Northern Suburbs Cable replacement (NMP1)

Regulatory Business Case (RBC) 2024-29

PowerWater

Contents

1. Summary

This business case has been prepared to support the 2024-29 Regulatory Proposal. The business case demonstrates that Power and Water has undertaken appropriate analysis of the need for the expenditure and identified credible options that will resolve the need and ensure that Power and Water continues to meet the National Electricity Objectives and maintain the quality, reliability, and security of supply of standard control services and maintain the safety of the distribution system.

The proposed investment identified in this business case will undergo further assessment and scrutiny through Power and Water's normal governance processes prior to implementation and delivery.

This business case addresses the increasing network risk posed by type issues present in the cable population in the northern suburbs of Darwin.

1.1 Business need

Power and Water has identified a type issue with cables that were installed in the northern suburbs of Darwin prior to 1985. At the time, the XPLE insulation material was a new technology and the construction methods of the outer sheath of the cable were deficient. The result is that water can enter the cable sheath which results in deteriorating insulation and deterioration of the earth screen, making it discontinuous. These two issues can result in cable failure and impaired operation of the earthing system.

Extensive condition data obtained from four different types of testing and outage data has been analysed to assess the extent of the issue. The data indicates that between 54% and 79% of the cable is highly likely (95% confidence) to have reached the end of its serviceable life. This is supported by the disproportionate amount of the northern suburbs cables that are found to be failing and interrupting supply, as recorded in the outage data. While the northern suburbs cables account for only 16% of the cable fleet, they have been contributing an average of 47% of the cable outages as measured by SAIDI and SAIFI.

This business case provides evidence of the type issues present in the cable population and demonstrates that without appropriate mitigation, there will be a continued and increasing risk to the network.

There is an existing program of works, which commenced in 2013 and was approved by the AER in the 2019-24 determination, which will replace approximately 21.6km of the cables by June 2024 leaving 122.0 km of the targeted pre-1985 XLPE cable in the northern suburbs.

1.2 Options analysis

To address the identified need, a range of options were identified and assessed. Two credible options were identified as shown in Table 1.

Table 1 Summary of Options

No.	Option Name	Description	Recommended
1	Replace on failure	Replace on failure (Counter factual). This option would involve continuing to repair or replace the faulted section of the cable upon failure.	No
2	Targeted (risk based) replacement	Targeted (risk based) replacement. Implement a program to continue the existing cable testing	Yes

		program and replace cables only if they fail testing.	

As part of a holistic assessment, non-network solutions, capex/opex trade-offs and retirement or derating options were also considered but found that none of these options addressed the underlying network issues.

A cost benefit analysis was completed for both options where the risk reduction, compared to Option 1, was used as the benefit achieved by the option. When assessing Option 2, the risk and cost benefit assessment was undertaken for different rates of cable replacement to identify the optimal program structure. A program which targeted the highest risk cables first and replaced approximately 8km of cable per year was determined to provide the best outcome.

1.3 Recommendation

The recommended option is Option 2 – Proactive replacement at an estimated cost of $24.4 million (real 2021/22) for the replacement of 37.5km of cable across the 2024-29 regulatory period.

Option 2

This option reflects a continuation of the NMP1 Northern cable replacement program operating since the commencement of the current regulatory period, hence the scope of work and assessment practices are known and proven to be deliverable. The approach builds on work implemented by Power and Water since the type issue was first identified in 2013.

The recommended option:

- is aligned to our strategy and asset objectives.
- mitigates the risk to an appropriate level over an acceptable timeframe given the limitations of understanding where the deteriorated services are located and capacity of the field crews to increase the replacements to the proposed volumes.
- is aligned to customer expectations for maintaining the reliability and safety of the network.

Table 2 shows a summary of the expenditure requirements for 2024-29 regulatory period.

Table 2 Annual capital and operational expenditure ($'000s, real 2021/22)

Item	FY25	FY26	FY27	FY28	FY29	Total
Capex	4,875	4,875	4,875	4,875	4,875	24,375
Opex	-	-	-	-	-	-
Total	**4,875**	**4,875**	**4,875**	**4,875**	**4,875**	**24,375**

The cost for total replacement of the type issue for affected assets (including the expenditure requested for the 2024-29 regulatory period) is estimated to be $76.9m (real 2021/22). Expenditure is expected to continue into subsequent regulatory periods.

2. Identified need

This section describes the ongoing issues being experienced in Darwin's northern suburbs with XPLE type cables that were installed prior to 1985.

In 2013 Power and Water identified that the XLPE cables installed before 1985 had a type issue that was causing early deterioration of the earthing screen and failure of the cables. This PBC describes the issue, historical approaches to manage the issue, and the current risk it poses to network reliability and safety.

2.1 Asset description

Underground cables are installed throughout the network and are comprised of a conductive core (typically copper or aluminium) surrounded by insulation and protective layers. The two main types of insulation in use are Cross-linked polyethylene (XLPE) and Paper Insulated Lead Covered (PILC) cables. XLPE started to replace PILC in the 1960's as a long life alternative with no electrical property degradation.

Following Cyclone Tracy in 1974 a significant portion of the affected network was rebuilt underground, and then in the early 1980's several new suburbs were established in the northern suburbs of Darwin. As part of these works a significant volume of HV XLPE cable was installed between 1975 and 1985. These cables make up a large portion of Power and Water' XLPE cables (143.7 km or 16% of total HV cable population).

2.2 Drivers of deterioration

Towards the end of the 1970's, Power and Water recognised that due to the materials and construction method used, XLPE cables undergo a degradation process called water treeing and an accelerated corrosion of the neutral / earthing wires when exposed to moisture and electrical stress. In the early 1980's an improved version of XLPE called TR-XLPE was introduced which has shown improved field service performance[1, 2] and is now the standard specification.

However, due to the network growth between 1975 and 1985, there is a significant volume of the early versions of XLPE cable in Darwin's northern suburbs. The defect results in water ingress that causes deterioration of the insulation and ultimately failure of the cable or the earth screen.

A compounding factor is that the cables installed in the northern suburbs have an aluminium screen. Aluminium oxidises in the presence of water causing the screen to turn into a powder and become electrically discontinuous (open circuit). The oxidisation process also increases the volume of the aluminium, causing the cable to swell and deform, and is a likely factor in the insulation failures.

Table 3 shows the total volumes of the assets with the type-issue currently installed in the northern suburbs of Darwin. Table 13 in Appendix B.1 provides a breakdown of the volumes by suburb.

[1] LONG-LIFE XLPE INSULATED POWER CABLE, Nigel HAMPTON, NEETRAC, Georgia Tech, USA

[2] Global Trends and Motivation Toward the Adoption of TR-XLPE Cable, The Dow Chemical Company

Table 3 Volume of cables (km) with type issue by installation year

	1970 – 1979	1980 – 1985	Grand Total
Single phase	0	73.97	73.97
Three phase	26.08	43.64	69.72
Total	**26.08**	**117.62**	**143.69**

Figure 1 shows the geographical area where the affected cable is located. Approximately 21.6km of the cable fleet has been replaced or is planned to be replaced as a result of failing tests.

