HV Underground Cable Asset Methodology – Framework

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1. Introduction

1.1 Purpose

In order to implement the organisation's Asset Management Strategy a specific asset management methodology must be developed for each major asset group within Powerlink.

This document sets out the whole of life management philosophy for Powerlink's underground cable assets, provides a planning tool for asset management activities and acts as a reference for the development of maintenance and project plans.

1.2 Scope

This document covers the asset life cycle of the following Powerlink high voltage (HV) underground cable assets:

- HV underground cables forming a part of a transmission feeder
- HV underground cables located within Powerlink substations.

It excludes land maintenance activities and associated processes for vegetation management on underground cable easements, provision of access to the cables and management of corridors for co-use activities. Easement and vegetation management are addressed within the scope of the Land Asset Methodology Framework.

Underground Cable Ratings are not covered within the scope of this document. Refer to the Transmission Line Ratings document for further details.

1.3 Defined terms

Terms	Definition
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
DBYD	Dial Before You Dig is a referral service for information on locating underground utilities anywhere in Australia. Powerlink provides our asset information to DBYD.
DCA	Dedicated Connection Assets
DTS	Delivery and Technical Services (internal Powerlink division)
DTS	Distributed Temperature Sensing
EMF	Electric and Magnetic field produced from voltages and alternating current.
IUSA	Identified User Shared Assets
MSP	Maintenance Services Provider, OSD or external party that provides a maintenance service.
OSD	Operations and Service Delivery (internal Powerlink division)
RCM	Reliability Centred Maintenance
SAP	Computerised maintenance management system - SAP is the enterprise business application which supports the core processes of asset management, including project management and maintenance. SAP facilitates the flow of information between all asset management functions within Powerlink, including those activities undertaken by external maintenance service providers.
SCFF	Self-Contained Fluid Filled cables contain cable conductor, insulated with paper impregnated with a low viscosity fluid, which permeates the entire cable through the oil channel, ensuring that any voids are completely filled with the fluid.
SBD	Strategy and Business Development (internal Powerlink division)

Terms	Definition
“Turn Key”	The provision of a complete cable system including; design, procurement, construction, testing, spares.

1.4 Monitoring and compliance

The success of this document can be measured by the corporate use of Asset Management Plans, Lifecycle planning, condition assessments and management of asset data. This document should be reviewed every five years to ensure compliance is maintained with regard to current legislation and standards.

The Lines Strategies Team will review relevant strategic Asset Management documents on a five yearly basis and will promote the development of documentation and field guides to ensure transmission cable strategies remain relevant and in accordance with good industry practice.

2. Asset Management Overview

Powerlink's Asset Management System ensures assets are managed in a manner consistent with the Asset Management Strategy, and with the organisation's overall corporate vision objectives to deliver cost-effective and efficient services for customers and stakeholders.

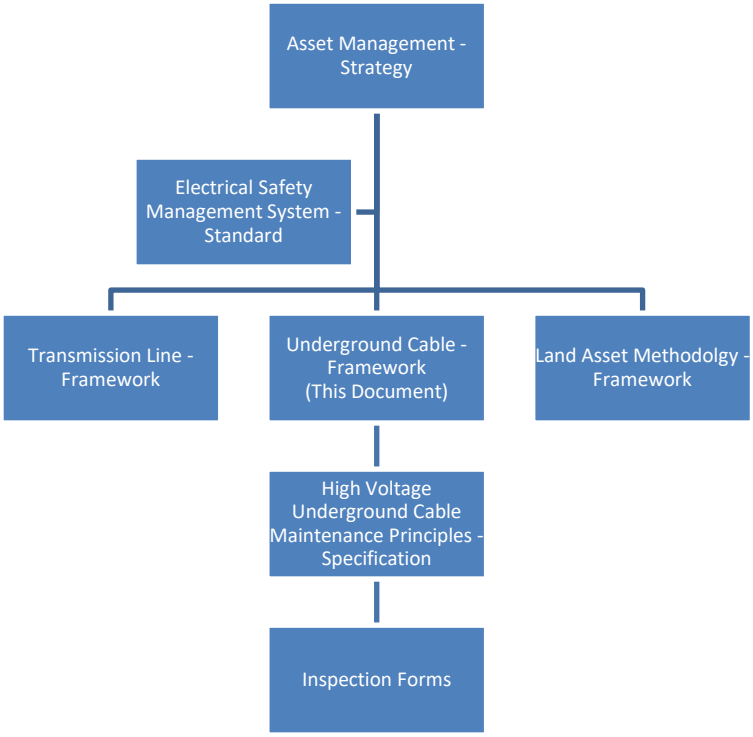
The Underground Cable Asset Methodology considers the following matters:

- Identifies the statutory, economic and community obligations that drive the underground cable asset management methodology.
- Details the major tasks undertaken throughout the life cycle of the underground cables.
- Identifies common specific risks associated with underground cables.
- States the principal maintenance strategies employed by Powerlink in the management and application of underground cables.
- Identifies mechanisms to monitor performance and achieve continuous improvement in the management of underground cables over time.

