Asset Management Plan

Pole Mounted Transformers – Distribution

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Authorisations

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Responsibilities

This document is the responsibility of the Asset Strategy Team, Tasmanian Networks Pty Ltd, ABN 24 167 357 299 (hereafter referred to as "TasNetworks").

Please contact the Asset Strategy Team Leader with any queries or suggestions.

- Implementation All TasNetworks staff and contractors.
- Compliance All group managers.

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Record of revisions

Section number	Details
	New Document

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1 Purpose

The purpose of this document is to describe for pole mounted transformers and related assets:

- TasNetworks' approach to asset management, as reflected through its legislative and regulatory obligations and strategic plans;
- the key projects and programs underpinning its activities; and
- forecast CAPEX and OPEX, including the basis upon which these forecasts are derived.

2 Scope

This document covers pole mounted transformers in the distribution network.

3 Strategic alignment and objectives

This asset management plan has been developed to align with both TasNetworks' Asset Management Policy and Strategic Objectives.

It is part of a suite of documentation that supports the achievement of TasNetworks' strategic performance objectives and, in turn, its mission. The asset management plans identifies the issues and strategies relating to network system assets and detail the specific activities that need to be undertaken to address the identified issues.

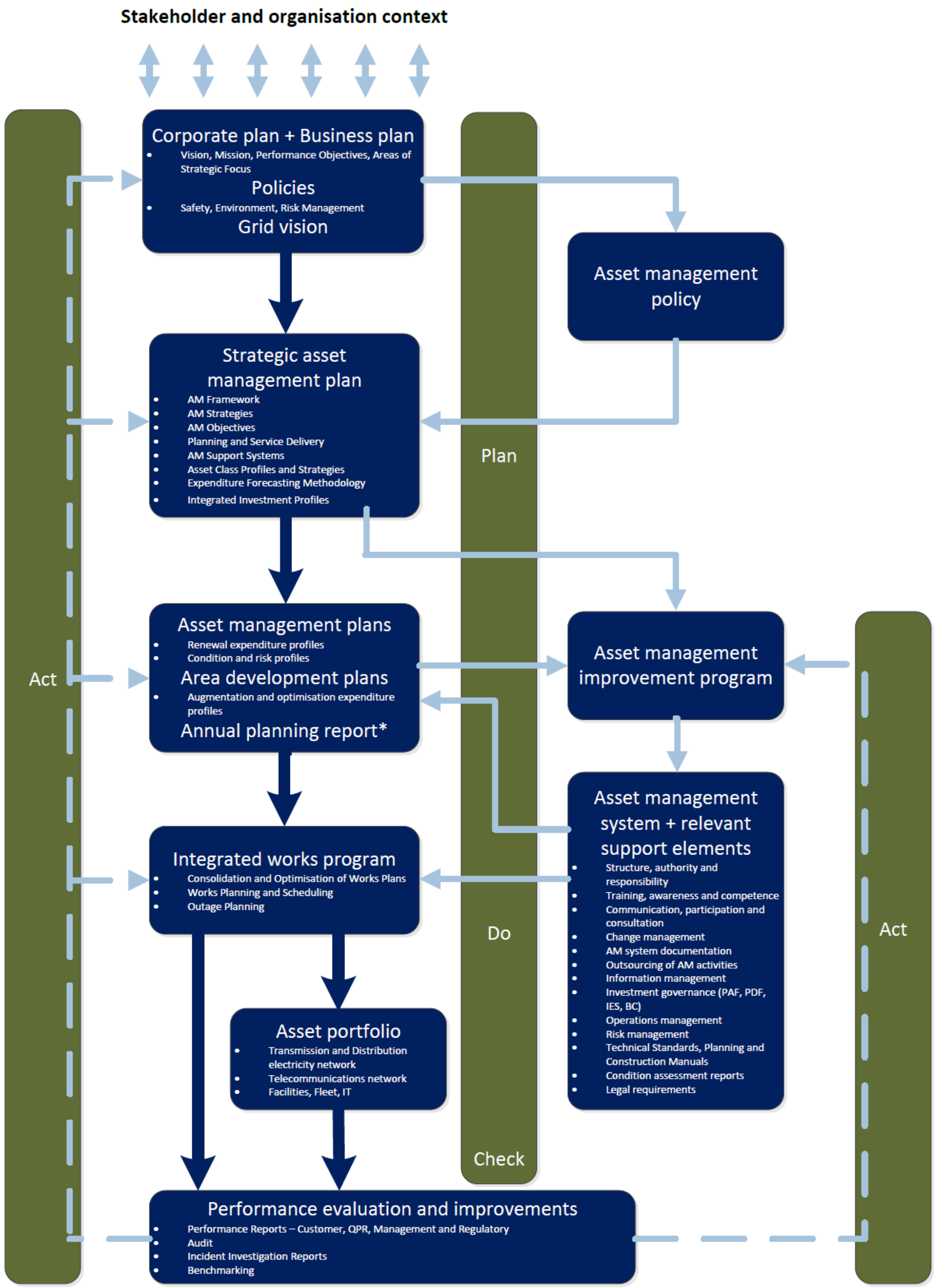
The asset management policy, contained within the Strategic Asset Management Plan, states 'Consistent with our vision and purpose, we strive for excellence in asset management and are committed to providing a safe working environment, value for our customers, sustainable shareholder outcomes, care for our assets and the environment, safe and reliable network services, whilst effectively and efficiently managing our assets throughout their life-cycle'.

The asset management objectives focus on six key areas:

- Zero Harm will continue to be our top priority and we will ensure that our safety performance continues to improve.
- Cost Performance will be improved through prioritisation and efficiency improvements that enable us provide predictable and lowest sustainable pricing to our customers.
- Service Performance will be maintained at current overall network service levels, whilst service to poorly performing reliability communities will be improved to meet regulatory requirements.
- Customer Engagement will be improved to ensure that we understand customer needs, and incorporate these into our decision making to maximise value to them.
- Our Program of Work will be developed and delivered on time and within budget.
- Our asset management Capability will be continually improved to support our cost and service performance, and efficiency improvements.

Figure 1 represents TasNetworks documents that support the asset management framework. The diagram highlights the existence of, and interdependence between, the Plan, Do, Check, Act components of good asset management practice.

Figure 1: TasNetworks asset management documentation framework



* The Annual Planning Report (APR) is a requirement of sections 5.12.2 and 5.13.2 of the National Electricity Rules (NER) and also satisfies a licence obligation to publish a Tasmanian Annual Planning Statement (TAPS). The APR is a compilation of information from the Area Development Plans and the Asset Management Plans.

4 Asset management information

4.1 Asset management information systems

Transformer asset data is stored in GTECH and WASP. Transformer earthing data is currently managed through WASP and spread sheets.

To deliver the asset data, business processes and asset information management practices required for the prudent and efficient management of network assets, TasNetworks is developing a comprehensive asset management information system (AMIS).

TasNetworks maintains an Asset Management Information System (AMIS) that contains detailed information relating to the power transformer population. AMIS is a combination of people, processes, and technology, applied to provide the essential outputs for effective asset management, such as:

- reduced risk;
- enhanced transmission system performance,
- enhanced compliance, effective knowledge management;
- effective resource management; and
- optimum infrastructure investment.

AMIS is a tool that interlinks asset management processes through the entire asset lifecycle and provides a robust platform for extraction of relevant asset information.

4.2 Asset management information improvement initiative

To realise this capability at TasNetworks, the AMIS improvement program is delivering a rigorous and methodical series of targeted initiatives designed to build capability. When implemented, this program will deliver trusted, timely and high quality asset information that supports the strategic and operational asset management processes required for best-practice asset management. This program is complimentary with the current TIBS project and will rely on and benefit from the integrated asset and works management system provided by that project.

The AMIS improvement program is currently delivering the fundamental underpinnings of a mature asset management system including the establishment of:

- asset hierarchies;
- asset data integrity standards; and
- asset nomenclature standards.

The establishment of a contemporary asset condition inspection system for network assets (including, but not limited to distribution poles) has also been identified as a priority initiative within the scope of the AMIS improvement program. TasNetworks currently relies on an outdated and unsupported product for pole mounted transformer inspections. Whilst this tool captures rudimentary pole mounted transformer condition data, the application is no longer supported and cannot be enhanced to take account of altering asset management practices, changing work practices or varying asset configurations. Options for an enhanced, extensible and future-proofed solution are currently being investigated by TasNetworks.

4.3 Asset information

Information such as geographical location, kVA rating, number of connected customers and number of connected life support customers are generally well documented however it is acknowledged that asset information: accuracy, integrity and quality for pole mounted transformers requires improvement.

Installation data is missing for 1,400 of the 30,000 transformers, and is suspect for an unknown number (audits found the installed transformer to be much newer than the asset data records, suggesting that records were not updated when a transformer was replaced.

Failure data is of poor quality, with the reason for failure usually not documented.

Other asset data such as manufacturer, and fuse arrangements is sporadic and inconsistent.

Condition data is not recorded for pole mounted transformers. The exception to this is for transformers that are logged as defects under the pole inspection program because they are leaking and needing replacement.

A component of the transformer earthing inspections is to collect missing asset data.

The AMIS improvement program initiative plan underpins TasNetworks' strategy to improve asset information and thereby enable improved decision making.

5 Related standards and documents

- ENA EG 0 Power System Earthing Guide
- General Specification – GS12 for pole mounted distribution transformers (11 kV and22 kV – ratings up to and including 500 kVA)
- AS2067 Substations and High Voltage Installations exceeding 1 kV a.c
- ENA EG 0 Power System Earthing Guide
- Strategy for PCB management
- ENA DOC 18-2000 Interim Guide for the Fire Protection of Electricity Substations

6 Description of the assets

Pole mounted transformer can be separated into the following types:

- Single phase and three phase transformers;
- Single Wire Earth Return (SWER) transformers; and
- Isolating transformers.

With the exception of Single Wire Earth Return (SWER) devices, pole mounted transformers have off-load tap changers. These allow the output of the transformer to be adjusted (with the transformer not connected to any load) to vary the level of output voltage by small increments (tap settings) to regulate output voltages to within acceptable limits.

