PowerWater

Power and Water Corporation
Preliminary Business Case – Category A

PRD30402
Replace Berrimah Zone Substation

Proposed:

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Power Networks
Date: 6 / 2 /2018

Approved:

Michael Thomson
Chief Executive & Chair
Investment Review Committee
Date: 23 /02 /2018

Endorsed:

Djuna Pollard
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Date: 15/ 2 /2018

Refer to email
D2018/72353

Finance Review Date:
06/02/2018

Refer to email
D2018/59608

PMO QA
Date: 8/02/2018

1 RECOMMENDATION

It is recommended that the Chief Executive approve project PRD30402 – Replace Berrimah Zone Substation, to replace the existing Berrimah zone substation with a new 2 x 20/27MVA transformer, 66/11kV zone substation located adjacent to the existing substation by June 2021 for an estimated capital cost of [redacted] The expenditure includes [redacted] to be incurred in the next regulatory control period.

Approval is sought for expenditure of up to $0.5M of the total forecast expenditure to undertake the necessary work to proceed to the next approval gateway (Business Case Approval), including:

- Site selection, site survey, geotechnical investigation and earth grid assessment for the new ZSS;
- Detailed design; and
- Detailed cost estimate by seeking a construction price offer from external contractors through a competitive tender.

Note that budget is available for [redacted] in the 2017/18 Power Networks CAPEX budget and the SCI forecast

The project has a 95% likelihood of being delivered at [redacted]

2 PROJECT SUMMARY

Project Title:	Replace Berrimah Zone Substation		
Project No./Ref No:	PRD30402	**SAP Ref:**	
Anticipated Delivery Start Date:	Jan 2018	**Anticipated Delivery End Date:**	June 2021
Business Unit:	Power Networks		
Project Owner (GM):	Djuna Pollard	**Phone No:**	8985 8431
Contact Officer:	Peter Kwong	**Phone No:**	8924 5060
Date of Submission:	23/02/18	**File Ref No:**	D2017/394263
Submission Number:		**Priority Score:**	
Primary Driver:	Renewal	**Secondary Driver:**	Service Improvement
Project Classification:	Capital Category A		

2.1 Prior Approvals

Document Type	Sub Number	Approved By	Date	Capex Value
BNI	8241	John Baskerville	17/06/2013	[redacted]

3 INVESTMENT NEED

The Berrimah Zone Substation was commissioned in 1981. It comprises a 66kV outdoor air insulated 66kV switchyard, two 66/11kV 25/31.5/38MVA power transformers, and an 11kV indoor metalclad switchboard and associated secondary systems. The site was also a connection point for 2 x 10 MW gas turbines, decommissioned in 2010/11.

It currently supplies over 30MVA of peak demand, which is forecast to increase over the next five years beyond the firm capacity of the substation.

Many of the assets are at, or approaching the end of their serviceable life, with 66kV circuit breakers in the poorest condition.

Consistent with good industry practice, PWC's asset management strategy requires prudent replacement of zone substation primary plant and secondary systems prior to failure to reduce safety and reliability risk and to optimise the whole-of-life cost of the assets.

3.1 Poor Asset Condition

3.1.1 Poor Condition 66kV Switchgear

The 66kV switchyard consists of 5 x [redacted] minimum oil circuit breakers that were manufactured in 1980 – they are currently 37 years old. The sixth circuit breaker was installed in 2002 to replace the [redacted] circuit breaker that previously failed in service.

Industry experience and the maintenance and test results for the PWC circuit breakers at Berrimah indicates that even with regular maintenance the end-of-life for these assets is at about 40 years:[1]

- This type of circuit breaker has a high failure rate within the electricity industry and PWC has previously experienced multiple failures with its other [redacted] circuit breakers;
- The circuit breakers at Berrimah ZSS are obsolete models and parts for the remaining units are sourced from old decommissioned circuit breakers replaced at other sites. They incur high maintenance costs and operational risk due to oil leaks and water ingress. Oil must be drained and replaced regularly. The poor condition of these circuit breakers increases the risk of explosive failure, posing the risk of fatal injury to PWC personnel working within the substation.

[1] Berrimah ZSS Asset Condition Report, PWC Ref: D2013/576014

3.1.2 Poor Condition Power Transformers

The two 66/11kV [redacted] power transformers were manufactured in 1980 are in poor condition with a high level of moisture in the insulating oil and windings, largely due to significant oil leaks moisture ingress,[2] and high furan levels, indicating that the transformer internal structure has weakened significantly with time, condition and the operating environment. In 2013, transformer No 1 was found to contain significant amounts of sludge and metal debris. The metal debris was likely to be from a failing oil pump (which has since been replaced). Attempts have been made to remove the sludge and metal debris in 2013 by flushing the tank in situ, but with limited success. The presence of the hardened sludge and metal particles increases the risk of transformer failure, increases the aging rate and impacts the achievable continuous rating.

The test results for both transformers indicate the insulation is near its end-of-life. Based on common industry benchmarks, the transformers should be replaced within 3-5 years.[3]

Whilst the poor condition of the transformers indicates that explosive failure is possible, the highest risk is to supply reliability. In the case of catastrophic failure of a transformer at Berrimah ZSS, it is likely that the Class C supply criteria would not be satisfied because: (i) PWC does not have a spare 25/31.5/38MVA transformer, and (ii) there is limited distribution transfer capacity to contiguous substations.

3.1.3 Poor condition 66kV Instrument transformers

The 66kV instrument transformers at Berrimah Zone Substation are mostly the original units (or units of the same vintage which have been used as spares) manufactured in the late 1970s. The instrument transformers have experienced condition-related problems in recent years, including:

- Two voltage transformers currently have low insulation resistance,
- Two voltage transformers and a current transformer currently have poor dissolved gas analysis results indicating heating,
- Two voltage transformers have high levels of partial discharge activity,
- One set of voltage transformers is unable to be tested, as they have internal earth connections which cannot be removed,
- Two current transformers have failed testing and been replaced at Berrimah since 2010.

The poor condition of these units results in a significant cost and resource burden, with high maintenance (testing and repair) costs.

The poor asset condition increases the risk of explosive failure which typically results in access restrictions on the yard, making it more onerous and costly to perform other regular maintenance activities. It also presents a risk of fatal injury to PWC personnel working within the substation.

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[2] Berrimah ZSS Condition Assessment Report, PWC Ref: D2013/576014

[3] *Ibid*

3.1.4 Unsafe 11kV Switchboard

The 11kV switchboard was commissioned with bulk oil circuit breakers but was subsequently retrofitted with vacuum circuit breakers in 2009 following the explosive failure at Casuarina Zone Substation that involved a similar type of bulk oil circuit breakers. While the vacuum breakers are an improvement in safety, operations have been impacted by the retrofit as the full functionality and features of the original switchboard have been compromised[4]. In addition, the switchboard itself is not arc-fault contained (unlike modern switchgear) and there is a growing concern for the safety of operational staff working in and around this equipment.

The original frame leakage bus protection for the switchboard is no longer operational due to failure of the insulating medium. While operating time adjustments to the transformer incomer backup protection scheme have been made, this failure increases the energy involved with bus faults and arc flash incidents as the switchboard fault clearance rely on this slower operating backup protection.

Reducing the safety risk to operational staff from the inadequate arc containment risk requires replacement of the switchboard. In the interim, operational instructions restrict the time staff spend in the switch room to a practical minimum.

In 2017 there was an arc-flash incident where a high voltage operator was injured while earthing a switch into the live bus of the switchboard. While it was concluded that operator error played a part PWC is committed to reduce the likelihood of such incidents to as low as reasonably practicable with the preference to error tolerant systems and equipment.

3.1.5 Obsolete secondary systems

The majority of the protection relays are over 15 years old with a significant number over 25 years old and are no longer supported. There has been an upgrade to one transmission line protection due to the construction of new zone substation at Leanyer to match line protection on the remote end.

3.1.6 Control building

The control building has not be refurbished or modified since the original commissioning of the substation and generation site. While the building is structurally sound, it does contain asbestos and a register[5] has been developed to identify and notify the known locations of the asbestos containing materials. This will need to be taken into account when any work is conducted on the control building.

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[4] Rear bus connection is no longer possible with the retrofitted breaker due to a design flaw. Alignment between the retrofit CB and original switchgear is poor resulting in operational challenges.

[5] Asbestos Register Berrimah Power Station, Berrimah – Reviewed 2016

3.1.7 Capacitor banks

There is one 2 x 3MVAr 11kV capacitor bank installed at Berrimah Zone Substation. It consists of a number of outdoor capacitor units installed in parallel. The size of the power factor correction is inadequate for the load at Berrimah Zone Substation and the current PWC standard is to install one 2 x 3MVAr units per bus section.

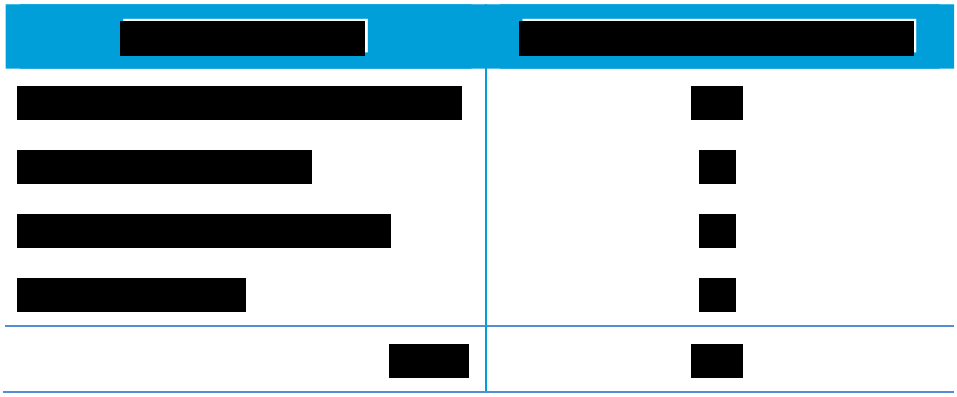
3.2 Peak demand and capacity forecasts

This section provides a summary of the peak demand and firm capacity forecast for Berrimah ZSS, based on AEMO's forecasts undertaken on behalf of PWC.[6]

3.2.1 New load developments in the region

New developments in the Berrimah, Wishart and East Arm areas and the maximum demand that they are expected to draw over the next 10-15 years are listed in Table 1. The total area maximum demand is projected to be approximately 75MVA by 2030.

Table 1: Sources of forecast load growth and horizon load forecasts[7]



3.2.2 Berrimah ZSS

Berrimah ZSS's firm capacity is 41MVA.[8] As shown in Figure 1, load at Berrimah ZSS is forecast to increase through to 2021/22 before declining slightly due to the impact of distributed energy sources (such as roof top PV installations), energy efficient appliances, and other energy conservation measures.

Despite the slight forecast reduction in peak demand, Berrimah substation is required on an ongoing basis to supply customers in the area and due to the potential of future developments in the area.