2.1 Document Hierarchy

Powerlink's document hierarchy for underground cables is as follows.

Figure 2-1 – Asset Management Framework



3. Asset Information

Powerlink owns and operates a variety of high voltage underground cables at voltages from 11kV to 275kV. The age profile of underground cable assets is available from Powerlink's Annual Report.

Powerlink's Underground cables are typically feeder cables linking substations or overhead transmission line built sections where there are strict limitations on the available easements and/or electrical clearances.

The number of 11kV, 22kV and 33kV cables located in substations is not reported in the Annual Report separately, but is included in the substation statistics. To ensure their visibility for accurate and appropriate maintenance, operation and disposal, these are managed as separate assets and the relevant asset data is captured in the computer maintenance management system (Powerlink uses SAP).

4. Levels of Service

4.1 Stakeholder Requirements

Powerlink has a number of service levels derived from its strategic drivers, statutory authorities, transmission licence and associated operating obligations. These are considered below where applicable to underground cables.

4.1.1 Safety Compliance

The fundamental requirement is for Powerlink to ensure that underground cables are electrically safe in terms of their design, configuration and construction, and that they are operated in a way that is electrically safe. Other physical attributes of the underground cable asset, including integrity of the cable easement and signage must be managed to ensure a safety compliance outcome.

Of equal importance is to have safe work practices in place for the maintenance activities, to ensure that Powerlink's target for zero accidents is achieved. To ensure this outcome, Powerlink uses a number of design and maintenance measures, some of which are listed below.

Design measures include:

- compliance with the Electrical Safety Act, Section 4, Electricity Safety Code of Practice for Works 2020, which covers the requirements for design and installation of underground electric cable systems. It specifies required cable depth, requirements for identification and record keeping, protective earthing of cables, mechanical protection of cables and cable separation distances.
- Safety in Design as per the Work Health and Safety Act.
- ensuring that the location of cable terminations is within securely fenced areas or at inaccessible heights on suitable structures.
- implementation of adequate:
    - cable and termination structure earthing arrangements
    - lightning and switching overvoltage protection
    - suitably located safety signage
    - structural integrity

Operation and maintenance measures include:

- routine patrols and an annual review of patrol outcomes.
- active application and use of the Dial Before You Dig (DBYD) scheme.
- routine earth sheath resistance measurement to ensure the appropriate cable earthing and insulation level.
- routine earth grid injection testing at transition sites or footing resistance measurement at transition towers.

- the development of effective asset information systems, particularly geospatial mapping and asset registers, in order to appropriately record the location of underground cable assets. These systems are used to advise staff and members of the public of potential electrical hazards associated with excavation activities.
- annual review of the continuous current and fault current ratings.
- monitoring of forced outage data to identify actions for improvement of underground cable performance where necessary.

As with all of Powerlink's assets and related work practices, there is a requirement to ensure overall compliance with all workplace health and safety legislation, translated into Powerlink's Safety Management Systems when designing, working in close proximity to , maintaining or switching underground cable systems.

4.1.2 Reliability of Supply

Powerlink ensures underground cables that are required to meet the long term needs of the network are maintained or replaced where indicated necessary through condition assessment, to meet the statutory and community expectations for ongoing safe and reliable operation of underground cables.

Powerlink has established a business process for obtaining outages that involves negotiation of a suitable time with regard to market impacts and customer impact (generators and direct connect loads). All planned outages are managed and co-ordinated by Network Operations in periods of low loads, where possible. Routine maintenance is reviewed by OSD regularly to ensure only appropriate routine maintenance is undertaken, especially those tasks involving plant outages.

For unplanned outages, a business process and complementary system have been developed to facilitate review of the root cause of underground cable outages by the Technical and Network Solutions group, to enable the identification of actions or plans to improve reliability where required.