6.1 Single phase and three phase pole mounted transformers

Single phase transformer largest size is 63kVA.

Pole mounted transformers are devices used to step up or step down voltages within the distribution system. The majority of distribution transformers installed within the distribution system step down voltages from high voltage (HV) (44 kV, 33 kV, 22 kV or 11 kV) to low voltage (LV) (230/400 V), which the majority of customers use within their electrical installations.

Pole mounted transformers are mounted on a single or double pole structure. The physical size and weight of the unit limits pole mounted transformers to a maximum size of 500 kVA.

Pole mounted transformers contain mineral insulating oil for both electrical insulation of the internal components and cooling.

6.2 Single Wire Earth Return transformers

Single Wire Earth Return (SWER) systems are used in several relatively remote rural locations within the distribution system where there is light load. In SWER systems, one wire is used as the phase conductor and the earth is used as the return conductor. SWER systems typically consist of a SWER isolating transformer and one or more SWER transformers. SWER transformers operate at a voltage of 12.7 KV.

6.3 Isolating transformers

The isolating transformer isolates the earth currents (zero sequence currents) of the SWER system from the three-phase main supply feeder. This limits the exposure to telephone interference and allows the main supply feeder to maintain its sensitive earth fault detection protection.

There are also two LV isolating transformers in the system. These particular LV isolating transformers do not step voltage up or down. Its function is to isolate the low voltage network entirely from the power source. Isolation transformers provide isolation primarily to protect against HV earth faults transferring on to the LV earthing system. These transformers are utilised by TasNetworks in rare situations where the earthing conditions are particularly poor. Due to the isolation, the transformer contains no reference to earth, so in the event of a fault there is no path for current to flow to back to the source.

7 Pole mounted transformer population

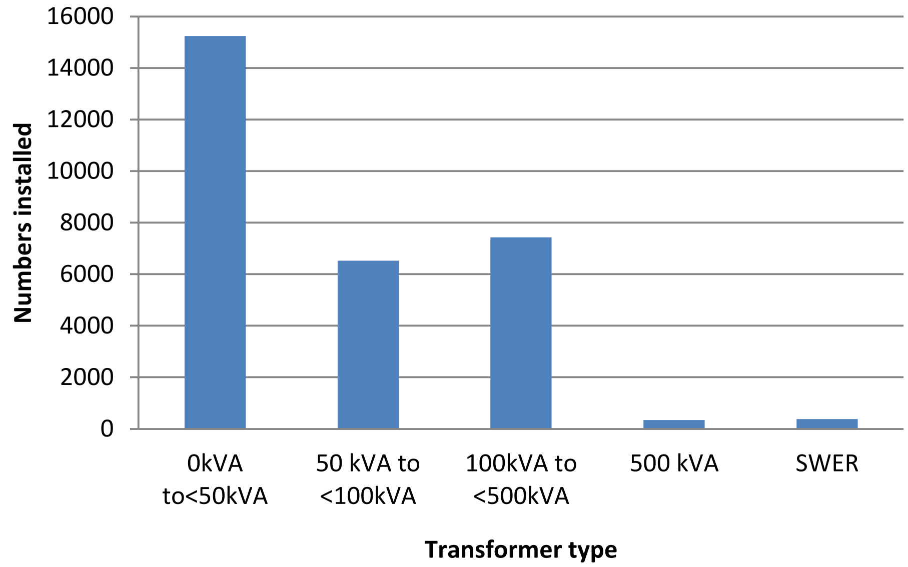
Table 1 and Figure 1 show the pole mounted transformer population by type, voltage, and size.

Table 1: Pole mounted distribution transformer types

Transformer Size	22kV	11kV	6.6kV	12.7kV SWER	LV Isolating	Number Installed
0kVA to <50kVA	11174	4058	2	0	2	15236
50kVA to <100kVA	4416	1842	0	0	0	6258
100kVA to <500kVA	5626	1799	2	0	0	7427
500kVA	272	74	0	0	00	346

Transformer Size	22kV	11kV	6.6kV	12.7kV SWER	LV Isolating	Number Installed
SWER	0	0	0	379	0	379
Total	**21488**	**7773**	**4**	**379**	**2**	**29646**

Figure 2: Pole mounted distribution transformer types



There are an additional 1,441 transformers where no installation data exists.

The other note of caution around the age profile is that anecdotal evidence suggests that for an unknown number of transformers, the new installation date is not recorded when the transformer is changed-out under fault. Therefore the actual population may have an overall younger profile. Periodic inspections and audits aim to improving data integrity in addition to ensuring stricter data requirements on installation of change- out.

The transformer age population profile is shown by transformer capacity in Figure 3.

This transformer age profile indicates a majority of the pole mounted transformer population are those of small capacity transformer of less than 100 kVA (the red and green) which with a small number of SWER transformers (the thin dark blue line) mostly supply the rural and remote located customer loads.

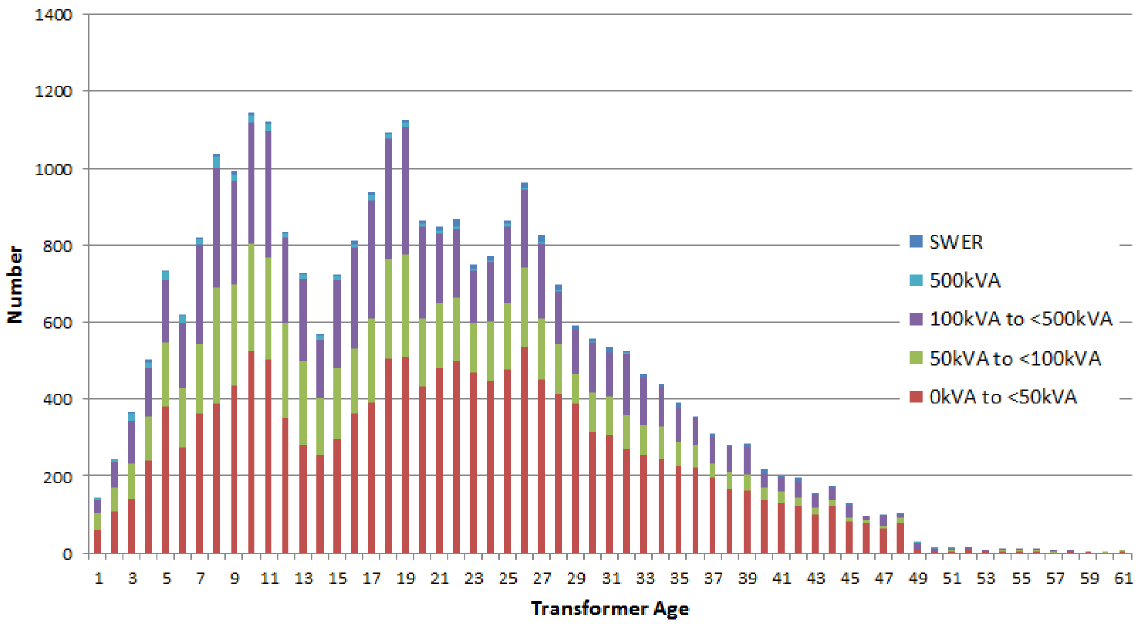
The larger rating transformers, (100-500kVA and 500kVA, mostly are supplying suburban, commercial, light industrial, public infrastructure loads and increasing private irrigation supplies.

In Figure 3, the typical distribution transformer asset service life is showing indicative 50 years, but that can be location- limited by uprating needs, such as site load capacity growth or decline. Also obsolescence changes arising for required Quality of Supply in Australian Standard Low Voltage setting to customer installations (Noting limits of inbuilt voltage tapping range)

Transformer asset site interchange can be physically difficult without substantial pole redressing. For example pole mounted transformers of legacy designs, such as two pole substation platform transformers are an example of standard design mounting matching needs with an onsite pole dressing.

SWER transformers include 12.7kV/ 440-240V power transformers and the SWER Isolating Supply (“Isolators”) pole mounted transformer installations that supply SWER overhead line spurs feeding earth return HV supply to the SWER pole mounted substations. SWER supplies are widely dispersed in Tasmanian Network and in total over 390 SWER spurs. Many SWER Isolators are of dual purpose multi-winding design including a low voltage local customer supply winding.

Figure 3: Transformer age profile



8 Asset risk

TasNetworks has adopted the risk management principles detailed in Australian Standard AS4360 ‘Risk Management’ in managing risks associated with its supply transformer population. The primary goals of the risk management strategy are to:

- ensure the safety of personnel and the public as far as practicable;
- reduce the likelihood of power transformer failure; and
- minimise the impact of a power transformer failure on transmission system performance.

The risks associated with pole mounted distribution transformers are summarised in Table 2. Apart from the risks associated with the inadequate earthing systems of the transformers and the disposal of transformers oil, the risks associated with the pole mounted transformer population remain within TasNetworks’ stated risk appetite. The reasons for these risks falling outside TasNetworks’ stated risk appetite if uncontrolled are:

- The adequacy of pole mounted transformers earthing, if not tested and corrected, and found to be no compliant, would not only in breach the earthing requirements as required by AS2067 but would present a safety and environmental risk.
- The uncontrolled risk associated with the disposal of transformers and transformer insulating oil is very high, but once controlled the risk is low.
- The structural failure of an H-structure has the potential to cause serious injury but the probability of occurrence is considered unlikely. This risk of failure is future reduced by the asset management strategies detailed in the document.

