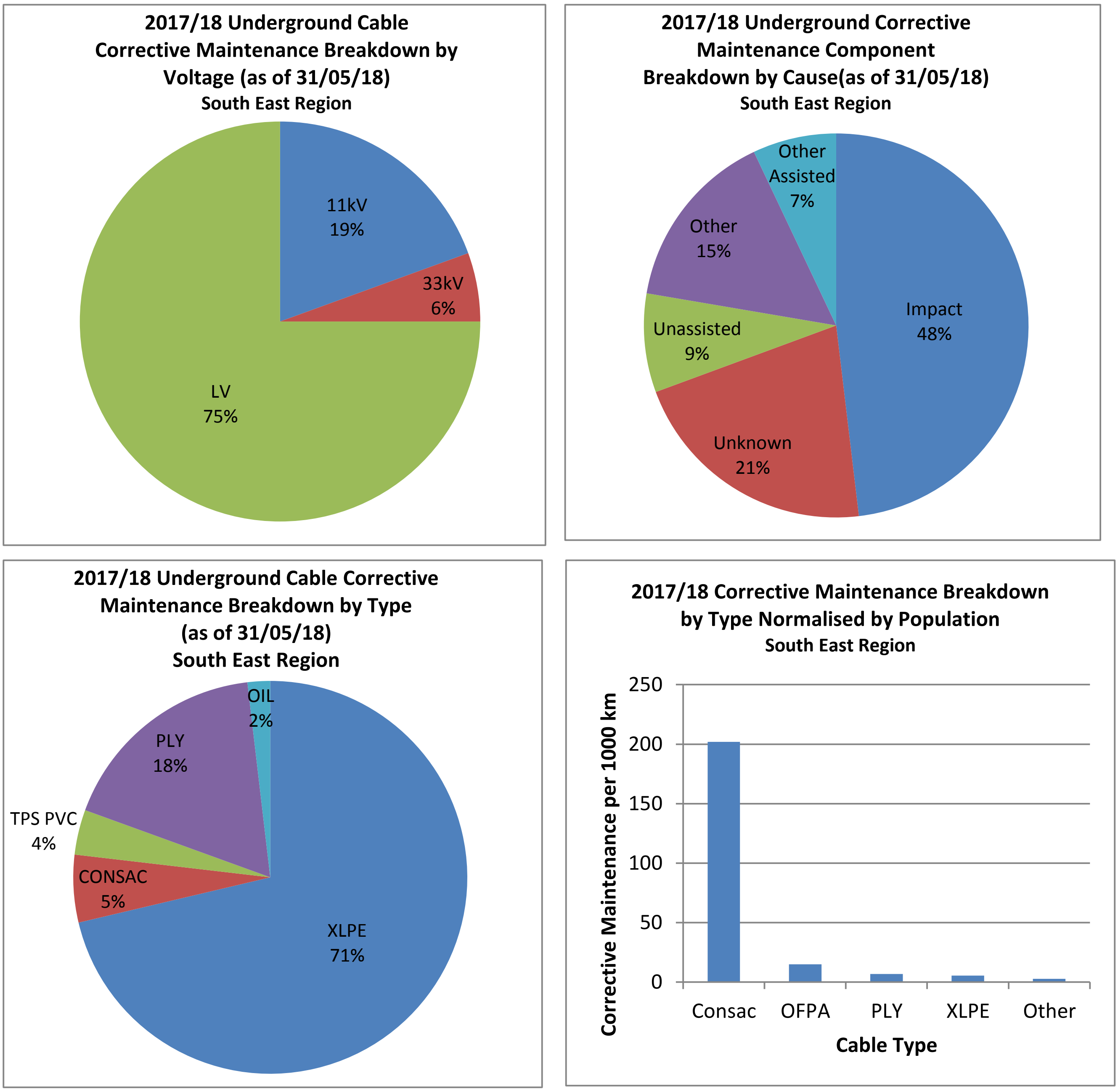

Figure 11: South East Region 2017/18 MSSS Analysis

3.5 Desired Levels of Service

Performance requirements for this asset class are not anticipated to change in the foreseeable future. Asset management strategies will focus on delivering continual improvement to efficiencies whilst maintaining the current levels of service.

4 Asset Related Corporate Risk

As detailed 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, maintenance and replacement to mitigate the risks to SFAIR/ALARP.

Figure 12 displays a threat-barrier diagram for the failure of underground cable assets.