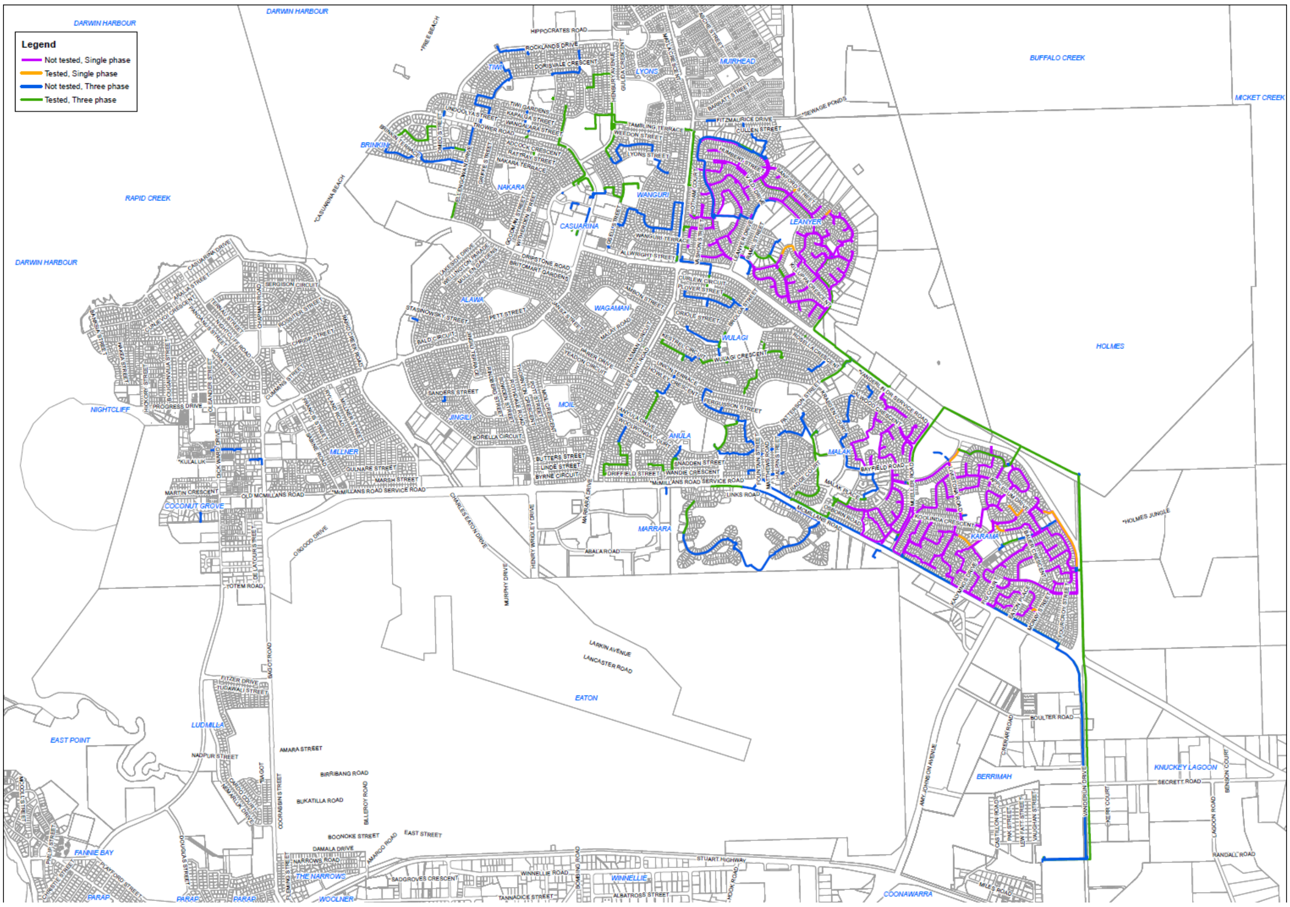

Figure 1 Northern suburbs cables identified with the type issue

2.3 Historical and current management programs

The risk of the pre-1985 XLPE cables was first identified in 2013. As part of the 2014-19 regulatory determination (by the Utilities Commission of the Northern Territory), the need to invest to mitigate the risk was identified and a moderate replacement program for $7.7 million (real $2013/14) was initiated[3].

[3] D2013/323329 Sub8260 - BNI - Power and Water High Voltage (HV) Cable Replacement Program

In the 2019-24 regulatory determination (by the AER), the program was continued with a larger volume as the size of the problem and risk it posed was more clearly defined. The AER allowed for the replacement of 44.2km of the cable with a budget of $20.6 million (real $2017/18).

However, in 2020 the implementation of the program was delayed:

- The COVID19 pandemic impacted the business and its ability to obtain appropriate expertise from interstate to continue with testing and project development. This impacted the dry season which is the period where the majority of construction takes place.
- The program delivery method in place was based on engaging contractors once a cable was tested and confirmed to be at end of life. However, this resulted in multiple small packages of work being issued, increasing the time required for preparing packages of work and going through the market tendering process, therefore resulting in delays the project.

During 2021 a concerted effort was made to improve the delivery method to improve the efficiency and speed of delivery. The change has been to package the work into larger scopes of work, using the expanded database of testing results, to obtain economies of scale from the civil contractor(s). Contracting has also changed from a contract per cable to a period contract to secure the services of the contractor(s):

- Power and Water has awarded contracts to three civil contractors who will provide between three and five crews for eight month to focus on the northern suburb cables. They are expected to complete approximately 13km of cable installation during 2022.
- During the eight month contract, Power and Water will establish another contract that will be awarded to a single contractor to cover a period of two years with an optional extension of two years. The contract will require the contractor to provide up to seven crews and it will cover the civil components of all underground works (including the government funded UPP, Northern Suburbs cables, Cullen Bay LV Cables and the Port Feeder replacement).

This revised approach will ensure certainty of delivery capacity and the competitive market process will facilitate an efficient unit rate.

Figure 2 shows the actual historical volumes and costs (adjusted to 2021/22 dollars) that have been implemented and the projected volumes and expenditure to the end of this period. The step increase from FY22 to FY23 is a result of the new contracting arrangements in place that has, and will continue to enable an increased volume of replacement.

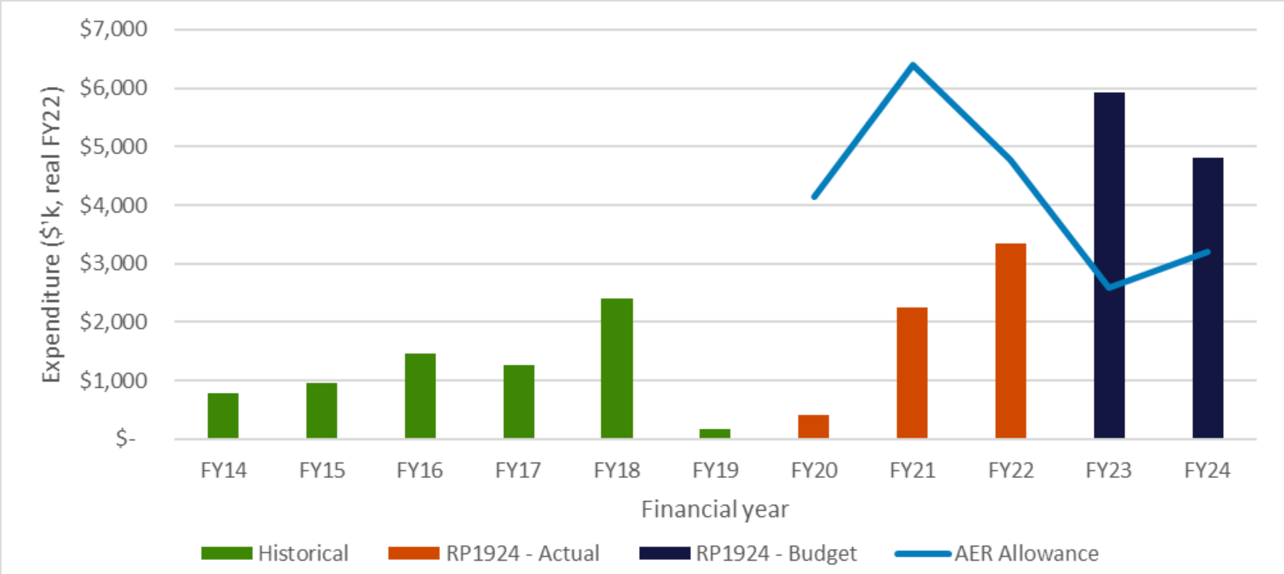

Figure 2 Expenditure on the northern suburbs cables

By end of the current regulatory period, Power and Water expects to have replaced 25.4 km of cable. The estimated cost to the end of the current regulatory period is $15.9 million compared to the original forecast included in the capex allowance of $21.1 million (real 2021/22), which is 75% of the forecast expenditure.

Project delays due to COVID and the changed contracting approach has also resulted in an increased unit rate. This is primarily due to increased material and service costs impacted by global supply chain pressures, increasing costs of fuel and polymer materials arising from the conflict in Ukraine and increasing inflationary costs.

It is estimated that there will be 122.0 km of the pre-1985 XLPE cable with the identified type-issue still in service on the network at the start of the next regulatory period (1st July 2024).

2.4 Asset condition

Power and Water undertakes cable testing to assess the condition of its cable asset fleet. The testing is carried out as a business-as-usual practice and completed in line with common industry practice. The testing requirements are set out in the Cable Maintenance Specification. In general, cables are tested:

- prior to returning the cable to service following repair of a fault
- prior to returning the cable to service when an associated asset is maintained and the cable is disturbed, for example, when a cable is disconnected then reconnected without work being undertaken on the cable specifically.
- targeted proactive testing of cables to understand fleet condition or to investigate a specific cable or issue. For example, testing of cables in the northern suburbs to gain a better understanding of the extent of the type-issue.

There are four types of tests that Power and Water undertakes:

- **Sheath integrity**: this is a pass or fail test that assesses if there is damage to the cable sheath by assessing the resistance between the metallic screen and outside of the cable sheath (outer covering). High resistance is good.

- **Insulation resistance**: this is a pass or fail test that measures the insulation between the phases of the cable. High resistance is good.
- **Earth continuity**: this is a pass or fail test that assess if there is a continuous earth screen along the cable by assessing the resistance of the earth screen. Low impedance is good.
- **Tan Delta**: this tests the condition of the cable insulation. The result provides the degree of cable deterioration and can be trended over time to assess the progressive deterioration of cable condition.

