

Underground Cables Renewal and Maintenance Strategy

Summary

This strategy guides the management of TransGrid's existing underground cable assets.

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1. Purpose

This document defines the renewal, disposal, and maintenance strategies for TransGrid's underground cable fleet. In doing this it applies the overarching asset management strategy and objectives, and relevant Lifecycle Strategies.

The document identifies the emerging issues with TransGrid's Underground Cable assets, and details the renewal and maintenance initiatives to be implemented in response to these issues. The output of the strategy is the asset management program of works, which is derived via distinct paths as follows:

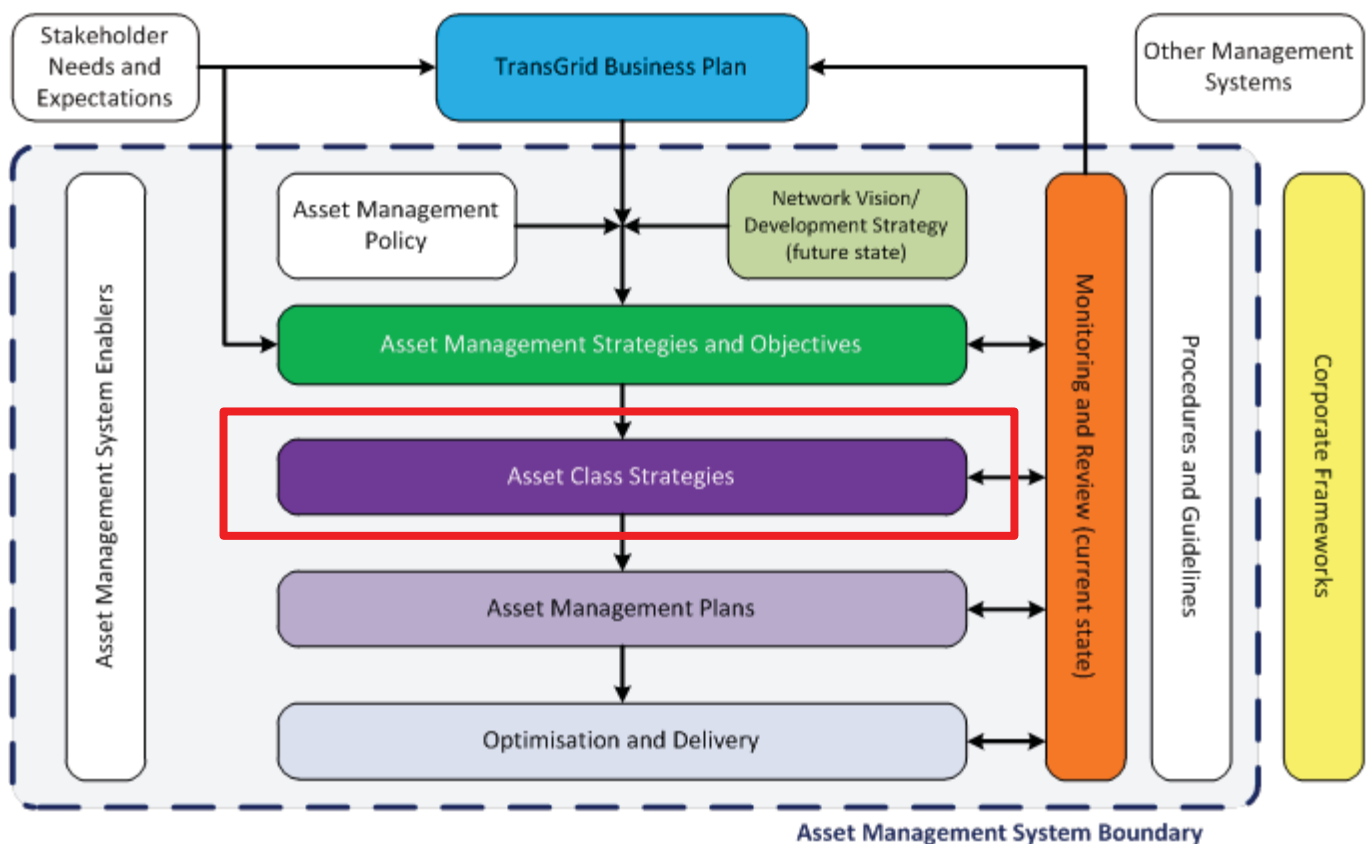
- > The renewal and disposal initiatives are considered through the prescribed capital investment process and managed through the Portfolio Management group, which then leads to the resource-optimised capital works program.
- > The maintenance initiatives directly drive the maintenance regimes which are detailed within the Maintenance Plan – Underground Cable Assets. The maintenance plans are then resource-optimised through TransGrid's Enterprise Resource Planning (ERP) system, *Ellipse*.

The strategies contained in this document cover the period to June 2023.

2. Positioning within the Asset Management Framework

The *Underground Cables Renewal and Maintenance Strategy* document is one of several that comprise the Asset Management Strategies within TransGrid's Asset Management System. This document sits below the Asset Management Strategy and Objectives document as shown in Figure 1.

Figure 1: Asset Management System Document Hierarchy



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3. Definitions

Table 1: Definitions

Term	Definition
Asset Management Objectives	<ul style="list-style-type: none">• Specific and measurable outcomes required of the assets in order to achieve the Corporate Plan and objectives; and/or• Specific and measurable level of performance required of the assets; and/or• Specific and measurable level of the health or condition required of the assets; and/or• Specific and measurable outcomes or achievement required of the asset management system.
Key Hazardous Events	They events of most concern associated with the assets that prevent the achievement of the corporate and asset management objectives.
Emerging Issues	Newly identified issues with an asset that pose a risk to the achievement of the corporate and asset management objectives.
Asset Management Strategy	<p>Documents setting out the long term and short term approach to:</p> <ul style="list-style-type: none">• Management of the assets to achieve the required asset management objectives.• Balancing the cost, risk and performance of the assets over the complete asset lifecycle.• Making better asset management decisions.• Continual improvement of the asset management system to support the achievement of the asset management objectives. <p>Continual improvement of asset management.</p>
Asset Management Plans	Documents specifying activities, resources, responsibilities and timescales for implementing the asset management strategy and delivering the asset management objectives.

4. Asset Management Strategy ‘Line of Sight’

The renewal and maintenance strategic initiatives set out in this document support the achievement of the strategies set out in the Asset Management Strategy and Objectives document. The strategic alignment of the initiatives in this document to the Asset Management Strategy and Objectives document is shown in Table 2 and Table 3.

Table 2: Underground Cable Asset Outcomes

Asset Management Objectives	Asset Management Performance Indicators
<ul style="list-style-type: none"> Manage Underground Cable related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) Manage Underground Cable related bushfire risks (people safety) to ALARP/SFAIRP 	<ul style="list-style-type: none"> Zero asset related LTI's Zero asset related fire starts Maintain Key Hazardous Events at 5 year average level (by calendar year): <ul style="list-style-type: none"> Catastrophic failure Structure failure Uncontrolled discharge/contact with electricity Maintain average age of asset class population to a sustainable level.
Minimise environmental harm and property damage	<ul style="list-style-type: none"> Maintain 5 year level average of fire starts (by calendar year). Maintain 5 year average level of environment related Key Hazardous Events (contaminant or pollutant release)
Maintain network reliability	<ul style="list-style-type: none"> Maintain 5 year average level of loss of supply events due to Underground Cable asset faults (by calendar year).

Table 3: Transmission Line and Cable Asset Contribution to Financial Outcomes

Asset Management Objectives	Asset Management Performance Indicators
Improve CAPEX Performance	<ul style="list-style-type: none"> Improve Capital project performance
Improve OPEX Performance	<ul style="list-style-type: none"> Perform within -5/+10% of Asset Management Program of Works relevant to underground cable assets
Pursue STPIS revenue where cost effective	<ul style="list-style-type: none"> Better than average performance of the STPIS measures (by Calendar Year): <ul style="list-style-type: none"> Transmission line fault and forced outage rates

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5. Review of Previous Renewal, Disposal and Maintenance Strategies

This section discusses the progress of the previous renewal, disposal and maintenance strategic initiatives, and their effectiveness at meeting the previous overarching strategies and objectives. It also identifies any outstanding renewal and disposal initiatives, and outcomes from the previous maintenance strategy, for which strategic initiatives need to be considered going forward.

5.1. Review of Renewal and Maintenance Initiatives

5.1.1. Historical Expenditure

5.1.1.1. Renewal Initiatives

Table 4a: Historical Renewal Expenditure

Renewal Item	Estimate	Actual
MetroGrid Tunnel Life Extension	\$6.2 million	\$2.55 million*
Sydney Park Ground Water Treatment Plant	\$2.0 million	\$1.98 million

* Note: this project was closed off with several major items outstanding.

5.1.1.2. Maintenance Initiatives

Table 5b: Maintenance Initiatives Expenditure

Maintenance Initiative	Estimate	Actual
Cable 41 Online Oil Monitoring	\$200K	\$100K*
Cable 41 Bexley Cable Bridge Remediation	\$354K	\$277K*
Cable 41 Backfill Sampling and Determining Firm Rating	\$1.5 Million	\$1.27 million
Cable 42 JB35/36 Pit Methane	N/A	\$13K

* Project essentially complete but not yet closed off

5.1.1.3. Disposal Initiatives

Table 6c: Disposal Initiatives Expenditure

Renewal Item	Estimate	Actual
Disposal of surplus cable spares	\$50.3K	\$50.3K

5.1.2. Effectiveness of Renewal, Maintenance and Disposal Initiatives

Table 7 outlines the ongoing renewal and maintenance initiatives from the previous iteration of this strategy.