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[6] AERReportForPWC_V3

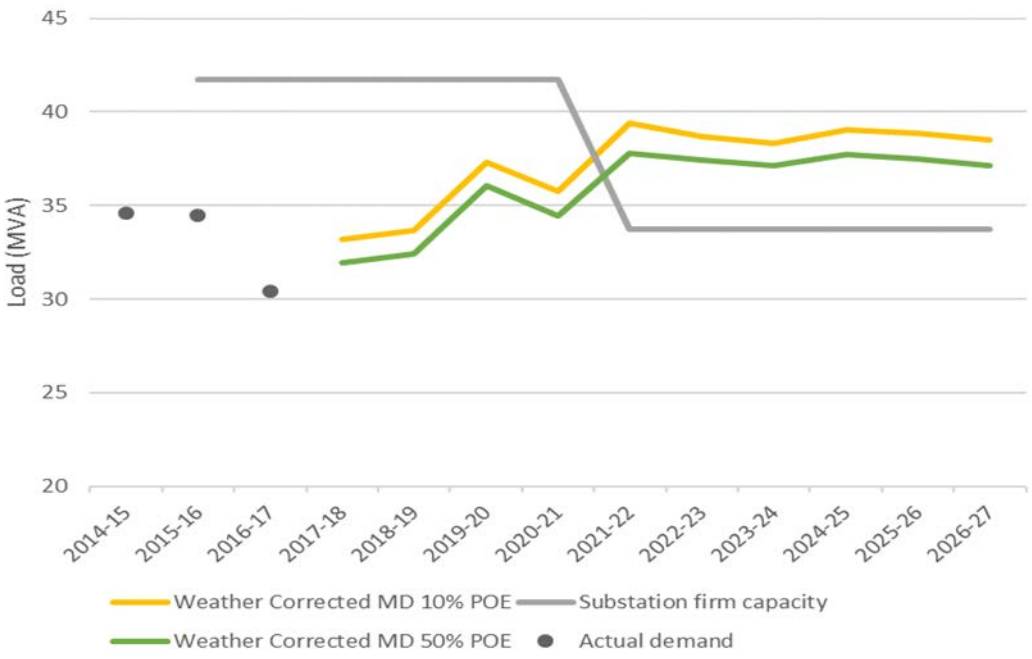
[7] Based on PWC's appraisal of development plans and the recent history of take up of vacant land in similar residential, commercial and industrial estates

[8] Transformer capacity of 38MVA and distribution transfer capacity of 3MVA

As discussed in more detail in section 8 below, the plan is to replace the existing Berrimah substation with a new substation initially configured with two standard sized 20/27MVA 66/11kV transformers with provision for a third transformer circuit.[9] Figure 1 shows that the firm transformer capacity will reduce to 34MVA once the new substation is commissioned.[10]

To enable Berrimah ZSS to operate within its firm capacity, load will be transferred to the proposed new 2 x 20/27MVA 66/11kV Wishart Zone substation to be established on the Hudson Creek Terminal site.[11] This arrangement provides improved ability to meet demand growth in the broader area and also maintain power quality to areas more distance from the Berrimah zone substation.

Figure 1: Berrimah ZSS peak load AEMO forecast and firm capacity



3.3 Risk analysis

Figure 2 shows the current rating, inherent rating (in 2024, i.e. if no action is taken in the interim), and the residual (post-treatment) risk ratings associated with the condition of assets in the Berrimah ZSS.

(i) *Current rating:* The Current rating (2017) is assessed to be 'High' due to the aggregate safety risk posed to PWC workers by the poor condition primary assets in Berrimah ZSS. The probability of

[9] This is PWC's standard 66/11kV ZSS configuration

[10] N-1 capacity of the transformer (30.1MVA) plus distribution load transfer (3MVA) able to be enacted within 60 minutes

[11] Refer to PRD33001 – Preliminary Business Case PBC – Construct Wishart ZSS

explosive failure of primary plant assets is rated as 'unlikely', but should such an event occur, the consequence could be serious injury to PWC operational personnel (or even a fatality).[12] There would also likely be adverse media attention and temporary disruption to electricity supply.

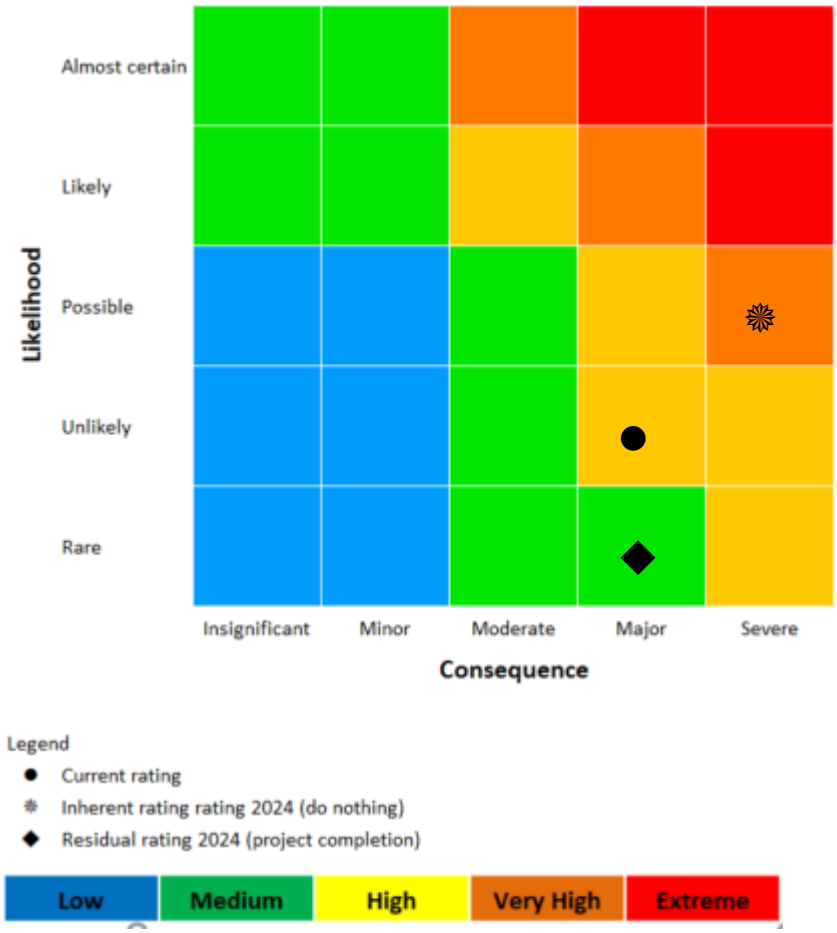
(ii) *Inherent rating:* If the poor condition assets are not replaced by 2024, the likelihood of explosive failure of primary plant is assessed to increase from 'unlikely' to 'possible'. Given the number and frequency of operational personnel that will need to be on site to address the increasing maintenance (inspection and repair) issues of the increasingly poor condition assets, it is more likely that the consequence could be a fatality. There would likely be prolonged adverse media attention and temporary disruption to electricity supply. The inherent risk rating is therefore 'Very High'.

(iii) *Residual rating:* The proposed project will replace all the poor condition assets. Fewer personnel will need to be on site on average over the course of a year because much less maintenance and repair will be required. The likelihood of explosive failure of primary plant will be reduced to 'rare'. The consequence of explosive failure is likely to be severe injury (or, even less likely, fatality). Adverse media attention and temporary disruption to the electricity supply is less likely. The residual rating is therefore 'Medium'.

Figure 2: Berrimah/Wishart load area supply risk assessment[13]

[12] The 66kV circuit breakers, instrument transformers, and power transformer bushings all contain porcelain components which can explode, sending high velocity porcelain shards long distances/

[13] Based on Power Network's Risk Assessment Guide



It is Power and Water's current practice to take action on risks that have an inherent rating of 'HIGH' or above. The PBC summarises the proposed response to this impending risk.

4 STRATEGIC ALIGNMENT

This project aligns with the Corporation's key result areas of operational performance and customer centricity, where the goals are to be an efficient provider of services and delivering on customers' expectations.

This project will allow PWC to safely and reliably meet current and future demands for the Berrimah, Wishart and East Arm areas.

5 TIMING CONSTRAINTS

This project will need to be completed by June 2021 to manage safety and reliability risks associated with the zone substation. The trigger for the replacement is the [redacted] minimum oil 66kV circuit breakers, which are 40 years old by 2020/21 and have a high risk of explosive failure.

6 EXPECTED BENEFITS

Driver/Objective	Benefit	Current State	Future State
Safety	Reduced risk of injury (including fatality) from explosive failure of primary plant	Elevated level (very high) of personnel safety risk due to poor condition of a high proportion of primary assets	Risk of injury to personnel reduced to acceptable levels (medium)
Reliability	Increased reliability and reduced maintenance (inspection and repairs)	Risk of asset failure is very high and increasing maintenance costs	Risk of failure is low for new equipment and reduced maintenance costs

7 REQUIREMENTS

The solution selected must resolve the need to renew the existing assets currently operating at Berrimah Zone Substation to minimise the risk of failure that will result in outages to customers and possible injury to PWC staff. It is also required to meet the current and future demand of the Berrimah, Wishart and East Arm areas.

PWC will also require compliance with the following:

- Northern Territory Electricity Reform Act
- Power and Water' Network Licence as issued by the Utilities Commission
- Network Technical Code and Network Planning Criteria.

8 OPTIONS

8.1 Options identification

Several of the options for addressing the risks posed by the poor condition of assets at Berrimah ZSS discussed in this section are dependent on replacement of the temporary Wishart Modular substation[14] with a permanent Wishart zone substation (comprising 2 x 20/27MVA 66/11kV transformers).[15]

[14] A 'NOMAD' mobile substation located in Wishart adjacent to Hudson Creek Terminal, comprising 1 x 12MVA 66/22/11kV transformer and associated primary and secondary equipment

[15] PWC's standard zone substation design is based on 20/27MVA 66/11kV transformers

8.1.1 Option 1 – Do nothing (continue to maintain/repair Berrimah ZSS)

This option involves no proactive capital expenditure to replace assets assessed as being in poor condition at Berrimah ZSS. The existing Wishart Modular substation is retained.

The advantage of this approach is deferment of capital expenditure to address risks associated with the poor asset condition at Berrimah ZSS.

However, continuing to operate Berrimah ZSS beyond 2020/21 is not prudent given the risks to personnel safety from explosive failure of the primary plant assets and the increasing risk of disruption to power supplies in case of unavailability of one of the transformer circuits - noting that in event of failure of one of the two 38MVA transformers, no spare transformer is available. This risk will continue to increase with time as the equipment condition continues to deteriorate and the load at risk continues to grow.

The operational costs will also rise over time due to increasing number of planned and unplanned outages as the equipment reaches the end of operational life.

8.1.2 Option 2 – In situ 'brownfields' renewal of the existing Berrimah ZSS with 38MVA 66/11kV Transformers

Progressively replace the existing obsolete standard 38MVA 66/11kV transformers at Berrimah with like-for-like 38MVA transformers at an approximate cost of [redacted]

This option involves progressively replacing the existing primary and secondary plant and systems at Berrimah ZSS.[16] All works will need to be completed with the substation remaining operational and during periods when equipment can be taken out of service for extended periods of time. To minimise safety risk from explosive failure of the assets considered to present the greatest safety risk, the five ASEA HLC circuit breakers would be replaced first.

This will provide firm capacity of approximately 50MVA for as long as the Wishart Modular substation is retained. Once the area load grows beyond approximately 50MVA (forecast to occur in 2024), either a third transformer circuit will need to be established at Berrimah or the permanent Wishart Zone Substation will need to be constructed.

The advantage of this option is that it retains the current level of firm capacity, which should be sufficient until 2024/25 according to the current load forecast.