Underground cable performance is also analysed by monitoring the number of forced outages, number of notifications involving breakdown and maintenance testing results captured within measurement documents.

To minimise the number of unplanned outages, Powerlink has implemented feeder protection where possible to allow circuit breaker auto-reclose even on those feeders which incorporate a length of underground cables.

4.1.3 Compliance with National Electricity Rules

As part of network investment, Powerlink is required to:

- plan network development in accordance with our Transmission Authority, the Electricity Act and the National Electricity Rules
- monitor the condition of all underground cables to provide safe, reliable electricity supply
- minimise the risk of actual loss of supply events
- meet the needs of our customers
- provide information for Identified User Shared Assets.

This is achieved through careful monitoring of load growth and network capability. Where the network capability is identified to be in need of further augmentation, various options are considered and an appropriate solution analysed and planned to meet the need. Where the investigation determines that there are requirements to consider the use of underground cables to meet the reliability, quality of supply, resilience of the network or surrounding land use constraints, high voltage underground cables will be considered based on life cycle cost analysis performed on a case by case basis. In practical terms, high voltage underground cables are typically utilised in short lengths to overcome surrounding land use limitations, particularly with regard to protected vegetation and existing community infrastructure.

4.1.4 Customers and Connection Agreements

Powerlink is required to meet the terms of Connection and Access Agreements. Each connection agreement specifies the requirements of the particular customer with respect to the availability and reliability of the connecting assets. Forced outages are routinely analysed and those that relate to a Powerlink customer are reviewed with the Network Customers group where there is a significant impact on the affected customer.

Powerlink's maintenance programs are also coordinated to occur in conjunction with shut down of customer plant or at times of lower load to minimise production impact or associated market impacts.

4.1.5 Identified User Shared Assets (IUSA)

These assets are not owned by Powerlink, however they are operated and maintained by Powerlink under a Network Operating Agreement. These assets will be operated and maintained in accordance with Powerlink current policies and procedures unless otherwise stated. Powerlink contracts out emergency maintenance and operational repairs for cable restoration, including associated accessories and ancillary items.

The Network Operating Agreement should include information on the following:

- Powerlink supplied feeder number
- Powerlink supplied Built Section number and Structure numbers
- Powerlink functional locations and asset data requirements for SAP
- Patrol and Inspection cycles that don’t align with Powerlink standards
- maintenance requirements for components that don’t align with Powerlink standard requirements should be provided by Owner/third party.

4.1.6 Environmental Compliance

Powerlink has an obligation to comply with the Environmental Protection Act and other environmental legislation.

A significant environmental issue during project planning phases involves the management of magnetic fields on cable easements, as per the levels stipulated in ARPANSA guidelines. These aspects are managed through the application of appropriate route selection and cable design practices, in a similar manner to high voltage transmission lines.

During construction, the major impact on the environment involves the clearing of cable easement for construction and maintenance access. Powerlink employs directional drilling and other available methods to minimise such impact. Powerlink has guidelines for vegetation that can be used on underground cable easements without impacting reliability of supply.

Another significant environmental issue with underground cables relates to the management of potential fluid leaks from self-contained fluid filled cables. Powerlink has implemented routine inspection and testing programs to monitor this issue in conjunction with on-line monitoring of cable pressure and oil levels.

Compliance with environmental, planning and cultural heritage legislation is common across all Powerlink assets and is being applied to underground cables.

5. Lifecycle Management

In order to achieve the best outcome for its stakeholders, Powerlink must optimise the asset's whole of life cycle cost, risks and benefits. This is the basis of Powerlink's asset management approach and involves the following:

- optimisation of the concept development and the design process
- consideration of the asset's likely operating life
- effective management of the asset's lifecycle through targeted maintenance, refurbishment, replacement and disposal activities.

This approach is often referred to as the Asset Life Cycle and includes three main stages:

- planning and investment
- operation, maintenance and refurbishment
- end of life.

5.1 Planning and Investment

The Planning and Investment stage involves consideration of the various options available to achieve the required forecast demand capacity.

Once all the requirements are clarified and agreed upon and the majority of the easement known, specific project outcomes are defined, in order to:

- achieve the desired Levels of Service over the life of the asset
- ensure that the expected or desired asset life is achieved
- optimise total lifecycle costs
- ensure the maintainability and supportability of the asset over its intended life
- comply with corporate and statutory environmental and safety requirements.