5.1.2.1. Renewal Initiatives

The MetroGrid tunnel life extension project has significantly reduced this sludging on the tunnel floor. However, the project was closed off with several major items remaining. Whilst issues with the draining were remediated as much as practical the remaining items posed significant concerns. The residual works from this project were as follows:

- > Replacement of the pumping station and associated rising main and auxiliary main.
- > Repairs of various galvanising coatings.
- > Replacement of heavily corroded steelwork.
- > Replacement of SPK airlock roller door, panel door and associated frame.
- > Completion of tunnel survey and installation of survey points for the purpose of ongoing tunnel subsidence monitoring.

The residual works were moved to the upcoming cable tunnel accessories project. However the pump station and rising main were in a critical condition and were addressed under a separate Project Approval Document. The urgent works for the pumping station and rising main have recently been completed (actual expenditure unavailable). The completion of this item has allowed the specific three-monthly inspection of the rising main to be removed from the Maintenance Plan. The new rising main can now be inspected on a six-monthly basis as part of other inspection/maintenance work.

The installation of the GWTP has not seen a reduction on routine inspection and maintenance. This plant was installed for compliance purposes. The OEMP, updated in 2015, now requires TransGrid to have a water extraction licence, which required reporting on water outflows. To do this efficiently some modifications to the plant is required.

5.1.2.2. Maintenance Initiatives

Since the last issue of the Renewal and Maintenance Plan there have been the following completed renewal and maintenance strategies:

- > Online differential monitoring on Cable 41:
 - The installation has been completed and was operating with little issue until the cable was reenergised after an extended outage. The switching transient has made 4 out of 8 sites non-operational.
 - When the above issue is addressed, the monthly gauge reading in the Maintenance Plan can move to 6-monthly as part of alarm checks.
- > The Cable 41 Bexley Cable bridge remediation has been recently completed. It will extend the life and reduce the risk of future failure of the asset in the medium term.
- > The completion of the Cable 41 backfill sampling project was completed on time and on budget. Subsequently Cable 41 has now been further derated (to 426 MVA in summer). This new rating is firm using the lowest credible moisture content. The previous 575 MVA rating was subject to review and could have been reduced in the event of long periods without rain, which is unacceptable from a network planning perspective.
- > Augmentation of the Cable 42 JB35/36 pit ventilation system – Repairs to the ventilation system have been made and atmosphere is no longer dangerous.

5.1.2.3. Disposal Initiatives

With the retirement of the oil filled 132kV cables at Beaconsfield and the internal Sydney South 132kV cables, unique spares for these items were surplus and able to be scrapped. Some items were able to be transferred to Ausgrid. This transfer provided a saving as the items would have cost TransGrid money to scrap.

Whilst this disposal was approved in 2012, an audit in 2016 found that the goods not transferred to Ausgrid were yet to be scrapped. The remaining items that were scrapped had a book value of \$50,300.

Table 7: Previous Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Current Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Cable 41	<ul style="list-style-type: none"> Manage Underground Cable related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) 	Keyholes on Cable 41 Gatic lids are failing.	Replace Gatic lids at Athelstane Public school (JB28/29 – both sides) as a priority. Other locations to be replaced under ORPS project	Awaiting cost estimate from service provider	Need ID: 1677 Gatic lids for Cable 41 Oil Pits – Condition Assessment
Cable 41	<ul style="list-style-type: none"> Minimise environmental harm and property damage Improve OPEX Performance 	Cable 41 oil alarms are absolute pressure only.	Installation of online monitoring with differential alarm capabilities.	All sites installed. Some minor defects to be addressed. \$100K expenditure	Internal memorandum: Online Oil Monitoring on Cable 41
Cable 41	<ul style="list-style-type: none"> Maintain network reliability Improve CAPEX Performance 	Possible overheating of Cables	Conduct sampling of cable backfill and determine a firm rating.	Backfill sampling completed. New rating determined and ratings advice issued. \$1.27M expenditure	Need ID: DCN43, 1096.
Cable 42	<ul style="list-style-type: none"> Maintain network reliability 	Ground temperatures higher than design assumption	Ensure that the Cable 42 DTS remains operational to protect against thermal runaway.	Cable 42 DTS planned EOL replacement required completion June 2016. DTS failed March 2016. Due to project delays anticipated completion March 2017. \$250K expenditure	Need ID: DCN440 Cable 41 30 Year Condition Assessment. Cable 41 Investigation Summary Report
Cable 41	<ul style="list-style-type: none"> Maintain network reliability 	Ground temperatures higher than design assumption	Consider the impacts of the higher ground temperatures with the ratings and spares management of Cable 41.	New Cable 41 rating issued September 2016.	Need ID: DCN43, 1096.
Cable 41	<ul style="list-style-type: none"> Maintain network reliability 	Stability concerns and water ingress affecting the Cable 41 tunnels.	Monitor through routine inspections with tunnel specialist.	Ongoing as per Maintenance Plan	Maintenance Plan – Underground Cable Assets

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Assets	Asset Management Objective	Current Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
HV Cables outside substations	<ul style="list-style-type: none"> Manage Underground Cable related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) Maintain network reliability 	<ul style="list-style-type: none"> Members of the public digging in the vicinity of TransGrid HV cables 	<ul style="list-style-type: none"> Monitor via daily patrols of Cable 41 and 42. Proactive approach in communication with contractors via DBYD. Provide TransGrid "standby" to contractor during works that potentially impact on the cable installation. 	Ongoing	<p>Maintenance Plan – Underground Cable Assets.</p> <p>Management of External Work in the Vicinity of TransGrid Underground Cables</p> <p>Information Brochure: Requirements for working in the vicinity of TransGrid Underground Cables (public document)</p>
Cable 41	<ul style="list-style-type: none"> Maintain network reliability 	Potential cable joint core movement on Cable 41	<ul style="list-style-type: none"> Continue to inspect and monitor the cable for signs of core movement. Investigate methods to determine locations where core movement may be a problem, subject to resource and budgeting. 	Ongoing	<p>Cable 41 – 1992 Burrows road failure reports.</p> <p>Cable 41 – 2011 Canal / Burrows Road Core Movement investigations and subsequent joint replacements</p>
All cable assets	<ul style="list-style-type: none"> Improve OPEX Performance Improve CAPEX Performance 	Not all maintenance checksheets are loaded into Ellipse.	Move cable maintenance onto AIM in the stage 2 rollout	In progress	Nil
Cable 41	<ul style="list-style-type: none"> Maintain network reliability Minimise environmental harm and property damage 	Deterioration of Bexley Cable Bridge.	Repair concrete spalling, treating corroded reinforcement and other remediation works as required.	Complete \$277K expenditure (project not yet closed off).	DCN 42 – Option Q
Cable 42 JB35/36	<ul style="list-style-type: none"> Manage Underground Cable related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) 	Methane in oil monitoring pit	Augmentation of the pit ventilation system.	Complete \$13K expenditure	Working group meetings.

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Assets	Asset Management Objective	Current Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Cable 42	<ul style="list-style-type: none"> Maintain network reliability Minimise environmental harm and property damage Pursue STPIS revenue where cost effective 	Cable 42 CMS is at end of life	Replace Cable 42 CMS including local controllers	Cable 42 DTS planned EOL replacement required completion June 2016. DTS failed March 2016. Due to project delays anticipated completion March 2017. \$250K expenditure	Need ID: DCN440
Cable 42 MetroGrid cable tunnel	<ul style="list-style-type: none"> Manage Underground Cable related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) Maintain network reliability 	MetroGrid tunnel pumping system is in a dangerous state (not completed as part of life extension project).	Replace pumps, rising main and install davit crane to enable pump change-outs.	Replacement completed July 2016. \$452K Expenditure	Need ID: DCN560 PDR T.2277 MetroGrid Tunnel Life Extension
Cable 42 MetroGrid cable tunnel	<ul style="list-style-type: none"> Manage Underground Cable related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) Maintain network reliability 	<p>MetroGrid tunnel accessories in poor condition.</p> <p>Poor condition of tunnel steelwork not remediated during life extension project.</p>	<p>Complete refurbishment and replacement of tunnel steelwork and air lock doors.</p> <p>Replace Cable Tunnel Management System (CTMS)</p> <p>Move pump control functionality from CTMS to GWTP.</p> <p>Complete ventilation repairs and replacements.</p> <p>Complete Australia Technology Park (ATP) repairs and replacements.</p>	PAD Issued to be complete by July 2017. \$130K Expenditure	Need ID: DCN560 PDR T.2277 MetroGrid Tunnel Life Extension

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6. Review of Maintenance Program

The current planned maintenance and inspection regime for TransGrid's underground cables are summarised below:

- > Cable route patrol and inspections to identify potential risks to the cable such as excavation works or excessive vegetation.
- > Tunnel, bridge and structure inspection and maintenance.
- > Cable and cable accessories maintenance and tests.
- > Condition monitoring systems maintenance and tests.
- > Plant and equipment maintenance and tests.
- > Comply with TransGrid's "dial before you dig" obligations to notify work parties of the presence and location of high voltage cables or tunnels in the vicinity of their proposed works.

These maintenance and inspection tasks and frequencies have been refined over a number of years and are based on consideration of the specific asset failure modes, and seek to strike an optimised balance between preventative and reactive maintenance.

The regime for the new Cables 43/44 and 45 and the ground water treatment plant is as specified by the manufacturer.