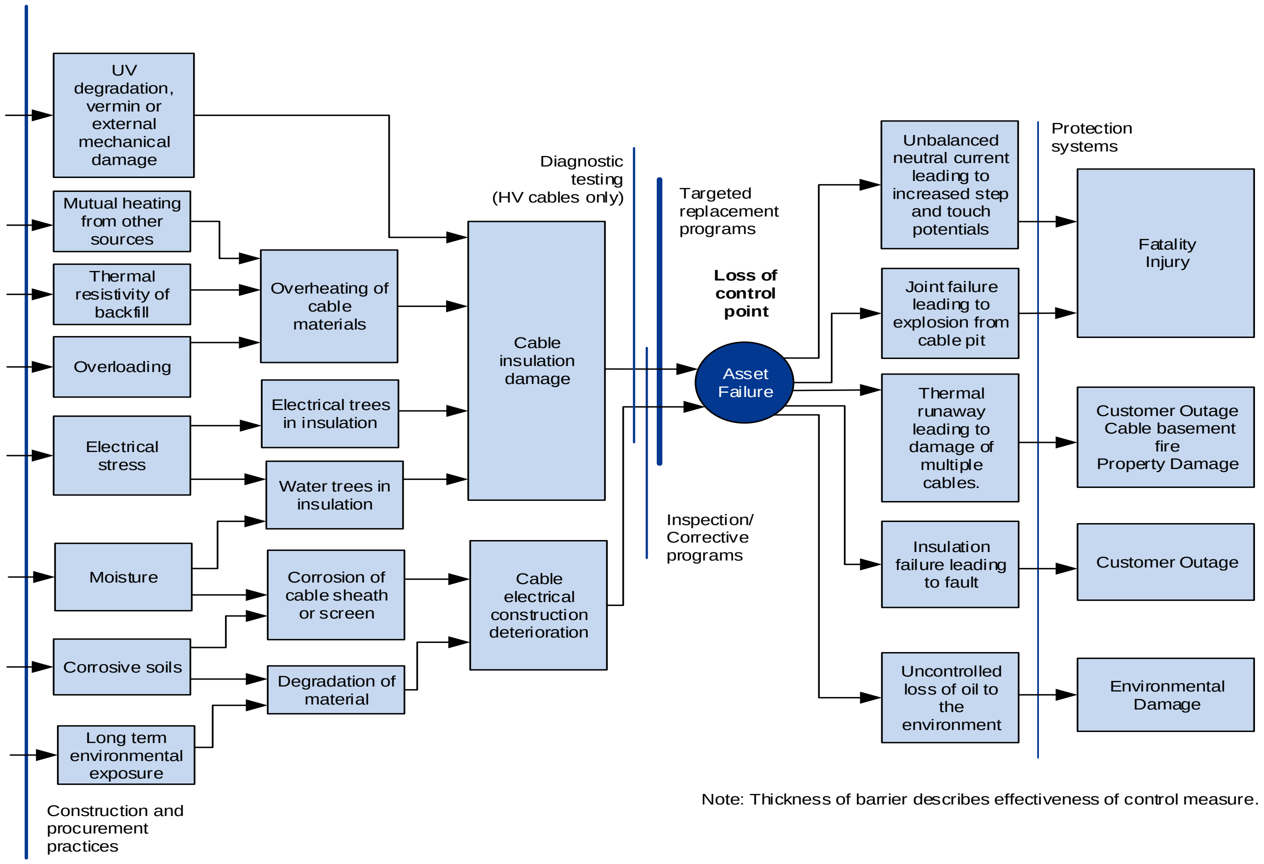

Figure 12: Underground Cable Threat Barrier Diagram

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.

5 Health, Safety & Environment

5.1 Electromagnetic Fields (EMF)

EQL has adopted a policy of prudent avoidance for the design, construction and operation of its facilities with regards to electromagnetic fields. Based on current industry guidelines and best practice, underground cables are configured and constructed with specific clearances to minimise exposure.

5.2 Safety Hazards from the Use of Lead

In preparing a lead sheathed cable for jointing or terminating, the process of cutting or filing may produce lead dust that may be inhaled and absorbed into the body through the lungs or through contact with the skin. Blood lead levels (BLL's) in the body may be raised above safe levels if there is insufficient attention paid to means of reducing exposure and absorption.

In its resting state in the cable itself, the lead is a reasonably inert and stable material and presents no health hazard.

Two publications of the National Occupational Health and Safety Commission have been identified as providing codes of practice for the control and safe use of inorganic lead at work, namely The "National Standard for the Control of Inorganic Lead at Work [NOHSC: 1012 (1994)]" and The "National Code of Practice for the Control and Safe Use of Inorganic Lead at Work [NOHSC: 2015 (1994)]".

It has been the policy in the South East Region to eliminate or reduce wherever possible and economically feasible and practicable the use of lead sheathed cables. Refer TSD-07-41 Report on use of PLY cables in ENERGEX.

5.3 Cable Fluid

Fluid filled cables use a combination of paper insulation and oil under pressure to provide electrical insulation between conductors and/or to metallic sheathed earth. When there is a leak there is a resultant drop in pressure that directly affects the performance of the cable and subsequent environmental contamination and/or public health and safety risks.

Dealing with oil spills is documented in Standard 00508 – Energex Safety Manual Section 8 - Worksite Hazard Management, Clause 2.5 - Oil Spill Management. Additional information can be obtained in Standard 00345 - Guide for Managing Minor and Major Oil Spills.

Legacy transmission and sub transmission pressure assisted oil filled cables exist on the EQL network although these are gradually being replaced on condition.