Failing any of the four tests indicates that there is an issue with the cable. In the northern suburbs, given the known type-issue, failure of a test indicates end of serviceable life for the cable.

Power and Water has an ongoing cable testing regime in the Northern Suburbs. Tests are completed through return to service testing of cables and associated assets and targeted proactive testing where issues are suspected and for planning the replacement program. To date, 39.2km of cables comprised of 109 segments have been tested between 2013 and 2021.

The targeted proactive testing has been prioritised based on past performance and cable criticality:

- cables with evidence of historical outages or poor test results
- the impact on reliability in terms of the number of customers that would be affected by an outage, and
- the proximity of the cable's physical location to public infrastructure to provide a proxy for the impact on public safety.

As a result of this in-depth testing regime, Power and Water has developed a significant database of test results since the type-issue was first identified. Table 4 summarises the outcomes.

Table 4 Test results

No. tests failed[1]	Segments	Length (km)	Percentage (by km)
Passed all tests	42	13.0	33%
Passed tests post return to service[2]	3	0.7	2%
Failed 1 test	34	11.5	29%
Failed 2 tests	18	8.1	21%
Failed 3 tests	11	5.3	14%
Failed 4 tests	1	0.6	1%
Total	**109**	**39.18**	**100%**

1. Note: not all tests are always performed on each cable, typically only one or two tests are done.
2. These cables faulted and were repaired prior to return to service

The results shows that 67% of the cables failed at least one of the tests or were tested due to a fault occurring. Power and Water has used population sampling statistics to assess how well this represents the rest (untested portion) of the northern suburbs pre-1985 cable fleet.

The cables tested cover all cable sizes and configurations (1 phase and 3 phase) and are located across the entire northern suburbs area. While there has been less testing of the single-phase cables, since they are all the same construction materials and were all installed within a defined period of time using the same method, the results are expected to be indicative of the fleet. The additional testing scheduled includes a higher proportion of single-phase cables.

Not all cables have been tested as a result of having a fault. As described above, testing is undertaken as standard practice when a cable is disturbed while working on another asset (e.g. an RMU). and planned proactive testing has also been undertaken across the northern suburbs. The breadth of the testing undertaken and the drivers for the testing limits any bias of the data set only reflecting failed cables.

This sample is considered to be representative of the population of all cables in the northern suburbs.

Standard population sampling statistics results in a 95% level of confidence that between 54% and 79% of the fleet (67% ± 12%) have deteriorated to the point where they would fail testing and have therefore reached end of functional and technical life.

This provides strong evidence that the fleet has reached the end of its serviceable life. As required by the National Electricity Objectives, Power and Water must undertake actions to mitigate the risk posed to network reliability and safety.

The consequence of failure and resulting risk are discussed in the following sections.

2.5 Consequence of failure

There are three key consequences of cable failure that are aligned to the Risk Quantification Procedure. These are:

- **Health and Safety**. There are three failure modes that can impact safety:
    - Cable fault can cause potential rise on exposed metallic objects or on the ground which can pose a risk of electric shock or electrocution to the public and workers. This is exacerbated by the failure of the cable earth screen. A report by Safearth Consulting in 2017[4] identified that due to ground conditions, the earth potential rise, and therefore the risk of electric shock, will increase without a continuous earth.
    - Failure of the earth screen continuity can impact the functioning of protection devices which require the earth return path.
    - Physical damage to the cable, such as excavation works digging up cables, can cause the cable to fault. In these circumstances the correct operation of the protection devices and a continuous earth screen to manage the fault current is required. If the earth screen is discontinuous, the fault current has no return path which will increase the likelihood of hazardous voltages and therefore the risk of electric shock or electrocution of the workers who damaged the cable.

  Fortunately, there have not been any reported incidents of electrocution or shock as a result of cable failure.

[4] HV Cable Screen Deterioration – Wulagi, Safearth Consulting, August 2017

- **Service delivery.** Asset failure generally results in an outage to customers. This has been measured in the outage data and is included in the SAIDI and SAIFI reporting. The historical values and trends are shown in Figure 3 below. It demonstrates that while there is significant volatility from year to year, both SAIDI and SAIFI are showing increasing trends, which means decreasing reliability performance.

  Further analysis shows that the northern suburbs cables have contributed an average of 47% of the SAIDI and SAIFI caused by the cable fleet, even though the Northern Suburbs cables only make up 16% of the cable fleet. This shows that they are overrepresented in causing outages, further supporting that they are at the end of their serviceable life.

  The impact of each cable varies depending on the degree to which it is in a meshed network. In many cases, network switching can restore supply to the majority of customers. However, customers on radial feeders will be without supply until the fault is repaired.
  The quantified risk assessment shown in section 2.6 below includes the economic cost of outages to customers.
- **Direct financial costs**. Reactive repair of assets has an increased cost compared to proactive and planned replacement. Analysis of historical cost data has demonstrated that there is a significant increase in the cost of cable replacement in reactive replacement scenarios (responding to a cable fault) compared to planned replacements. The difference was estimated to be $10k (real 2021/22)[5]. This value is included in the risk analysis shown in section 2.6 below.

There is no risk to the environment, fire ignition or of property damage as a result of these cables failing.

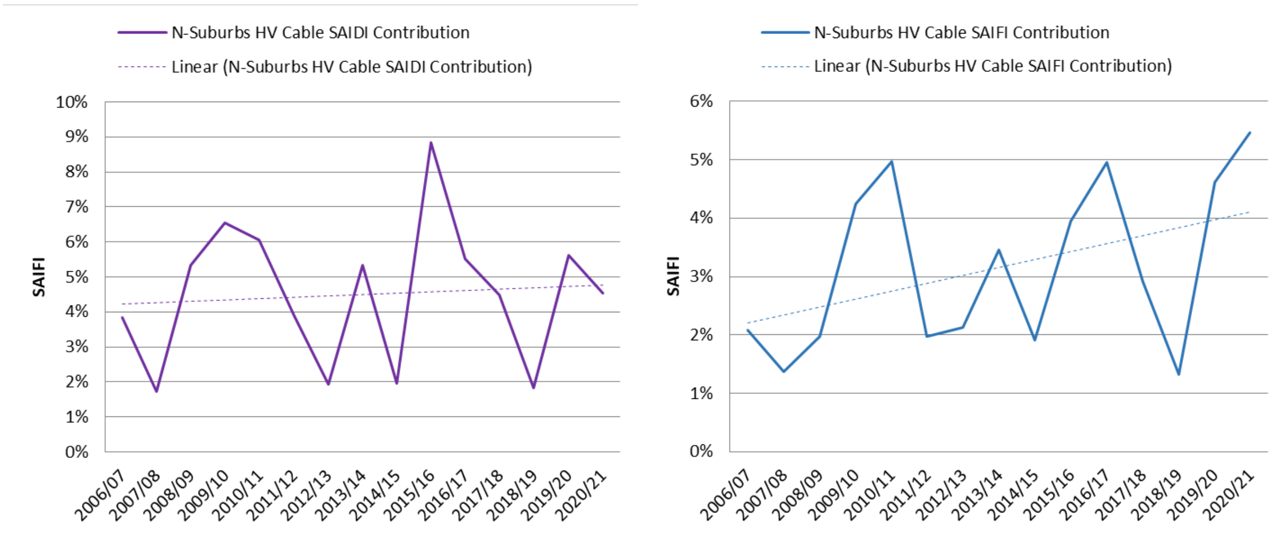

Figure 3 Reliability performance of the Northern Suburbs cables

2.6 Risk assessment

The risk posed by this cable fleet due to the identified type issue has been quantified by applying Power and Water Risk Quantification Procedure[6]. These frameworks have been developed based on good industry

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[5] Refer to Appendix A for a description of the build up of this cost.

[6] CONTROL0932, Risk Quantification Procedure for Investment Decision making

practice and take into account recent guidelines and determinations made by the AER, AS ISO 31000 Risk Management, and other professional publications.

The assessment has been undertaken based on the counterfactual case, that is, on the basis that Power and Water does not undertake any specific measures to address the risk and only addresses faults reactively. Figure 4 below shows the initial decrease in risk due to the existing committed program, then an increasing level of risk that would be incurred by Power and Water in the absences of any mitigating actions. The dominant components are the economic impacts of outages, calculated based on the Value of Customer Reliability (VCR). While the consequences of health impacts are significant, the probability of them materialising is considered very low. Historical data of health impacts is not available. Therefore, probabilities suggested by Ofgem as documented in the Risk Quantification Procedure have been applied.