The Service Providers report, on a monthly basis, their actual performance in achieving the planned work to the TransGrid Executive. The results of the service provider's actual performance are published via Executive Dashboard reporting on TransGrid's intranet, called *The Wire*.

Asset Managers review the actual performance of the service providers to deliver the Renewal Plan and the Maintenance Plan. Significant variances between planned performance and actual performance are analysed and discussed by the Asset Manager with the service provider. The outcomes of these discussions may result in the:

- > Service provider undertaking additional work to address any backlogs in order to get back on track with the plan.
- > Asset Manager modifying the plans.

The actual performance for the 24 month period to June 2016 was:

Table 8 – Underground Cable Asset Maintenance Expenditure

Financial Year	Inspection and Routine Maintenance*		Corrective Maintenance (defect)	
	Budget	Actual	Budget	Actual
FY2014/15	\$587K	\$534K	\$25K	\$79K
FY2015/16	\$265K	\$525K	\$39K	\$201K

There appears to be a reporting issue for the FY2015/16 inspection and maintenance budget. This was unable to be resolved. The actuals spent were in line with previous years.

The actual performance for the 12 month period to June 2016 is:

- > 96.27% of planned maintenance schedule to be achieved on time and on budget.

Note that maintenance task completion is a KPI metric.

6.1. Past Performance – Asset Management Performance Indicators

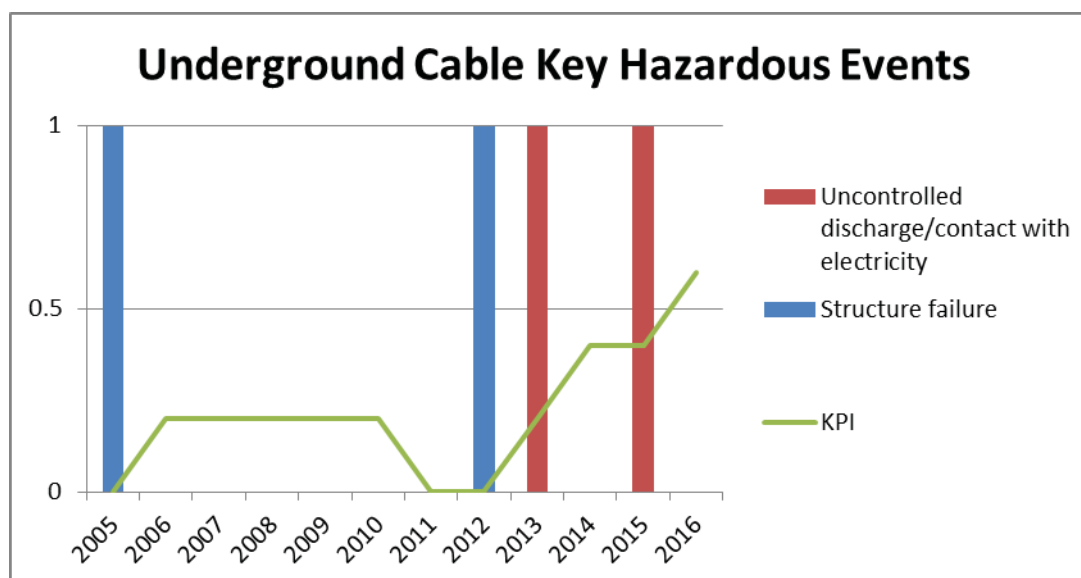
The KPI's that demonstrate the effectiveness of this Renewal and Maintenance Strategy to mitigate the network related safety, reliability environment, financial, compliance and reputational risks in support of the achievement of the asset management targets and objectives are the number of failures shown in Table 9. The performance with the Key Hazardous Events is shown in Figure 2.

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Table 9 – Performance against Asset Management Performance Indicators

Asset Management Objectives	Asset Management Performance Indicator	Past Performance
Manage Underground Cable related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP)	<ol style="list-style-type: none"> 1. Zero asset related LTI's 2. Zero asset related fire starts 3. Maintain Key Hazardous Events at 5 year average level: <ol style="list-style-type: none"> a. Catastrophic failure b. Structure failure c. Uncontrolled discharge/contact with electricity 	<ul style="list-style-type: none"> • Zero LTI due to asset failure KPI was met. • There have been no cable related fire starts. • There have been no catastrophic cable failures within the last 5 years. • For key hazardous events, these are very low on underground cables that the KPI is less than one, meaning a single event will result in KPI not being met. • Where the cable asset was damaged but did not trip, such as contractor undermining, this was considered a "structure failure" • The last uncontrolled discharge/contact with electricity was in February 2015, where a contractor drilled into Cable 43. This one event resulted in the Key Hazardous Events for the 2015 calendar year not being met. <p>The underground cable key hazardous events performance is shown in Figure 2.</p>
Minimise environmental harm and property damage	<ul style="list-style-type: none"> • Maintain 5 year level average of fire starts. • Maintain 5 year average level of environment related Key Hazardous Events (contaminant or pollutant release) 	<p>There have been no recorded fire starts due to TransGrid underground cables for at least 10 years.</p> <p>There have been no detectable cable oil leaks since 2011.</p>
Maintain network reliability	Maintain 5 year average level of loss of supply events due to Underground Cable asset faults (by calendar year)	There has been no recorded loss of supply events due to TransGrid underground cables for at least 10 years so this KPI was met.
Improve OPEX Performance	Perform within -5/+10% of Asset Management Program of Works relevant to underground cable assets.	This KPI was not met in the 2014/15 or 2015/16 financial years. The routine inspection and maintenance was 9% underspent in 2014/15 and 98% overspent in 2015/16. It should be noted that the large overspend in 2015/16 is due to reporting error, the actual cost differential between 2014/15 and 2015/16 was \$9K.
Pursue STPIS revenue where cost effective	<p>Better than average performance of the STPIS measures:</p> <p>Underground Cable fault and forced outage rates</p>	STPIS performance does not report on underground cables, so this KPI is not applicable.

Figure 2: Underground Cable Failures by Hazard Type



Note: Counts are by calendar years. There were no events in the 5 years prior to 2005.

7. Underground Cable Asset Overview

7.1. Scope of Assets

The following assets are considered within the scope of this strategy:

- > 330 kV underground cable assets and associated pilot and optical fibre cables.
- > 132kV underground cable assets; this includes short lengths of 132kV cables within Haymarket, Beaconsfield and Rookwood Road substation boundaries.
- > Cable civil assets such as bridges, tunnels and structures.

The following underground cable assets are outside the scope of this strategy:

- > TransGrid also has short lengths of cable energised at 66 kV, 33 kV and 11 kV which in general, though not exclusively, run within substation boundaries. These cables are covered by the *Network Renewal and Maintenance Strategy – Substations*.
- > The Gas Insulated Lines at Beaconsfield are not considered cables and are also covered by the *Network Renewal and Maintenance Strategy – Substations*.

7.2. Asset Base

As detailed in the 2016 FY RIN, TransGrid has a total of 78 km 330 kV and 4.2 km of 132kV underground cable circuit. A snapshot of the underground cable asset base is provided in Table 10.

Table 10: Underground Cable Asset Base

Asset	Year Commissioned	Operating Voltage	Circuit Length	Description	Nominal Lifespan
Cable 41	1979	330 kV	19.7 km	<ul style="list-style-type: none"> Cable 41 is a Self-Contained Fluid Filled (SCFF) circuit that runs between Sydney South Substation at Picnic Point and Beaconsfield Substation in Alexandria. Associated with Cable 41 is a short 330kV tie cable of identical construction. The tie-cable connects the two outdoor switchyards at Beaconsfield. Oil pressure alarms are via twisted pair pilot cable UPC160. 8 pair pilot cables UPC160A and UPC160B are used for alarms on the sealing ends at Sydney South and Beaconsfield. An online oil pressure monitoring system was installed in 2016. This system provides differential pressure alarm functionality. Associated with Cable 41 are two small lengths of tunnel. 	40 years
Cable 42	2004	330 kV	28 km	<ul style="list-style-type: none"> Cable 42 is a polypropylene laminated paper (PPLP) fluid filled cable circuit that runs between Haymarket Substation and Sydney South Substation at Picnic Point. Associated with Cable 42 cable is a 4 km length of tunnel between Sydney Park, St Peters and Haymarket substation. This cable is monitored by a Cable Monitoring System (CMS). The CMS receives pressure information from the stop/feed joints. A Distributed Temperature System (DTS) provides temperature along the route as well as dynamic rating capabilities. 	40 years
Cables 43 and 44	2014	330kV	16 km	<ul style="list-style-type: none"> Cables 43 and 44 are cross-linked polyethylene (XLPE) circuits that run between Holroyd Substation at Greystanes and Rookwood Road Substation at Potts Hill. A CMS is installed on this asset providing DTS and dynamic rating capabilities. 	40 years
Cable 9S4 (Cable 45)	2013	132 kV	3.5 km	<ul style="list-style-type: none"> This cable in an XLPE circuit that runs through TransGrid's existing tunnel between Haymarket substation and the Sydney Park portal. The cables are rated at 330kV but operated at 132kV. Ausgrid complete the links from the Haymarket basement to the GIS termination and Sydney Park to TransGrid's Beaconsfield substation. DTS capabilities are provided on the Cable 42 CMS host machine at Haymarket. 	40 years
Haymarket connectors	2004	132 kV	< 1 km	<ul style="list-style-type: none"> The Haymarket connectors are 4 XLPE circuits that link the transformers and reactor to the gas-insulated switchgear (GIS) within Haymarket Substation. 	40 years

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Asset	Year Commissioned	Operating Voltage	Circuit Length	Description	Nominal Lifespan
Beaconsfield connectors	2012	132 kV	< 1 km	<ul style="list-style-type: none"> The Beaconsfield connectors are 4 XLPE circuits that link the reactive plant to the gas insulated switchgear (GIS) within Beaconsfield Substation. Two (2) XLPE circuits tie the West and South switchgear. 	40 years
Rookwood Road connector	2014	132kV	< 1 km	<ul style="list-style-type: none"> The Holroyd connector is an XLPE circuit that links the 132kV shunt reactor to the gas insulated switchgear (GIS) at Rookwood Road Substation. 	40 years

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8. Underground Cable Asset Review

This section discusses the emerging issues and the associated strategies to address these with respect to the Underground Cable asset population. The discussion results from the renewal, maintenance and disposal decision process outlined in the *Asset Management Strategy and Objectives* document.