5.4 Cypermethrin – Termite Repellent

In 2007, a decision was made in the South East Region to include cypermethrin, a chemical repellent added to the jacket of all underground cables as a repellent to termite attack. Cypermethrin has gone through extensive testing by the United States Environmental Protection Agency (US EPA) and has been determined to be a non-toxic substance. Notwithstanding, field staff reported adverse health effects when dealing with cypermethrin dosed cables and it has subsequently been removed from the current specification of almost all cables in favour of alternative, non-chemical based termite treatments. As of 2018, only current contract 132kV transmission underground cables contain cypermethrin in the outer sheath. Small populations may also exist in the Northern and Southern Regions as a result of aligning cable specifications under joint workings.

Populations of installed cypermethrin dosed cable are present throughout the network and currently managed through awareness and appropriate handling. Refer Energex Standard Alert StdsA350c and Ergon Operational Update #T-1350.

5.5 Asbestos Containing Material in the Underground Cable System

The health risks associated with exposure to asbestos are well documented. In the underground cable system, asbestos may be present in legacy materials including pits, pillars, conduits and some cable insulation sheaths.

The overarching drivers, principles and objectives regarding EQL's corporate approach to asbestos management are documented in EQL's Asbestos Management Plan. EQL employs a Permit to Work System to control all risks when removing asbestos.

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 Corrosion of Cast Iron Cable Potheads

Cast iron potheads are an obsolete legacy cable termination used to transition from the underground to overhead system. Each core of a multicore cable is terminated through porcelain bushings contained in a cast iron box. A dielectric material, such as hydrocarbon oil or asphalt, is used to fill the box. Corrosion of the outer casing leads to water ingress and potential catastrophic failure of the termination.

The South East Region implemented a program of replacement, and all known cast iron potheads are to be removed from the network. This program is due to finish at the end of the 2020/21 financial year. Due to data quality issues, small populations of these terminations may still exist and are to be replaced on discovery.

There is currently an active replacement program in the Northern and Southern Regions to remove known cast iron potheads from the network. This will be completed in the 2015-20 regulatory period.

Action 6.1-1: Review S14.3 of the Lines Defect Classification Manual to ensure appropriate action is taken when cast iron potheads are discovered during routine inspection. This will ensure ongoing removal once dedicated programs have ceased. Raise awareness through communications to field staff and develop an ad hoc reporting process where unknown cast iron potheads are identified on site during other works.

6.2 Concentric Neutral Solid Aluminium Conductor (CONSAC) Cable

CONSAC (Concentric Neutral Solid Aluminium Conductor) is a legacy aluminium sheathed paper insulated LV cable installed on the network during the 1970's. The aluminium sheath also serves as the neutral conductor in this cable construction. The aluminium sheath is susceptible to corrosion which can lead to open circuit of the neutral and therefore can pose a significant safety risk. EQL has undertaken proactive replacement programs to remove CONSAC to reduce the risks associated with CONSAC cable failures. This program is due to end at the end of the 2020/21 financial year. Due to data quality issues, small populations of this cable may exist and will be replaced on discovery.

Action 6.2-1: Review and update S14.4 of the Lines Defect Classification Manual to include LV CONSAC cable to ensure appropriate action when discovered in service. Raise awareness through communications to field staff and develop an ad hoc reporting process where unknown LV CONSAC cable is located on site during other works.

6.3 Hochstadter Screened Separately Lead Sheathed (HSL) Cable

Hochstadter screened separately lead sheathed (HSL) is a legacy 33kV three phase cable type where each core is separately insulated with oil impregnated paper, lead sheathed and surrounded by jute bedding and armoured with steel wire. The majority of the population is greater than the expected design life of 60 years. The South East Region has experienced increased failures of HSL cables around this age.

EQL uses Condition Based Risk Management (CBRM) to forecast the retirement of underground cables greater than or equal to 33kV. An important measure for underground cable condition models is the sheath test result. Their direct buried installation and age-based degradation restricts the ability to obtain a valid sheath test result. In order to address the risk associated with the unplanned failure of 33kV HSL cable, an age cap of 60 years has been implemented to forecast the retirement timing in the absence of available test data.

An active replacement program has been established in the South East region to remove 33kV HSL cable from the network during the 2015-20 regulatory period.

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 Water Treeing in XLPE

Water trees form as moisture enters the insulation and forms discrete, micro voids in the polymer structure. These voids reduce the dielectric strength of the insulation, leaving the area more susceptible to partial discharge under high electrical stress than the surrounding insulation. Water trees may provide a location to initiate partial discharge and electrical tree growth. The formation of water trees may not lead to failure even if the water tree bridges the insulation. It is the ongoing growth of electrical trees formed at the site of water trees that cause the ultimate failure of the insulation.