There are a number of asset management guidelines to ensure that the underground cable system design meets all the requirements for future maintenance, operation and disposal of the cables in the most cost effective way, and ensuring minimal impact on safety and the environment.

The final aspect of the Planning and Investment phase includes determination of arrangements for procurement, contracts, project and construction management, variations, testing, commissioning, production of "as built" documentation and final handover. The majority of HV underground cable systems are constructed using "turn-key" systems, although design of transition sites is usually done using internal resources.

5.2 Operation, Maintenance and Refurbishment

Once the underground cable system is constructed, tested and energised, the Operation, Maintenance and Refurbishment stage begins. Over the expected 40-50 year life of the asset, management policies and procedures must be in place to ensure all assets are operated within their technical parameters and continue to perform to their initial specifications.

Underground cables are very sensitive to overheating caused by either overloading or changes in soil profiles along the cable route. These differences have to be catered for by the application of an appropriate protection system, catering for both overhead and underground cable faults and by the appropriate operation and monitoring of the load on such circuits.

Underground cable forced outages will generally be of longer duration than those of overhead lines and the emergency response system has to cater for this.

Powerlink has adopted Reliability Centred Maintenance (RCM) analysis of plant maintenance requirements which provides a framework for logically analysing the potential failure modes of plant, equipment and systems, as well as their likely effects and consequences.

5.3 End of Life Determination

As the high voltage underground cable system approaches its nominal end of life, condition assessments and/or other analysis is required. The analysis will aid in assessing the cable system's capability considering its condition, performance, availability, reliability and supportability.

Powerlink considers that the age of an asset does not provide for automatic justification of its replacement. The condition assessment process includes an assessment of whether the underground cable system has reached its end of life state due to issues with capacity, capability or compliance.

The terms capacity, capability and compliance are used to broadly describe a number of specific issues (such as poor performance, new standards, rising fault levels and obsolescence) that may lead to asset reinvestment action. Where possible, underground cable replacement needs are coordinated with the load-driven capital works program. This is the most common approach used for the replacement of the underground cables located within Powerlink substations.

Due to the nature of underground cables and the proximity of their installation to urban areas, it is unusual to be able to re-use the existing easement without causing significant impact to the public and to the operation of other infrastructure. It is more probable that a different cable easement will be required and thus, to minimise both the cost and any such impact, the old cables may have to be secured, sealed, earthed and left underground. In such instances, the cable's identification and records are maintained with DBYD.

6. Asset Management Driver

Asset management practices must consider all risks associated with the planning, investment, operation, maintenance, refurbishment, and end of underground cable system life. This is intended to optimise the asset's operating life and whole of life cost. This can only be achieved by adopting an asset management strategy that incorporates a timely response to a range of internal and external factors, including:

Internal

- the condition assessment process,
- technical investigations,
- data recording, visualisation, modelling and reporting, and
- underground cable ratings management.

External

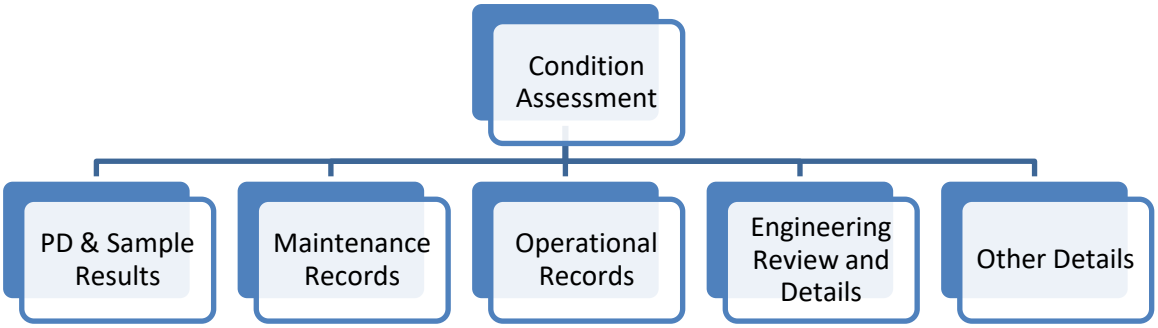
- emerging issues (e.g. climatic),
- environment and duty,
- change of legislation, standards or other requirements, and
- demand and energy consumption.