All strategic initiatives with respect to TransGrid's Underground Cable assets are outlined in this section, including the renewal, disposal and maintenance initiatives that feed into the capital works program and the maintenance plans. Further details can be found in the relevant Maintenance Plan, and the referenced governance documents.

8.1. Implementation of the Renewal and Maintenance Decision Process

TransGrid undertakes a variety of performance, cost, risk and compliance analyses to capture the range of current and emerging issues that are apparent with respect to individual assets and asset groups. The analysis takes into consideration:

- > Population age profiling against nominal asset lifespan.
- > Asset inspection and condition assessments.
- > Diagnostic testing – such as electrical, structural and oil testing.
- > Failure mode.
- > Failure and defect rates.
- > Failure investigations.
- > Maintenance program outcomes.
- > Communication from maintenance staff through the working groups.

Once the entire scope of issues are captured and the appropriate analysis undertaken, the asset manager will consider a number of options and determine the most appropriate course of action to address the issue and associated risks. The course of action is generally to monitor the asset, undertake maintenance, renew, or dispose of the asset. The decision making process is described further in the *Asset Management Strategy and Objectives* document.

TransGrid's maintenance regimes for cable assets have been refined over a number of years, and with each re-evaluation further opportunities to refine the processes are considered. They are based on consideration of the specific asset failure modes, and seek to strike an optimised balance between preventative and reactive maintenance.

Renewal initiatives are developed through TransGrid's Prescribed Capital Investment Procedure¹. A Needs Opportunity Statement (NOS) is first developed, which captures the current and emerging issues and assesses the risks associated with an asset or group of assets. The NOS is followed by an Options Screening Assessment (OSA) which briefly summarises potential options to address a need and/or opportunity generated as part of an options workshop, identifying those options which require further study and those which can be discarded or screened at that point. This document formally initiates Option Feasibility Studies (OFS), which provide a desktop review of the options in the OSA that have not been discarded as part of the screening process. The Options Evaluation Report (OER) then summarises the need and/or opportunity, the options available to address that need and/or opportunity and the technical and commercial evaluation of those options and identifies the preferred option. The preferred options are combined to produce a resource-optimised capital works program.

Disposal initiatives are also developed through TransGrid's Prescribed Capital Investment Procedure. Disposal of goods and materials are managed in accordance with TransGrid's:

- > Disposal work instructions.
- > Disposal Strategy as defined in the parent Asset Management Strategies and Objectives document.

¹ Details of the relevant project planning documents for these renewal initiatives can be obtained in PDGS at <http://thewire/projects/prew/Pages/Default.aspx>.

TransGrid's maintenance regimes for assets have been refined over a number of years, and with each re-evaluation further opportunities to refine the processes are considered. They are based on consideration of the specific asset failure modes, condition, criticality, performance, and risk, and seek to strike an optimised balance between preventative and reactive maintenance. The maintenance initiatives directly drive the routine maintenance regimes which are detailed within the Underground Cables Maintenance Plan.

The following changes have been made to the FY2016/17 maintenance plan. These changes are a result of recently (or soon to be) completed renewal and maintenance initiatives:

- > Cable 41 fluid and joint movement readings – from monthly to 6 monthly.
 - The enabler for this change is the installation of the online.
- > Removal of the three-monthly inspection of the Sydney Park rising main.
 - The steel rising main, which was in a dangerous condition, was replaced in June 2016.

These changes, in addition to tasks noted in the budget that were out of step with the maintenance plan since corrected has resulted in an annualised average routine maintenance savings of approximately 8%.

8.2. Underground Cable Asset Review

8.2.1. Population Review

A good indication of asset health and obsolescence at a total population level can generally be provided by the age profile of the asset population – where assets have increased probability of deteriorating in health or becoming obsolete as they advance in age, and particularly as they approach the end of their nominal lifespan.

It is noted that TransGrid's underground cable assets are supported by associated systems, which typically have varying nominal lifespan to the cables themselves. The associated Cable Monitoring Systems (CMS) typically have a limited lifetime due to computer components and operating systems becoming unsupported and some components may require renewal from 5 years after commissioning.

The age profile of TransGrid's underground cable assets is illustrated in Figure 3 and Figure 4.

Figure 3 330kV Underground Cable Age Profile.

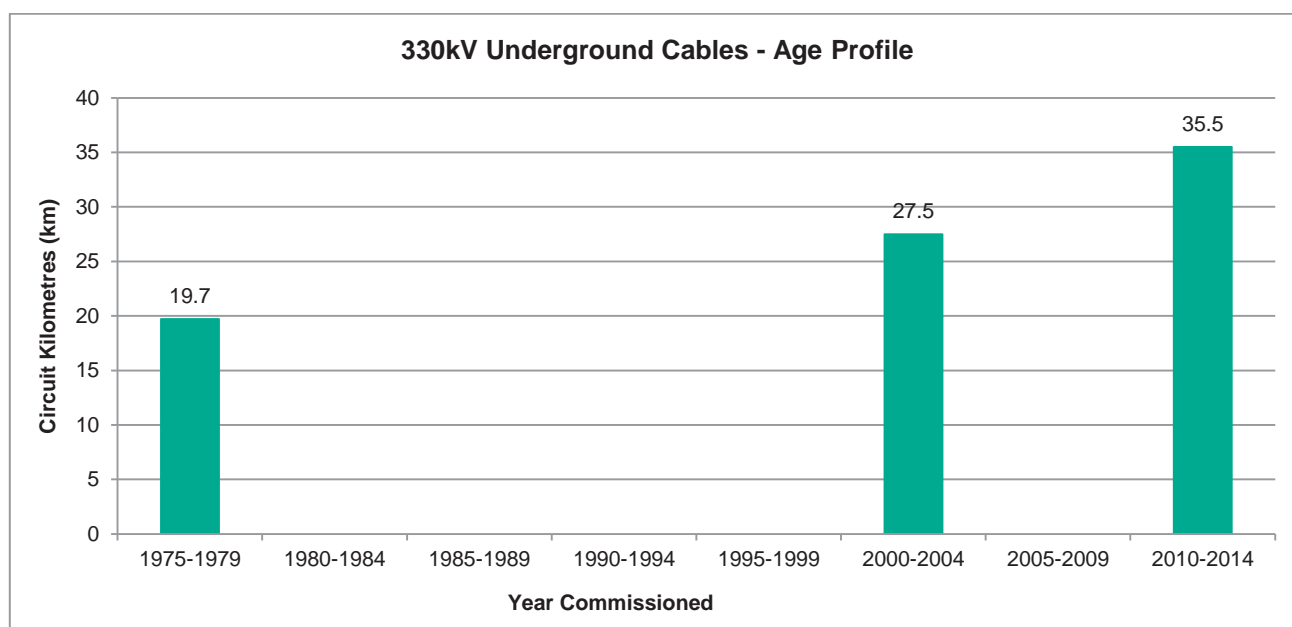
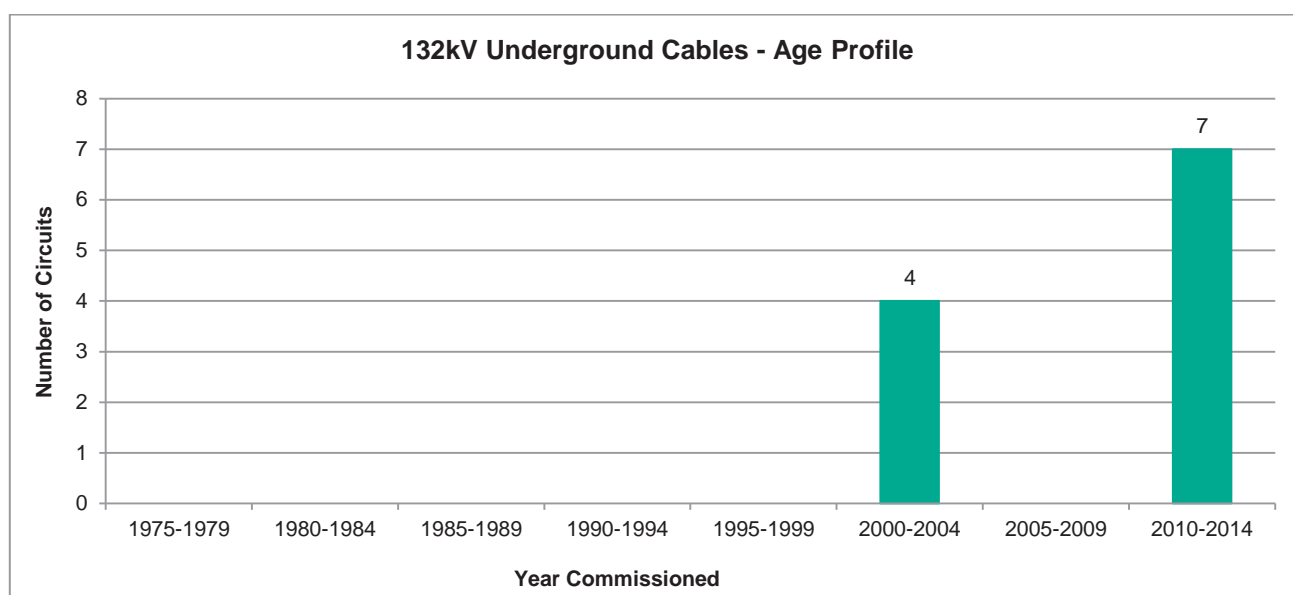


Figure 4 132kV Underground Cables – Age Profile



Notwithstanding any intervening actions, this will result in the following outcome by June 2023:

- > All underground cables except for Cable 41 will remain within the first 50% of their nominal lifespan.
- > Cable 41 will be having exceeded its nominal lifespan (40 years).