EQL has experienced increasing numbers of premature XLPE insulated distribution cable failures attributed to the presence of water trees in the cable dielectric. Many of the reported failures of XLPE at distribution voltages are anecdotal as post-failure laboratory analysis is required to confirm if trees are present, and this is not typically done at lower voltage designations. Current contract XLPE cables have an improved tree retardant TR-XLPE formulation which has better resistance against this failure mode. Water blocking tape and yarn has also been introduced to stem the longitudinal movement of water through the cable.

Transmission and sub-transmission cables are less at risk as these cables typically have a solid metallic sheath which is impervious to radial moisture ingress. However, water can enter cables at faulted locations or via cable joints which have historically been the weakest point of cable systems. Laboratory analysis of failed, early generation 66kV XLPE, copper wire screened cable confirmed the presence of water trees (refer INC-1136936 Cannonvale No 1 feeder).

Laminated Aluminium Tape (LAT) has been introduced in lieu of a lead or solid copper sheath moisture barrier at 33kV. The longevity of this construction is yet to be proven in Queensland although is commonly employed in Europe. The performance of this cable over time will be monitored.

Action 7.1-1: Investigate non-destructive diagnostic techniques and tools to assist in the identification and condition assessment of water tree propagation in cross-linked polyethylene (XLPE) insulated cables.

Action 7.1-2: Establish processes for post fault analysis of prematurely failed underground cable where water tree propagation is suspected as the cause of failure. Re-establish partnerships with universities to enable further research and development of this failure mode.

7.2 Aging Population of Legacy Cable Types

Legacy paper insulated, lead alloy sheathed, and oil pressure assisted cables are an ongoing concern within this asset class. The most likely mode of failure will be the thermal or chemical degradation in the insulating papers resulting in electric trees leading to dielectric failure.

EQL has a small number of oil filled sub-transmission cables. Oil filled cables have a corrugated aluminium metallic sheath to contain the oil under pressure within the paper insulation and the sheath. Oil pressure inside the cable must be maintained within acceptable limits to ensure ongoing performance of the cable. Therefore, managing oil levels and addressing cable leaks is imperative. Oil filled cables carry an increased risk of fire propagation and pose an environmental hazard if they fail in service.

Repair of legacy cable is in most cases achievable through transition joints to modern XLPE cable types although this can introduce reliability issues, particularly at the joint itself. Transitioning from legacy fluid filled cables to solid insulation requires redesign of the hydraulic circuit to ensure the appropriate pressure is maintained. Subject matter experts have advised that range taking, oil-XLPE transition joints are available that may provide effective spares coverage for this population at minimal cost.

At distribution voltages, physical constraints such as duct or conduit dimensions promote like-for-like replacement as the only feasible option. Where feeder capacity is a driver for replacement this leads to increased civil works as new, larger conduits are required to accommodate the replacement cable.

Sourcing replacement cable and accessories such as joints and terminations for obsolescent cable technologies can prove difficult particularly if required in an emergency situation. As such, sufficient spares holdings for these cable types are critical.

Action 7.2-1: Review standards, solutions and spares holdings to enable the prompt repair of legacy cable types such as paper insulated, lead alloy sheathed and pressure assisted, oil filled cables.

7.3 Cable Jointing Skill and Capability

Underground cable jointing is a low frequency task that when required, demands specialised technical skill. In general, the required jointer skill and ability increase with operating voltage. The reliability of the joint is highly dependent on the training and experience of the cable jointer.

Transmission, submarine, and legacy cable types, in particular, require specialist skills that can only be developed through training, experience and exposure over time. Due to the relatively low populations of transmission and submarine cable and the diminishing populations of lead sheathed or pressure assisted cables, maintaining the appropriate in-house skill level to repair and maintain these assets may prove challenging in the future.

The reduced number of available skilled jointers may lead to increased repair and restoration time on these assets during crisis events, particularly if contract labour is required.

Action 7.3-1: Audit and, where required, develop appropriate in-house jointer capability to ensure adequate skills are available to reduce the risk of extended outages on legacy cable types during emergency events.

7.4 Submarine Cables

EQL has three major submarine cable installations that provide supply to island communities on Magnetic, Dunk and Hayman Islands. Details of these cable installations are shown in Table 5.

Location	Type	Age	Length (km)	Construction	Status
Magnetic Island 1	PLY	1956	12	Sitting on Sea bed	Decommissioned
Magnetic Island 2	PLY	1956	12	Sitting on Sea bed	Decommissioned
Magnetic Island 3 (Feeder TM-03, Townsville Marina No. 03)	150 mm2 Cu 11KV PLY	1983	12	Buried under Sea bed close to Marina and Nelly Bay, rest sitting on Sea bed.	Operational
Magnetic Island 4 (Feeder TM-10, Townsville Marina No. 10)	150 mm2 Cu 22KV PLY	1991	12	Buried under Sea bed close to Marina and Nelly Bay, rest sitting on Sea bed.	Operational
Magnetic Island 5	150 mm2 Cu 22KV	-	-	-	Applied Permit
Dunk Island	35 mm2 Cu 22KV PLY	1982	5.1	Buried under Sea bed	Operational
Hayman Island	150 mm2 Cu 22KV XLPE	1999	30	Sitting on Sea bed	Operational

Table 5 – EQL Submarine Cables

Minor 11kV submarine cables are also installed in the South East Region to service island communities in Moreton Bay, including:

- 11kV cable servicing Russel Island (RIS2)
- 11kV cable servicing Bribie Island (BISTPT3).