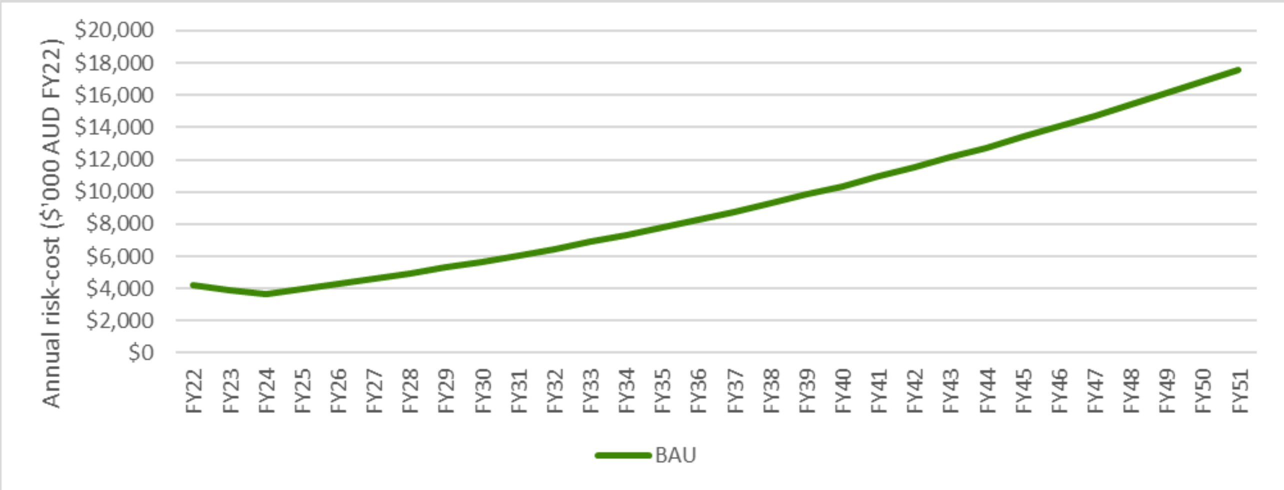

Figure 4 Annual risk cost applying the Values and Model Framework if only replacing at failure

The risk assessment demonstrates that there is an increasing risk, that across the fleet of assets, is likely to materialise. The reduction in risk that is achieved by different credible mitigation options, along with the cost of the option and any other direct financial cost savings, is used to identify the preferred option in section 3.

Analysis was undertaken for individual cables to rank them from highest to lowest risk. A summary of this analysis is provided in Appendix B.6.

2.7 Summary

At the end of the current regulatory control period there will be 122.0 km of XLPE cable in the northern suburbs that has an identified type issue.

The condition data indicates that between 54% and 79% of the cable is highly likely (95% confidence) to have reached the end of its serviceable life. This is supported by the disproportionate amount of the northern suburbs cables that are found to be failing and interrupting supply, as recorded in the outage data.

The risks posed by cables have been examined and the impacts quantified using the Risk Quantification Procedure. This demonstrates that without appropriate mitigation, there will be a continued and increasing risk to the network and public safety.

Further, programs to address this known issue have been approved during the past two regulatory determinations, setting a precedent that the need is recognised by the business and regulators and action must be taken to mitigate the risks.

Section 3 assesses the options to most efficiently manage this risk.

3. Options analysis

This section describes the options analysis that was undertaken, including how they are assess based on their ability to address the identified need, commercial and technical feasibility, deliverability, costs and benefits of the option (including risk assessment).

3.1 Comparison of credible options

Based on the compelling analysis of the test data, Power and Water has determined that action must be taken to address the fleet of XLPE cables installed in the northern suburbs prior to 1985.

Credible options are identified that address the identified need, are technically feasible and can be implemented within the required timeframe. The following options have been identified:

- Option 1 – Replace on failure (Counter factual). This option would involve continuing to replace the faulted section of the cable upon failure.
- Option 2 – Targeted (risk based) replacement. Implement a program to test all cables and then replace only if they fail testing.

A comparison of the two identified credible options and the issues they address in the identified need is depicted in the table below. A detailed discussion of each option is provided below.

Table 5 Summary of options analysis outcomes

Assessment metrics	Option 1	Option 2
NPV ($'000, real FY22)	- Note 1	$43,734 Note 3
BCR	-	1.655
Capex ($'000, real FY22) (RP2429 only)	$10,200 Note 2	$24,375
Meets customer expectations	○	●
Aligns with Asset Objectives	○	●
Technical Viability	◑	●
Deliverability	●	●
Preferred	✗	✓

● Fully addressed the issue   ◕ Adequately addressed the issue   ◑ Partially addressed the issue   ○ Did not address the issue

Notes:

1. Option 1 was the used as the base case and the NPV for Option 2 is calculated as the incremental benefit compared to Option 1, so the NPV of Option 1 is zero.
2. The Capex for option 2 is the direct financial cost, predominately from the incremental cost of reactive replacement
3. NPV assessed across the 30 year analysis horizon

3.1.1 Option 1 – Replace on failure (Counter factual)

This option proposes to only replace cables in a reactive manner post failure. This means incurring the cost of the outages and accepting the risk to public and worker safety. In addition, the per unit replacement of cables post failure is higher than a planned outage.

Our assessment of this option took the following approach which applies the principles of the Risk Quantification Procedure. The resultant quantified risk-cost of this option is shown in the Figure 5 below. This option was assessed to result in the highest risk cost of the three options, indicating the worst network performance.

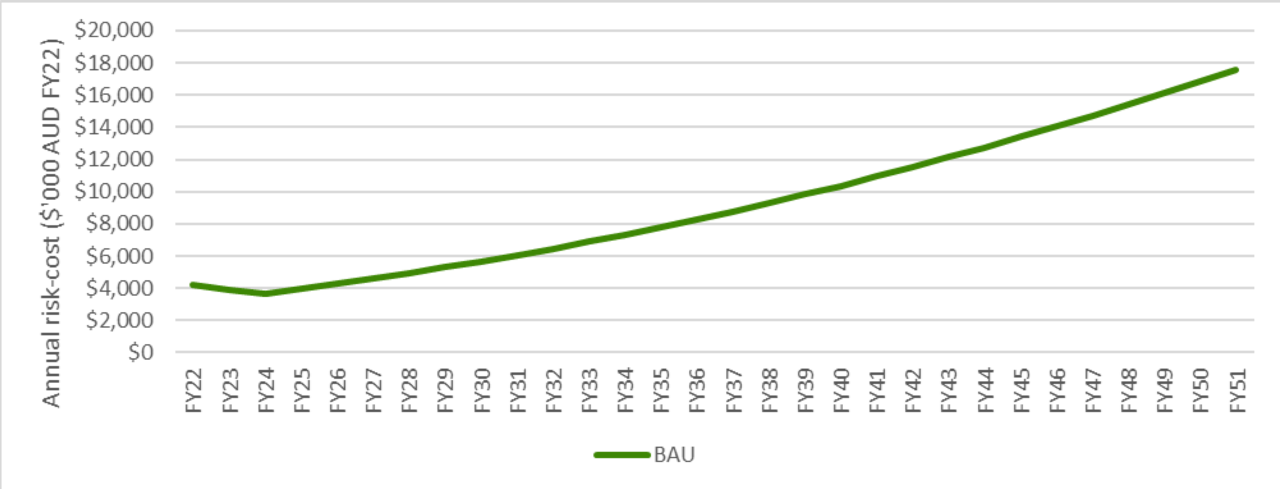

Figure 5 Risk profile achieved through Option 1

The reduction in risk through to FY24 as shown in Figure 5 is a direct result of the existing replacement program continuing for the remainder of the current regulatory period.

While this option is considered to be deliverable, and it is technically feasible, it results in deteriorating network performance and increasing safety risk to both the public and workers.

It also fails to directly address the underlying need which is the large volume of cable that is known to be in poor condition and at end of its serviceable life. Therefore, it does not achieve the Asset Objectives of maintaining reliability and safety of the network.

The scope of this option is expected to involve the replacement of an increasing number of cable sections as the cables continue to deteriorate. At each failure, a 10m length is installed to replace the faulted section. Cable replacements will be direct buried or in conduit as required by the existing installation.

This option does not manage network risk and does not meet Power and Waters requirements, nor customer expectations for a safe and reliable network. **This option is not recommended.**

3.1.2 Option 2 – Targeted (risk based) replacement (current practice)

This option proposes to continue with the current approach of replacing cables once they have failed testing. A list of cables requiring replacement has been developed using a risk-based prioritisation approach that uses condition from the testing results and criticality based on demand and proximity to the public, which is consistent with the principles of our Risk Quantification Procedure. The list and priority of cables to be replaced is ‘live’ and will be continually updated as cables are tested and new information is added.

By taking a risk-based approach, Power and Water will be able to replace the cables over a longer timeframe, therefore reducing the cost to customers, while maintaining network safety and reliability.