Table 2: Uncontrolled Risk Summary for Pole Mounted Distribution Transformers

Risk category	Risk	Uncontrolled risk rating
Financial	Excessive payouts from reliability incentive schemes (NCEF, GSL, STPIS) resulting from transformer failures in service	Low
Financial	Inadequate earthing causes uncleared transformer faults, resulting in a catastrophic bushfire or fatality. Insurance providers refuse to cover TasNetworks for future events.	Medium
Customer	Disruption to customers resulting from transformer failures in service	Medium
Regulatory compliance	Breach the earthing requirements of AS2067	High
Regulatory compliance	Breach the guidelines under the Act for safe disposal of transformer oil	Very high
Network performance	Localised interruption to supply from transformer failure in service	Medium
Environment and community	Transformer failure causes localised damage to surrounding environment (e.g oil spill into adjacent waterways, etc)	Low
Environment and community	Inadequate earthing causes a protection mal operation. Results in a catastrophic bushfire with widespread loss of property	Medium
Environment and community	Inadequate earthing causes a protection mal operation. Results in a minor bushfire with damage to property	Low
Environment and community	Inadequate processes for disposing of transformer oil leads to significant detriment to local environment	High
Safety and people	Transformer failure causes risk to members of the public (e.g through leaking oil or pole top fire)	Low
Safety and people	Inadequate earthing causes a fatality or permanently impairs a person	Medium
Safety and people	Structural failure of H-structure causes transformer and live conductors to fall to ground causing injury to member of the public	Medium

8.1 Risk mitigation strategies

To reduce the risk of a pole mounted transformer failure, TasNetworks has adopted the following specific strategies to address the predominant causes and consequences of failure:

- preventive maintenance;
- contingency planning;
- standardisation;
- prescriptive technical specifications;
- quality control measures;

- failure point awareness; and
- environmental.

A synopsis of these mitigation strategies is highlighted as follows:

Preventive maintenance program

TasNetworks have implemented preventive and targeted condition monitoring programs to determine condition deterioration within its population of power transformers.

Contingency planning

To mitigate the risk of inadequate response levels, in the event of a pole mounted pole transformer failure, TasNetworks is developing a set of contingency plans to minimise the impact on the reliability and availability of electricity supply.

For most distribution pole mounted transformers ratings and mounting types the contingency plan meets risk in seasons, such as wind and lightning storm damage, bushfire, vehicle impact and other emergency replacements, initially by deploying a limited stores stock range of adaptable standard types and sizes at key depot stores, with supply chain replenishment.

In the event of a legacy transformer design failure, an updating of the substation to a standardised new asset design is an option to keeping a legacy spare, based on the remaining in service numbers at risk. For example a legacy two pole platform transformer would be replaced with a single pole mounted transformer if time permitted.

Spare transformers for specialty and/or slow lead times, such as legacy instrument transformers and isolators, need a risk managed approach otherwise they require a Just In Time (**J.I.T.)** approach in their current contract resupply. The TasNetworks Spares Policy for the Transmission Network is a useful reference for a contingency planned approach. When necessary, TasNetworks' System Spares Policy details the minimum spares holdings for specific criticalities and timely restoration of supply.

Grid resilience requires a timely customer supply recovery after the incident that interrupted supply, it needs to be proactive and flexible to adapt, especially for very extreme disaster impacts such as major bushfire storm damage.

Keeping a large spare transformer idle has the risk of cold transformer oil winding water ingress, while any field returned transformers are risk assessed and stored in the oil farm, at Rocherlea.

Standardisation

To mitigate the risk of a major failure of a pole mounted transformer, TasNetworks has, as far as practical, standardised on the design and construction of pole mounted transformers.

While the failure rates for power transformers are relatively low, the consequences of such a failure are relatively high. Through the introduction of standardised transformer designs and construction, the consequences of a failure are minimised.

Prescriptive technical specifications

To address potential design issues, TasNetworks has developed comprehensive, prescriptive standard specifications for the purchase of new pole mounted transformers. The specification requires new pole mounted transformers to be designed and tested to ENA DOC 007.

Quality control measures

To mitigate the risk of inadequate quality control during manufacturing, TasNetworks requires pole mounted transformer manufacturers to have AS/NZ ISO 9001 certification and conform to its requirements. The additional need for the intending supplier to have demonstrated a three year Australian market supply experience, as this can minimise the risk of developmental product warranty defects, dispersed in the fleet. TasNetworks also requires sample routine tests, as well as certain type tests, to be performed on transformers to prove the batch quality of manufacture prior to dispatch from the manufacturer's works.

Failure point awareness

Studies[1] have shown that there are a limited number of reasons which account for the majority of transformer failures. These include bushing failures, tap-changer failures, winding failures and failures of cable boxes and terminations.

Particular attention is paid to these failure points and all are directly addressed in the transformer specifications to ensure an appropriate level of reliability is achieved.

Environmental

To reduce the environmental risks associated with pole mounted transformer insulating oil handling and disposal, TasNetworks has adopted strict management measurements for the management of Polychlorinated Biphenyls (PCBs) in transformer oil.

TasNetworks' general specification for distribution pole mounted transformers also stated that transformers are to contain less than 500 litres of oil. In addition, each transformer shall be supplied with new mineral insulating oil that meets the requirements of AS1767 or IEC 60296. The oil shall be certified to contain PCBs at not detectable concentrations.

To mitigate the risks associated with PCB contamination, TasNetworks has implemented a program to manage transformer oil containing PCBs. This program is managed according to TasNetworks' documents, TNM-SY-0114, Strategy for PCB management.

Due to Tasmania being an island state the majority of transformers installations are exposed to salt pollution, in order to ensure longevity in this corrosion prone environment the preferred protective coating to the exterior and interior surface is galvanised and unpainted.

To offer an adequate level of lightning protection all new transformers irrespective of size are supplied with approved high voltage (HV) surge diverters, mounted on brackets that are incorporated in the design.

The Interim Guidelines for Fire Protection of Electricity Substations ENA DOC 18-2008 identifies fire precautions for pole mounted transformer distribution substations (page 18), including public safety, personnel safety, proximity to adjacent property, equipment design ,and siting to minimise hazard exposures to adjoining fire hazards including bushland and vehicle impact.

[1] Peterson, A. and Austin, P., "Impact of recent transformer failures and fires – Australian and New Zealand experience"

9 Key performance indicators

TasNetworks monitors distribution assets for major faults through its outage and incident reporting processes.

Asset failures resulting in unplanned outages are recorded in the In-Service outage management tool by field staff, with cause and consequence information being subsequently made available to staff for reporting and analysis. Those outages with a significant enough consequence are also recorded in RMSS and are investigated by the business to establish the root cause of the failure and to recommend remedial strategies to reduce the likelihood of reoccurrence of the failure mode. Reference to individual fault investigation reports can be found in RMSS.

TasNetworks also maintains a defect management system that enables internal performance monitoring and statistical analysis of asset faults and/or defects that either may not result in unplanned outages, or whose failure may only result in a minor consequence not requiring full investigation.

TasNetworks' Service Target Performance Incentive Scheme (STPIS), which meets the requirements of the Australian Energy Regulator's (AER's) Service Standards Guideline, imposes service performance measures and targets onto TasNetworks with a focus on outage duration and frequency. While the STPIS does not target specific asset classes, good asset performance will have a significant impact on TasNetworks' ability to meet the STPIS targets.

STPIS parameters include:

- System Average Interruption Duration Index (SAIDI); and
- System Average Interruption Frequency Index (SAIFI).

Details of the STPIS scheme and performance targets can be found in the "Electricity distribution network service providers - Service target performance incentive scheme - November 2009".

9.1 Benchmarking

TasNetworks participates and works closely with distribution companies in key industry forums such as CIGRE (International Council on Large Electric Systems), IEEE, ANSI, AS/NZ and Energy Networks Australia (ENA), to compare asset management practices and performance to ensure we keep abreast of industry good practice and contemporary asset management. In addition, affiliation and representation on Australian Standard and other international standards bodies, helps TasNetworks maintain influence on designs and standards and ensure that TasNetworks maintains a strong asset management focus with the objective being continually improvement.

10 Lifecycle management plan

The lifecycle management of distribution pole mounted transformer assets is based on achieving the maximum availability of the asset for the lowest lifecycle cost. This process begins prior to the purchase of the transformer, with standards and designs management to ensure that all transformers purchased are specified to fully meet TasNetworks' technical design requirements and constructed to the prescribed quality standards.

The failure of distribution pole mounted transformers can be shown to follow the classic 'bath tub' curve. This implies that transformers are more likely to fail at either the beginning or end of their lives with the probability of failure increasing exponentially as the transformer approaches end of life. Prudent monitoring and maintenance at this critical life stage can help prevent many unplanned outages. Failures which occur at infancy and during the normal lifespan can generally be considered as random failures. TasNetworks does however review technical design on a regular basis to ensure designs are aligned with industry good practice and asset management strategies and practices are also periodically reviewed to align with contemporary asset management principles.

10.1 Historical management strategy

Most transformers have historically been managed on a run-to-failure basis. The Asset Management strategic objectives informing this approach included:

- minimising the cost of supply to the customer to the lowest sustainable level;
- maintaining network performance;
- managing the business risks at an appropriate level; and
- complying with regulatory, contractual and legal responsibilities.

As most pole mounted transformers are hermetically sealed units, oil samples are not able to be taken (all new transformers are sealed units). Dissolved Gas Analysis (DGA) from oil samples is a primary means of assessing the health of a transformer and is substantially lower in cost compared with the electrical testing method. Electrical testing for distribution transformers has proven not to be economically viable due to their small size, low cost, large volumes and need to be removed from service for testing.

In order to more effectively and efficient manage distribution pole mounted transformers through their life TasNetworks has introduced asset management strategies. These strategies are described in the following Section.

10.2 Reactive maintenance program

Pole mounted transformers are exposed and transformer replacement under fault conditions is normally associated with insulation failure due to deterioration as a result of service life, duty cycles, and being subjected to fault currents and overload during its life. Other system events such as overvoltage also stress the insulation of transformers resulting in premature failure. Storm or bushfire damage in terms of lightning or fires, including trees falling across the line causing the pole mounted transformer to also fall to the ground and subsequently be damaged.

Pole mounted transformers are replaced on a reactive basis to ensure customer supplies are restored.

10.3 Preventative and condition monitoring maintenance program

Preventive maintenance is, by its nature, a planned and scheduled maintenance activity that is completed to a predetermined scope, and can be described as follows:

- Condition assessment: Condition assessment is routine inspection, testing and monitoring of assets to ascertain their condition.
- Maintenance: Assets are maintained either on pre-determined frequency basis (time-based) or require planned maintenance following condition assessments.