These age profiles indicate that:

- > Cable 41 which was installed in 1979 is the only cable likely to have issues with the cable itself and basic infrastructure. However due to the internally wiped joint design on Cable 41, the chance of oil leaks are much less likely than 132kV cables of similar age with externally wiped joints.
- > The cables installed from 2000-04 are unlikely to have issues with the cables and basic infrastructure, however, defects and obsolescence associated with the CMS may be an issue.
- > The cables installed from 2010-14 are unlikely to have any current or emerging issues

8.3. Cable 41 Asset Review

Cable 41 runs from Sydney South Substation to Beaconsfield Substation. It is an oil filled cable and operates at 330kV and was commissioned in 1979 with a nominal lifespan of 40 years. The cable is now approximately 37 years old and will have exceeded its nominal lifespan by 2023.

8.3.1. Emerging Issues, and Renewal and Maintenance Initiatives

Table 11 maps out the line of sight of the Cable 41 emerging issues, renewal, maintenance and disposal initiatives to the Asset Management Objectives.

8.3.1.1. Cable 41 Emerging Issues

Cable 41

Current and emerging issues concerning Cable 41 are summarised as follows:

- > **Overheating:** The maximum electrical power transfer capacity, or “rating”, of a cable is fixed by its thermal operating limit. If the cable is operating at temperatures above its thermal limit this will accelerate the deterioration of its electrically insulating sheath. As the electrical insulation deteriorates the cable’s probability of failure increases.

The bedding in which a cable is buried plays a critical role in dissipating heat from the cable. The heat dissipating properties of the thermal bedding are factored into the circuit design and are a critical variable used to determine the cable rating.

In 2005 contractors excavating close to Cable 41 caused ground subsidence under the circuit. Following work to repair the damage it was found that the cement proportion in the thermal bedding (originally a 14:1

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sand/cement mixture) was significantly reduced. Investigations at other locations found this to be consistent over the whole cable route.

Further analysis indicated that the cable may be operating above its thermal limit under certain circumstances as a result of the degradation of the thermal bedding. Essentially the analysis found that the heat dissipation is significantly lower than the cable's design specifications.

Further compounding the issue of poor heat dissipation, it is the suspected ambient ground temperatures along the cable route being higher than was assumed when determining the cable rating. This is indicated by the Cable Monitoring System (CMS) which operates with Cable 42; Cable 42 follows a similar route to Cable 41 and the Cable 42 CMS shows higher ground temperatures than the Cable 41 design specifications.

A recent initiative has installed temperature monitoring on Cable 41 to provide information on the operating conditions of the cable at six discrete points. The system also will allow system operators to react dynamically to prevent damage to the cable as temperatures vary.

In 2016 a comprehensive program of backfill sampling was conducted along Cable 41. Using the TR vs moisture and applying a minimum credible moisture contents the cable was subsequently derated to 425 MVA.

It should be noted that a planning initiative is currently assessing options for the supply to Sydney CBD and inner metropolitan areas; known as "Powering Sydney's Future" which captures Cable 41 within its scope.

- > Oil Monitoring: Cable 41 oil pressures are managed by analogue gauges and alarm contacts which operate on "absolute" pressures. The current three-tier oil pressure alarm system is likely to be activated only in cases of large oil loss. To address this issue an online system with differential alarm functionality has been implemented. This will allow a maintenance savings by allowing inspections to be reduced. Due to the superior design of the cable joints, fluid leaks are a very rare occurrence; however the consequence can be extreme.
- > Core movement: Core movement at cable joints is a common failure mode for underground cables. In 1992 Cable 41 suffered an electrical fault at a cable joint which was attributed to core movement.

In 2011 core movement was detected on two further "straight through" joints. The core movement was confirmed by x-ray and the joints were replaced with "stop" joints to prevent further movement. The core movement was only detected due to the installation of core movement sensors and oil-line sampling installations following the 1992 failure. The remaining straight through joints on the cable are not equipped with movement sensors or oil sampling capability.

It is likely that core movement is also occurring on the remaining joints which are not equipped with sensors and oil sampling capability.

- > Sheath fault in JB5/6 – A sheath fault has been detected in JB 5/6 in the centre of red phase joint. It is hypothesised that the cause is a weeping oil impregnation nipple within the joint, dissolving the pitch within the joint coffin, allowing moisture ingress to short the joint casing to earth. The Cable 41 cable sampling and Cable 43/44 end of warranty liability inspections are delaying repairs. Calculations show that the increased circulating currents are negligible. Risk of oil leaks are being addressed by monitoring oil pressure as part of routine inspections.

Cable 41 Civil Infrastructure

Current and emerging issues have been identified concerning two cable tunnels and the Gatic lids on the oil monitoring pits. The identified issues are summarised as follows:

- > Cable tunnels: There are two cable tunnels associated with Cable 41 that have had access restrictions imposed on them due to concerns surrounding stability and water ingress. Inspections are conducted by a tunnel engineer every four years and prior to any major works. Any replacement works in the tunnel should occur within 3 months of one of the planned inspections.

These inspections have identified small areas of the crown requiring supporting works within the next 10 years. Ongoing replacements of rotten timber lagging have also been recommended.

- > Gatic lids: The keyholes on the Gatic lids are near end of life. The failures are a safety concern and also result in significant access delays for maintenance. Attempts at repair have been unsuccessful. There are no like-for-like replacements of the lids; the entire frame needs to be replaced.

8.3.1.2. Cable 41 Renewal Initiatives

Cable 41 is almost at the end of its scheduled life. The strategic renewal initiatives do not change the age profile; however there will be an overall improvement in condition and thus a reduction in risk of the applicable components of the cable system. Cable 41 specific renewal initiatives are planned from the date of this plan until June 2023 are as follows:

- > Backfill Renewal – Backfill replacement above the slabs only – this is being considered as part of several options as part of the proposed Powering Sydney's Future (PSF) project. PSF is subject to a regulatory approvals and a RIT-T. If the PSF project does not go ahead then a backfill replacement as a standalone project may be considered. From an asset management perspective, the risk of cable over temperature has been mitigated by the recent derating. Commencement of this initiative will be on the advice from Manager/Power System Analysis that restoration of the rating is required and successful endorsement from the regulator.

8.3.1.3. Cable 41 Maintenance Initiatives

Current maintenance initiatives on Cable 41 are as follows:

- > Replace Gatic lids on the oil monitoring pits at Athelstane Public school (JB28/29 – both sides) as a priority. Other oil monitoring locations to be replaced under ORPS project by June 2018.
- > Take a sample of Cable 41, including a cable joint for destructive sampling to determine cable system condition. The sampling has been complete with the report due late November 2016. The purpose of this sample is to determine remaining life. If there is little remaining life then backfill replacements would no longer be considered credible.
- > Finalise installation of online oil monitoring on Cable 41 with differential pressure alarming capabilities.
- > Cable 41 Tunnels - Works to support fretting of tunnel walls/ crown as advised by tunnel engineer. This work is planned for delivery in the 2018-2023 regulatory period. As part of routine maintenance the tunnel is being inspected to monitor the tunnels for signs of further deterioration.
- > Proactive measures to protect cables in public areas from external interference
- > Repair sheath fault in red phase joint in JB5/6 when outages allow.
- > Core movement is monitored on a small number of joint bay locations which has previously seen movement by the use of Hall Effect sensors and/or Dissolved Gas Analysis. It is hypothesised that the movement is caused by wave riding caused by heavy vehicle traffic. Core movement may be present at other locations and is a major risk for Cable 41. The installation of Hall Effect sensors and oil lines to allow oil sampling is very costly. The use of other methods, such as vibration monitoring (in link pits), as a possible way to determine if wave riding is at a particular location is being considered by the Asset Manager.

8.3.1.4. Cable 41 Disposal Initiatives

There are no current Cable 41 disposal initiatives.