These assets are subjected to risks not normally associated with a buried cable, including tidal movements and those associated with extreme weather, vessel anchor damage, and environmental factors such as sea worms and corrosion. Due to the location and relatively long route lengths, locating and repairing faults in submarine cables is a difficult task, requiring divers and specialised labour and equipment.

An outage can take several days to repair in good weather. Repairs can take longer if weather conditions are poor. Due to the specialised nature of these assets, sourcing skilled labour and materials to repair these assets can result in extended outages and reduced reliability.

Action 7.4-1: Develop dedicated test methodologies and contingency plans to adequately manage the risk presented by the critical population of submarine cables servicing island communities.

7.5 Cable Joint Failures

Due to the catastrophic nature of many joint failure events, determining the cause of failure can be difficult. Workmanship and moisture ingress are considered the primary causes of joint failure. Water can enter cables at fault locations or at cable joints which have are historically the weakest point in a cable system. It is difficult to achieve a watertight joint, particularly with ‘shrink’ based accessories due to the expansion and contraction of cables under load. Three core cables are particularly difficult to seal due to the interstices between cores. Transitioning between different cable types can also prove challenging.

Joint and termination kits have subsequently been modified to contain all required materials including bi-metallic, range taking, sheer bolt connectors where available to reduce workmanship issues. Cable specifications have also been modified to include water blocking tapes and yarns to stem the longitudinal flow of water through the cable.

The shelf life of joint components, particularly the resin compound used in filled joints, has also been identified as an emerging issue. It appears that the environmental conditions in Queensland may contribute to the premature expiry of the material and affect the ability of the resin to cure. This can allow moisture to ingress leading to failure of resin filled joints.

Distribution joints are typically installed in cable pits in the footpath services corridor with access through a solid, removable cover. Distribution cable pits are not typically backfilled to allow for new cables or to perform cable repair on existing cables as required. The failure of distribution cable joints in service may dislodge pit covers and pose a safety risk, particularly in urban centres. Further investigation is warranted to determine if a detailed cable pit inspection program is required to mitigate this risk.

Action 7.5-1: Establish appropriate data collection and post fault, forensic analysis of cable joint failures to enable continuous improvement through improved jointing materials or work practices.

Action 7.5-2: Determine if a detailed cable pit inspection program is warranted to identify and mitigate the risk of distribution joint failures.

7.6 Recovery of Redundant Cable

Underground cable was historically directly buried in the ground due to the increased initial cost of ducted or conducted installation.

At end of life, direct buried cables are typically cut, capped and left in place due to prohibitive cost of digging up the cable and reinstating the finished surface. Increasingly, councils and road authorities are requesting recovery of these assets at the time of decommissioning. If enforced by third-parties, this has the potential to add significant costs to underground feeder projects.

Action 7.6-1: Develop or modify existing Memorandum of Understanding (MOU) agreements with third-party stakeholders to ensure a consistent, agreed approach to the recovery of abandoned underground cable assets.

7.7 LV Underground Pillar Failures

A considerable number of defects and in-service failures are attributed to LV underground pillars. Pillars are typically installed above ground, adjacent to the footpath services corridor and as such are exposed to third-party vehicular damage and vandalism. A number of failures have been attributed to high impedance connections or failure of the combined fuse-switch (CFS) units housed within the pillar.

Routine thermoscanning of underground pillars was trialled and subsequently introduced on a five-year cycle within the South East Region. Thermoscanning is capable of detecting increases in temperature which occur inside the pillar as a result of high resistance joints and connections which can lead to failure and pillar fires. It is planned to introduce pillar thermoscanning to the Northern and Southern regions to mitigate the risk of catastrophic failure within these areas. Due to the consistently high temperatures in the Northern parts of the state, there are concerns that thermoscanning may not be suitable for all regions.

Action 7.7-1: Explore high impact resistant pillar materials or modifications to design standards to include additional mechanical protection such as protective bollards at high risk locations to reduce the likelihood of third-party damage to underground pillars.

Action 7.7-2: Investigate and trial thermoscanning of pillars as routine maintenance in the Northern and Southern Regions of EQL to align with the practices underway in the South East Region.

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 Asset Management Approach

EQL uses Condition Based Risk Management (CBRM) to forecast the retirement of underground cables greater than or equal to 33kV. Distribution and low voltage cables are replaced upon identified defect or ultimate failure. There is an opportunity to apply the concepts of the CBRM approach used at higher voltages to the lower voltage cable in order to gain a better understanding of the forecast life of these assets and ensure sustainable programs are in place to manage network risk.

Action 8.1-1: Investigate the application of CBRM for distribution and low voltage cables to gain a better understanding of the forecast life of these assets and ensure sustainable asset management strategies are in place.