The disadvantages of this option include:

(i) It maintains the current obsolete standard transformer size and substation design, which will limit operational flexibility, reduce asset utilisation over time, and increase costs (such as spare holdings);

[16] Commencing with the highest priority assets

(ii) It relies upon the continued use of the Wishart Modular substation, which as discussed in the Preliminary Business Case for project PRD 330001, is not considered to be technically prudent;

(iii) Even with new 11kV feeders, in the absence of a permanent Wishart ZSS, it is likely that undervoltage limits will not be able to be maintained in the East Arm (port) area;

(iv) Given the transfer limits of 11kV, Berrimah substation is a lot further from the forecast new load growth, increasing distribution losses significantly;

(v) Brownfields redevelopment requires a lot of construction personnel and operational personnel to be in the close vicinity of live assets that are at risk of explosive failure, increasing already high safety risk significantly for at least two years and increasing the probability of significant cost overruns.

(vi) The brownfields construction approach will take considerably longer than a greenfields approach (see option 3), prolonging the inherent safety and reliability risks; and

(vii) Brownfields redevelopment will require careful outage and commissioning management, and will still result in increased risk of extended supply interruption (i.e. for an unplanned plant/equipment outage whilst the planned outages are in place).

8.1.3 Option 3 – In situ 'brownfields' renewal of the existing Berrimah ZSS with non-standard 50MVA 66/11kV Transformers

Progressively replace the existing obsolete standard 38MVA 66/11kV transformers at Berrimah ZSS with 2 x 50MVA 66/11kV transformers at an approximate cost of [redacted]

The advantage of this approach compared to Option 2 is that it would provide firm capacity of approximately 50MVA without the need to retain the Wishart Modular substation. Once the load grows beyond approximately 50MVA (forecast to occur in 2024), either a third transformer circuit will need to be established at Berrimah ZSS or a permanent Wishart ZSS will be required.

The disadvantages of this option are the same as for Option 2.

There are limitations in the practical ability to distribute from high capacity sites due to localised congestion of underground and overhead circuits. Equally, this provides an additional 'point load' to the transmission system. These issues have resulted in PWC's current standard transformer size being the more practical size of 20/27MVA.

8.1.4 Option 4 – In situ 'brownfields' renewal of the existing Berrimah ZSS with standard 20/27MVA 66/11kV Transformers

Progressively replace the existing obsolete standard 38MVA transformers at Berrimah ZSS with 2 x 20/27MVA transformers at an estimated cost of [redacted].

The advantage of this option over Options 2 and 3 is that it:

- Would provide transformer circuits based on PWC's standard 20/27MVA 66/11kV transformers, which are supported by system spares;
- Aligns with the proposed establishment of a permanent Wishart zone substation (which is closer to the forecast areas of load growth), providing sufficient firm capacity and power quality in the region for the foreseeable future.[17]

The major disadvantages of this option are the risks associated with brownfields development outlined under option 2.

8.1.5 Option 5 – Construct a new air insulated switchgear (AIS) Berrimah Zone Substation (Preferred Option)

This option involves greenfield development of a replacement Berrimah ZSS on land adjacent to the existing substation.

To meet forecast load growth, minimise design costs, maximise operational flexibility, and minimise future capital and operating costs, the configuration of the substation would be based on an ultimate design of 3 x 20/27MA transformer circuits and up to four 66kV line entries. It would be established with 2 x 20/27MVA transformers at an estimated base cost of [redacted].

For reasons outlined under Options 2 and 3, establishing the new substation with non-standard transformers is an inferior approach to establishing the new substation with 2 x 20/27MVA transformers (initially) and is not considered further.

The scope of works includes:

- Construction new 66kV AIS switchyard adjacent to the existing 66kV switchyard.
- Construct two new 20/27MVA 66/11kV transformers with bays and oil containment for a third unit in the future.
- New 11kV switchboard with two bus sections in a new building with separate protection and control schemes for the 11kV and 66kV systems.
- Install two 11kV capacitor banks.
- Install two 11kv/415V auxiliary transformers with 11kV RMU.

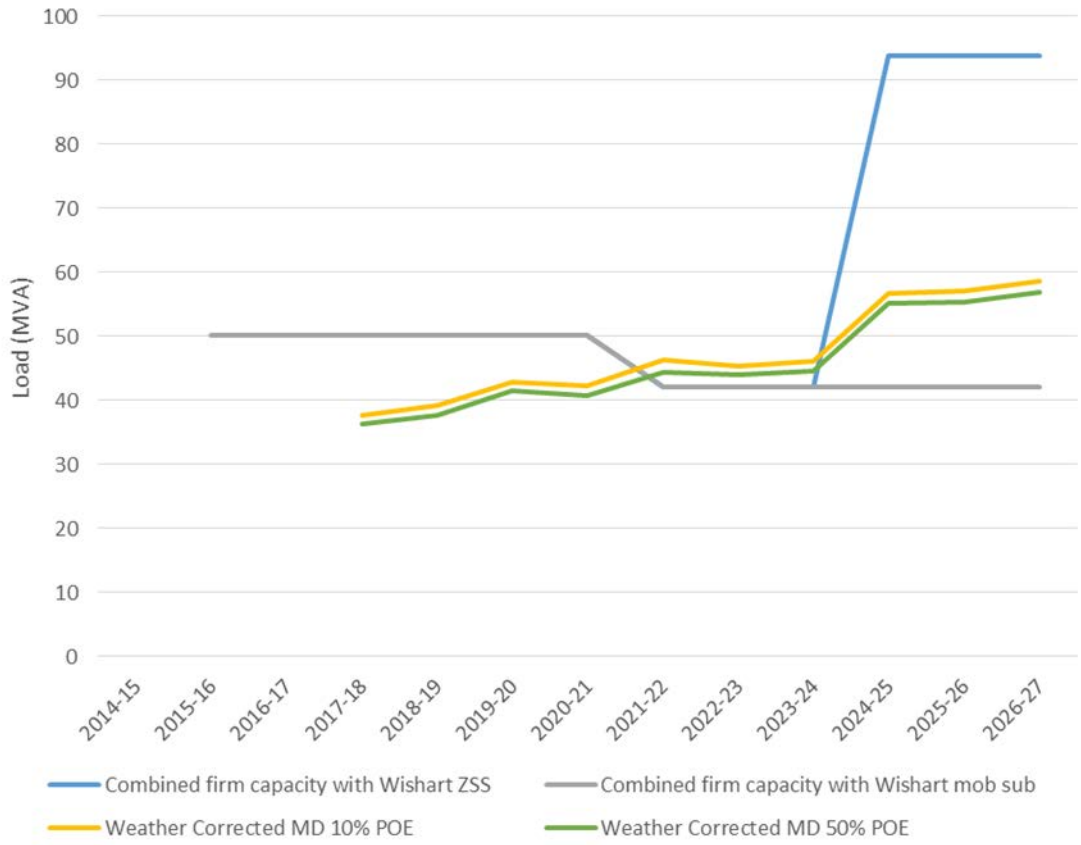
Appendix B shows the proposed layout of the new switchyard and building.

[17] The firm capacity of the proposed four 20/27MVA transformers at Berrimah and Wishart ZSSs combined is 81MVA

To enable existing and forecast demand in the region to be safely and reliably supplied in accordance with the PWC's planning criteria, if the new Berrimah ZSS is established with 2 x 20/27MVA transformers, a permanent Wishart ZSS is required by 2024 to cater for the forecast increase in demand.

As shown in Figure 3, with the addition of 27MVA firm capacity at the proposed Wishart ZSS, the firm capacity in the area increases to 81MVA which will be adequate for foreseeable peak demand.

Figure 3 – Berrimah/Wishart area load forecast and firm capacity with and without the proposed new Berrimah and Wishart ZSSs (option 5)



8.1.6 Option 6 – Construct a new gas insulated switchgear (GIS) Berrimah Zone Substation

This option is based on new indoor 66kV GIS equipment, new 11kV switchboard, and associated secondary equipment in a new building at an estimated cost of [redacted].

The scope of works includes:

- New control and switchgear building;
- New indoor 66kV Gas Insulated Switchgear;
- Identify suitable 66kV cable routes to connect existing 66kV feeders and the new 66/11kV transformers to the new 66kV GIS;

- Construct two new 20/27 MVA 66/11kV transformers with new bays and oil containment for a third unit in the future;
- New 11kV switchboard with three bus sections in the new building;
- Two 11kV capacitor banks.

Appendix C shows the proposed layout of the new switchyard and building.

There are no significant advantages attributable to the GIS solution compared to the AIS solution discussed in Option 3 because there is sufficient land available to accommodate the AIS solution (at a lower total cost).

8.1.7 Option 7 – Demand Management

Two demand management options are considered, Option 7a, which is based on delaying capital expenditure on extra firm capacity in the area (i.e. via options 2, 3 or 4) until at least 2024/25 and Option 7b, which is based on releasing the NOMAD mobile substation deployed in Wishart for its intended purpose. Both options are predicated on the new Berrimah substation being commissioned in 2021 with a firm capacity of 33.7MVA.

Based on PWC's research, the most likely source of demand management is via curtailment contracts with large commercial and industrial customers in the area.[18] PWC does not have access to other forms of demand management such as through ripple control or smart meter activated control of customer loads (such as air conditioners).[19]

To comply with the Class C Supply requirements, the load curtailment would have to be achieved within 60 minutes, which is relatively short notice.[20]

Option 7a – defer extra firm capacity until 2024/25

Referring to Figure 3, this option requires approximately 2-4MVA[21] of reliable peak demand reduction to be available in the event of a significant unplanned outage of a Berrimah ZSS transformer circuit for as long as the Wishart Modular substation is retained.

The estimated cost of this option is [redacted] over five years over the next RCP.[22]

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[18] Typically, this is arranged through a third party 'aggregator'

[19] It is unlikely that turning off air conditioner compressors, even for as little as 15 minutes at a time will be accepted as a demand management initiative in the Northern Territory due to the prevailing climatic conditions

[20] Based on PWC's research, advance notice of at least several hours is typically required to arrange the necessary arrangements within the business' premises

[21] Based on a combined firm capacity of (30.1 + 12) MVA = 42.1 MVA from the Berrimah and Wishart Modular substation

[22] If it is available, interruptible load can be assumed to cost between $75-$350/kVA, depending on the technology deployed (refer to AusGrid, Regulatory Proposal, 2014-19, Attachment 6.12, page 13, and Oakely Greenwood, Advice on the DMIS, pages 15-17)

The major advantage of Option 7a is that it delays the need to commit to capital expenditure to provide more firm capacity into the area, providing more time to assess the actual load growth and update demand forecasts.

The disadvantages of Option 7a are:

(i) PWC has no experience with securing reliable load curtailment;

(ii) The option is unlikely to be technically (or commercially) viable:

- 7MVA is a large amount of distribution-connected load in absolute terms, and it represents a significant proportion (approx. 15%) of the total demand in the area; and
- The required load may not be able to be curtailed within the required 60 minutes to satisfy the Class C Supply requirements

(iii) It requires ongoing operation of the Wishart Modular substation, which has the technical disadvantages outlined under Option 1.

PWC will continue to explore the technical and commercial viability of this option by engaging with experienced load aggregators prior to submitting the Business Case for Approval.

In the interim, Option 7a is not considered to be technically viable.