The quantified risk-cost of this option with replacement undertaken over three possible durations is shown in the Figure 6 below. BAU is the counterfactual case where any cables that fault are repaired and returned to service and there is no replacement program. The three replacement profiles all reduce to zero risk as the cable type is removed from the network. The risk contribution from the new cable was considered immaterial over the timeframe of this analysis and was not included.

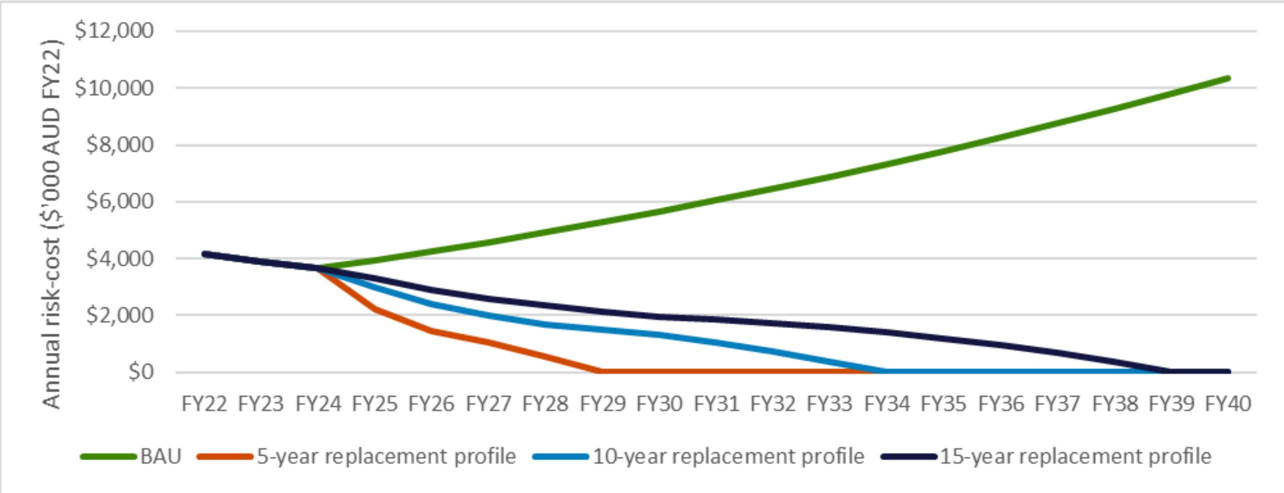

Figure 6 Risk reduction achieved through Option 2

The analysis of the timeframe for replacement was extended as shown in Table 6, which has the results for the cost benefit analysis for programs ranging from replacing all cables in 1 year up to a program duration of 20 years. In each case, it was assumed that an equal volume was replaced each year and the program commenced at the start of FY25.

As a targeted program, our analysis assumed that all the high criticality cables would be replaced first, then medium and finally low criticality. Additionally, it was assumed that the current plan for replacement of 21.6km of cable during the current regulatory period 2019-24 was completed and it targeted high and medium criticality cables only. As additional testing is undertaken, the criticality of cables is updated.

Table 6 Cost benefits analysis of total fleet replacement over different durations

Duration (years)	Annual Volumes (km)	Net Present Value ($'k)	Benefit Cost Ratio (BCR)
1	122.0	$ 46,522	1.561
2	61.0	$ 46,616	1.565
3	40.7	$ 46,791	1.572
4	30.5	$ 47,177	1.590
5	24.4	$ 47,238	1.601
6	20.3	$ 47,164	1.609
7	17.4	$ 47,057	1.617
8	15.3	$ 46,941	1.625
9	13.6	$ 46,718	1.632
10	12.2	$ 46,421	1.637

11	11.1	$ 46,085	1.642
12	10.2	$ 45,694	1.646
13	9.4	$ 45,285	1.650
14	8.7	$ 44,820	1.652
15	8.1	$ 44,287	1.654
16	7.6	$ 43,734	1.655
17	7.2	$ 43,125	1.655
18	6.8	$ 42,474	1.654
19	6.4	$ 41,778	1.652
20	6.1	$ 41,029	1.649

This option proposes to continue the current testing and replacement approach applied during the current regulatory period, to ensure the highest criticality cables are replaced first, ensuring the maximum network risk reduction is achieved. An annual volume of replacement up to 10km is considered to be deliverable and sustainable (up to a maximum of 50km over 5 years) as it is consistent with the contracted volumes for RY23 and RY24.

Power and Water expects that an annual volume of replacement greater than 10 km would not be sustainable over a long period of time and are not considered to be a credible option.

The NPV and BCR indicate that a project duration of approximately 16 years would have close to the highest NPV and BCR and includes replacement of approximately 7.5kms of cable per year.

This approach has the following benefits:

- It addresses the underlying need which is the large volume of cable that is known to be in poor condition and at end of their serviceable life.
- It will contribute towards achieving the Asset Objectives of maintaining reliability and safety of the network. As the fleet of cables is removed from the network, reliability and safety will be improved.
- Developing a pipeline of cable replacement will promote efficiency by enabling a longer term, market based contract
- Replacement based on testing will ensure cables are at end of life before being replaced, therefore maximising asset serviceable life.
- Reduce cost to customers by undertaking the replacement over a longer timeframe (reduces the present value of the capex).
- For each replacement, an assessment of the future capacity requirements and network reconfigurations will be undertaken to ensure long term network security and capacity. The expectation is for a like for like replacement with a standard modern equivalent cable.
- The approach is consistent with customer feedback to ensure network reliability and safety.
- The annual volume is within a reasonable range for delivery using existing resourcing models.

The scope of this option is expected to involve the replacement of 37.5km of cable across the 2024-29 regulatory period, and the remainder of the fleet by circa 2040, being a program length of 16 years from commencement. Replacement of the cable will be installed in conduit as required by the existing installation. Refer to Appendix B.6, Individual cable risk analysis, for detail on the priority of cables to be replaced.

The total capex for this option for the 2024-29 regulatory period is estimated to be $24.4m with a NPV of $43.7m, to replace of volume of 37.5kms of cable.

This option is recommended.

3.2 Non-credible options

Our analysis also identified options found to be non-credible. These options are described below and were not taken through to detailed analysis for the reasons provided.

3.2.1 Replace total length of cable – not considered prudent or deliverable

The cost of replacing the total length of 122.0km of at risk cable is estimated to be approximately $79.3 million (real 2021/22), based on the current unit cost estimate. This option was not included in the analysis as it is not considered deliverable, is not consistent with taking a risk-based approach and would increase the cost to customers above an efficient level of cost.

3.2.2 Defer replacement to extend life – does not address the need

Based on the risk to public safety and risk to network reliability, Power and Water does not consider full deferral of replacement to be a prudent approach to managing the risk. However, the options identified consider different approaches to replacement and rates of replacement in order to assess the most efficient approach to addressing the identified need.

3.2.3 Retire or de-rate assets to extend life – does not address the need

Total retirement of the assets is not a credible option as the cables are required for safe and reliable distribution of the electricity network. However, each option will assess where an individual cable can be retired or the topology can be changed to ensure prudency and efficiency of the option.

3.2.4 Non-Network alternatives – does not address the need

Due to the type and function of these assets, there are no non-network alternatives or solutions that can be implemented in place of direct asset replacement with like for like (modern equivalent) assets. When a cable is identified for replacement, Power and Water undertakes an assessment of whether the size or connection points can be changed to reduce cost or to meet future demand most efficiently.

3.2.5 Capex/Opex Substitution – does not address the need

Since the driver of this investment is significant deterioration across a fleet of assets caused by the same design deficiency, it is not feasible to substitute capital expenditure with operational expenditure to resolve the risk. Only capital expenditure to replace part or all of the cable will resolve the underlying issues.

4. Recommendation

The options analysis has identified Option 2 Targeted (risk based) replacement at an estimated cost of $24.4 million (real 2021/22) for the 2024-29 regulatory period to be the most prudent and cost effective solution to meet the identified needs.

The unit rates to develop this cost estimate are provided in Appendix A. The basis of the modelling is described in the Risk Quantification Procedure.

The proposed program is consistent with the National Electricity Rules Capital Expenditure Objectives as the expenditure is required to maintain the quality, reliability and security of supply of standard control services and maintain the safety of the distribution system.

4.1 Strategic alignment

The "Power and Water Corporation Strategic Direction" is to meet the changing needs of the business, our customers and is aligned with the market and future economic conditions of the Northern Territory projected out to 2030.

This proposal aligns with Asset Management System Policies, Strategies and Plans that contributes to the D2021/260606 "PWC Strategic Direction" as indicated in the table below.

Table 7 Strategic direction focus areas

No.	Strategic direction focus area	Strategic direction priority
1	Customer and the community at the centre	Enhance Customer Experience and Engagement
2	Sustainable solutions for the future	Cost Prudency
3	Always Safe	Improve Public Health and Safety

4.2 Dependent projects

There are no known projects or other network issues that are dependent on the resolution of this network issue, and this issue is not dependant on the completion of any other projects.