6.1 Condition Assessment Process

Underground cables typically deteriorate due to mechanical damage, thermal stress and an inherent material aging process. They are particularly sensitive to overvoltage and/or voltage surges, as well as soil movement, erosion or soil disturbance. Condition assessment provides an indication of defective and deteriorated components and initiates further investigation and analysis of the data. This determines the level of component deterioration, the holistic condition of each underground cable system and the potential options to achieve best asset reliability.

The condition assessment process for underground cable assets involves the analysis of physical condition, maintenance data, operational records, engineering data and technical investigations to develop a holistic view of the condition of the asset and any associated risks. The model below demonstrates how these inputs contribute to the condition assessment process.

Figure 6-1 – Input contribution to condition assessments



6.1.1 Condition Assessment Report

The Condition Assessment Report for an underground cable asset is the product of the Condition Assessment Process. The Condition Assessment Report will take the engineering and condition data and apply analytical techniques, modelling, expected future performance criteria and probabilistic evaluation to determine the decision criteria for the condition assessment. This activity will be managed by the Lines Strategies team and may include consultation with design groups and the respective maintenance service provider for the asset.

The objectives of the Condition Assessment Report are to:

- determine the condition of the asset with respect to the decision criteria
- validate or recommend changes to the maintenance strategy of the asset, based on condition
- determine the possible options for replacement/refurbishment/decommissioning of the asset if required
- document and communicate all condition issues.

6.2 Condition Data History

The historical condition data should be collated from information relating to the known underground cable condition and performance. This could include:

- cable sample tests for water and electrical treeing and/or termite damage
- partial discharge measurement on cable, cable joints and/or cable terminations, accessories and cable system components
- previous condition assessment reports
- forced outage history
- preventive and corrective maintenance reports and plant service history.

This activity will be undertaken by Lines Strategies and design groups and the respective maintenance service provider.

6.2.1 Data Modelling

The SAP maintenance system model for underground cable assets forms a part of the condition reporting process between maintenance service providers, the Technical and Network Solutions group and the Lines Strategies Team. The data is audited on an annual basis by the responsible maintenance service providers as well as by the Technical and Network Solutions group. This includes a review of associated maintenance costs and root causes of defects and, based on these and other inputs, the overall strategy may be modified if required.

6.3 Engineering Review

The engineering review will collate information relating to the designed performance of the asset. This could include electrical, hydraulic and layout design information and easement information. It will also include consideration of material performance in the service environment, design vulnerabilities and assumptions, historical performance of similar assets and industry experience. This activity will be undertaken by Lines Strategies and design groups and may include distributed temperature measurements, actual current and voltage measurements and analysis, fault current capability assessment, over-voltages withstand capacity, etc.

6.3.1 Technical Investigations

To support the development of underground cable asset strategies, technical specialists are engaged from time to time to assist with the investigation and resolution of site, technical and/ or asset performance issues.

Investigations can be initiated by a task request for internal specialists or a commercial arrangement with a subcontractor or industry specialist. These activities include termite management, earthing, arborist work, land development near and at cable easements, circuit performance, component performance, special investigations, water and electrical treeing and the use of new technology.

6.3.2 Underground Cable Ratings

Powerlink reviews and calculates underground cable ratings for the majority of Powerlink feeder type cables. As the cable ratings are dependent on the condition and types of surrounding soil, the re-calculation of the cable ratings is triggered on a case by case basis where there is a significant change (e.g. major road extension).

6.4 Emerging Issues

6.4.1 Double Circuit Reliability

The Lines Strategies Team, which is responsible for strategies for underground cables, is continuously looking at technology and methods to monitor cable condition and the protection of hybrid feeders (overhead lines containing underground sections) in such a way to minimise double circuit outages and their outage duration. Whilst underground cables have a very limited exposure to the environment, overhead transmission line double circuits are more prone to outages caused by lightning and/or bird activity. To minimise the impact of these, Powerlink has adopted and is implementing the use of “smart” protection relays on all hybrid feeders to allow the use of an automatic reclose function when the detected faults are in the overhead section.

The automatic reclose is disabled if the fault is detected in the underground section as transient faults on underground cables are very rare. In this way, the outage duration is reduced where possible and at the same time the integrity of underground cables is not compromised.

High voltage underground cables installed in Powerlink substations are included in the protection zone of the power transformer current differential protection. In the case of a cable fault, the power transformer will trip and this event will be investigated as a power transformer fault at the first instance.

To have immediate and clear indication of a cable fault, additional current transformers have to be installed between a cable and a power transformer. Powerlink has installed toroidal current transformers suitable for the installation on power cables up to and including 145kV cables.