Option 7b – To release the Wishart Modular substation for its intended purpose as a mobile substation, an estimated 16MVA peak load reduction is required in the Berrimah/Wishart/East Arm region. More peak demand reduction may be required from 2026/27 onwards.

The main advantages of Option 7b are the same as Option 7a, with the additional advantage of releasing the NOMAD substation for its intended purpose.

Option 7b is much less likely to be technically viable than Option 7a and a cost estimate has not been derived for it.

8.2 Comparative cost analysis (including sensitivity analysis)

PWC is currently developing a probabilistic risk-cost methodology which, when completed will be used to compare options and confirm the economically optimum time for investment.

Table 2 summarises the results of a comparative cost analysis, the details of which are included in Appendix D. Of the technically viable options, Option 3a – Build a new (greenfields) AIS Berrimah ZSS – has the lowest NPC.

Table 2: Summary of comparative capital cost analysis

Option	Capital cost ($M)	Net Present Cost ($M)	Comments
1 – Do nothing	[redacted]	[redacted]	Not technically viable
2 – Brownfields renewal of Berrimah ZSS (2 x 38.1	[redacted]	[redacted]	Assumes Wishart ZSS needs to be established in [2027] to

transformers, AIS)			provide sufficient firm capacity to meet the regional peak load projection
3 – Brownfields renewal of Berrimah ZSS (2 x 50MVA transformers, AIS)	[redacted]	[redacted]	Assumes Wishart ZSS needs to be established in [2027] to provide sufficient firm capacity to meet the regional peak load projection
4 – Brownfields renewal of Berrimah ZSS (2 x 20/27MVA transformers, AIS)	[redacted]	[redacted]	Assumes Wishart ZSS needs to be established in [2021] to provide sufficient firm capacity to meet the regional peak load projection
5 – Greenfields replacement of Berrimah ZSS (2 x 20/27MVA transformers, AIS)	[redacted]	[redacted]	Assumes Wishart ZSS needs to be established in [2021] to provide sufficient firm capacity to meet the regional peak load projection Lowest NPC option (Preferred Option)
6 – Greenfields replacement of Berrimah ZSS (2 x 20/27MVA transformers, GIS)	[redacted]	[redacted]	Assumes Wishart ZSS needs to be established in [2021] to provide sufficient firm capacity to meet the regional peak load projection
7 – Demand management	[redacted]	[redacted]	Not technically viable (pending further research)

8.3 Non-cost attributes

An analysis of the non-cost attributes for each option has been completed using the multi-criteria analysis method. The attributes are selected considering major risks and priorities to achieve Project Objectives. A weighting is allocated to each, totalling 100%. Each attribute is given a score out of 5 (from 1 – Fails to satisfy, to 5 – exceeds requirements); the score is then multiplied by the relevant weighting to give the weighted score that is summarised in the table below.

8.3.1 Evaluation Summary

	Project Objectives			Technical & System Risk			Stakeholder Risk			Env. Risk		Commercial
Criteria	**Reduced Risk Asset Failure**	**Maintain System Security**	**40 Year Design Life**	**Standard Assets**	**Constructability**	**Continuity of Supply**	**Safety**	**Community Impact**	**Approvals**	**Oil Contamination**	**Land Clearing**	**NPV/C**
Weighting (%)	10	10	10	5	5	10	10	5	5	5	5	20
Option 1	0.1	0.2	0.1	0.05	0.2	0.2	0.2	0.1	0.2	0.1	0.2	1.0
Option 2	0.4	0.4	0.4	0.2	0.1	0.2	0.2	0.3	0.15	0.15	0.2	0.8
Option 3	0.4	0.4	0.4	0.2	0.1	0.2	0.2	0.3	0.15	0.15	0.2	0.7
Option 4	0.4	0.4	0.4	0.2	0.1	0.2	0.2	0.3	0.15	0.15	0.2	0.6
Option 5	0.4	0.4	0.4	0.2	0.25	0.4	0.4	0.4	0.15	0.15	0.1	0.5
Option 6	0.4	0.4	0.4	0.2	0.25	0.4	0.4	0.4	0.15	0.15	0.15	0.4

Weighted Scores:

Option 1: Deferral	2.65
Option 2: Brownfields 2 x 38.1MVA	3.50
Option 3: Brownfields 2 x 50MVA	3.40
Option 4: Brownfields 2 x 27MVA	3.33
Option 5: Greenfields 2 x 27MVA AIS	3.75
Option 6: Greenfields 2 x 27MVA GIS	3.70

8.4 Preferred Option

The preferred option (Option 5) is the greenfield AIS replacement of the existing Berrimah ZSS with a new 2 x 20/27MVA 66/11kV substation on a site adjacent to the existing substation.

This option best fulfils the project objectives of asset renewal but at the same time having minimum impact on system security whilst under construction. It also presents minimum safety risks during construction. Option 6 is more expensive but has added benefits of reduced space requirements and

pollution resistance. In this instance, the benefits are not required as there is abundant land owned by PWC and pollution levels are low.

This option will allow the new substation to be constructed and commissioned while the existing substation continues to operate without any interruptions. Once the new substation is ready to be energised, the 66kV and 11kV feeders will be progressively cut over from the existing substation.

There is little risk of public opposition to the construction of this zone substation as it located in an industrial area and underneath the existing commercial aircraft flight path. PWC currently owns the land that surround the existing zone substation.

The design of the substation will be to the existing PWC Substation Standards and will be similar in layout to current zone substations. This will maximise constructability and reduce design cost risk.

There will be minimal clearing of the site as there is no significant native vegetation on the PWC owned land. As with other zone substations, power transformers will be installed with current oil containment systems that will prevent hydrocarbon release.

8.4.1 Other Considerations

The two transformer configuration with provision for a third unit assumes that the planned Wishart Zone Substation will be constructed by 2021 (i.e. at the same time at the new Berrimah ZSS is commissioned) to provide sufficient firm capacity for the area. If the permanent Wishart Zone Substation is deferred, the expected load growth in the area will rapidly advance the need for the construction of a third transformer and 11kV switchgear extension at Berrimah to provide the extra capacity.

9 PROJECT OUTLINE

9.1 Project Description

This project is to construct the replacement 66/11kV zone substation at Berrimah.

Work includes a new 66kV AIS (air insulated switchyard) with two 66/11kV 20/27MVA power transformers, 11kV switchboard, along with the associated protection and control equipment.

9.1.1 Scope Inclusions

The scope of the project includes:

- Construct a new 66KV AIS switchyard allowing for four incoming 66kV transmission lines and three 66/11kV transformers;
- Install associated 66kV outdoor switchgear and equipment;
- Install two 20/27MVA 66/11kV ONAN/ONAF power transformers;
- Construct building for the 11kV switchboard and secondary control systems;

- Install 11kV switchboard (two bus sections with an allowance for a third) with arc containment and ducting;
- Install associated control and protection equipment in the new control building;
- Install two 11kV capacitor banks with an allowance for a third;
- Minor transmission and distribution line works to turn existing feeders into the new switchyard;
- Minor remote end control and protection equipment upgrades.

9.1.2 Scope Exclusions

- Decommissioning of existing Berrimah Zone Substation.

9.1.3 Dependencies

- The scope of the project will be dependent on the permanent Wishart Zone Substation proceeding as planned.

9.1.4 Assumptions

- It is assumed that the construction of Wishart Zone Substation will proceed as planned.

9.1.5 Key Stakeholders

Name	Title / Business Unit
Internal – Governance Stakeholders	Chief Executive
	Investment Review Committee
	Executive General Manager Power Networks
	Chief Engineer
	Group Manager Service Delivery
Internal – Design Stakeholders	Senior Manager Networks Development and Planning
	Manager Major Projects
	Senior Manager Network Assets
	Manager Protection
External – Authorities	Darwin City Council
	Environmental Protection Authority
	Aboriginal Areas Protection Authority

External - Other	Local Residents
	Ministers
	Utilities Commission / Australian Energy Regulator

9.2 Capital Cost

A preliminary cost estimate for the proposed Berrimah ZSS has been prepared. A risk adjusted cost estimate (RACE)[23] was conducted on the preferred option based on latest design, scope and cost information.

Based on the analysis, the project has a 90% likelihood of being delivered [redacted] The contingency attributable to risk is calculated as P95 – P50 [redacted] The calculated P_{50} risk-adjusted cost is the estimated cost of the project.

[redacted]

[23] Berrimah Zone Substation RACE Model, PWC Ref: D2017/464893

9.2.1 Base Capital Cost

Table 1 – Base Capital Cost Estimate

9.2.2 Risk and Contingency

The current estimate has been developed largely based on PWC internal and consultant estimates considering previous experience with similar works. In addition, the RACE process integrates risk into cost estimates based on a monte-carlo simulation of expected pricing and risk realisation.

The contingency amount, calculated as the P95 value minus the expected P50 value, is currently $2.4M.

9.3 Estimated Operating Cost Impact

The average annual maintenance cost for Berrimah Zone Substation based on the previous four years is $330,574 per annum. The costs are comprised of planned, unplanned and preventative maintenance.

The expected maintenance cost for the new AIS zone substation is expected to be approximately $142,677 per annum. This is based on the recently commissioned AIS Zone Substations in PWC. This represents a reduction of maintenance costs of approximately $187,897 per annum once the new zone substation is operational.

Item	Annual Incremental Cost ($'000)
Planned Maintenance	78,844
Preventative Maintenance	6,300
Unplanned Maintenance	57,533
TOTAL	**142,677**

Table 2 – Estimated Operating Cost Impact

9.4 Project Milestones

Project Phase (end)	Investment Planning	Project Development	Commitment	Implementation	Review
Original Plan (BNI)	06/2013	06/2014	06/2015	06/2017	09/2017
Current Forecast			06/2018	06/2021	09/2021
Actual Completion	06/2013	09/2017			

10 RISK MANAGEMENT AND COMPLIANCE

A preliminary risk register has been established to address project risk. This is included in Appendix E. This register will form the basis of the Project Risk Register into the project delivery phase. The register will be regularly reviewed and updated as required to ensure all identified risks are managed as the project progresses.

10.1 Technical and System Issues

The existing 66kV switchyard and 11kV switchboard at the Berrimah Zone Substation will remain in service whilst the new zone substation is constructed adjacent to the existing site.

For all construction work adjacent to an energised switchyard, PWC has policies and procedures that must be adhered to, such as the Power and Water Access to Apparatus Rules and Access to High Voltage Apparatus Procedure.

Change over from existing to new 66kV switchyards will involve short term line outages to complete the transfer. These outages will be scheduled away from peak periods and in detail to minimise system security risk in close consultation with System Control.

11 PROJECT IMPLEMENTATION

This project is to be managed by the Power Networks' Major Projects group. It is planned that the project will be delivered using the "Design and Construct" (D&C) methodology through an external contractor.

- This project will follow the requirements of the investment planning framework (gating process); and
- The project will comply with PWC designs.

Testing and commissioning will be managed by Power Networks' Test and Protection group.

To ensure efficient costs are achieved, the majority of the electrical equipment and construction will be procured through the D&C contract, with detailed specifications prepared by PWC.