Table 11: Cable 41 Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Forecast Expenditure	Reference Documents
Cable 41	<ul style="list-style-type: none"> Manage Underground Cable related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) 	Keyholes on Cable 41 Gatic lids are failing	<p>Replace Gatic lids at Athelstane Public school (JB28/29 – both sides) as a priority.</p> <p>Other locations to be replaced under ORPS project</p>	Awaiting cost estimate from service provider	Need ID: 1677 Gatic lids for Cable 41 Oil Pits – Condition Assessment
Cable 41	<ul style="list-style-type: none"> Minimise environmental harm and property damage Improve OPEX Performance 	Cable 41 oil alarms are absolute pressure only.	Installation of online monitoring with differential alarm capabilities - All sites installed. Some minor defects to be addressed.	\$200,000	Internal memorandum: Online Oil Monitoring on Cable 41
Cable 41	<ul style="list-style-type: none"> Maintain network reliability Improve CAPEX Performance 	Possible overheating of Cables	Take a cable sample and joint for destructive sampling to determine cable system condition.	\$4.26 Million	Need ID: DCN42
Cable 41	<ul style="list-style-type: none"> Maintain network reliability Improve CAPEX Performance 	Possible overheating of Cables	Pending Powering Sydney's Future option review and confirmation of cable condition, replace backfill above the slabs on Cable 41.	\$127 Million	Need ID's: DCN42, DCN43
Cable 41	<ul style="list-style-type: none"> Maintain network reliability 	Stability concerns and water ingress affecting the Cable 41 tunnels.	<ul style="list-style-type: none"> Works to support fretting of tunnel walls/ crown as advised by tunnel engineer. Monitor through routine inspections with tunnel specialist. 	\$240,000	Need ID: 1088 Maintenance Plan – Underground Cable Assets
Cable 41	<ul style="list-style-type: none"> Minimise environmental harm and property damage Maintain network reliability 	Sheath fault in red phase joint in JB5/6	<ul style="list-style-type: none"> Monitor oil pressures for signs of escalating issue until repairs can be made. Repair sheath fault (Planned for repairs in Spring 2017) 	\$500,000 (service provider estimate)	Briefing Note – C41 Sheath Fault JB5/6

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Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Forecast Expenditure	Reference Documents
HV Cables outside substations	<ul style="list-style-type: none"> Manage Underground Cable related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) Maintain network reliability 	<ul style="list-style-type: none"> Members of the public digging in the vicinity of TransGrid HV cables 	<ul style="list-style-type: none"> Monitor via daily patrols of Cable 41 and 42. Proactive approach in communication with contractors via DBYD. Provide TransGrid "standby" to contractor during works that potentially impact on the cable installation. 	Not Available	Maintenance Plan – Underground Cable Assets
Cable 41	<ul style="list-style-type: none"> Maintain network reliability 	<ul style="list-style-type: none"> Potential cable joint core movement on Cable 41 	<ul style="list-style-type: none"> Monitor for core movement via DGA and core movement sensors as part of routine maintenance. Consider further investigations of core movement in other areas. 	Not Available	Maintenance Plan – Underground Cable Assets

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8.3.2. Cable 41 Maintenance Program

Routine patrols mitigate and address the possibility of damage to the cable by external parties. The greatest routine maintenance cost on this cable is the daily patrols. This cable plays a vital role in the reliable supply of electricity to the Sydney CBD and surrounding suburbs. Repair times are long, very costly and very disruptive to the public. These patrols have prevented damage on a number of occasions and as such there will be no changes to the frequency of this item. In addition to the daily patrols, TransGrid provides a “standby” to monitor safety aspects during works by an External Party in the vicinity of a TransGrid underground Cable.

Cable 41 is 37-years old, almost at end of life. This drives the frequency inspection and maintenance tasks. For example, DGA of oil samples from the feed/stop joints on Cable 41 are completed on an annual basis, whilst Cable 42, an oil cable within the first 50% of life is completed on a 3-yearly basis. The older asset would naturally have more defects.

Cable 41 oil pressures are managed by analogue gauges and alarm contacts which operate on “absolute” pressures. The current three-tier oil pressure alarm system is likely to be activated only in cases of large oil loss. To address this issue an online system with differential alarm functionality has been installed. Once the system has been proven functional the gauge reading inspection task (monthly) will be scaled back to a 6-monthly task, to be completed at the same time as the alarm checks.

The “Underground Cables Condition Monitoring Manual” outlines acceptable limits for inspection and maintenance measurements and the required responses.

8.4. Cable 42 Asset Review

Cable 42 runs from Sydney South Substation to Haymarket Substation. It is an oil-filled cable and operates at 330kV and was commissioned in 2004 with a nominal lifespan of 40 years. The cable is now approximately 10 years old and will remain within the first half of its nominal lifespan at the end of the 2014 -19 period. It is in good condition and has not sustained any failures.

The MetroGrid Tunnel provides a path from Sydney Park to Haymarket Substation for Cables 42 and 45. It was completed in 2003 and has a specified design life of 100 years. Two main pumps (and one emergency backup) are in the sump located 620 metres from Sydney Park access shaft. A Ground Water Treatment Plant (GWTP) has been installed at Sydney Park. The GWTP treats the groundwater that seeps from the MetroGrid cable tunnel walls before final discharge to the adjacent Munni Channel. Solids unable to be discharged into the channel are diverted to the Sewer.

8.4.1. Emerging Issues, and Renewal and Maintenance Initiatives

Table 12 maps out the line of sight of the Cable 42 emerging issues, renewal, maintenance and disposal initiatives to the Asset Management Objectives.

8.4.1.1. Cable 42 Emerging Issues

Cable 42

Cable 42 is monitored by a Cable Monitoring System (CMS). The CMS monitors major functions of the cable including temperature readings each metre along its length and fluid pressure at each stop/feed joint.

Similarly to Cable 41, Cable 42 is installed direct buried in 14:1 sand cement bedding. This is expected to be subject to similar degradation to Cable 41 bedding. The installation was also designed for a lower ground temperature than is now being indicated by the CMS. These two issues have the potential to cause the cable to operate at a higher temperature than designed, however at present the CMS history indicates that the cable has never exceeded its thermal operating limit since commissioning. The temperature monitoring and dynamic rating functionality of the CMS removes the need to derate the cable due to these higher ground temperatures.

The L1/L2 pressure alarms require the CMS host to be operational. Only the final level alarm (L3 Trip) is independent of the host. An oil leak would not be detected until the cable trips if the host is not operational. In that time significant oil loss would have occurred. Redesigning the alarm system when the CMS is replaced can allow for full functionality without the host.

Many of the electronic components of the CMS will reach the end of their nominal lifespan during the 2004-2019 period, and condition assessments indicate that they will require renewal consistent with this timeframe.

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Additionally, the system operates software that is expected to become unsupported, and the updated software is expected to be incompatible with the current electronic control components. Without a functioning CMS, fluid pressure alarms will be non-operational.

Cable 42 Associated Infrastructure

Current and emerging issues have been identified concerning the MetroGrid Tunnel, which provides a path from Sydney Park to Haymarket Substation for Cables 42 and 45. It was completed in 2003 and has a specified design life of 100 years.

Due to contractor insolvency some aspects of the tunnel were not completed. This has resulted in problems with the tunnel, in particular:

- > Water ingress.
- > Infrastructure and steel fittings corroding and failing.

The life extension project to address the above issues was closed off, despite several omissions, some posing significant concerns. The residual works from this project are as follows:

- > Replacement of the pumping station and associated rising main and auxiliary main (urgent works).
- > Repairs of various galvanising coatings.
- > Replacement of heavily corroded steelwork.
- > Replacement of SPK airlock roller door, panel door and associated frame.
- > Completion of tunnel survey and installation of survey points for the purpose of ongoing tunnel subsidence monitoring.

In addition to these outstanding items, condition assessments on the condition of the tunnel recommend that various works would be required to enable the tunnel to meet its nominal lifespan. These findings include renewal of the following:

- > Cable tunnel management system.
- > Tunnel ventilation.
- > Australian Technology Park panels.

Two main pumps (and one emergency backup) are in the sump located 620 metres from Sydney Park access shaft. The pumping of the oxide sludge laden water from the cable tunnel places greater wear on the pumps. With the current tunnel conditions, each pump has a life of 12 months and is replaced on a rotating basis during the 6-monthly sump maintenance.

8.4.1.2. Cable 42 and Associated infrastructure Renewal initiatives

The following renewal initiatives on Cable 42 and associated infrastructure are planned from the date of this plan until June 2023:

- > Renew CMS and local controllers, provide connection to the OLCM server, and incorporating oil alarm functionality that is independent of the CMS Host.
- > Complete Cable Tunnel Accessories Renewal and remaining items from the life extension project.

8.4.1.3. Cable 42 Maintenance Initiatives

The following maintenance initiatives on Cable 42 and associated infrastructure are planned from the date of this plan until June 2023:

- > Proactive measures to protect cables in public areas from external interference.

8.4.1.4. Cable 42 Disposal Initiatives

There are no Cable 42 disposal initiatives.