4.3 Deliverability

The new contracting approach implemented during the current regulatory period has secured long term civil contractor resources based on a market tested contract, with the electrical works completed by Power and Water. This approach to contracting will result in a more efficient delivery model as it reduces the procurement effort and provides certainty to contractors, allowing economies of scale. This approach will also ensure there are known quantities of cables requiring replacement and will provide a visible pipeline for contractors.

There will be some interdependencies that may affect delivery schedules depending on the preferred solution identified, other underground cables projects being undertaken by Power and Water (ie, the Port Feeder, Bayview LV and the Undergrounding Power Project) and other commitments by the contractor.

Power and Water is confident that the scope of works can be delivered based on historical practices and resources available.

4.4 Customer considerations

As required by the AER 's Better Resets Handbook[7], in developing this program Power and Water has taken into consideration feedback from its customers.

Feedback received through customer consultation undertaken at the time of writing this PBC, has demonstrated strong support amongst the community for appropriate expenditure to enable long term maintenance of the network to ensure continued reliability, security and safety of supply[8].

4.5 Expenditure profile

Table 8 shows a summary of the expenditure requirements for Regulatory Period 2025-29 and financial evaluation metrics, respectively.

Table 8 Annual capital and operational expenditure ($'000, real 2021/22)

Item	FY25	FY26	FY27	FY28	FY29	Total
Capex	4,875	4,875	4,875	4,875	4,875	24,375
Opex	-	-	-	-	-	-
Total	**4,875**	**4,875**	**4,875**	**4,875**	**4,875**	**24,375**

4.6 High-level scope

The scope for this project is to replace 37.5km of cables based on the prioritised score using criticality (demand and proximity to the public) and condition (based on test results). Under this option, only cables with a confirmed failed test result are scheduled for replacement.

The annual volumes are based on the risk modelling and cost benefit analysis that showed it was the optimal timeframe from an economical point of view, and are consistent with the existing project. This improves certainty regarding the deliverability of the program.

As there will be ongoing testing during the remainder of the current 2019-24 regulatory period, additional cables that require replacement will be identified and prioritised based on their risk relative to the other cables. Therefore, the exact cables to be replaced are not yet defined, however, the expected list is shown in Table 9 below. This table excludes the cables that are planned for replacement during the current period

[7] Better Resets Handbook – Towards Customer Centric Network Proposals, Australian Energy Regulator, Dec 2021
[8] Darwin Peoples Panel forum, 2 and 3 April 2022

and includes cables that have not yet been tested (on the basis that 54% to 79% of cables are expected to be at end of life).

Our approach to delivery will be to create work packages of appropriate size and to engage external civil contractor(s) through a market process. This will ensure cost efficiencies due to a large defined program of works resulting in a lower unit cost and time efficiencies.

Table 9 summarises 39.3 km of candidate cables that are the most likely to require replacement between July 2024 and June 2029 based on the current risk (criticality and condition) prioritisation.

Table 9 Summary of likely cable replacements based on prioritisation criteria for 2024-29.

Suburb	400 mm^2	240 mm^2	95 mm^2	35 mm2 (1ϕ)	Total
ANULA	1,372		908		2,281
BRINKIN	292				292
CASUARINA	523				523
HOLMES	934			316	1,251
KARAMA	3,921	1,888	186	19,817	25,812
KNUCKEY LAGOON	436				436
LEANYER	2,901		269	212	3,381
MALAK	891	15	1,040	221	2,168
MARRARA	165				165
NAKARA	88				88
TIWI	362		853		1,215
WANGURI	1,033		434		1,467
WULAGI	182				182
Grand Total	**13,100**	**1,903**	**3,690**	**20,566**	**39,259**

Appendix A. Cost estimation

A.1 Unit cost derivation

The unit rate has been derived based on recent cable projects undertaken under the new contracting arrangement in the Northern Suburbs.

12 projects were analysed with 5 of the projects including directional drilling, which adds a significant cost to the work. The analysis was undertaken based on the breakdown of materials, internal and external labour and the directional drilling component. Overall, 15% of the works require directional drilling on average. A summary is provided below in Table 10.

The new contracting arrangement provides a competitive market environment, and the known scale of the issue provides a secure pipeline for contractors, so this should provide downward pressure on the unit rate.

However, the downward pressure on costs is expected to be counteracted by the limited competition in Darwin amongst appropriately skilled and qualified contractors, global supply chain issues and the inflationary environment. As a result, the unit rate derived is expected to be maintained throughout the next regulatory period.

Table 10 Summary of projects used to calculate the unit rate ($'000, real 2021/22)

Project ID	Length (m)	Directional drilling	Project cost	Cost per km
PRD33886	483.7		$203.8	$421.2
PRD33897	295		$105.9	$358.9
PRD33898	332	Yes	$310.9	$936.6
PRD33899	354.2		$203.4	$574.3
PRD33903	181.7	Yes	$256.9	$1,413.9
PRD33924	706.7		$379.6	$537.1
PRD34084	350	Yes	$245.2	$700.5
PRD34135	935		$457.9	$489.7
PRD33777	229.7		$238.6	$1,038.7
PRD33949	584.3		$186.4	$319.0
PRD33965	564	Yes	$668.9	$1,186.0
PRD34033	391	Yes	$292.0	$746.9
Average based on detailed analysis				**$652.4**

A.2 Reactive replacement premium

For the analysis included in this business case, a unit rate of $650 per metre for 11kV XLPE cable is assumed. Based on historical data alone, a unit rate of $704 per meter is indicated, however, the revised contracting arrangement is expected to yield efficiencies and result in a reduced average unit cost.

The cost per asset fault repair used in the risk model has been derived from the costs of 27 fault repairs between 2020 and 2022. The costs were escalated to 2021/22 and assessed to calculate the incremental additional cost compared to a planned replacement.

Table 11 Cost build up for cable fault repair

Values ($ real 2021/22)	2020	2021	2022	Total
Count of Work Order	4	15	8	27
Sum of Cost	$80,905	$441,379	$339,335	$861,619
Sum of Cable length used in repair	31	200	102.3	333.3
Average cost per metre	$2,610	$2,207	$3,317	$2,585

The analysis in Table 11 shows an average of $2,585 per meter across the three year period for reactive replacement compared with $650 per metre for planned replacements. The average length replaced during these faults was 12.3m. This equates to:

- $32.7k (real 2021/22) per average reactive replacement
- $24.7k (real 2021/22) incremental additional cost compared to a planned replacement

A value of $24.7k (real 2021/22) has been assumed in our risk assessment model.

Appendix B. Detailed asset information

B.1 Asset Portfolio Context

Power and Water owns and maintains a portfolio of 916 km of high voltage cables distributed across the four regions of Alice Springs, Darwin, Katherine and Tennant Creek. The portfolio consists of mainly Paper Insulated Lead Covered (PILC), Polyvinyl Chloride (PVC), and cross-linked polyethylene (XLPE). XLPE makes up the majority and the largest population is located in the Darwin Region.

Table 12 HV cable population by region

Region	HV Cables Total	HV - XLPE	HV - PILC	HV - PVC	HV – Unknown
Alice Springs	111	85	19	0	7
Darwin	781	562	209	2	9
Katherine	22	9	1	-	12
Tennant Creek	3	1	1	-	1
Total	**916**	**656**	**229**	**2**	**29**

XLPE started to replace paper cables in the 1960's as a long life alternative with no electrical property degradation. However, towards the end of the 1970's field service performance recognised that XLPE cables undergo a degradation process called water treeing and an accelerated corrosion of the neutral / earthing wires when exposed to moisture and electrical stress. In the early 1980's an improved version of XLPE called TR-XLPE was introduced, and has shown much improved field service performance[9 & 10]. A large portion of Power and Water' XLPE cables (103 km or 12% of total HV cable population) were installed from the 1960's to mid-1980's in the northern suburbs of Darwin. These cables are also unique in the fact that the screen conductor is aluminium.

Table 13 shows the distribution of the cables being targeted by suburb, length installed and installation year.