8.2 Cable Diagnostics and Condition Trending of Critical Cables

In general, routine tests of sub-transmission and transmission cable types to prove cable condition are limited to sheath tests and visual inspection only. These tests can only provide pass/fail results against pre-defined criteria.

Advanced, non-routine test methods such as partial discharge or dissipation factor (tan δ) are available that can provide trending on the deterioration of the cable insulation and in some cases location of degradation sites. These tests have historically been performed by EQL where deemed necessary, by request only.

Lifecycle Engineering Lines is currently developing routine testing methodologies in order to establish a process for condition monitoring of submarine cables. Further development of routine, condition-based cable test methodologies would enable trending and targeted monitoring of all critical cables on the EQL network.

Action 8.2-1: Develop inspection techniques and diagnostic test methodologies to accurately assess cable condition to inform an underground cable CBRM model.

8.3 Distributed Temperature Sensing (DTS) and Resistive Temperature Device (RTD) of Critical Cables

Distributed Temperature Sensing (DTS) has been employed by many utilities to enable real-time rating of critical underground assets. In addition to the dynamic rating of feeders, DTS may be used to detect impending failure by identifying hot spots caused by changed environmental conditions or imminent faults in cables or accessories.

EQL has recently commissioned DTS on several 22kV feeders in the far North of Queensland. These feeders have fibre optic cable installed in the lay of the cable screen during manufacture, and permanent DTS equipment installed at the substation. RTDs are also installed to provide point cable surface measurements.

A fibre optic cable has been installed alongside sub-transmission and transmission feeders as standard design to enable communication, control, and future DTS within the South East Region for many years. Although the fibre optic cable is in place on several feeders, poor reliability and ongoing cost of the DTS equipment has led to limited application of this technology in the South East Region. As the fibre is not laid up in the cable there are also concerns over the accuracy of the acquired data.

Accurate and detailed DTS data may help to predict the location of faults on critical feeders and allow for targeted maintenance prior to catastrophic failure.

Action 8.3-1: Investigate Distributed Temperature Sensing (DTS) as a maintenance tool for critical sub-transmission and transmission feeders. In order to enable this technology, baseline temperature profiles and calibration of the readings based on the geometric position of the fibre would be required.

8.4 Soil Thermal Resistivity

Cable rating and lifecycle performance are directly related to the environment that the cables are installed in. Cables are an inherent heat source and therefore installations are designed to maintain operating temperatures within safe limits. Thermal resistivity is a measure of how well the material surrounding the cable can dissipate heat away from the cables. Thermal runaway can occur when the heat generated from the cable installation causes the backfill material to dry out, increasing the thermal resistivity which further increases the cable temperature in an uncontrolled feedback loop.

Backfill material with a constant thermal resistivity is used; however, there can be wild fluctuations in the native soil surrounding this layer due to the influence of moisture, soil composition, compaction or temperature.

Soil thermal resistivity profiles of critical cables, particularly of native soil layers should be explored to enable a better understanding of the performance of these assets.

Action 8.4-1: Review EQL soil thermal resistivity testing methodologies and consolidate historical records into a central repository to improve monitoring of this parameter. This will assist in future planning and rating studies.

8.5 XLPE Rejuvenation / Moisture Removal

Cable rejuvenation technology is available to restore the insulating properties of water XLPE insulation in aged power cable. Several rejuvenation products were trialled successfully in the Northern Region in the early 2000's however the technology was not adopted for widespread use. Since this time, there have been advancements in both the rejuvenation fluid and the method of application. However, it should be noted that other Australian utilities have reported poor results using this technology.

Nitrogen purging is a technique proposed by vendors to remove moisture in XLPE cables that are known to be wet. This technology requires further investigation to see if there is any benefit to EQL.

Action 8.5-1: Explore cross-linked polyethylene (XLPE) rejuvenation technologies as a possible refurbishment option for aged XLPE cables.

Action 8.5-2: Investigate nitrogen purging as a means of removing moisture in critical cross-linked polyethylene (XLPE) cables that are known to be wet.

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

Condition Based Risk Management (CBRM) predictive methodology is used to determine end of serviceable life of underground cables at voltage designations of 33kV and above.

EQL does not currently have aged or condition-based strategies in place to manage the lifecycle of LV and distribution underground cables. Cables at this voltage designation are replaced upon identified defect or ultimate failure. Replacement programs are generally driven by repeat failures from within a population that are of safety or reliability concern to the business.

Where possible, underground cable replacement is scheduled to occur in coordination with network augmentation works otherwise, is repaired or replaced as required on condition.

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 consistently working to improve its data quality.

Underground cables are inherently challenging to audit due to their being largely inaccessible having been buried underground. As such, verification of the data to ensure reliable asset population counts and age profiling is difficult to accurately determine.

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

Action 9.2-1: 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'. Underground cable assets are specified in line with relevant Australian Standards, industry best practice and in consultation with stakeholders and subject matter experts. Underground cable assets are procured on period contracts awarded through technical and commercial evaluation in line with Queensland Government's QTenders process.