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Table 12: Cable 42 Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Forecast Expenditure	Reference Documents
Cable 42	<ul style="list-style-type: none"> Maintain network reliability 	Ground temperatures higher than design assumption	<p>Ensure that the Cable 42 DTS remains operational to protect against thermal runaway.</p> <p>Renew Cable 42 CMS - Replacement required completion June 2016. DTS failed March 2016. Due to project delays anticipated completion is March 2017.</p>	\$947,000	<p>Need ID: DCN440</p> <p>Cable 41 30 Year Condition Assessment.</p> <p>Cable 41 Investigation Summary Report</p>
HV Cables outside substations	<ul style="list-style-type: none"> Manage Underground Cable related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) Maintain network reliability 	<p>Members of the public digging in the vicinity of TransGrid HV cables</p>	<ul style="list-style-type: none"> Monitor via daily patrols of Cable 41 and 42. Proactive approach in communication with contractors via DBYD. Provide TransGrid "standby" to contractor during works that potentially impact on the cable installation. 	Included in routine maintenance budget.	<p>Maintenance Plan – Underground Cable Assets.</p> <p>Management of External Work in the Vicinity of TransGrid Underground Cables</p> <p>Information Brochure: Requirements for working in the vicinity of TransGrid Underground Cables (public document)</p>
All cable assets	<ul style="list-style-type: none"> Improve OPEX Performance Improve CAPEX Performance 	Not all maintenance checksheets are loaded into Ellipse.	Move cable maintenance onto AIM in the stage 2 rollout	\$1.342 Million (includes both stages for all asset classes)	Need ID:1068 (IT Project)

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Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Forecast Expenditure	Reference Documents
Cable 42 MetroGrid cable tunnel	<ul style="list-style-type: none"> Manage Underground Cable related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) Maintain network reliability 	<p>MetroGrid tunnel accessories in poor condition.</p> <p>Poor condition of tunnel steelwork not remediated during life extension project.</p>	<p>Complete refurbishment and replacement of tunnel steelwork and air lock doors.</p> <p>Replace Cable Tunnel Management System (CTMS)</p> <p>Move sump pump control functionality from CTMS to GWTP.</p> <p>Update the GWTP to enable export of outflows (water extraction licence reporting purposes)</p> <p>Complete ventilation repairs and replacements.</p> <p>Complete Australia Technology Park (ATP) repairs and replacements.</p>	<p>\$3.0 Million</p> <p>PAD Issued to be complete by July 2017.</p>	<p>Need ID: DCN560</p> <p>PDR T.2277 MetroGrid Tunnel Life Extension</p>

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8.4.2. Cable 42 Maintenance Program

Routine patrols mitigate and address the possibility of damage to the cable by external parties. The greatest routine maintenance cost on this cable is the daily patrols. This cable plays a vital role in the reliable supply of electricity to the Sydney CBD and surrounding suburbs. Repair times are long, very costly and very disruptive to the public. These patrols have prevented damage on a number of occasions and as such there will be no changes to the frequency of this item. In addition to the daily patrols, TransGrid provides a “standby” to monitor safety aspects during works by an External Party in the vicinity of a TransGrid underground Cable.

The completion of the pumping station and rising main replacements in 2016 has allowed for the removal of the requirement for three-monthly inspection of the rising main. The GWTP inspections and maintenance are as specified by the manufacturer. About 80,000 to 100,000 litres per day is pumped from the tunnel sump to the GWTP at Sydney Park. About 10% of the extraction is normally sent to Trade Waste and the rest of the treated water sent to the adjacent canal. The management of equipment that process these volumes of water is a significant portion of the maintenance costs for Cable 42.

The maintenance tasks for Cable 42 are outlined in *Maintenance Plan – Underground Cable Assets*.

The current Maintenance Plan assumes a functional CMS. In the event of CMS failure pressure readings from site would have to increase in frequency significantly.

The maintenance initiatives directly drive the routine maintenance regimes which are detailed within the Underground Cables Maintenance Plan.

In 2015 TransGrid was directed to obtain a ground water extraction licence. The compliance requirements of reporting to the applicable state government department must not be overlooked. These requirements are outlined in the Maintenance Plan.

8.5. Cable 43/44 and 45 Associated Infrastructure Asset Review

Cables 43/44 run between Holroyd and Rookwood Road substations. They are XLPE insulated operating at 330kV and were commissioned in 2014 with a nominal lifespan of 40 years. The cables are in an as-new condition.

Cable 45 is of the same construction between the Haymarket basement and Sydney Park. It operates at 132kV and was commissioned in 2012. Ausgrid owned 132kV rated cable connect to the Haymarket GIS and Beaconsfield substations.

Cable 43/44 temperature is monitored with a Distributed Temperature System (DTS). The optical fibre is located in a micro-duct attached to the centre phase conduit for each cable. Electronic components of the DTS will reach end of their nominal lifespan in 2019, however, based on current condition they are expected to remain serviceable throughout the period. The Cable system was designed for higher ground temperatures than Cable 41 and 42 and as there is no oil monitoring, the CMS is a non-critical system. This makes “run to failure” a credible option. There are currently no other emerging obsolescence issues that have been identified. The operating temperatures of Cable 43/44 and the performance of the DTS will be monitored by the Asset Monitoring Centre and Asset Manager on ongoing basis in order to assess the future requirements of the system.

The monitoring functions for the Cable 45 DTS are performed by the Cable 42 “CMS Host” machine. The database, monitoring software, and contact equipment are separate from Cable 42 functions and suffer from the end of life issues noted in 8.4.1.1.

8.5.1.1. Cable 43/44 and 45 Emerging Issues

Recent land developments near Cable 43/44 on section 10 (Palmer and Parkes St in West Guildford), has highlighted an installation issue. Instead of the Earth Continuity Conductor (ECC) conduit being placed in the main ductbank, it was installed above in its own 25 MPa trench (shown below). This blocks installation of service crossings over the top of the asset as the thin trench is treated the same as the main concrete bank under the Power System Safety Rules. The treatment of this cable trench requires review by the safety rules committee.

8.5.1.2. Cable 43/44 and 45 Renewal Initiatives

There are no renewal initiatives for Cables 43/44. The Cable 45 DTS is run on the same server as the Cable 42 CMS. The temperature monitoring and dynamic rating functionality on Cable 45 will be updated with the Cable 42 CMS renewal.

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8.5.1.3. Cable 43/44 and 45 Maintenance Initiatives

The resultant strategy for Cable 43/44 and 45 and associated infrastructure is to continue with the existing maintenance regime. In addition, the strategic initiatives identified in Table 11 will be implemented to address the current and emerging issues discussed above.

These cables are still within their warranty. There will be some significant costs to complete a thorough inspection prior to the end of defects liability period in the first half of 2017. These costs have been budgeted under the residual costs of the project. After this period the annual maintenance costs will be quite low, due to the cable being XLPE, in ductbank, and mostly being located in areas unlikely for damage by external parties.

8.5.1.4. Cable 43/44 and 45 Disposal Initiatives

There are no disposal initiatives for Cables 43/44 and 45.

Table 13: Cable 43/44 and 45 Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Forecast Expenditure	Reference Documents
Cable 43/44 CMS	<ul style="list-style-type: none"> Improve CAPEX Performance Improve OPEX Performance 	<p>Computer components of the Cable 43/44 DTS approaching end of nominal lifespan (2019).</p>	<ul style="list-style-type: none"> Continue to monitor the situation. Further action to be considered if health and obsolescence issues begin to emerge. A review for the continued need of the system should be undertaken between January and July 2018. 	Incorporated in Asset Management BAU OPEX budget.	Manufacturer's manuals
Cable 43/44 Section 10	<ul style="list-style-type: none"> Improve OPEX Performance 	<p>Services cannot be installed over Cable 43/44 Section 10 without taking a cable outage.</p>	<ul style="list-style-type: none"> Review classification of the ECC trench in section 10 under the Power System Safety Rules and appropriate safe work methods (if any) for working whilst in service. Consider scabbling the top off the mini trench in targeted areas during the upcoming cable outage. 	Not available - Under review	UrbanGrowth Development

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8.5.2. Cable 43/44 and 45 Maintenance Program

The resultant strategy for Cable 43/44 and 45 and associated infrastructure is to continue with the existing maintenance regime.

These cables are still within their warranty. There will be some significant costs to complete a thorough inspection prior to the end of defects liability period. These costs have been budgeted under the residual costs of the project. After this period the annual maintenance costs will be quite low, due to the cable being XLPE, in ductbank, and mostly being located in areas unlikely for damage by external parties.

The main maintenance tasks are route patrols. As most of the route is not in roads, it is envisaged that these cables would be less likely to be struck by members of the public carrying out excavation work as reflected in the maintenance regime.

8.6. Short 132kV Cables within Substations

8.6.1.1. Emerging Issues

TransGrid has short lengths of 132kV cables in service at its Haymarket, Beaconsfield and Rookwood Road substations. The current and emerging issues associated with each are as follows:

Haymarket Substation: A total of 4 circuits connect each transformer and the reactor to the 132kV Gas Insulated Switchgear (GIS). These circuits were commissioned in 2004 with a nominal lifespan of 40 years. The cables are in good condition.

Cables 43/44 run between Holroyd and Rookwood Road substations. They operate at 330kV and were commissioned in 2014 with a nominal lifespan of 40 years. The cables are in an as-new condition.

Beaconsfield Substation: Beaconsfield has the following 132kV cables, commissioned in 2012:

- > One circuit, from the South switch room to No.1 Reactor.
- > Three circuits, between the northern switch room and each capacitor and No.2 Reactor.
- > Two "Tie" circuits, between the South and old West switch-rooms.

The overall health of the underground cables and associated supporting structures is considered satisfactory. They have no current or emerging compliance or obsolescence issues.

Rookwood Road Substation: One circuit connects the 132kV Shunt Reactor to the 132kV Gas Insulated Switchgear (GIS). The overall health of the underground cables and associated supporting structures is considered satisfactory. They have no current or emerging compliance or obsolescence issues.

8.6.1.2. Renewal Initiatives

There are no renewal initiatives for the short 132kV cables within substations.

8.6.1.3. Maintenance Initiatives

The resultant strategy for these cables and associated infrastructure is to continue with the existing maintenance regime.

8.6.1.4. Disposal Initiatives

There are no disposal initiatives for short 132kV cables within substations.

8.7. Short 132 kV Cables within Substations Maintenance Program

The resultant strategy for these cables and associated infrastructure is to continue with the existing maintenance regime. Works are minor in nature when compared to the much longer 330kV cables outside substations. The maintenance regime is mostly consists of inspections. Tests to check for sheath insulation and bonding system integrity occur between every 2 to 4 years.