6.4.2 Distributed Temperature Sensors/Sensing (DTS)

Powerlink ensures that all future cable installations outside substations include fibre optic cable which can be used with DTS equipment. DTS provide a real time temperature profile of the cable along its route. It can be used to provide the indication of critical points on a cable route, to monitor changes in conditions on the cable route (additional soil layer, for example) and if used on a line, can provide capabilities for increased cable rating. From time to time Powerlink uses portable DTS units to check existing cables which have fibre optic cables installed alongside the power cables.

6.4.3 Climate Change Adaption

Climate Change adaptation dictates that the resilience and durability of infrastructure needs to be determined, and that asset managers have a solid understanding of the conditions that the asset will face over its useful life.

The impact on any individual asset will need to be determined and assets may require modification to adapt to meet changes in environmental conditions.

The major impact on underground cables may be caused by:

- change in annual rainfall and increased evaporation (thermal soil resistivity will change)
- more frequent and severe droughts and increased fire risk
- increase in severe storm events and flash flooding (to be considered during the cable easement selection process).

7. Asset Management Activities

Electricity transmission assets have a relatively long expected operating life during which a range of asset management activities will be conducted, as outlined in the following sections.

7.1 Planning and Investment

At the Planning and Investment stage, the range of underground cable augmentation, and replacement needs are considered and coordinated to ensure an optimum program of overall underground cable investment. An essential requirement for initiation of underground cable replacement is to establish the ongoing requirement for the asset to meet the long term needs of the network. Hence, there is an imperative for asset reinvestment planning to be structured to reflect future network needs and also for network planning to be undertaken with cognisance of the underlying condition of the asset.

The approach to planning and investment also involves ensuring the proposed configuration of the underground cable asset, established through forums that steer network investment decisions, meets the high level Planning and Investment objectives discussed in Section 5.

7.2 Operation, Maintenance and Refurbishment

7.2.1 Operation

Powerlink has established a business process for obtaining high voltage network outages that involves negotiation of a suitable time for planned outages with all interested parties (customers).

While underground cable faults are rare, their outages can be lengthy. A key component of underground cable management involves ensuring easy and quick access to trained cable jointers as well as to immediately available maintenance spares for fault restoration. A number of other asset management initiatives have been implemented for the operations and maintenance of underground cables, identified below:

- Powerlink has established a standard cable specification for use in substations up to and including 33kV voltage level and is working to standardise 145kV rated cables to ensure that cable spares with a short shelf life are readily available.
- Powerlink owns and maintains emergency restoration structures that can be also deployed in the case of underground cable failure. These are accompanied by contingency plans for all major underground cables.
- All planned outages are managed and co-ordinated by Network Operations in periods of low loads. Routine maintenance is reviewed every two years to ensure only appropriate routine maintenance is undertaken, especially when those tasks involve plant outages.

The underground cable performance is also analysed by monitoring the number of forced outages, number of notifications involving breakdown, number of DBYD enquiries and maintenance testing results captured within measurement documents. Since Powerlink's underground cable population is still relatively small, the analysis is done on a cable by cable basis. The number of outages caused by failure/s of underground cables is very small, but the impact is often high and repair/replacement times can be lengthy.

7.2.2 Maintenance

Maintenance strategies for underground cables were developed using Reliability Centred Maintenance (RCM). RCM provides a rigorous and auditable analysis framework for identifying only those maintenance tasks that are applicable and effective in managing possible failures. RCM analysis was undertaken by facilitated review teams of technical experts and field personnel with the greatest knowledge of the assets being analysed. RCM also identified failure modes that could not be dealt with effectively by maintenance alone and thus required other approaches to deal with them. This ensured that only practicable, achievable and effective maintenance tasks were adopted.

RCM identified the following cable subsystems:

- cable system components (cable, terminations, joints, earthing, optic fibre temperature monitoring system, link boxes, earth sheath)
- condition monitoring and protection devices, if any (pressure transducers, distributed temperature monitoring, communication equipment, etc.)
- oil system (oil tanks, pressure meters, pipe work and valves) – for Self-Contained Fluid Filled (SCFF) cables only
- transition/support structures (transition and support structure, surge arresters and counters)
- cable pits (sump pumps, waterproofing, doors, security, maintainability), if any
- easement (land-slides, land use changes, signage, vegetation).

Each cable system is maintained by managing its major component groups as identified above.