Underground cable 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 own, operate, maintain and replace these assets from the date of acceptance.

9.4 Operation and Maintenance

Operation and maintenance include 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.

9.4.1 Preventive Maintenance

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

At transmission and sub-transmission voltages, routine maintenance monitors the electrical condition of the cable over sheaths and sheath voltage limiters, the performance of pressure feeds, the accuracy and condition of pressure gauges and alarm systems and the physical condition of the above ground structures and terminations.

A routine test methodology to enable condition monitoring of critical submarine cables in the Northern and Southern regions is underway.

At distribution voltages, periodic inspections check the external condition of distribution cable systems including link pillars, link boxes and service pillars to ensure equipment remains in an acceptable condition.

The following maintenance standard documents contain task and frequency requirements for Underground Cable Systems:

- EX STD01119 / EE STNW1143 — Maintenance Standard for Distribution Cable Systems
- EX STD01120 / EE STNW1141 — Maintenance Standard for Pressure Assisted Cable Systems
- EX STD01123 / EE STNW1142 — Maintenance Standard for Non Pressure Assisted Sub transmission Cable Systems.

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, underground cables are typically replaced to the current standard where cost effective and technically feasible. Known augmentation plans are considered prior to carrying out corrective maintenance.

Emergency maintenance may be required at any time of the day or night due to failure of cable, joints or terminations or damage arising from third parties such as cable dig in during excavation. This requires experienced and skilled staff, a range of tools and equipment well maintained records and instructions and adequate stocks of cable, joints, terminations and fluid.

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. Consumable items such as resin compounds are reviewed and replaced from jointing kits as required to ensure they remain fit for purpose.

It is impractical to carry spares for all cable types and accessories. Critical or obsolete cable types require special attention in order 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 underground cable assets to ensure they remain safe and fit for purpose. Inspection driven refurbishment is typically limited to items ancillary to the cable itself such as pillars or terminations. Where an underground cable fails in service, the faulted section is typically removed and replaced by a new cable section, jointed to remaining system.

Refurbishment of the underground environment may also be undertaken where reduced cover, subsidence or vermin activity is present.

9.5.2 Replacement

Underground cable 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 end of life and planned replacement is proposed.

9.6 Disposal

To minimise the civil cost of recovery, underground cable assets where appropriate are cut, capped in left in situ in lieu of recovery and disposal. Pressure assisted oil filled cables are purged prior to abandonment or recovery to safely remove as remove as much oil as possible to minimise the threat to the environment. Used high voltage cable fluid is not generally suitable for reclamation or reconditioning and be is disposed of via an approved, licensed contractor.

Care must be taken to dispose of impregnated, non-draining paper cable or other contaminated materials such as bitumen or oil filled potheads or terminations.

Recovered underground cable, which may include the copper or aluminium conductor together with other materials, is disposed of via scrap merchants. Refer RED 00914 Copper Cable Recovery and Recycling.

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: Review S14.3 of the Lines Defect Classification Manual to ensure appropriate action is taken when cast iron potheads are discovered during routine inspection. This will ensure ongoing removal once dedicated programs have ceased. Raise awareness through communications to field staff and develop an ad hoc reporting process where unknown cast iron potheads are identified on site during other works.

Action 6.2-1: Review and update S14.4 of the Lines Defect Classification Manual to include LV CONSAC cable to ensure appropriate action when discovered in service. Raise awareness through communications to field staff and develop an ad hoc reporting process where unknown LV CONSAC cable is located on site during other works.

Action 7.1-1: Investigate non-destructive diagnostic techniques and tools to assist in the identification and condition assessment of water tree propagation in cross-linked polyethylene (XLPE) insulated cables.

Action 7.1-2: Establish processes for post fault analysis of prematurely failed underground cable where water tree propagation is suspected as the cause of failure. Re-establish partnerships with universities to enable further research and development of this failure mode.

Action 7.2-1: Review standards, solutions and spares holdings to enable the prompt repair of legacy cable types such as paper insulated, lead alloy sheathed and pressure assisted, oil filled cables.

Action 7.3-1: Audit and, where required, develop appropriate in-house jointer capability to ensure adequate skills are available to reduce the risk of extended outages on legacy cable types during emergency events.

Action 7.4-1: Develop dedicated test methodologies and contingency plans to adequately manage the risk presented by the critical population of submarine cables servicing island communities.

Action 7.5-1: Establish appropriate data collection and post fault, forensic analysis of cable joint failures to enable continuous improvement through improved jointing materials or work practices.

Action 7.5-2: Determine if a detailed cable pit inspection program is warranted to identify and mitigate the risk of distribution joint failures.

Action 7.6-1: Develop or modify existing Memorandum of Understanding (MOU) agreements with third-party stakeholders to ensure a consistent, agreed approach to the recovery of abandoned underground cable assets.

Action 7.7-1: Explore high impact resistant pillar materials or modifications to design standards to include additional mechanical protection such as protective bollards at high risk locations to reduce the likelihood of third-party damage to underground pillars.