Table 13 Volume and installation year by suburb of pre-1985 XPLE cables in the northern suburbs

Suburb	1975	1980	1982	1983	Total
ALAWA	0.07				0.07
ANULA	6.09		1.34		7.43
BRINKIN	0.79			2.49	3.28
CASUARINA	2.10				2.10
FANNIE BAY	0.06				0.06

9 LONG-LIFE XLPE INSULATED POWER CABLE, Nigel HAMPTON, NEETRAC, Georgia Tech, USA
10 Global Trends and Motivation Toward the Adoption of TR-XLPE Cable, The Dow Chemical Company

JINGILI	1.42				1.42
KARAMA		2.68	39.58		42.26
LEANYER	0.08	0.48	37.15	0.01	37.72
LYONS	0.70		0.00		0.70
MALAK			20.43		20.43
MARRARA	0.13		3.71		3.84
MILLNER	0.01				0.01
MOIL	0.60				0.60
NAKARA	0.33				0.33
NIGHTCLIFF	0.00				0.00
PARAP	0.15				0.15
RAPID CREEK	0.01				0.01
TIWI	4.33				4.33
WAGAMAN	0.03				0.03
WANGURI	4.54				4.54
WULAGI	4.10		0.07		4.17
Grand Total	**25.54**	**3.16**	**102.28**	**2.50**	**133.48**

B.2 Northern Suburbs XLPE Cable Condition Observations

In 2011 an investigation into the cause of cable failures was launched due to the significant contribution of cable failures to reliability performance and consistent reports from field crews that cables were in poor condition, affecting their reparability. The investigation confirmed the consistently poor condition of XLPE cables in the northern suburbs.

Water ingress has been identified as the main factor causing the cable failures. It is believed that small cracks in the cable jacket - due to poor installation practices, mechanical damage or age degradation – allow moisture to enter the cable. The aluminium screens oxidise and swell, deforming the cable. As a result the cable jacket is damaged further, exacerbating the moisture ingress. The old XLPE insulation suffers from water- treeing and mechanical stress and eventually fails.

A proactive testing and replacement program commenced in 2013/14. After development of internal cable testing capability, further condition assessments were undertaken over the period June 2014 to August 2017 involving 13 (42%) of the 31 northern suburb feeders.

The condition assessments found varying levels of degradation, but overall the test results were very poor. 40% of tested cables, representing 54% of the tested feeders, failed the earth screen testing. This indicates that the affected cable screens are completely discontinuous or at best exposed directly to moisture and in the process of corroding. A significant portion of the cables (39%) also failed tan delta insulation testing, indicating a high operating risk according to the IEEE 400.2:2013 standard. It is expected that the poor insulation test results are predominantly due to moisture ingress as there is a high correlation of insulation failure with screen failure. The results of the testing program are summarised in Appendix A.

Visual inspection of many sections of cable (during repairs or when exposed as part of other work) within these areas corroborates the poor cable condition. Swelling and damage to cable jackets has been observed consistently, indicating that damaging water ingress and corrosion has already occurred.

Table 14 Number of cable tests per year

Year	Number of tests
2013	2
2014	9
2015	0
2016	22
2017	13
2018	20
2019	4
2020	25
2021	26
Total	**121**

B.3 Public and Worker Risk

Cable degradation is also a risk to public and worker safety.

Failure of the cable screens is linked to potential earth system integrity failure. Cable screens serve a primary function in terms of cable design to provide an effective earth return path for fault current in the event of a cable failure, either an internal failure due to insulation degradation, or an external impact such as being struck by earth moving equipment by a member of the public, Power and Water maintainers or contractors/developers. Since 2012, damage to live cables caused by earth moving equipment has occurred more than 3 times per year including LV, HV and Transmission cables[11].

The absence of a continuous screen substantially increases consequence of an externally caused fault due to:

- The fault return path is no longer provided by the screen but by the equipment or tool that strikes the cable, likely to be in contact with a person.
- The impedance of the fault current return path increases, slowing the response time of protection systems.
- Safe work methods for cutting cables also rely on the existence of a screen to provide a defence against possible misidentification of cables being cut, such as what occurred in the October 2011 incident that resulted in severe burns and permanent injuries to two Power and Water[11] employees.

[11] D2017/498719 - Incident Event History Analysis - Grace & RISQ Data Extract.

Additionally, the increasing frequency of HV cable faults poses significant risks to public and worker safety. More faults mean more public exposure to Earth Potential Rise (EPR) on the potentially compromised earthing system, increasing the both the likelihood of an electric shock and its severity.

Personnel working adjacent in the proximity of live HV cables are also at risk. This is a relatively frequent occurrence during emergency repairs or preliminary inspections for capital works. There has been at least one instance of a cable failing in the months after it was inspected via vacuum excavation of a cable pit. The photo in Figure 2 was taken during the inspection, and shows the cable and the location of the fault prior to the fault occurring.

Figure 7 Cable inspected prior to failure

B.4 Earthing System Design Impacts

Arguably the most critical function provided by cable screens is providing the backbone of the underground network earthing system. The climate and soil conditions for much of the NT are such that soil resistivity is extremely high for portions of each year (Dry season), rendering the local equipment earthing almost ineffective and relying heavily on the interconnectedness of the earthing system. Extreme wet conditions for the other proportion of the year significantly reduces soil resistivity meaning earthing design needs to cater for vastly different soil conditions.

To mitigate this risk, Power and Water network design requires the interconnection of screens and a common earth conductor at every termination point. Under HV fault conditions, HV cable screens provide the primary return path for fault current due to the magnetic coupling between the faulted phase and its screen. This ensures that fault current returning via local earth grids around HV equipment is minimised, limiting EPR and associated touch and step voltage hazards to members of the public to allowable levels. This approach ensures that Power and Water meets WHS legislation requirements related to power system earthing without the need for significant design and engineering reviews of individual distribution substations and switchgear. It ensures that the earthing hazards associated with abnormal system conditions are effectively mitigated and allows testing to be conducted to verify the continuity of the earthing conductors between termination points, without which failures of earthing conductors would be undetectable.

However, as cable screens continue to corrode and become discontinuous, the basis for the underground network earthing design is compromised. The risks to the public and workers will increase as the earth return paths provided by cable screens fail, particularly in areas of limited HV cable interconnectivity. As these earth paths fail, the proportion of fault current returning via earth grids and other public infrastructure increases, subsequently increasing EPR and the safety risk.

In 2017, engineering consultants specialising in utility earthing system design and performance analysis were engaged to quantify the increasing risk to earthing system performance associated with screen degradation. An interim report has confirmed the step and touch voltages increase as the earth return path provided by HV cable screens fail. Table 3-1 of the report summarises the output from initial modelling, and shows increases of EPR from 30% to 82% for various scenarios. A key basis for the scenarios is the local earthing grid performance, which can vary greatly due to soil and climate conditions. The report recommended the replacement of cables with discontinuous screens and additional testing to mitigate the risk until replacement.

B.5 Reliability performance

This table shows the historical reliability statistics for the Northern Suburbs Cables compared to the total cable fleet and demonstrates that the number of outages caused by the Northern Suburbs Cables is continually disproportionate compared to the proportion of the fleet it makes up.

Table 15 Cable reliability statistics

Financial Year	SAIDI			SAIFI		
	All Cables	Nth Suburbs	Percentage[1]	All cables	Nth Suburbs	Percentage[1]
2011/12	17.233	9.071	52.6%	0.1354	0.0629	46.4%
2012/13	6.870	4.108	59.8%	0.0941	0.0721	76.6%
2013/14	9.645	5.917	61.3%	0.1078	0.0570	52.9%
2014/15	20.436	3.418	16.7%	0.1340	0.0346	25.8%
2015/16	28.557	15.441	54.1%	0.2387	0.1032	43.3%
2016/17	23.338	10.242	43.9%	0.1950	0.1286	66.0%
2017/18	12.068	7.302	60.5%	0.2003	0.0764	38.1%
2018/19	9.120	2.598	28.5%	0.1726	0.0334	19.3%
2019/20	16.824	8.325	49.5%	0.1613	0.1049	65.0%

2020/21	12.983	6.549	50.4%	0.1722	0.1151	66.9%
Average			**47.1%**			**46.9%**

Note: Percentage is calculated as the Northern Suburbs Cables contribution divided by the contribution from All Cables

B.6 Individual cable risk analysis

The individual cables have been prioritised based on a multicriteria analysis. The condition was ranked according to the test results available then weighed and summed to calculate a condition score on a scale of 1 to 5. The criticality was then assessed and given a score of 1 to 5 based on the demand and location (as a proxy for risk to the public). The condition and criticality scores were multiplied to give a relative risk ranking to each cable.

The cables shown in Table 16 are the cables currently identified and planned for replacement.