9. Future Outlook

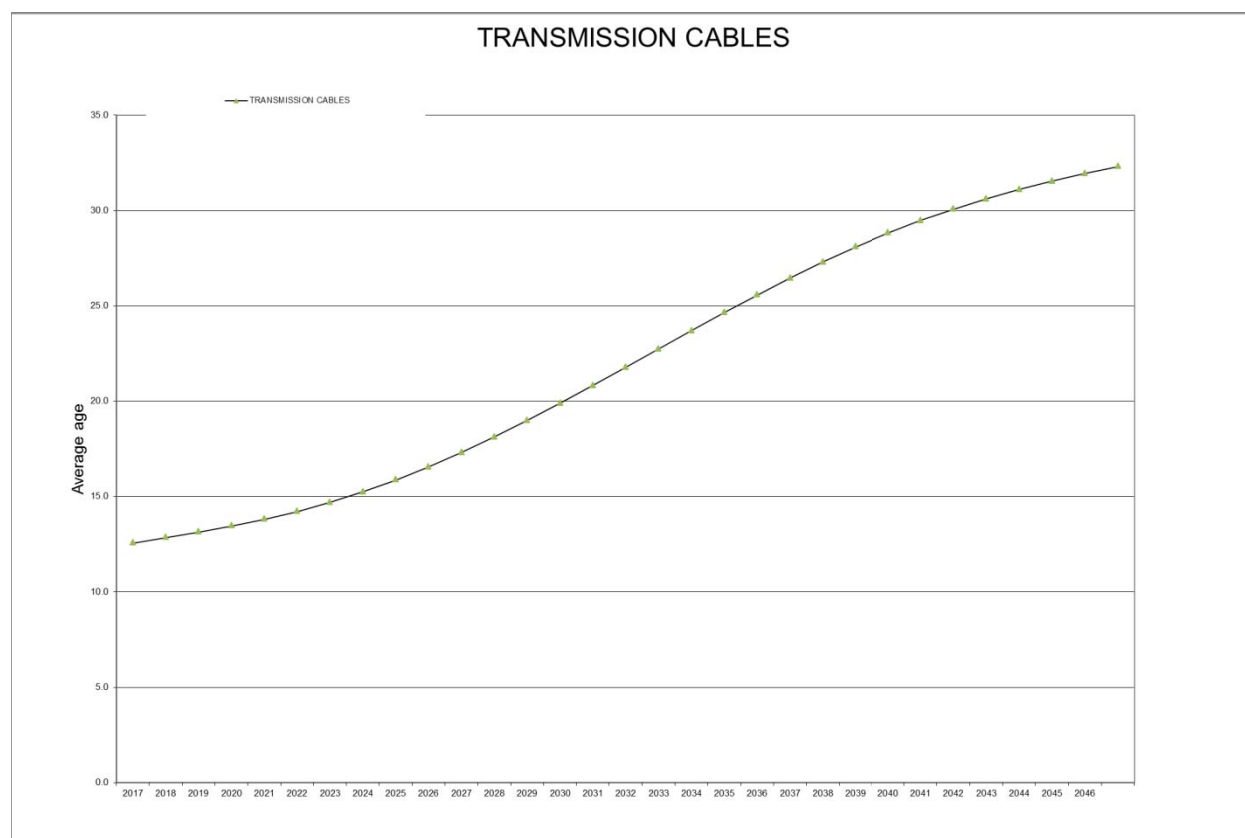
9.1. Forecast Expenditure

The forecast expenditure has predicted zero long term REPEX for transmission cables to 2046. Cable projects impacting on the asset base are generally AUGEX projects.

9.2. Forecast Expenditure

The forecast average age is shown in Figure 5.

Figure 5: Long Term Forecast Average Age



9.3. Anticipated Changes to the Asset Base

Anticipated changes to the underground cable asset base within the 2016-23 periods are as follows:

- > 220kV cables at Deer Park terminal station in Victoria
- > 132kV cables associated with transformer replacements at Beaconsfield.
- > New cables from Rookwood Road to Beaconsfield (subject to regulatory approval).

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10. Spares

Spares are items of serviceable equipment that are booked into and stored in TransGrid's storage facilities for maintenance and project purposes. This document does not cover the spares required for project purposes.

TransGrid has purchased a range of strategic spare equipment to improve the organisations ability to restore supply and system security in a timely manner, following the major failure of an in-service unit.

The spares strategy for Underground Cable assets, including required holding is described in the document "Underground Cable Assets Spares Policy" which is currently under review.

11. Asset management capability and continual improvement

For underground cable assets most routine maintenance checksheets are not being loaded into ellipse, or any other corporate information system. Reporting capabilities are also required to be improved, for example, it is impossible to run reports of monthly pressure readings over time. Having maintenance data readily available enhances asset management decision making. Stage 2 of the Asset Inspection Manager (AIM) system will include rollout to underground cables and will greatly assist in this regard.

Recording of defects into Ellipse needs improvement. A new suite of standard jobs have been created to enable useful analysis of data.

TransGrid's asset information strategy calls for continual improvement of the scope and quality of current and accumulated asset information. This extends to enhance the existing systems used for automated and online condition monitoring, to provide real-time data that ensures a robust evidence base for time-critical decision making. This asset information strategy is set out in the Asset Information Strategy document.

Asset management capabilities are those elements that facilitate best practice asset management decision making. These include:

- > Risk management practices.
- > Asset information.
- > Staff skills and competency.
- > Continual improvement initiatives for the system.

The table below describes the strategic asset management capabilities initiatives for the Underground Cable fleet, and their alignment with the overarching strategies in the Asset Management Strategy and Objectives document.

Table 14: Continual Improvement Initiatives

Asset Management Objectives	Asset Management Actions	Enablers / Status
Deliver a successful revenue determination	1. Documentation required for RP2 submitted	<ul style="list-style-type: none">Enhance asset management decision making through better risk management, asset data, and asset lifecycle cost optimisation.
<ul style="list-style-type: none">ISO 55001 CompliantContinually improve the Asset Management System	<ol style="list-style-type: none">Asset information improvements (governance, data, reporting and systems) implementedAsset replacement life optimisedAsset maintenance scope and frequency optimisedAsset management competency enhancedPlant and design standards optimised	<ul style="list-style-type: none">Utilisation of the risk tool to provide a more granular view of the pre and post-investment risks associated with building new or replacing assets.Asset data improved through the rollout of AIM Stage 2 to Underground Cable assets.Overhaul of the Ellipse Data rules for underground cables has been completed and implemented.

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Asset Management Objectives	Asset Management Actions	Enablers / Status
<ul style="list-style-type: none"> AS 5577 compliant Continually improve the Electricity Network Management System 	7. Formal Safety Assessments complete and externally audited	<ul style="list-style-type: none"> Public Electricity Safety Awareness (PESA) Plan reviewed on an annual basis.
Improve CAPEX performance	8. REPEX and risk scenarios understood 9. Investment governance/ prioritisation/ optimisation process enhanced	<ul style="list-style-type: none"> Utilisation of the risk tool to provide a more granular view of the pre and post-investment risks associated with building new or replacing assets. ALARP analysis completed for proposed RP2 maintenance activities. NPV analysis completed on all solutions to ensure value for money.

Asset management capabilities are those elements that facilitate best practice asset management decision making. These include:

- > Risk management practices.
- > Asset information.
- > Staff skills and competency.
- > Continual improvement initiatives for the system.

12. Implementing the Strategies

To implement the strategic renewal, disposal and maintenance initiatives stemming from this document, actions are to be established via the:

- > Underground Cables Maintenance Plan: The maintenance plan outlines the routine maintenance tasks and frequencies for each asset type.
- > Capital Works Program: The capital works program outlines the approved asset renewal and disposal projects.
- > Asset management enabler plans detail how the asset management capability improvements are being implemented

The Transmission Lines and Cables Asset Manager is responsible for preparation of the maintenance plans and referring the renewal and disposal initiative to the network investment process. Field Services is responsible for delivering the maintenance plans as per the Service Level Agreements, and Portfolio Management group/Project Services are responsible for delivering the renewal and disposal initiatives detailed in the approved capital works program.

13. Monitoring and review

Implementation of the Underground Cable Renewal and Maintenance Strategy is monitored and reviewed by the Transmission Lines and Cables Asset Manager, Manager/Asset Strategy and Asset Management Committee annually.

14. Roles and Responsibilities to Develop this Asset Strategy

The roles and responsibilities of those responsible for the development of this asset strategy are as follows:

- > The Asset Strategy Manager is responsible for the approval of this strategy.
- > The Transmission Lines and Cables Asset Manager is responsible for the development and regular review of this strategy. The document will be reviewed biannually and as significant changes to investment needs become apparent.

15. Change history

Revision no	Approved by	Amendment
4	L. Wee Group Manager/Asset Strategy	Formatting Update.
3	L. Wee Group Manager/Asset Strategy	Review and update to deliver the 2016/17 Business Plan and further enhance the strategy. Significant revisions made due to the change in template
2	L. Wee Group Manager/Asset Strategy	Review and update to deliver the 2015/16 Corporate Plan and further enhance the strategy.
1	Garrie Chubb Group Manager/Asset Performance	Updated to reflect the continual improvement in the “top down” approach for the line of sight to the Asset Management Strategy and the Corporate Plan and an enhanced description of the asset management decision process and the strategic initiatives to be undertaken.

16. References

Asset Management Strategy and Objectives
Asset Management System Description
Underground Cables Maintenance Plan
Capital Works Program list (maintained by the Portfolio Manager)

17. Attachments

Nil