During the life of a pole mounted transformers a program of continuous inspections, testing and monitoring is employed to detect any early signs of degradation beyond what would normally be expected.

The condition of distribution pole mounted transformers is predominantly based on the following key areas:

- safety and environment;
- physical condition;
- technical and design issues;
- bushings condition;
- performance; and
- maintenance requirements.

TasNetworks' strategy for condition monitoring of distribution pole mounted transformers is described fully in Section 7.

10.4 Refurbishment

Where pole mounted transformers are removed from the network in good operating condition by activities such as capacity and power quality drivers, these assets are assessed for redeployment back into the network, where such refurbishment is deemed to be an economic proposition.

10.5 Reliability centred maintenance (RCM)

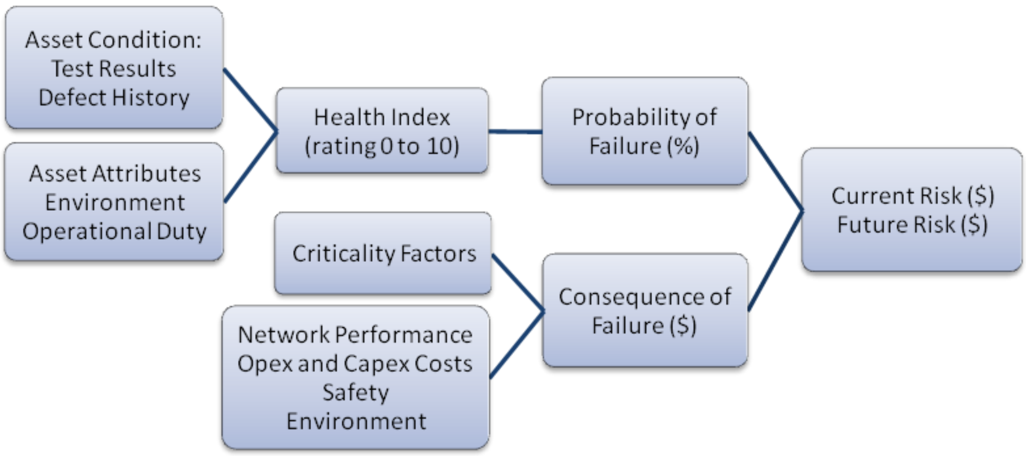
Reliability centred maintenance (RCM) analysis was undertaken in 2012 and under ongoing review.

To ensure the physical assets continue to do what the stakeholders want them to do, Reliability Centred Maintenance (RCM) analysis is used as a cost-effective process to determine in a systematic and scientific way, what must be done, while being concerned with reliability, productivity, safety, and environmental integrity in a systematic process improvement.

10.6 Condition based risk management (CBRM)

CBRM is a tool designed to analyse a fleet of assets and determine the effects of risk and cost trade-offs when considering asset replace and refurbish type decisions. By using a tool to quantify the asset risk, a better overall view of the asset class can be achieved ensuring replacement programs effectively target assets that are the highest risk to the distribution system. TasNetworks plans to introduce this methodology as part of its asset information improvement initiative as described in Section 4.2. Figure 4 shows the CBRM framework that will be employed to improve investment decision making.

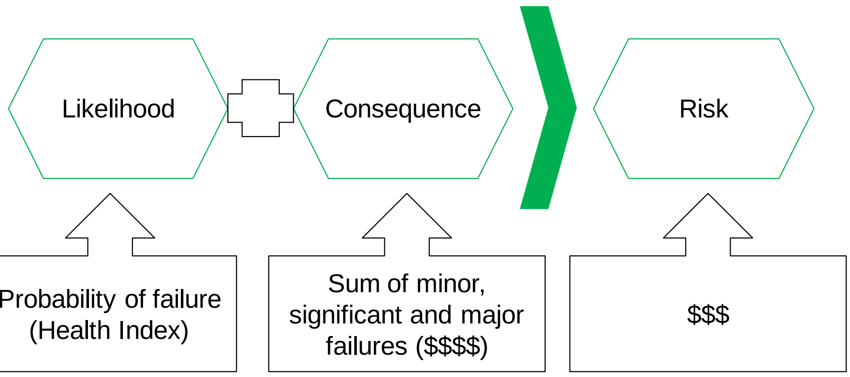
Figure 4: Asset risk framework



As with every risk decision, there are two main inputs, being likelihood and consequence.

Figure 5 shows what CBRM considers as the two risk inputs.

Figure 5: Risk derivation for CBRM



CBRM calculates the likelihood, or the probability, of failure of an asset by deriving a health index (HI). The health index of an asset is a means of combining information that relates to its age, environment and duty, as well as specific condition and performance information to give a comparable measure of condition for individual assets in terms of proximity to end of life (EOL) and probability of failure (POF).

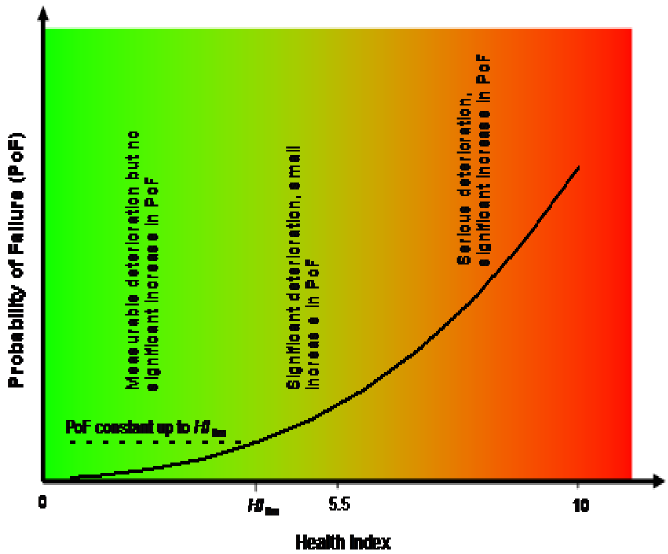
Figure 6: Health index interpretation

Condition	Health Index	Remnant Life	Probability of Failure
Bad	10	At EOL (<5 years)	High
Poor		5 - 10 years	Medium
Fair		10 - 20 years	Low
Good	0	>20 years	Very low

Notionally, any asset that has a health index of above 7 is expected reach end of life in less than five years. Any asset with a health index above five is expected to reach end of life in the coming ten years.

Once a health index for an asset is derived, a probability of failure can be found. Notionally, the POF is an exponential function as shown in Figure 7.

Figure 7: Deriving a probability of failure



It can be seen that assets with a low health index, even up to five, have quite low probabilities of failure, but this increases dramatically at higher health indices. The equation and steepness of this curve is calculated independently for each asset based on input data.

The consequences of a failure for each asset are calculated by considering the effects of safety, environment, repairs effort, replacement difficulty and potential loss of load. The consequences are all evaluated in dollar terms which allow the consequences to be quantified.

The combination of the probability of failure and the consequences provides the calculated risk, in dollar terms, for each asset.

In addition, the health index and probability of failure can be predicted for future years. Consequently, risk can also be recalculated for future years.

The analysis of present versus future health and risk is the real power of the CBRM tool.

11 Maintenance plan

The performance of distribution pole mounted transformers is sustained by the implementation of regular condition monitoring and preventive maintenance activities. Preventive and corrective maintenance practices are reviewed on a regular basis taking into account:

- past performance;
- manufacturer's recommendations;
- industry practice (derived from participation in technical forums, benchmarking exercises and discussions with other transmission companies); and
- the availability of new technology.

Requirements for operating expenditure is a function of the defined periodic condition monitoring regimes, defined preventive maintenance requirement and expected corrective distribution pole mounted transformer works.

Past performance and industry statistics, in association with an appreciation of the operating environment, physical and electrical condition of the transformer, is the best predictor of distribution pole mounted transformer condition.

The classifications listed in Table 3 cover all the management techniques that are being employed to prudently and efficiently manage distribution pole mounted transformers.

Table 3: Summary of preventive, condition and replacement programs

Work practice / program	Work Category	Frequency
Preventive and condition based practices	Visual inspections and condition monitoring	Five years (20 per cent per annum)
	Aerial inspections	Five years (20 per cent per annum) Targeted inspections - annual
	Thermal imaging inspections	Three year - targeted inspections
	Transformer earthing inspection and testing	Ten years
	Oil Management	Continuous
Replacement programs	Replace Transformers	At failure or on condition
	Replace transformer earthing	On condition – subject to testing
	Replace Transformer H-pole Structures	On condition

11.1 Preventative maintenance regimes

Preventive maintenance is, by its nature, a planned and scheduled maintenance activity that is completed to a predetermined scope, and can be broken down into the following areas:

- Condition assessment - Condition assessment is routine inspection, testing and monitoring of assets to ascertain their condition.
- Maintenance (routine and condition based) - With routine and condition based maintenance, assets are maintained either on pre-determined frequency basis (time-based) or require planned maintenance following condition assessments.

During the life of a distribution pole mounted transformer a program of continuous inspection and monitoring is employed to detect any early signs of degradation beyond what would normally be expected.

11.1.1 Overhead structure inspection and monitoring (AIOHS)

Pole mounted transformers are visually inspected from the ground as part of routine pole inspections every five years. The distribution pole mounted transformer inspections and condition monitoring form part of the structure and wood pole inspection and testing regimes and are not an independent practice.

The purpose of the visual inspection and condition monitoring is to ensure their physical state and condition does not represent a hazard to the public. For example transformers that are leaking oil will be identified by these inspections and schedule for remedial works if assessed as presenting any risks not consistent with TasNetworks' stated risk appetite.

11.1.2 Overhead system aerial inspections (AIOFD)

TasNetworks introduced aerial inspection for overhead structures in 2014/15 which included the inspection of distribution pole mounted transformers. Initial trials found that aerial helicopter inspections provided a cost effective and efficient method of assessing defects and condition not possible through ground patrols. The aerial patrols have been targeted in the following areas:

- High Bushfire Consequence Areas (HBCAs),
- High Soil Dryness Index areas (HSDIA), and
- worst performing feeders.