Central to the application of the RCM model is the timely collection of information on the condition and performance of the asset. To achieve this, Powerlink's underground cables are configured into Built Sections, each circuit being an individual Built Section with an individual asset value.

To accommodate replacement of a single core, Built Sections are further broken into cable cores where applicable and their technical details are captured separately.

At higher voltages (typically 66kV and above), the cable terminations are modelled separately either as part of the relevant substation or transition site structure. Transition sites are also modelled separately.

7.2.3 Refurbishment

Improvements can be made through refurbishment to bring the asset up to current standards and/or to meet improved safety or operational requirements. Examples of such activities include:

- refurbishment of sealing ends e.g. replacement of seals or insulating oil
- upgrade/modification of cable earthing
- upgrade/replacement of the underground cable signage
- upgrade of lightning protection
- additional installation of any condition monitoring devices (pressure transducers) or condition monitoring systems
- additional vermin or termite protection installation.

7.3 End of Life

An underground cable has as an expected service life of 40-50 years and is monitored for defects throughout its life. Some components get replaced throughout the technical life of underground cables. Despite this, there is a point where a condition assessment for an underground cable asset identifies that the cables are approaching or have reached their technical end of life.

The technical or economic end of life of an underground cable is when the asset no longer meets minimum technical requirements and presents an unacceptable risk to the business, or is uneconomic to retain.

The following options should be considered:

- cable replacement
- cable disposal.

To make the correct decision regarding these options, additional factors need to be considered such as:

- present and future load flows and network topology
- existing easement width, conditions and access for works
- level of difficulty involved in obtaining a new easement for the cable route
- condition of underground cable and the technical or cost implications associated with replacement
- maintenance costs.

The decision making process requires data associated with the asset to be gathered well in advance of the anticipated major deterioration of the asset to ensure that all options remain technically feasible for the asset (typically 7 years for underground cable condition assessments).

8. Emergency Response and Network Security

8.1 Emergency Response

One of the major advantages of underground cable usage in harsh climate areas such as North Queensland is that they are less susceptible to the impact of cyclones and natural disasters. The major impact on the cables during such events will be their exposure to over-voltages, caused by overhead line trips and automatic reclose. Flood water can also pose a threat, with the risks of erosion causing cable cover to be reduced, and pits being inundated.

Due to easement constraints, diversity of underground cable routes is typically not achievable for double circuit underground cables. Considering the prolonged repair times for underground cable faults (minimum 7 days), there is a requirement to develop and maintain emergency restoration plans for major cables. These may involve construction of a temporary overhead line if required and deployment of emergency restoration transmission line structures.

8.2 Network Security

Security is defined as the state of being protected against danger, loss or harm. It is achieved through the mitigation of adverse consequences associated with the intentional or unwarranted actions of others.

In-line with Powerlink's Security Management Framework the physical security of Powerlink's Operational Infrastructure is managed through Powerlink's Asset Risk Management Framework. Some of the control measures used on high voltage underground cables are trench designs to improve cable protection, species management of vegetation on easements, integration with DBYD services, and regular patrols to deter and detect security risks.

9. Supporting Activities

9.1 Project Handovers

The construction of new underground cables, component replacement or cable replacement involves the interaction of design, construction, project management, material acquisition and strategies groups both within and external to Powerlink. The transition from the practical completion of the underground cable system to an operational asset and the maintenance of that asset requires the recording and communication of critical information and related data about the asset.

The Project Handover process has been implemented to provide the conduit for transferring design and construction information between the Designers, Construction Contractor and the Maintenance Service Provider. It further provides an opportunity for the Strategy Engineers to proactively seek feedback from Project Managers, the project team and stakeholders about the project and the project handover process to ensure that opportunities for improvement are implemented.

9.2 Equipment Spares

An annual review of underground cable spares will be performed to ensure that:

- the quality and quantity of underground cable spares are adequate and appropriate
- the storage practices and facilities for underground cable spares are satisfactory to ensure component life span is not compromised as a result of incorrect or inadequate storage practices
- spares have been provided for new assets and component changes
- consumables for cable joints/terminations be reviewed every five years, however once they have expired they should not be purchased again as these items have a relatively short lead time. Details of the consumables shall be recorded in SAP to enable reordering as required.
- consolidation of cable spares should be considered where possible to enable spares to be used on multiple assets.