11.1.1 Resourcing Requirements (to next gateway)

Resource Type/Role	How Many?	Internal/ External?	Anticipated Start Date	Duration Required	Allocation (% time or # hrs/days/ wks/mths)
Project Manager	1	Internal	Jan 2018	6 months	10%
Planning Engineer	1	Internal	Jan 2018	6 months	10%
Design Engineer	1	External	Jan 2018	6 months	50%

12 FINANCIAL IMPACT

12.1 Funding Arrangements

The project will span over the 2014-19 and 2019-24 regulatory periods.

This project is currently included in the 2017/18 SCI budget for a total of [redacted]

12.2 Capital Expenditure

12.2.1 Variance Coverage

The variance ($0.402M) to the current SCI [redacted] is due to the further developed understanding of the options available for this project. It is expected that some minor works projects will be deferred to fund the variance.

12.3 Incremental Operating Expenditure

Ongoing costs of the new substation are related to operation and maintenance is expected to be $142,677. It is expected there will be a saving of approximately of $187,897 per annum in operating costs due to lower maintenance costs associated with the new equipment.

APPENDIX A

SLD, General Arrangement and Control Room Layout for Option 2 – In Situ Replacement

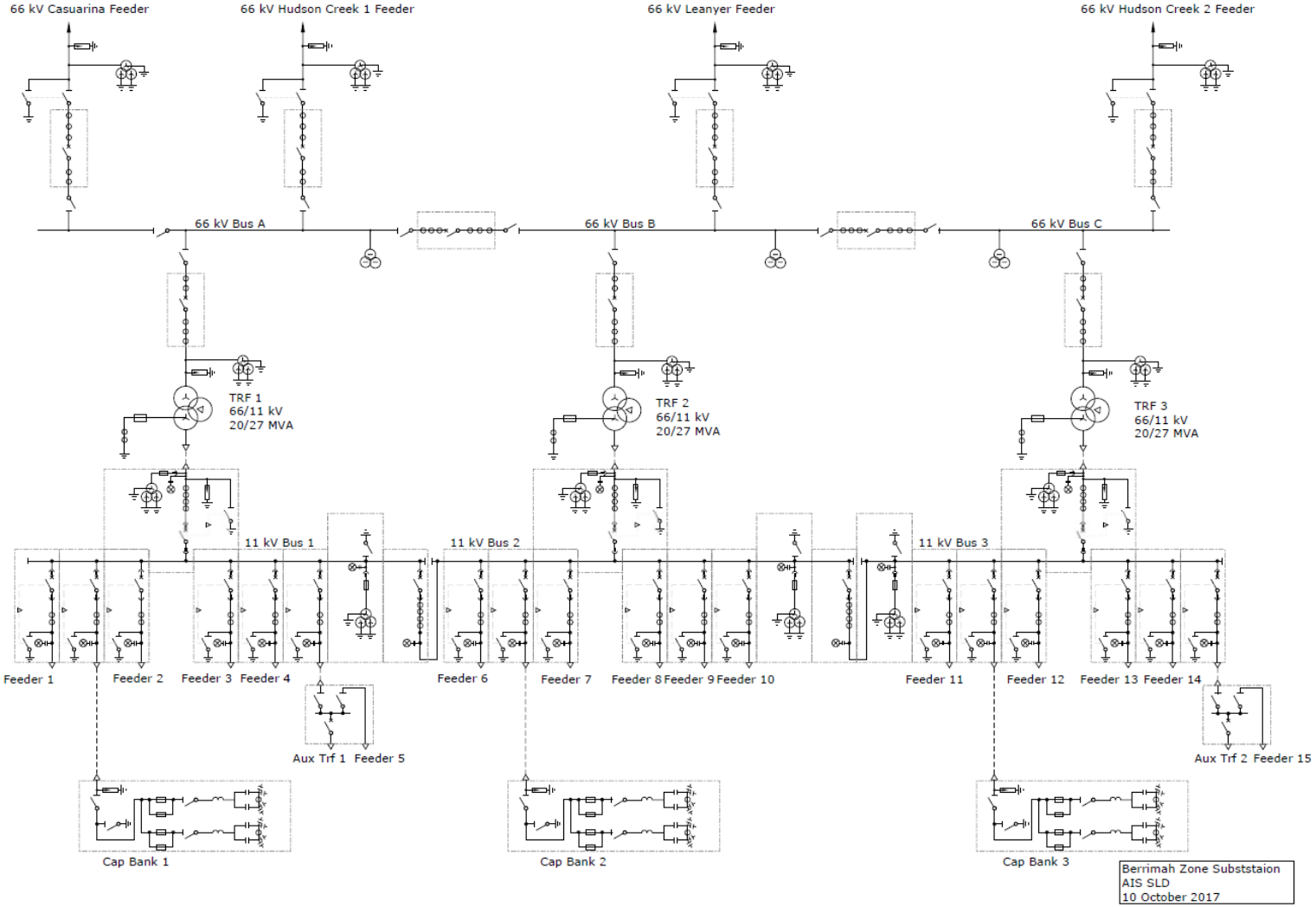


Diagram 1: SLD for Option 2 – In Situ Replacement

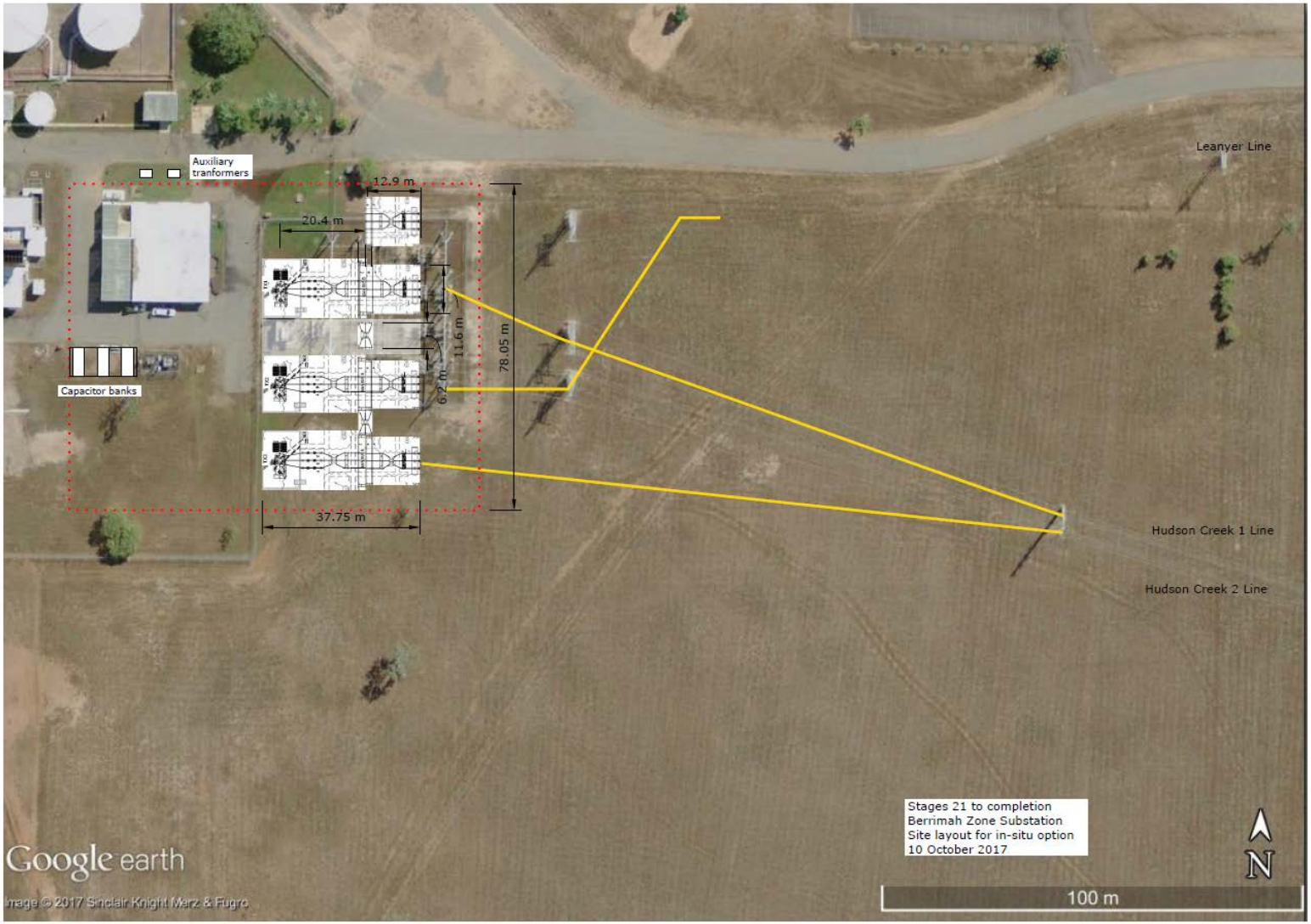
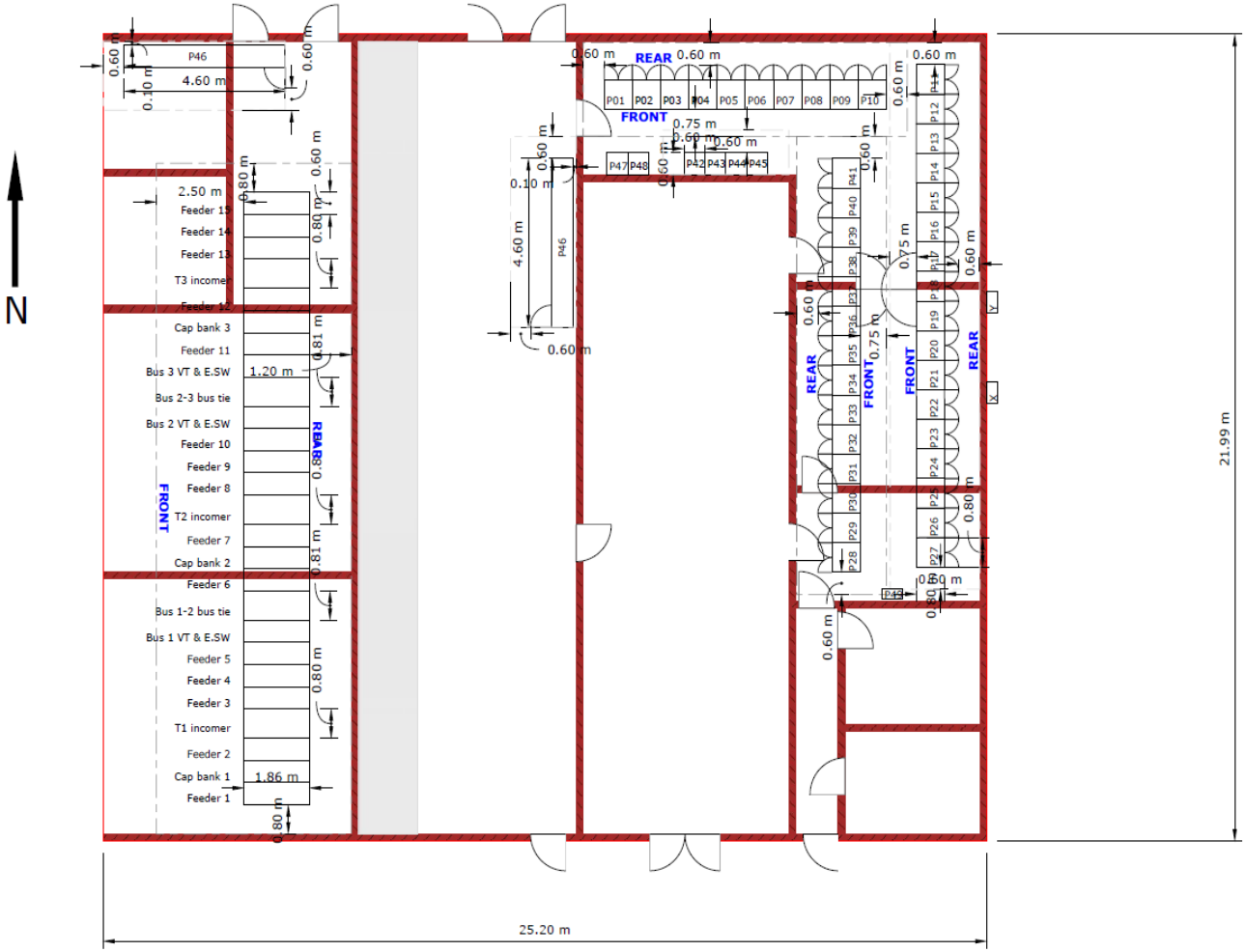