The patrols targeting the HBCA and HSHIA should be planned well prior to the start of the bush fire season to allow for any defects to be rectified.

Aerial inspection program are to be expanded to cover 20 per cent of the network on an annual basis with targeted aerial patrols planned for HBCAs pre bush fire session annually.

11.1.3 Thermal imaging (AIOTI)

The AIOTI program was implemented in 2013/14 FY as an outcome of reliability centred maintenance (RCM) review. The RCM review found that the taking no action to identify hot joins within the distribution network resulted in the exposure of the business to an unacceptable level of risk, with regards to bushfires which is consistent with TasNetworks' corporate risk appetite. A review of this program was recently undertaken, to determine the program's effectiveness, and recommendations were made on changes that could be made to improve value.

The original program required 1000 kVA of load to be connected downstream of an asset, for that asset to be to be inspected, to ensure that there is sufficient loading at that point in the network for defective connections to produce detectable heat. Through analysis of the locations in the network that hot joints have been found to date, it has been identified that further value may be developed by refining this connected kVA requirement to:

- 1000 kVA in high bushfire consequence areas, and on the "worst performing feeders"; and
- 4000 kVA in all other network areas.

Additionally, feeders should be excluded from analysis, where the loading is below 20 A for the vast majority of time.

The original program has been amended to ensure that inspections take place when loading is as high as possible, typically in the mornings and evening peak periods (7am-10am and 4pm-7pm).

The frequency of inspection to remains at three years which included the thermal inspection of distribution pole mounted transformer terminal bushing and overhead line connections.

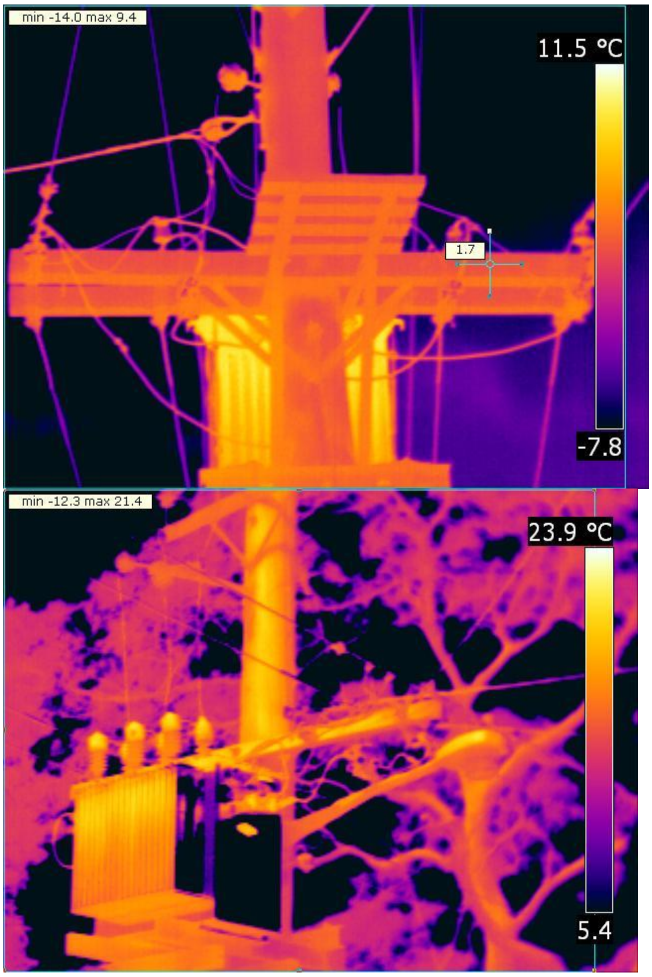


Figure 8: Thermal images showing warm transformer radiators and no hot spot defects

11.1.4 Transformer earthing inspection and testing (AIOTX)

RCM analysis undertaken in 2012 identified a risk from substandard earthing connections. This is both in terms of the safety risk if an earth fault does not clear, and a regulatory risk with compliance to AS2067. The drivers for this program are compliance with regulatory requirements and managing business risks.

The earthing systems for distribution pole mounted transformers are replaced based on performance using a probabilistic risk based methodology. This probabilistic approach is concerned with the voltages that members of the public or operators may be exposed to under fault conditions. Metallic surfaces that can be touched by members of the public in close proximity to a pole earth will require assessment, and could drive an augmentation of the transformer earthing system in order to ensure public safety.

This transformer earthing inspection and testing program will audit the condition of distribution pole mounted transformer earth connections, and identify any transformer installation where the earthing needs to be repaired, replaced or augmented. This audit will ensure pole mounted transformers and associated equipment is safely earthed and determines the current condition of transformer earths to justify and prioritise future replacement programs. The CAPEX program Replace transformer earths (RETXE) will then perform any remedial works necessary to rectify earthing found to be non-compliant.

Priority will be given to earths on aged transformers, as their condition is more likely to have deteriorated, and on SWER transformers due to their unique configurations.

This program will also identify sites for replacement where earths have been stolen or vandalised. In 2009/2010, TasNetworks recorded over 50 sites where transformer earths had been stolen or vandalised and this has reoccurred this year in a few localities.

Copper earthing conductor is a target for theft as the salvage prices for copper is high. Standard practice for TasNetworks is to have the earths covered and stapled to the pole when they are replaced at sites targeted by copper thieves. Records of copper theft from previous years are variable however as data improves TasNetworks will assess to better target risk areas.

Vandalism theft is presently a regular reoccurrence, in some locality sites. Where copper thefts of earths on poles have been ongoing, a new heavier duty steel cover has been deployed this year to try to reduce theft repetition. (See Figure 9)

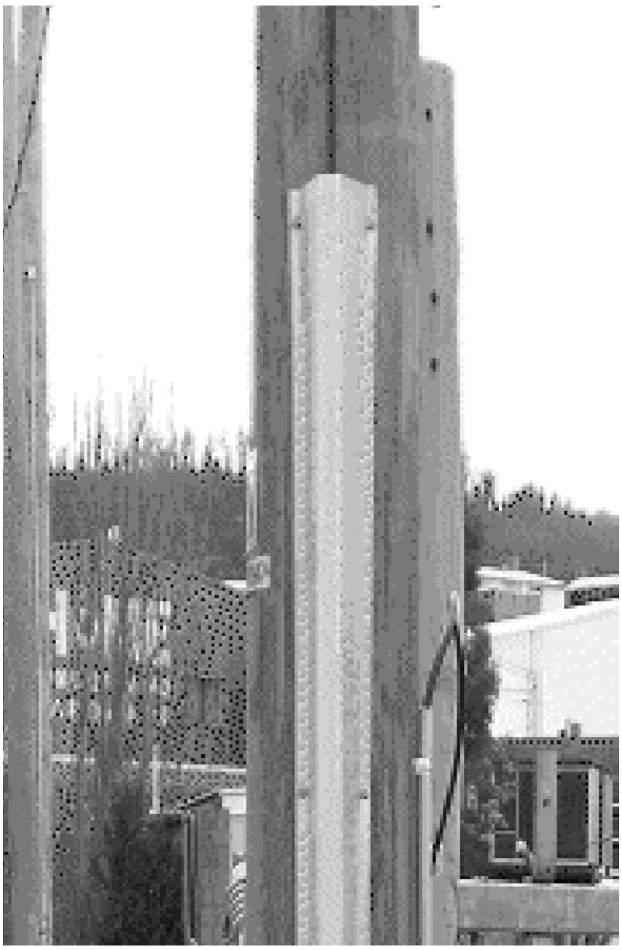
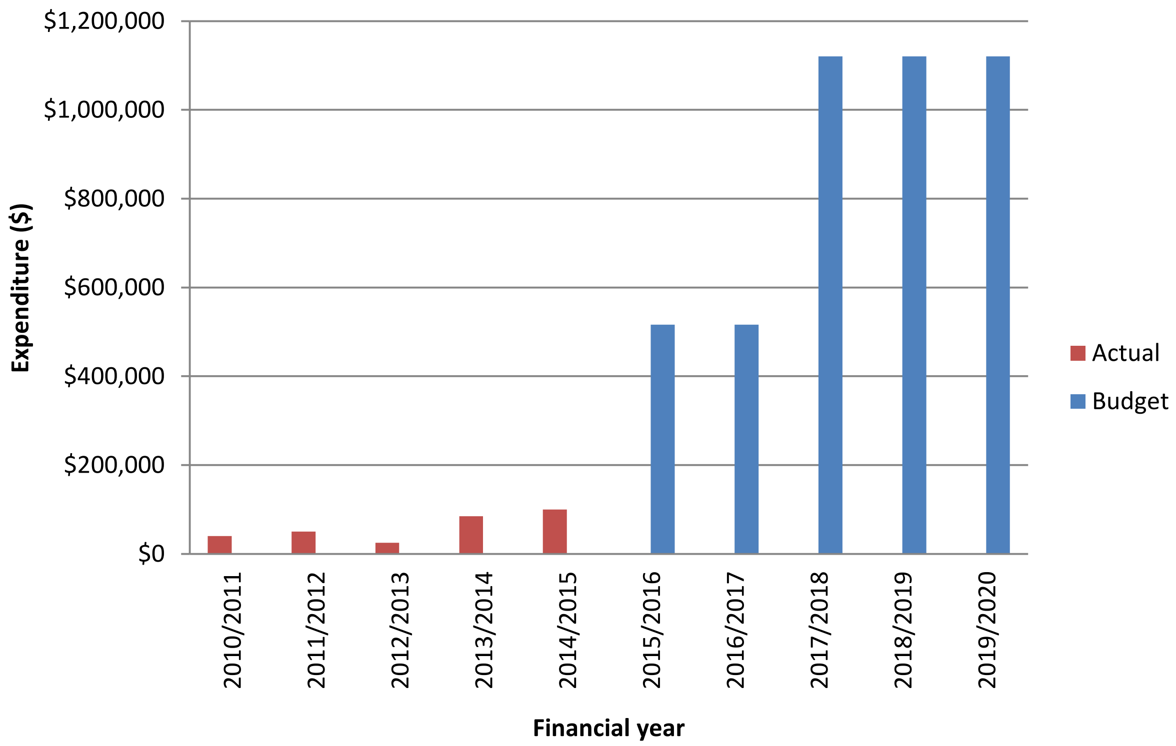


Figure 9: Earthing conductor security guard drawing D-OH1-1.8/30

The earthing installation and inspection programs completed by TasNetworks in the past have operated in a deterministic manner, aiming for a target earthing system resistance. A more appropriate application of the Australian Standard AS2067 would be to take a probabilistic approach to the safety of an earthing system. This probabilistic approach is concerned with the voltages that members of the public or operators may be exposed to under fault conditions. Metallic surfaces that can be touched by members of the public in close proximity to a pole earth will require assessment, and could drive an augmentation of the transformer earthing system in order to ensure public safety. The Australian Standard AS2067 outlines a probabilistic approach to the performance of an earthing system. This program will ensure the compliance to AS2067 Substations and High Voltage Installations exceeding 1 kV a.c as well as ENA EG 0 Power System Earthing Guide. Compliance with this standard in this manner will appropriately manage the performance of the earthing systems and the risk of electric shock to the public, and ensure compliance to AS2067 Substations and High Voltage Installations exceeding 1 kV a.c as well as ENA EG 0 Power System Earthing Guide.