Action 7.7-2: Investigate and trial thermoscanning of pillars as routine maintenance in the Northern and Southern Regions of EQL to align with the practices underway in the South East Region.

Action 8.1-1: Investigate the application of CBRM for distribution and low voltage cables to gain a better understanding of the forecast life of these assets and ensure sustainable asset management strategies are in place.

Action 8.2-1: Develop inspection techniques and diagnostic test methodologies to accurately assess cable condition to inform an underground cable CBRM model.

Action 8.3-1: Investigate Distributed Temperature Sensing (DTS) as a maintenance tool for critical sub-transmission and transmission feeders. In order to enable this technology, baseline temperature profiles and calibration of the readings based on the geometric position of the fibre would be required.

Action 8.4-1: Review EQL soil thermal resistivity testing methodologies and consolidate historical records into a central repository to improve monitoring of this parameter. This will assist in future planning and rating studies.

Action 8.5-1: Explore cross-linked polyethylene (XLPE) rejuvenation technologies as a possible refurbishment option for aged XLPE cables.

Action 8.5-2: Investigate nitrogen purging as a means of removing moisture in critical cross-linked polyethylene (XLPE) cables that are known to be wet.

Action 9.2-1: Align and improve defect, failure and dangerous electrical event data capture processes and reporting methodologies to ensure consistency across EQL.

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 Asset 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	EP26	Risk Management Policy	Policy
Ergon Energy	EP51	Defect Management Policy	Policy
Ergon Energy	SGNW0004	Network Optimisation Asset Strategy	Strategy
Ergon Energy	STNW0717	Standard for Preventive Maintenance Programs for 2017-18	Standard
Energex	00569	Network Risk Assessment	Procedure
Energex	502	Lines Defect Classification	Standard
Energex **Ergon**	STD01119 STNW1143	Maintenance Standard for Distribution Cable Systems	Standard
Energex **Ergon**	STD01120 STNW1141	Maintenance Standard for Pressure Assisted Cable Systems	Standard
Energex **Ergon**	STD01123 STNW1142	Maintenance Standard for Non Pressure Assisted Sub transmission Cable Systems	Standard

Appendix 2. Definitions

The following definitions may appear in this Asset Management Plan.

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 a 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
AIDM	Asset Inspection & Defect Management system
ALARP	As Low As Reasonably Practicable
AMP	Asset Management Plan
Augex	Augmentation Expenditure
BLL	Blood Lead Level
CBRM	Condition Based Risk Management
CB	Circuit Breaker
CFS	Combined Fuse Switch
CONSAC	Concentric Neutral, Solid Aluminium Conductor
CT	Current Transformer
CVT	Capacitor Voltage Transformer
DEE	Dangerous Electrical Event
DGA	Dissolved Gas Analysis
DLA	Dielectric Loss Angle
DTS	Digital Temperature Sensing
EQL	Energy Queensland Limited
EMF	Electromagnetic Fields
ESCOP	Electricity Safety Code of Practice
ESR	Queensland Electrical Safety Regulation (2013)
IoT	Internet of Things
GBRMPA	Great Barrier Reef Marine Park Authority
HSL	Hochstadter Separately screened Lead sheathed
HV	High Voltage
ISCA	In-Service Condition Assessment
LAT	Laminated Aluminium Tape
LDCM	Lines Defect Classification Manual
LV	Low Voltage
LY	Lead Alloy
MU	Metering Unit
MOU	Memorandum of Understanding
MVAr	Mega-VAr, unit of reactive power
MSSS	Maintenance Strategy Support System

Abbreviation or acronym	Definition
NOHSC	National Occupational Health and Safety Commission
NER	Neutral Earthing Resistor
NEX	Neutral Earthing Reactor
OFPA	Oil Filled, Paper insulated, Aluminium sheathed.
OLTC	On-load tap changers
OTI	Oil Temperature Indicators
PCB	Polychlorinated Biphenyls
PILC	Paper Insulated Lead Covered
PLY	Paper Lead Alloy
PLYDBT	Paper Lead Alloy Double Brass Tape
POC	Point of Connection (between EQL assets and customer assets)
PVC	Polyvinyl Chloride
POEL	Privately owned Electric Line
PRD	Pressure Relief Device
QLD	Queensland
REPEX	Renewal Expenditure
RIN	Regulatory Information Notice
RMU	Ring Main Unit
SCAMS	Substation Contingency Asset Management System
SDCM	Substation Defect Classification Manual
SHI	Security and Hazard Inspection
SM	Small
SFAIRP	So Far As Is Reasonably Practicable
SVC	Static VAR Compensator
SVL	Sheath Voltage Limiter
TR-XLPE	Tree Retardant Cross-Linked Polyethylene
US EPA	United States Environmental Protection Agency
VT	Voltage Transformer
WCP	Water Content of Paper
WTI	Winding Temperature Indicators
WTP	Wet Transformer Profile
XLPE	Cross-Linked Polyethylene