Diagram 2: General Arrangement for Option 2 – In Situ Replacement



P01 Bus 3 VT & E.SW/ Bus 3 prot
P02 Cap 3 prot/management
P03 T3 in/Feeder 15
P04 Feeder 13/Feeder 14
P05 Feeder 11/Feeder 12
P06 Communications 1
P07 Communications 2
P08 Communications 3
P09 Fibre Marsh 1
P10 Fibre Marsh 2

P11 DDR
P12 Tariff Metering
P13 Bus B-C coupler
P14 Bus A-B coupler
P15 Bus C prot
P16 Bus B prot
P17 Bus A prot
P18 TF3 AVR
P19 TF3 prot
P20 TF2 AVR
P21 TF2 prot
P22 TF1 AVR
P23 TF1 prot
P24 Feeder C
P25 Feeder HC2
P26 Feeder HC1
P27 Feeder L

P28 Feeder 1/Feeder 2
P29 Feeder 3/Feeder 4
P30 T1 in/Feeder 5
P31 Cap 1 prot/management
P32 Bus 1 VT & E.SW/ Bus 1 prot
P33 Bus 1-2 bus tie/spare
P34 Feeder 6/Feeder 7
P35 Feeder 8/Feeder 9
P36 T2 in/Feeder 10
P37 Cap 2 prot/management
P38 Bus 2 VT & E.SW/ Bus 2 prot
P39 Bus 2-3 bus tie/spare
P40 RTU 1/RTU 2
P41 RTU 3/RTU 4

P42 DC distribution board 1
P43 DC battery charger 1
P44 DC battery charger 2
P45 DC distribution board 2
P46 AC change over and main dist board
P47 Electrical services dist board
P48 Mechanical services dist board
P49 Battery isolation panel

X X protection cable penetration
Y Y protection cable penetration

Diagram 3: Control Room Layout for Option 2 – In Situ Replacement

APPENDIX B

SLD, General Arrangement and Control Room Layout for Options 3 – AIS Switchyard

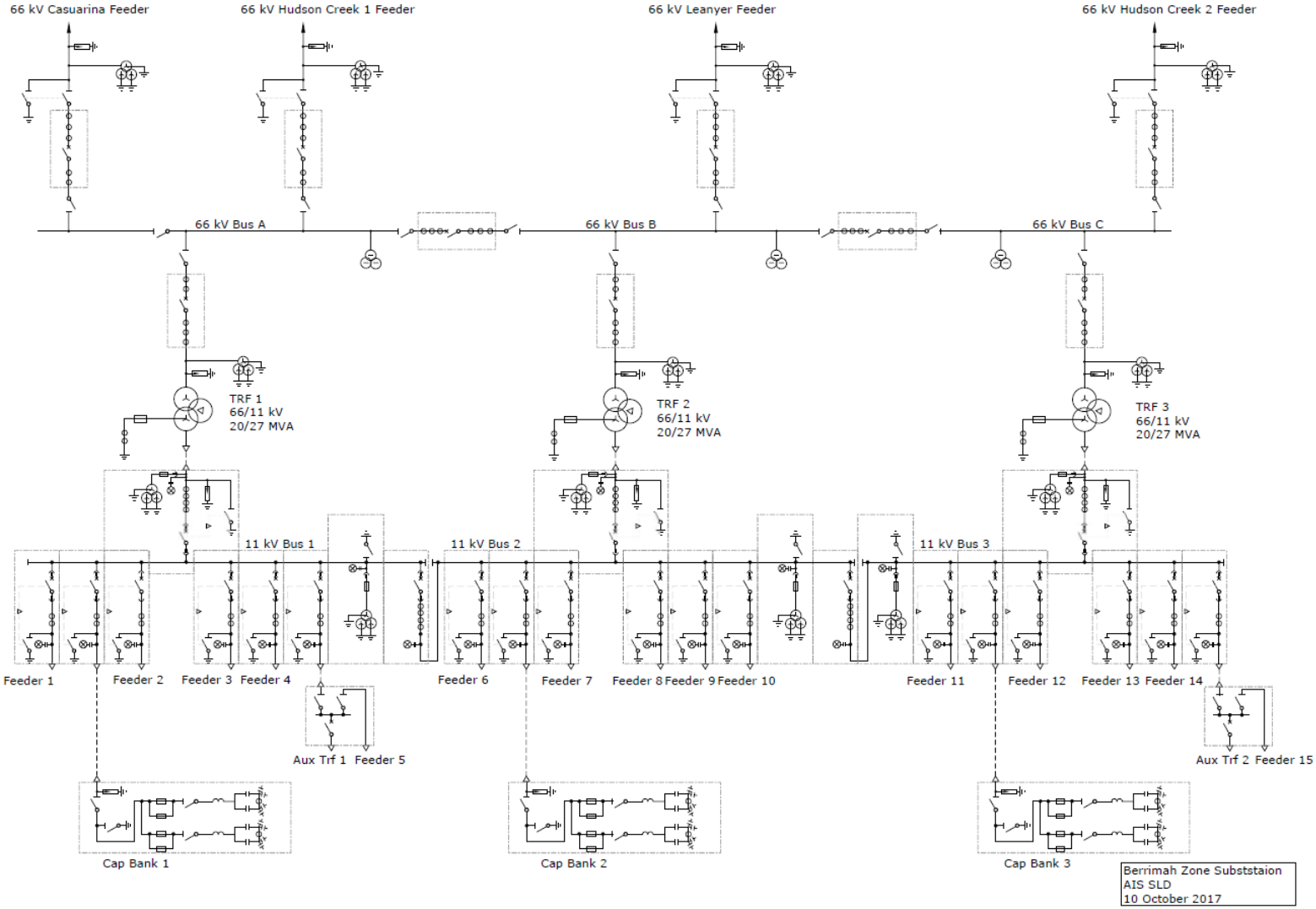


Diagram 4: SLD for Option 3 – AIS Solution

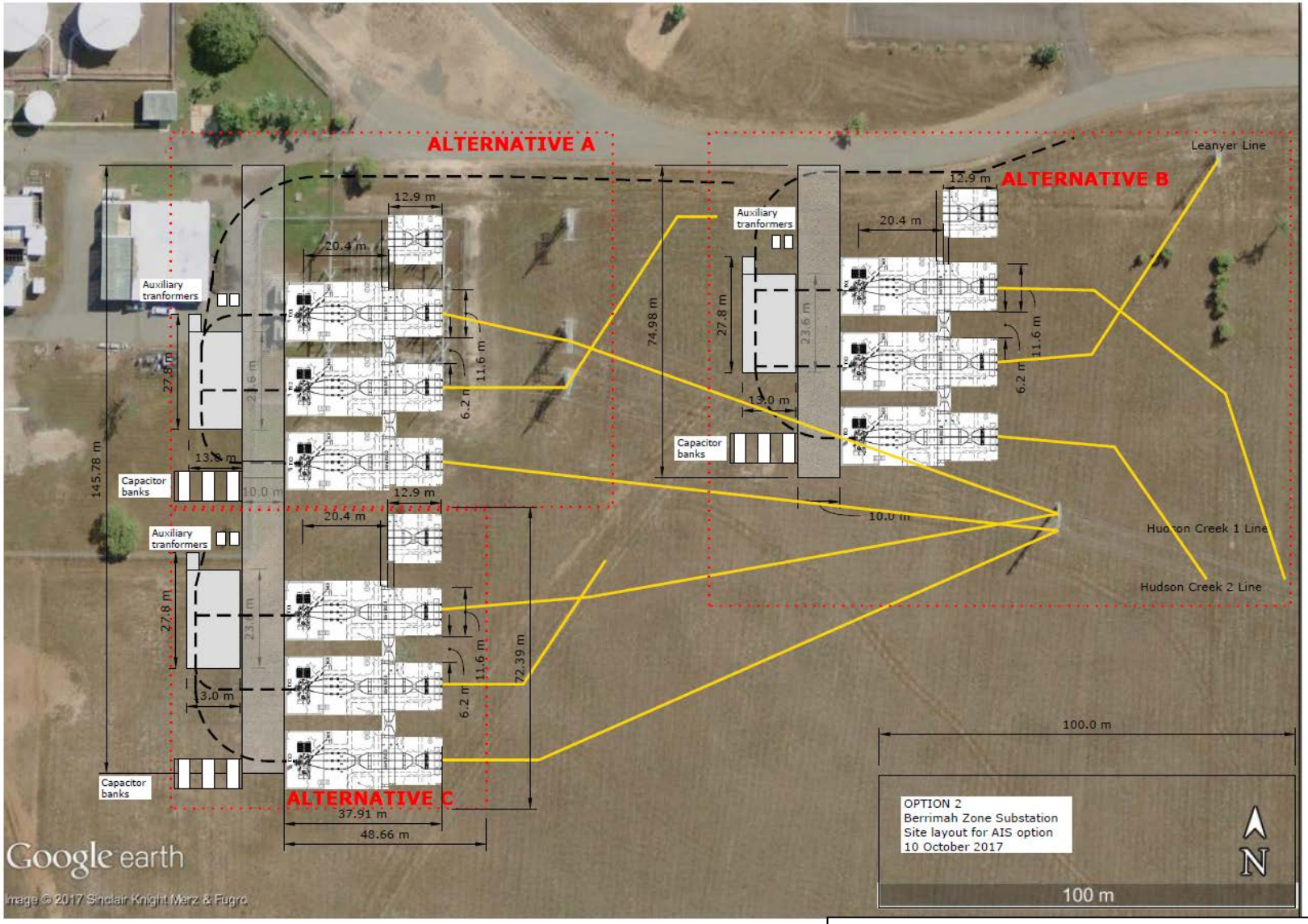


Diagram 5: General Arrangement for Option 3 – AIS Solution (Alternative C recommended)