Transformer earthing is inspected on a ten year cycle. All pole mounted distribution transformers are included in this program. Figure 10 shows the increase in the spend profile for this inspection practice driven by a compliance requirement.

Figure 10: Trend of planned work and spend (AIOTX)



11.1.5 Oil management (AROIL)

The drivers for this program are compliance with regulations and managing business operating risks (safety).

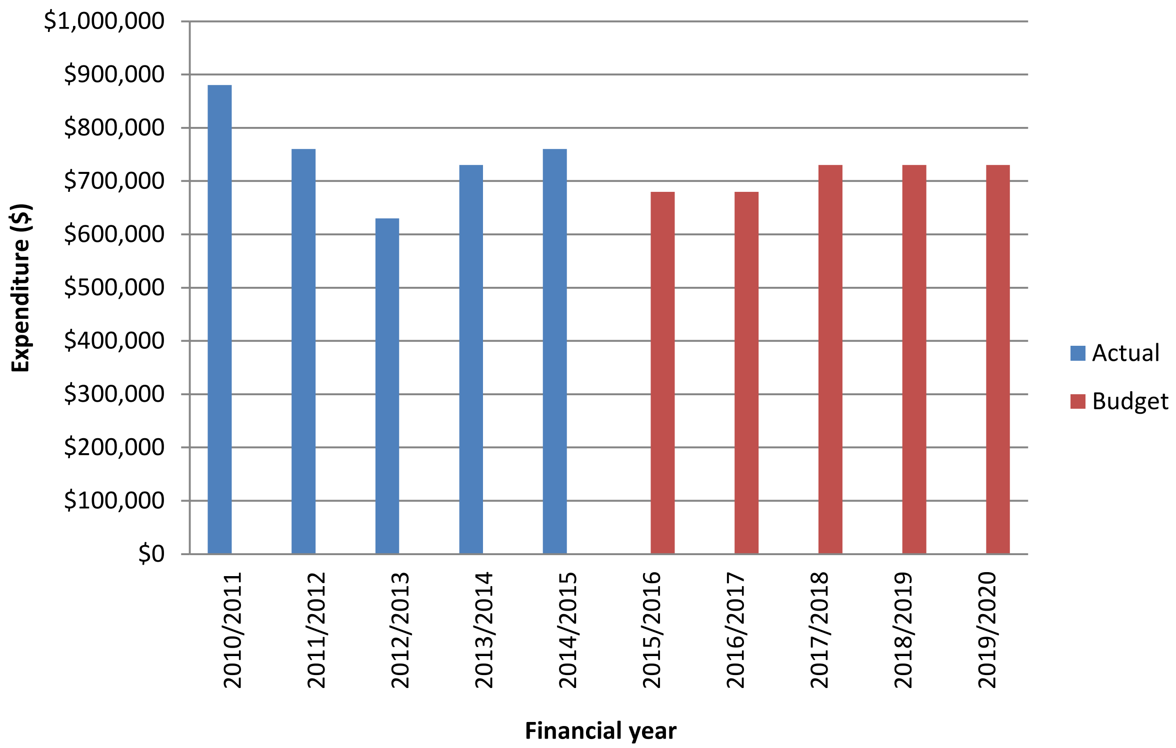
TasNetworks is required to dispose of oil and oil-contaminated assets in accordance with Australian Standards. This program funds TasNetworks' oil farms who manage the removal and disposal of oil from redundant oil-filled assets.

TasNetworks has over 30,000 transformers, over 300 oil filled switchgear and ground mounted oil filled assets in service in the distribution system. The 30,000 distribution pole mounted transformers each contain between 45 and 720 litres of oil. When the assets fails or reach the end of their useful life the oil has to be removed and disposed of.

The primary objective is to recover oil from assets that reached the end of their useful life along with response to oil spills, test for PCBs and dispose according to environmental requirements (including obtaining permits and arranging transport) and dispose of oil free equipment.

There are no major changes to this program and the proposed expenditure is to remain consistent with historical spend as shown in Figure 11.

Figure 11: Trend of planned work and spend (AROIL)



11.2 Replacement programs

11.2.1 Replace transformers (RETXL)

The drivers for these programs are managing business operating risks and maintaining network performance.

Consistent with other distribution companies, distribution pole mounted transformers are primarily replaced on failure. Investment evaluation and option analysis in 2014/15 show that run-to-failure distribution pole mounted transformer replacements remains the preferred option when compared to aged based and an intensive condition based replacement. An intensive condition based methodology for distribution pole mounted transformers being defined by TasNetworks as, routine condition monitoring and testing of the internal and external active components of the transformer such as Dissolved Gas Analysis (DGA) and various electrical testing. Condition monitoring does however occur for external components such as corrosion, pollution, bushing seals and leaks.

The risk associated with TasNetworks' replacement strategy for distribution pole mounted transformers is consistent with TasNetworks' stated risk appetite in terms of reliability, safety, environmental impact and network performance.

The transformer replacement program consists of the following two programs:

- Replace transformers (leaking/condition).
- Replace transformers under fault.

11.2.2 Replace transformers (leaking/condition)

The aim of this program is to reduce the risk of asset failure and oil spills by replacing transformers found to be in poor condition or leaking during asset inspections.

There is no specific transformer inspection program, but the asset inspectors who undertake pole serviceability inspections and aerial helicopter patrols inspectors also do visual inspections of pole mounted hardware and equipment. A follow up audit is then undertaken by an appropriately experienced person (e.g. the Asset Area Manager) who determines if the transformer is to be removed or if it is safe to leave in service for another inspection cycle. Transformers that show evidence of failing condition and/or substantial oil leaks will be replaced.

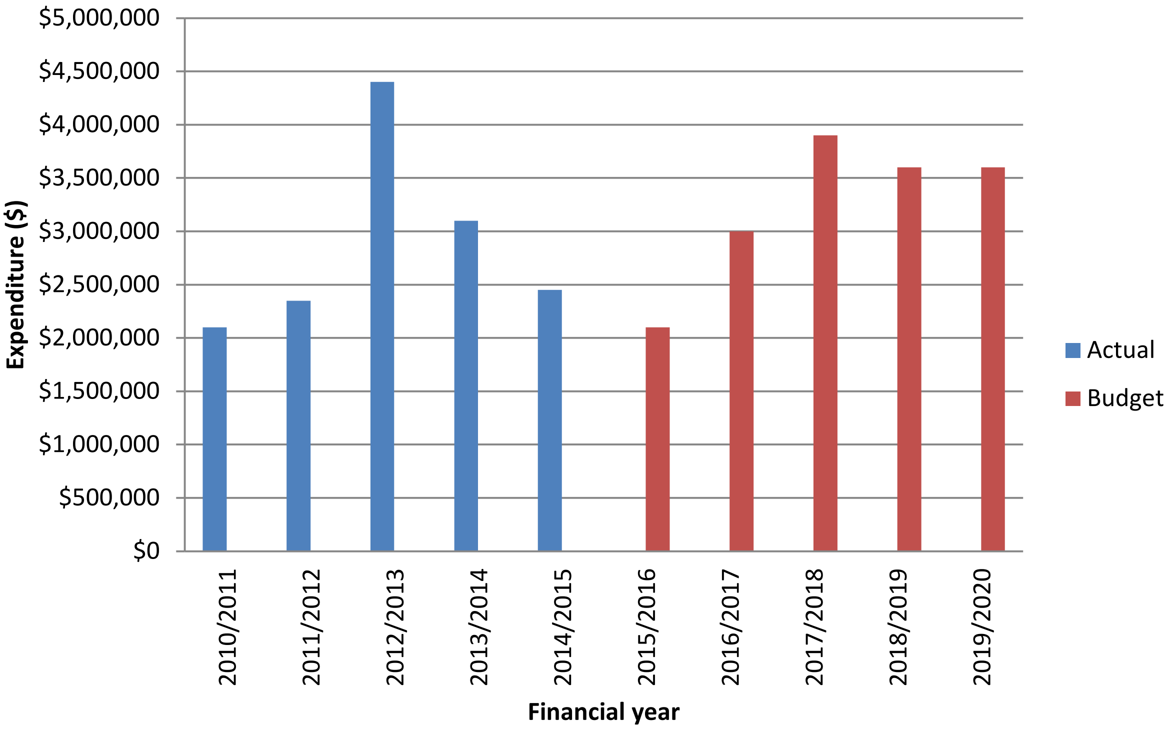
11.2.3 Replace transformers under fault

This is a reactive work program to cover the capitalisation of transformer replacement under fault and is normally associated with insulation failure due to deterioration as a result of service life, duty cycles, and being subjected to fault currents and overload during its life. Storm or bushfire damage in terms of lightning or fires, including trees falling across the line causing the pole mounted transformer to also fall to the ground and subsequently be damaged.