9.3 Human Resource Training

9.3.1 Training of Cable Jointers

Powerlink's underground cable asset base is small and would not provide sufficient work for dedicated cable jointers to maintain their competency. As such, Powerlink relies on agreements with third party cable jointers for some routine maintenance tasks, all emergency corrective maintenance and the majority of condition based work. These companies employ cable jointers who have jointing experience with cables at transmission level voltages.

9.3.2 Underground Cables Technical Training

The Lines Strategies and Technical and Network Solutions Teams will provide at least one underground cable technical training day annually to reinforce key concepts and strategies with service providers delivering across the asset lifecycle.

9.4 Documentation

The Lines Strategies Team will review relevant strategic Asset Management documents on a regular basis and promote the development of documentation and field guides to ensure underground cable strategies remain relevant and in accordance with good industry practice.

9.5 Strategic Linkages

The Lines Strategies Team will develop and maintain strategic linkages internally within the SBD Division and with other groups external to the division to ensure a seamless integration of network topography is maintained.

Ongoing management of underground cable assets will require that Lines Strategies maintain close liaison with Planning, Technical Services, and Primary System Design.

Planning shall be responsible for:

- Identification of requirements for new feeders due to load increase.
- Assessment of requirements for the use of HV cables as an alternative to overhead transmission feeders. Requirements for a new HV cable shall include full life cycle costs, based on a nominal 40 year life expectancy.
- Definition of the requirements such as cable continuous, emergency (cyclic) and fault current ratings based on predicted load flows and network configuration changes.
- Identification of cables with no enduring need.

The Primary System Design Group shall be responsible for:

- identification of requirements for HV cables within Powerlink substations
- identification of the cable routes within substations
- cable specification, layout design and cable ratings calculation
- provision of asset data
- analysis of Transition Site earth injection test results
- design of transition sites.

The Technical Services Group shall be responsible for:

- Annual review of cable performance (maintenance data and forced outage data)
- Investigations regarding condition based maintenance.
- Incident investigations.
- Recommendations for refurbishment projects.
- Recommendation for removal and disposal of redundant cables.

Channels of communication are maintained with other Transmission Network Service Providers through the Australian CIGRE B1 panel for Insulated Cables which provides access to discussion forums for work delivery protocols such as cable earthing, reduction methods for EMF, experience with DBYD, factory and commissioning tests, new materials for cables and any other new technology.

10. Health, Safety and Environment

The design and implementation of underground cable maintenance strategies will incorporate Powerlink's Health, Safety and Environment Policy. This includes the use of environmental risk assessment processes to identify and appropriately manage risks.

Health and safety is managed in accordance with Powerlink's Electrical Safety Management System HSE–STD-A1955230. This includes the use of risk and hazard management processes to ensure safety of workers, the safety of the public and the safety of plant and equipment.

11. Forward Planning

A 10-year Asset Management Plan is prepared by the Planning and Portfolio Optimisation team in SBD and is based on Area Plans, outlining capital projects by type, location and expected completion date as well as operational projects for major components.

All routine maintenance plans are developed in accordance with the High Voltage Underground Cable Maintenance Principles Specification by the Maintenance Facilitator Lines in OSD and entered into SAP by built section number to ensure automatic generation of work orders. The Maintenance Service Providers shall prioritise all notifications 12 months in advance assigning action by end dates for all high priority work.

Appendix A. Asset Maintenance Types

Maintenance Type		Activity	Frequency
Preventative Maintenance	Routine Preventative Maintenance	Underground cable patrols (ground patrols) – not applicable to cables located within substations and less than 110kV operating voltage.	Monthly
		Underground cable Level 1 Maintenance • Cables located in substations • All other cables	Aligned with other activities (RSM). 6 monthly
		Underground cable Level 2 Maintenance • Cables located in substations. • Cables not located in substations	6 yearly Annually
		Dial Before You Dig (DBYD)	Continuously as per inquires
		Transition site maintenance - Inspection - earth grid injection test	Annually 10 yearly
	Condition Based Maintenance	Cable termination replacement	Based on condition and type of cable termination.
		Distributed temperature measurement	Based on change of easement conditions
		Cable joint replacement	Triggered by joint damage, low reading of earth sheath resistance or by Partial Discharge (PD) indication
		Partial discharge measurement on cable, cable joints and/or cable terminations	Based on condition.
Corrective Maintenance	Emergency Corrective Maintenance	Cable termination explosive or non-explosive failure. Significant loss of oil pressure causing either alarm or trip of cable circuit.	
	Deferred Corrective Maintenance		