Table 16 Prioritised cables currently planned for replacement

Maximo Asset ID	Parent Circuit	Cable Size mm²	Cable Type	Length	Date Commission	IR	Tan Delta	Shearth Integrity	Screen Test	Health Index	Criticality Index	HI x CI	Unit Rate
MX139579	11BE06 KARAMA1	400 (AL.)	XLPE/PVC	414.5	1-Jan-80	Failed	Failed	Failed	Passed	**4.3**	**4.75**	**20.43**	652,000
MX134092	11BE06 KARAMA1	400 (AL.)	XLPE/PVC	1359.5	1-Jan-75	Failed	Failed	Failed	Passed	**4.3**	**4.75**	**20.43**	
MX135555	11LE08 PARKSIDE	400 (AL.)	XLPE/PVC	866.4	1-Jan-82	Failed	Failed	Failed	Passed	**3.8**	**4.75**	**18.05**	540,000
MX135517	11LE08 PARKSIDE	400 (AL.)	XLPE/PVC	520.2	1-Jan-82	Failed	Failed	Failed	Passed	**3.8**	**4.75**	**18.05**	
MX136093	11LE08 PARKSIDE	400 (AL.)	XLPE/PVC	69.8	1-Jan-82	Failed	Failed	Failed	Passed	**3.8**	**4.75**	**18.05**	
MX133580	11BE06 KARAMA1	35 (AL.)	XLPE/PVC	9.4	1-Jan-82	Data Not Available	Data Not Available	Data Not Available	Data Not Available	**3.1**	**4.75**	**14.73**	0
MX135552	11LE08 PARKSIDE	400 (AL.)	XLPE/NYL/PVC	980.7	1-Jan-82	Failed	Failed	Failed	Passed	**4**	**4.75**	**19.00**	484,000
MX135472	11LE08 PARKSIDE	400 (AL.)	XLPE/NYL/PVC	327.6	1-Jan-82	Failed	Failed	Failed	Passed	**4**	**4.75**	**19.00**	
MX133611	11BE06 KARAMA1	240 (AL.)	XLPE/PVC	590.8	1-Jan-82	Passed	Failed	Failed	Passed	**3.425**	**4.75**	**16.27**	245,429
MX133587	11BE06 KARAMA1	240 (AL.)	XLPE/PVC	229.7	1-Jan-82	Failed	Failed	Passed	Passed	**3.55**	**4.75**	**16.86**	105,370
MX140107	11CA24 PARER	95 (AL.)	XLPE/PVC	292.6	1-Jan-75	Passed	Passed	Failed	Failed	**3.825**	**3.75**	**14.34**	119,824
MX129821	11CA24 PARER	95 (AL.)	XLPE/PVC	286.9	1-Jan-75	Data Not Available	Data Not Available	Failed	Failed	**3.85**	**3.75**	**14.44**	126,903

MX140125	11CA24 PARER	95 (AL.)	XLPE/PVC	483.7	1-Jan-75	Data Not Available	Data Not Available	Failed	Failed	**3.85**	**3.75**	**14.44**	195,032
MX133601	11BE10 KARAMA 2	95 (AL.)	XLPE/PVC	35.2	1-Jan-82	Data Not Available	Data Not Available	Failed	Failed	**3.85**	**3.75**	**14.44**	328,375
MX133616	11BE10 KARAMA 2	35 (AL.)	XLPE/PVC	558	2-Jan-82	Data Not Available	Data Not Available	Failed	Failed	**3.85**	**3.75**	**14.44**	
MX133615	11BE10 KARAMA 2	35 (AL.)	XLPE/PVC	96	3-Jan-82	Data Not Available	Data Not Available	Failed	Failed	**3.85**	**3.75**	**14.44**	
MX133600	11BE10 KARAMA 2	35 (AL.)	XLPE/PVC	417	4-Jan-82	Data Not Available	Data Not Available	Failed	Failed	**3.85**	**3.75**	**14.44**	
MX133604	11BE10 KARAMA 2	35 (AL.)	XLPE/PVC	342	5-Jan-82	Data Not Available	Data Not Available	Failed	Failed	**3.85**	**3.75**	**14.44**	
MX133603	11BE10 KARAMA 2	95 (AL.)	XLPE/PVC	860	6-Jan-82	Data Not Available	Data Not Available	Failed	Failed	**3.85**	**3.75**	**14.44**	
MX133589	11BE06 KARAMA1	400 (AL.)	XLPE/PVC	584.3	1-Jan-82	Failed	Failed	Failed	Passed	**3.8**	**4.75**	**18.05**	228,000
MX139596	11BE10 KARAMA 2	400 (AL.)	XLPE/PVC	2,461.40	1-Jan-80	Data Not Available	Failed	Data Not Available	Data Not Available	**3.675**	**4.75**	**17.46**	957,023
MX133625	11BE10 KARAMA 2	400 (AL.)	XLPE/PVC	855.5	1-Jan-82	Data Not Available	Failed	Data Not Available	Data Not Available	**3.675**	**4.75**	**17.46**	
MX134090	11BE06 KARAMA1	400 (AL.)	XLPE/PVC	570	1-Jan-75	Data Not Available	Data Not Available	Failed	Failed	**4.05**	**4.75**	**19.24**	595,758
MX133590	11BE06 KARAMA1	400 (AL.)	XLPE/PVC	850.6	1-Jan-82	Data Not Available	Data Not Available	Failed	Failed	**4.05**	**4.75**	**19.24**	
MX140157	11LE08 PARKSIDE	95 (AL.)	XLPE/PVC	112.8	1-Jan-75	Data Not Available	Data Not Available	Failed	Failed	**3.85**	**3.75**	**14.44**	120,530
MX140159	11LE08 PARKSIDE	95 (AL.)	XLPE/PVC	128.2	1-Jan-75	Data Not Available	Data Not Available	Failed	Failed	**3.85**	**3.75**	**14.44**	
MX140158	11LE08 PARKSIDE	95 (AL.)	XLPE/PVC	53.4	1-Jan-75	Data Not Available	Data Not Available	Failed	Failed	**3.85**	**3.75**	**14.44**	
MX140155	11LE08 PARKSIDE	95 (AL.)	XLPE/PVC	166.6	1-Jan-75	Data Not Available	Data Not Available	Failed	Failed	**3.85**	**3.75**	**14.44**	133,591

MX140152	11LE08 PARKSIDE	95 (AL.)	XLPE/PVC	164.8	1-Jan-75	Data Not Available	Data Not Available	Failed	Failed	**3.85**	**3.75**	**14.44**	
MX136226	11BE16 AUNLA	95 (AL.)	XLPE/PVC	354.2	1-Jan-82	Data Not Available	Data Not Available	Data Not Available	Data Not Available	**3.1**	**4.75**	**14.73**	141,710
MX136219	11BE16 AUNLA	95 (AL.)	XLPE/PVC	137.1	1-Jan-82	Data Not Available	Data Not Available	Data Not Available	Data Not Available	**3.1**	**4.75**	**14.73**	102,789
MX129802	11BE16 AUNLA	95 (AL.)	XLPE/PVC	100.1	1-Jan-82	Data Not Available	Data Not Available	Data Not Available	Data Not Available	**3.1**	**4.75**	**14.73**	
MX136367	11BE16 AUNLA	95 (AL.)	XLPE/PVC	181.7	1-Jan-82	Data Not Available	Data Not Available	Data Not Available	Data Not Available	**3.1**	**4.75**	**14.73**	80,641
MX140124	11LE08 PARKSIDE	95 (AL.)	XLPE/PVC	200.2	1-Jan-75	Data Not Available	Data Not Available	Data Not Available	Data Not Available	**3.1**	**4.75**	**14.73**	89,249
MX133569	11BE10 KARAMA 2	35 (AL.)	XLPE/PVC	668.9	1-Jan-82	Passed	Failed	Not performed	Failed	**4.175**	**4.75**	**19.83**	296,367
MX5033134	11BE10 KARAMA 2	240 (AL.)	XLPE/PVC	697	1-Jan-82	Failed	Not performed	Not performed	Passed	**3.875**	**4.75**	**18.41**	308,740
MX129822	11CA24 PARER	95 (AL.)	XLPE/PVC	273.9	1-Jan-75	Passed	Failed	Not performed	Failed	**3.95**	**3.75**	**14.81**	109,500
MX133528	11BE10 KARAMA 2	400 (AL.)	XLPE/PVC	821	1-Jan-82	Failed	Failed	Failed	Passed	**3.8**	**4.75**	**18.05**	314,800
MX133640	11LE06 KARAMA 1	240 (AL.)	XLPE/PVC	552.6	1-Jan-82	Failed	Failed	Failed	Passed	**4**	**3.75**	**15.00**	215,400
MX133584	11BE06 KARAMA1	240 (AL.)	XLPE/PVC	11.1	1-Jan-82	Failed	Failed	Failed	Passed	**3.8**	**3.75**	**14.25**	
MX140132	11LE04 TAMBLING	95 (AL.)	XLPE/PVC	391	1-Jan-75	Failed	Not performed	Not performed	Failed	**4.175**	**3.75**	**15.66**	160,000
MX136153	11BE10 KARAMA 2	240 (AL.)	XLPE/PVC	552.6	1-Jan-82	Failed	Passed	Failed	Failed	**4.2**	**4.75**	**19.95**	270,959
MX129807	11CA24 PARER	95 (AL.)	XLPE/PVC	363.8	1-Jan-75	Passed	Failed	Failed	Failed	**4**	**3.75**	**15.00**	270,959

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