The work is initially performed under the fault and emergency budget and later transferred to this program.

Most of the transformer replacements in the distribution networks are done under fault. There is an average of 65 outages per year caused by transformer failure, due to condition, overload, internal and external failure of the transformer, break down of insulation, extreme weather events or third party collision with support structures. In 2013-14, transformer failures contributed 7.37 minutes (7 per cent) and 0.07 interruptions (8 per cent) to the total asset related failure SAIDI and SAIFI contribution of 109 minutes and 0.86 interruptions (Annual Distribution Performance Report 2013/14). Figure 12 shows a consistent spend profile for distribution pole mounted transformers.

Figure 12: Trend of planned work and spend (RETXL)



11.2.4 Replace transformer earths (RETXE)

The driver for this project is managing business operating risks and compliance with regulations.

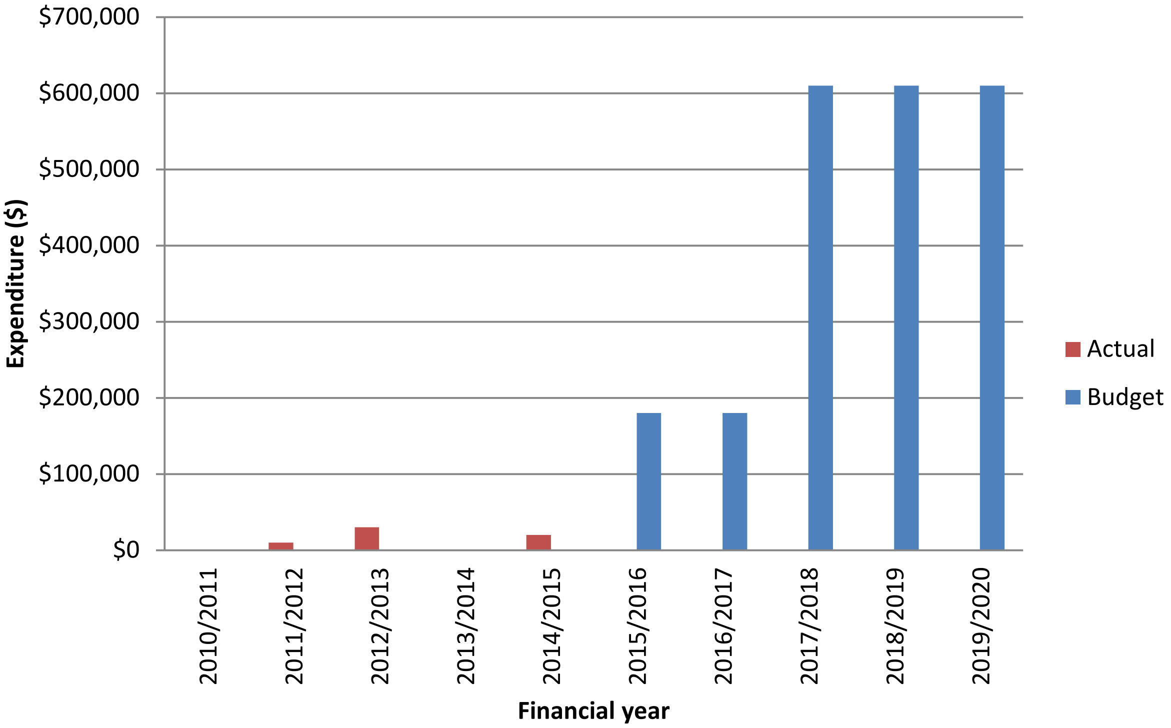
Inadequate earthing places the operators, members of the public and the system at risk. The aim of this program is to proactively replace transformer earths that are in poor condition or damaged and reactively replace transformer earths that are stolen or vandalised. The transformer earth inspection program is used to determine the condition of the assets, identify and prioritise sites for repair, replacement or augmentation and will determine the future scale of this program.

The transformer earths to be replaced, repaired or augmented are identified through two sources:

- Earths identified as being in poor condition through asset inspection and monitoring programs (AIOTX)
- Stolen copper earths

This program has existed for some years but only in response to chance reporting of missing or obviously damaged earths picked up by the asset inspectors as part of the pole inspection program. With the Overhead Transformer Inspection & Monitoring (Earthing) AIOTX program which commenced in 2014/15, this program is set to increase in volume and complexity as shown in Figure 13.

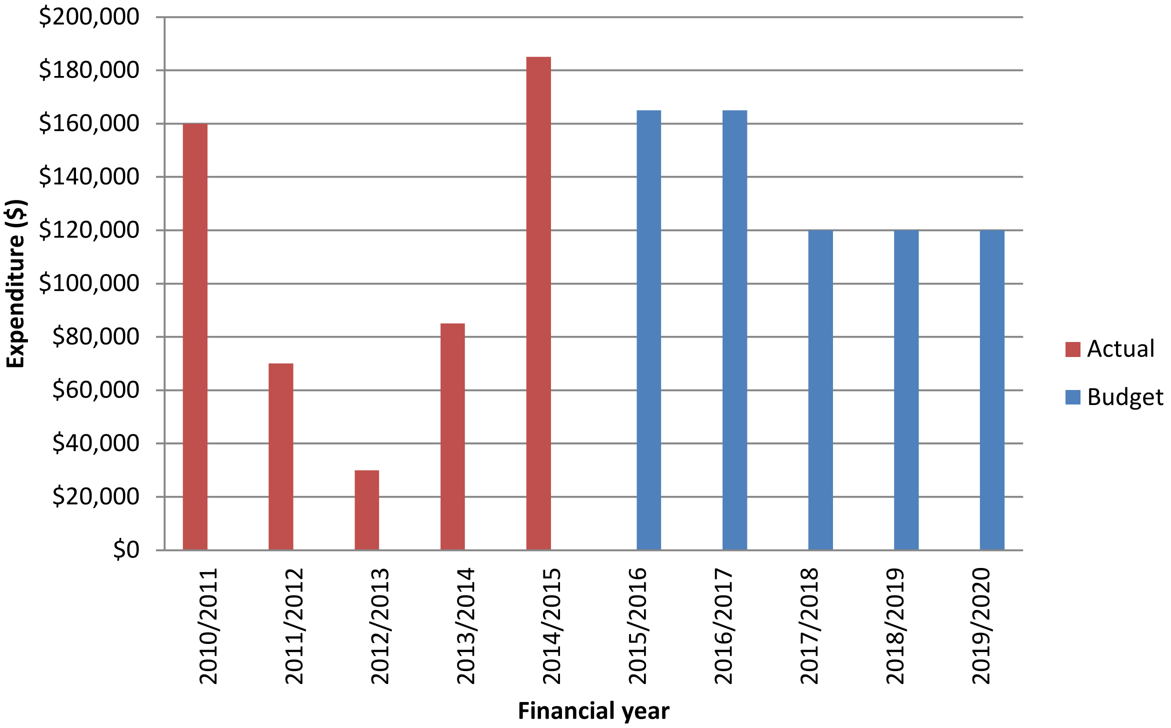
Figure 13: Trend of planned work and spend (RETXE)



11.2.5 Replace transformer 'H' structures (RETXH)

This program caters for the replacement of distribution transformers mounted on H-structures due to their condition (e.g. when one or both of the supporting poles are condemned) and includes a small number of sites overhanging roadways and are thus assessed as being vulnerable to being hit by high loads. These installations are general complex and as a result require detailed designs. This together with high removal costs, when compared to a transformer mounted on a single pole, requires such installations to be managed as a separate program. During the re-design stage alternative options are considered that can included a single pole substation for smaller loads, a ground mounted substation if the load is large, and relocation to another less risky site. The spend profile for the program is shown in Figure 14.

Figure 14: Trend of planned work and spend (RETXH)



12 Summary of programs

Table 4 provides a summary of all of the programs described in this management plan.

Table 4: Summary of distribution pole mounted transformer programs

Work Practice/Program	Work Category Description	Project/Program	Category
Preventive and condition based practices	Visual inspections and condition monitoring	Overhead Transformers Inspection and Monitoring (Earthing)	AIOTX
	Aerial inspections	Overhead system aerial inspections	AIOFD
	Thermal imaging inspections	Thermal imaging	AIOTI
	Transformer earthing inspection and testing	Transformer earthing inspection and testing	AIOTX
	Oil Management	Oil Management	AROIL
Replacement programs	Replace Transformers	Replace transformer (leaking/condition)	RETXL
		Replace transformers under fault	RETXL (MRBA)
	Replace transformer earthing	Replace Transformer Earths	RETXE
	Replace Transformer H-pole Structures	Replace Transformer ‘H’ Structures	RETXH

13 Investment evaluation

Investment evaluation is undertaken using TasNetworks’ Investment Evaluation Summary template. The template includes:

- a brief description of the asset(s);
- a description of the issues and investment drivers;
- alignment with regulatory objectives;
- alignment with TasNetworks’ corporate objectives;
- alignment with TasNetworks’ corporate risks;
- impacts to customers;
- analysis of options to rectify the issues including operational and capital expenditures;
- a summary of NPV economic analysis for the identified options;
- the preferred option and why;
- the timing of the investment; and
- the expected outcomes and benefits.

14 Spares management

Spares holding are assessed during the asset management plan review cycle and minimum and maximum stock levels and spares holdings are amended in alignment with TasNetworks' spares policy.

When transformers either fail prematurely during service, and repair is not economically feasible, or the electrical and mechanical condition of the power transformer has deteriorated to such an extent, then it is considered appropriate to retire a particular transformer. Replacement transformers are sources for the stock pool.

15 Disposal plan

Transformers are disposed of via the TasNetworks Oil Farm, at Rocherlea.

15.1 Disposal of transformers containing PCBs

TasNetworks manages PCBs in accordance with TasNetworks' Environmental procedure EM-M09 Management of PCBs (reference 9), which reflects the requirements of the Australian and New Zealand Environment and Conservation Council (ANZECC) Polychlorinated Biphenyls Management Plan (reference 10). Both plans satisfy the legislative requirements of the TAS Environmental Management and Pollution Control Act 1994 and the NEPM standards Act (references 11 and 12).