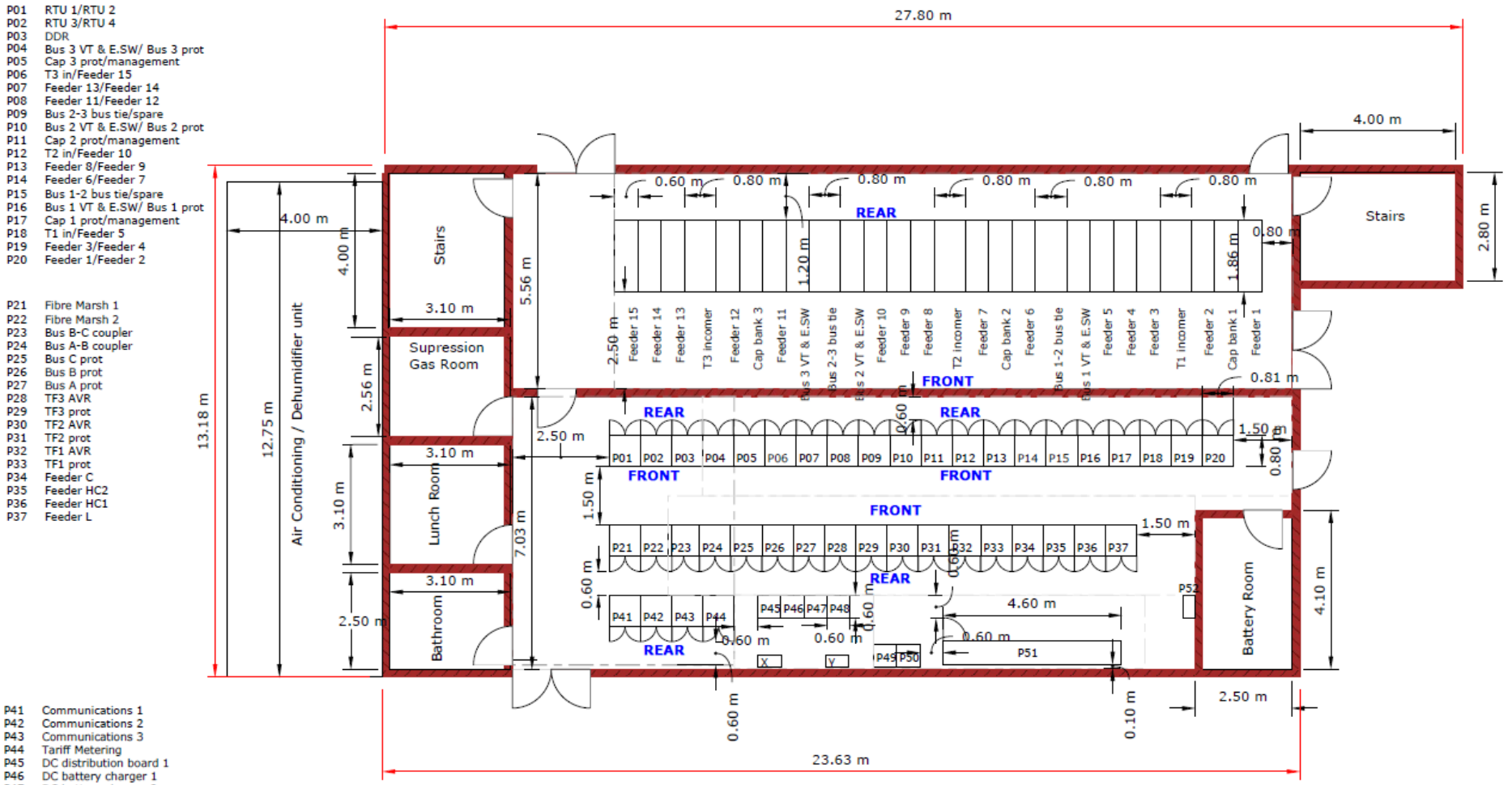


Diagram 6: Control Room Layout for Option 3 – AIS Solution

APPENDIX C

SLD, General Arrangement and Control Room Layout for Options 4 – GIS Switchyard

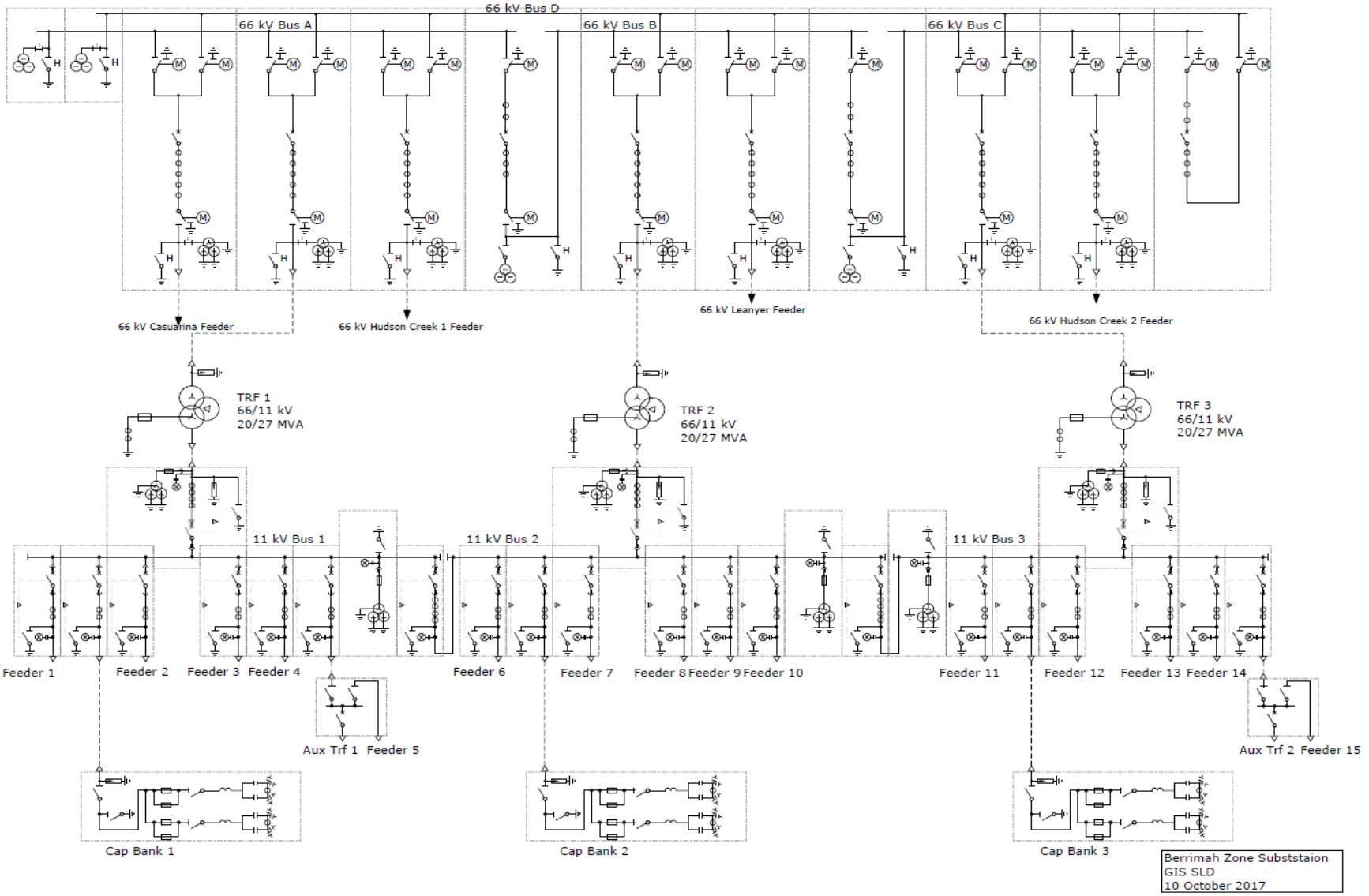


Diagram 7: SLD for Option 4 – GIS Solution

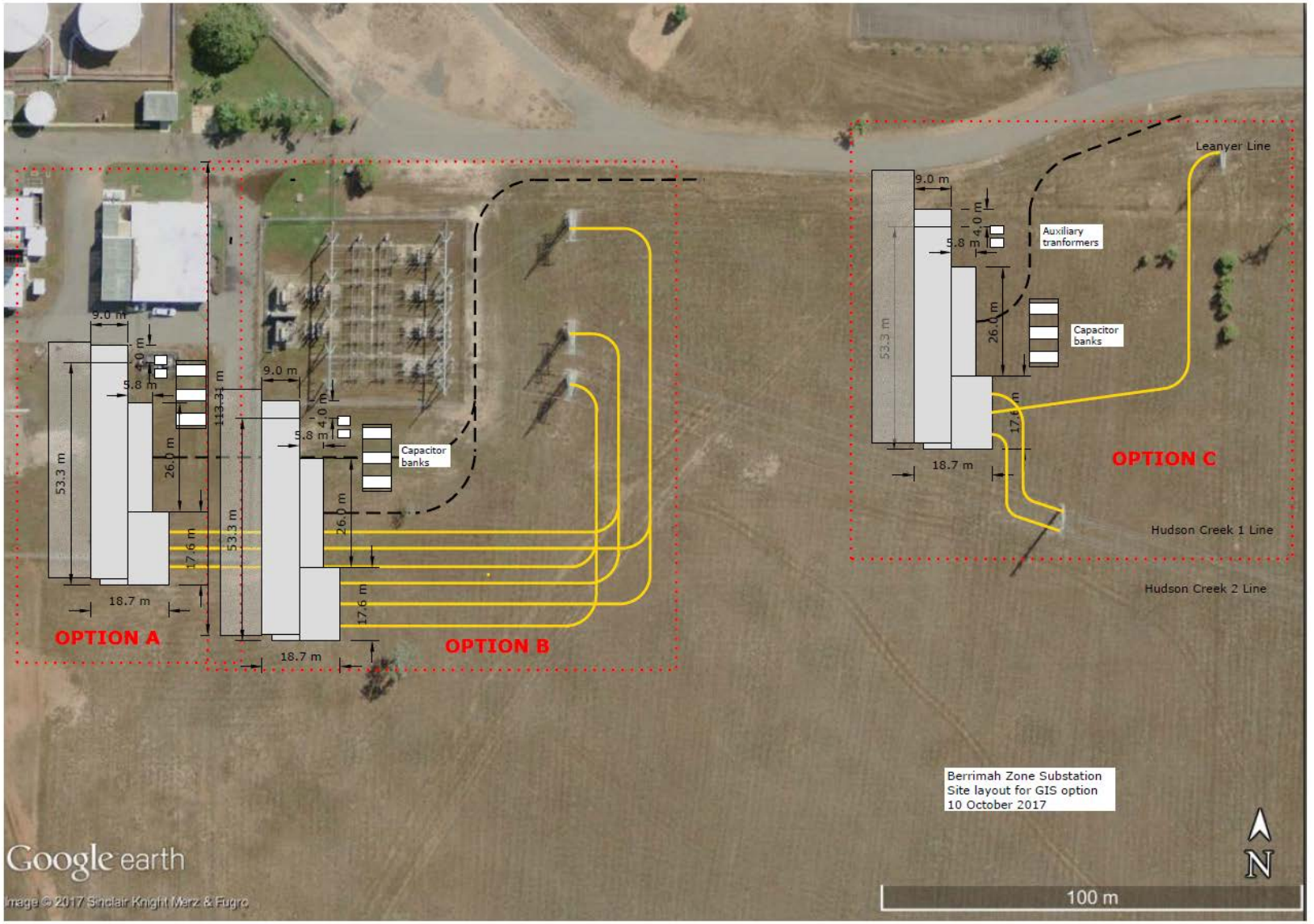
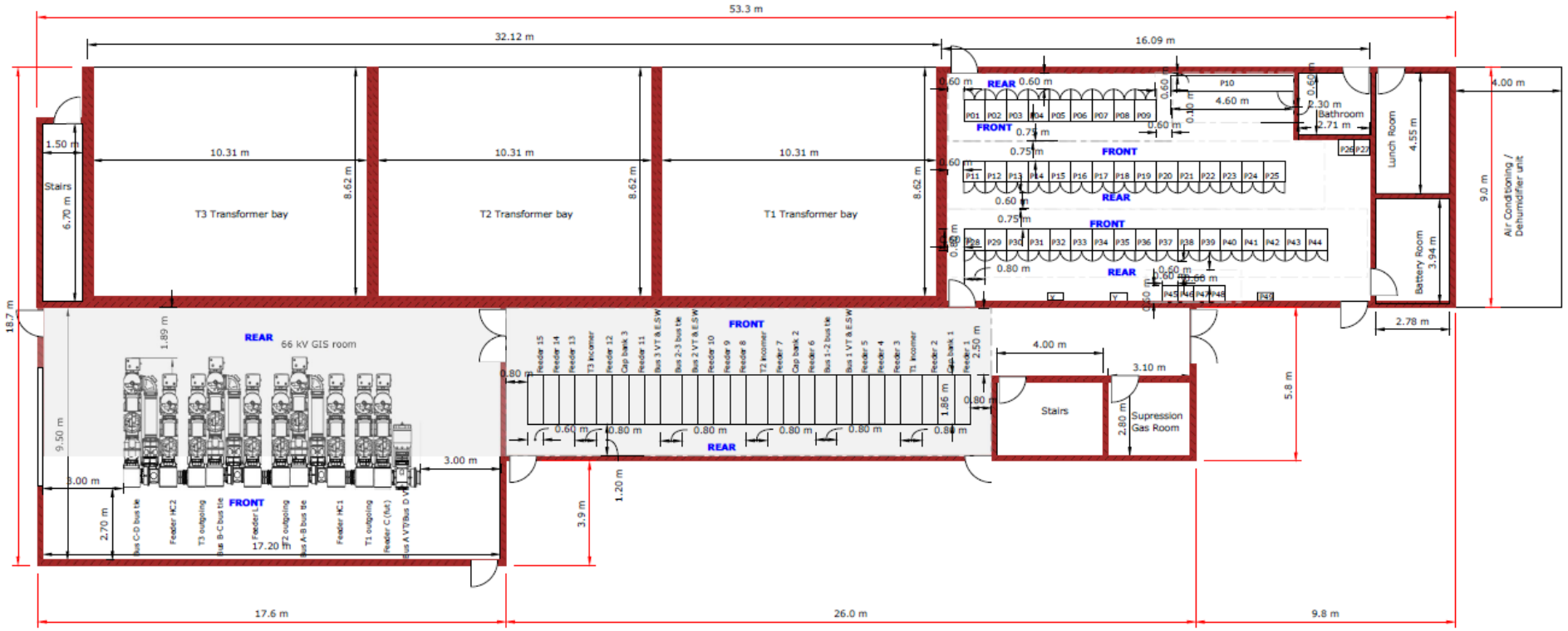


Diagram 8: General Arrangement for Option 4 – GIS Solution (Option B recommended)



P01	RTU 1/RTU 2
P02	RTU 3/RTU 4
P03	DDR
P04	Tariff Metering
P05	Communications 1
P06	Communications 2
P07	Communications 3
P08	Fibre Marsh 1
P09	Fibre Marsh 2
P10	AC change over and main dist board
P11	Bus B-C coupler
P12	Bus A-B coupler
P13	Bus C prot
P14	Bus B prot
P15	Bus A prot
P16	TF3 AVR
P17	TF3 prot
P18	TF2 AVR
P19	TF2 prot
P20	TF1 AVR
P21	TF1 prot
P22	Feeder C
P23	Feeder HC2
P24	Feeder HC1
P25	Feeder L
P26	Mechanical services dist board
P27	Electrical services dist board
P28	Bus 3 VT & E.SW/ Bus 3 prot
P29	Cap 3 prot/management
P30	T3 in/Feeder 15
P31	Feeder 13/Feeder 14
P32	Feeder 11/Feeder 12
P33	Bus 2-3 bus tie/spare
P34	Bus 2 VT & E.SW/ Bus 2 prot
P35	Cap 2 prot/management
P36	T2 in/Feeder 10
P37	Feeder 8/Feeder 9
P38	Feeder 6/Feeder 7
P39	Bus 1-2 bus tie/spare
P40	Bus 1 VT & E.SW/ Bus 1 prot
P41	Cap 1 prot/management
P42	T1 in/Feeder 5
P43	Feeder 3/Feeder 4
P44	Feeder 1/Feeder 2
P45	DC distribution board 1
P46	DC battery charger 1
P47	DC battery charger 2
P48	DC distribution board 2
P49	Battery isolation panel
X	X protection cable penetration
Y	Y protection cable penetration

Diagram 9: Control Room Layout for Option 4 – GIS Solution

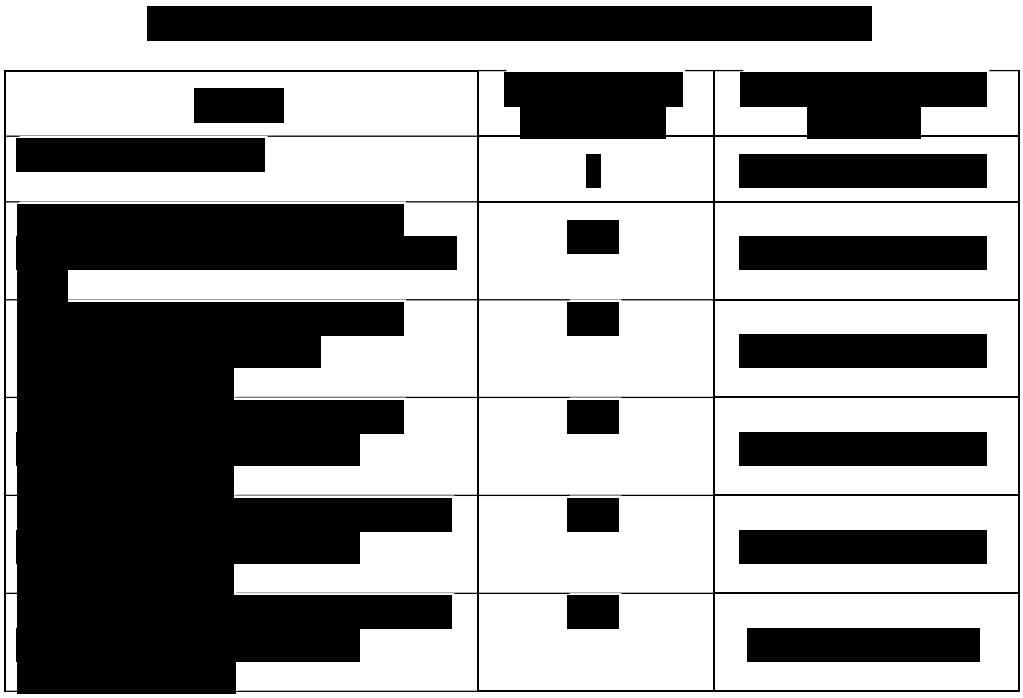
APPENDIX D

Summary of Financial Analysis

Introduction

The purpose of this Appendix is to provide details of the options analysis for Replace Berrimah Zone Substation.

Table A1 below outlines the estimated capital expenditure for Options 1, 2, 3, 4, 5 and 6. The operational cost of Option 6 Greenfields Replacement (GIS) is lower than Option 5 Greenfields Replacement (AIS) option. This is reflected in the operational cash flows below.



Assumptions

In modelling the options, technical, economic and cost parameters were included. The technical and cost data was provided by Power Networks and the economic data was sourced from Pricing and Economic Analysis (PEA). Base cost capital expenditure was based on the consultant's feasibility study.

In the assumptions, all costs exclude GST or other government charges.

The common variables employed in the Discounted Cash Flow (DCF) model are presented in Table A2 below.

These variables are consistent with the 2019-24 Regulatory Proposal to the AER and are considered appropriate for use in the detailed commercial analysis.

Table A2 – Common Variables

Variables	
Nominal Pre-Tax WACC	6.96%

CPI – 2017/18	2.42%
CPI after 2017/18	2.42%
Time Horizon of Project	40 years

Option 1 - Deferral

The analysis for this option does not require any capital expenditure. It is assumed that the current average annual opex of $330,574 will continue. However, it is expected it will increase as the equipment ages and the risk of failure increases.

Commercial analysis of Option 1 (deferral) was not undertaken as.

Option 2 – Brownfields renewal of Berrimah ZSS (2 x 38.1 transformers, AIS)

The analysis for this option includes capital expenditure of [redacted]

Option 3 - Brownfields renewal of Berrimah ZSS (2 x 50MVA transformers, AIS)

The analysis for this option includes capital expenditure of [redacted].

Option 4 - Brownfields renewal of Berrimah ZSS (2 x 20/27MVA transformers, AIS)

The analysis for this option includes capital expenditure of [redacted].

Option 5: Greenfields replacement of Berrimah ZSS (2 x 20/27MVA transformers, AIS)

The analysis for this option includes capital expenditure of [redacted].

Option 6: Greenfields replacement of Berrimah ZSS (2 x 20/27MVA transformers, GIS)

The analysis for this option includes capital expenditure of [redacted]

Least cost analysis

Based on the DCF analysis undertaken, the least cost option is Option 1 (Do Nothing). However, this is not considered to be a viable alternative due to the risk of major outages as a result of equipment failure. The next least cost option is Option 5 (Greenfields AIS). This is summarised in Table A3 below.

Table A3 – Net Present Cost of Options

Option	NPC ($M)
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

Tariff cover

A portion of this project capex (2019/20 and 20120/21 expenditure) will be submitted as part of the 2019 Regulatory Proposal to the AER. The AER's Final Determination will provide the approved level of net capital expenditure for the 2019-24 period. In so far as the Regulated Networks annual capital expenditure program remains at this level (or lower), Networks will earn a guaranteed rate of return through standard control service charges until the commencement of the next regulatory control period in 2024-25.

APPENDIX E

DETAILED RISK REGISTER

Refer:

PRD30402 Risk Analysis Berrimah Zone Substation

PWC Ref: D2017/465696

APPENDIX F

SUMMARY PROJECT PROGRAM

Task	*Baseline*			*2017*		*2018*				*2019*				*2020*				*2021*	
	Plan Start	*Plan Duration*	*Percent Complete*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*
Options Study	Jul 17	12 wks	100%																
Concept Design	Oct 18	12 wks	50%																
Planning and Permits	Jan 18	20 wks	20%																
Detailed Design	Jun 18	28 wks																	
Procurement	Jan 19	44 wks																	
Civil Construction	Apr 19	24 wks																	
Primary Electrical Construction	Jun 19	40 wks																	
Secondary Electrical Construction	Jan 20	40 wks																	
Commissioning and Energisation	Oct 20	20 wks																	
Cutover Existing Services	Apr 21	8 wks																	

APPENDIX F

CONDITION ASSESSMENT REPORT

Refer:

Berrimah BEZSS Condition Assessment

PWC Ref: D2017/569042