Polychlorinated biphenyls (PCBs) were used in transformers and capacitors amongst other things from the 1930s to the 1970s. However, they were shown to be toxic and carcinogenic and have been banned in Australia in the 1970s.

Whilst records indicate that no distribution transformers were purchased with PCB insulating material, contamination has occurred over time where oil management was undertaken using equipment also used for oil management of PCB-contaminated assets (such as Extra High Voltage instrument transformers). This has led to a number of transformer sites with PCB contamination.

All pole mounted transformers are classified as 'Small Items' by EM M09 Management of PCBs, i.e. containing less than 1,000 litres of oil. As such if any is identified as containing PCBs above the threshold concentration, they are:

- Collected at the end of their useful life and managed as scheduled PCB waste – if not in a priority area (as defined in EM-M09); or
- Removed within two years of identification and managed as scheduled PCB waste – if in a priority area (as defined in EM-M09). Current contractor for disposal is Hazell Bros Pty Ltd, and they submit the Sustainability Report.

16 Technology and innovation

TasNetworks recognises that a proactive approach to lifecycle management of its assets is an established and accepted practice within the electrical industry. This is evident through TasNetworks' participation in various benchmarking and best practice activities, locally and internationally. As part of this participation TasNetworks may make provision for, identify, develop, participate and or pilot various initiatives in the normal course of business. Initiatives are likely to be made and pursued in the areas as represented in Table 5.

Table 5 Technology and innovation initiatives

Initiative	Rationale	Driver
Improved utilisation of modern substation and recloser/sectionaliser protection and system monitoring equipment to inform transformer repair, refurbish, and replacement investments decisions	The introduction of new measurement techniques and technologies Increased utilisation of intelligent condition monitoring systems	Improved assessment of asset condition Improved lifecycle management
Light Detection And ranging (LiDAR)	3-D engineering model provides profile of as-installed distribution lines Increased and improved utilisation of technology to assess asset health	Ability to identify high risk asset issues in a timely manner Improved assessment of asset condition Cost effectiveness compared with traditional ground base patrols Provide a bench and fingerprint for subsequent inspections
Condition Based Risk Management (CBRM)	Build knowledge of asset base Enhance asset information Centralised and transparency of asset information Alignment with business processes Contemporary asset management and good asset management practice	Improved ability to analyse the transformer fleet and determine the effects of risk and cost trade-offs Inform asset repair, refurbish and replacement decisions Enable targeted intervention based on asset health and risk Enhanced ability to forecast investment
Asset Management information system (AMIS)	Build knowledge of asset base Enhance asset information Centralised and transparency of asset information Alignment with business processes Contemporary asset management and good asset management practice	Deliver trusted, timely and high quality asset information that supports the strategic and operational asset management processes Deliver the fundamental underpinnings of a mature asset management system

17 Financial summary

17.1 Operational expenditure plan

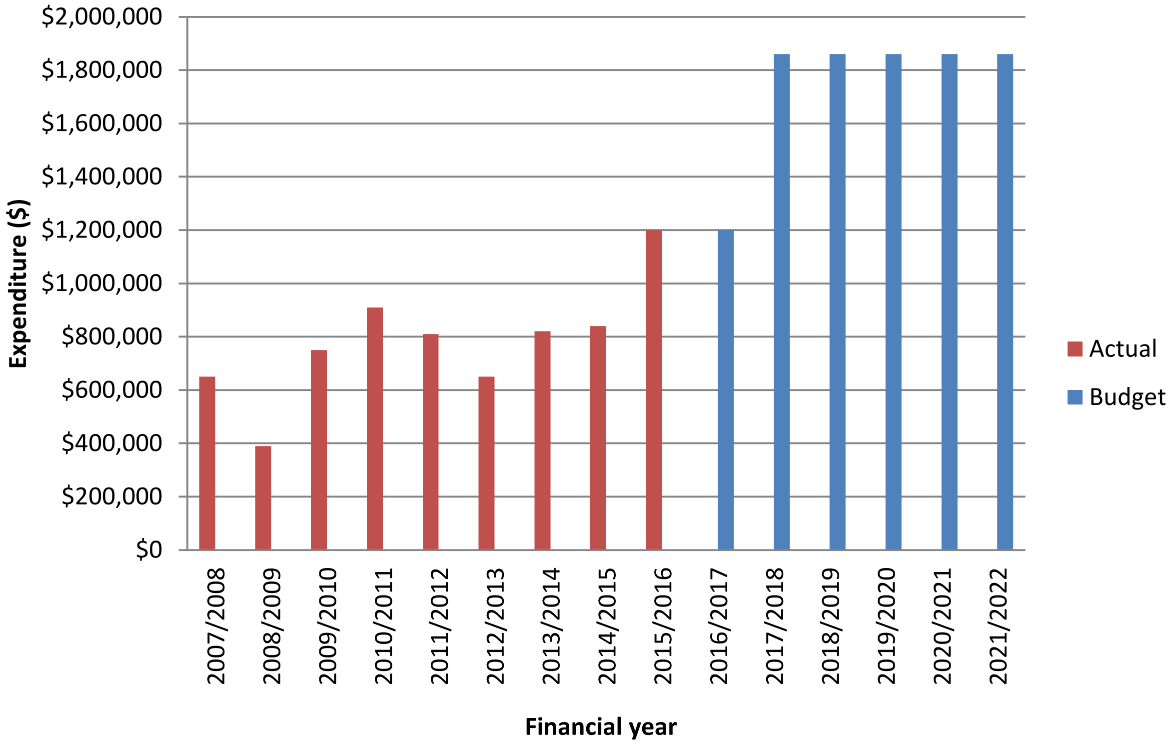
TasNetworks proposes a total operating expenditure of $8 million over the next 5 years (FY2015/2016 – FY2019/2020) on pole mounted distribution transformers, with an average expenditure of $1.6 million per annum.

The increase in OPEX spend is due to the new regimes around earth testing.

Table 6: OPEX for this regulatory period (FY2012/2013 to FY2016/2017)

	FY12/13	FY13/14	FY14/15	FY15/16	FY16/17
AER Allowance	$749,474	$741,632	$744,206	$743,007	$739,278
Budget	$744,530	$625,465	$996,000	$1,193,893	$1,196,000
Actual	$662,900	$832,393	$856,195	$ -	$ -

Figure 15: Expenditure profile (OPEX) over previous, current and future regulatory periods.



17.2 Capital expenditure

The capital programs and expenditure identified in this management plan are necessary to manage operational and safety risks and maintain network reliably at an acceptable level. All capital expenditure is prioritised expenditure based on current condition data, field failure rates and prudent risk management.

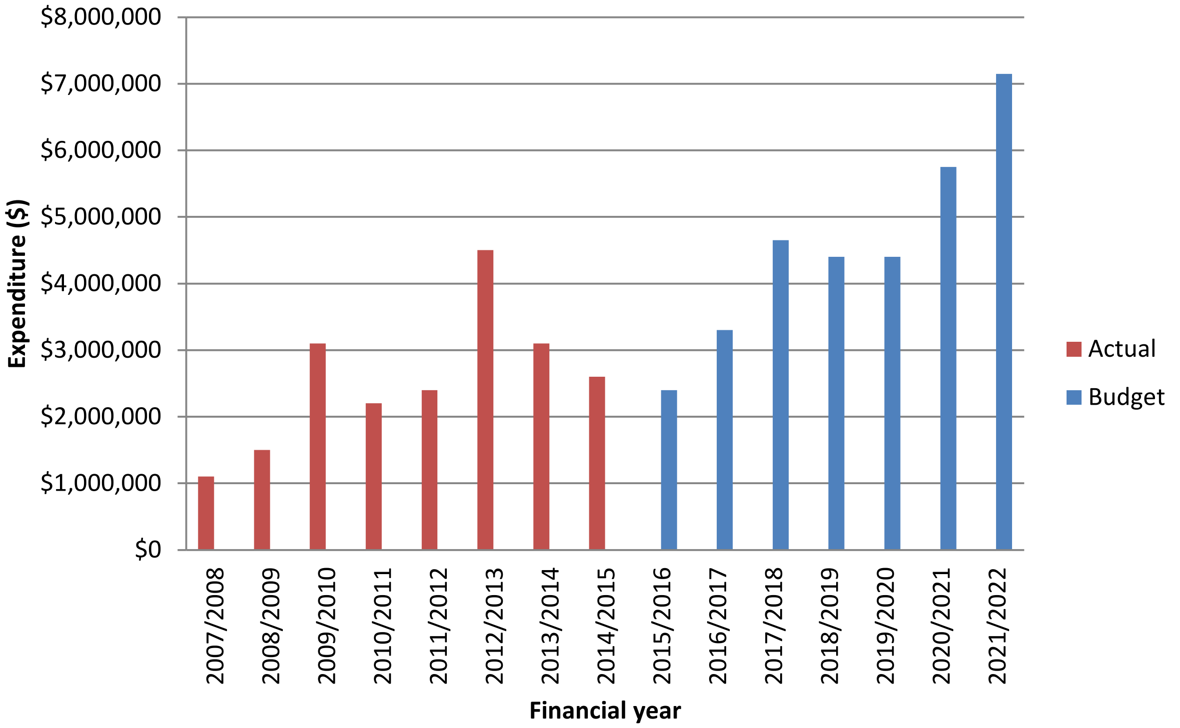
TasNetworks proposes a total capital expenditure of $19.3 million over the next 5 years (2015/2016 – 2019/2020) on pole mounted distribution transformers, with an average expenditure of $3.9 million per annum.

The forecast increase spend in Capex is due to both the new transformer earthing repair program, and an expected increase in transformer replacements under fault due to the age profile of the asset fleet.

Table 7: CAPEX for this regulatory period (FY2012/2013 to FY2016/2017)

	FY12/13	FY13/14	FY14/15	FY15/16	FY16/17
AER Allowance	$4,054,612	$4,071,678	$4,112,318	$4,151,224	$4,152,887
Budget	$2,493,778	$2,972,450	$2,130,000	$2,460,049	$3,355,000
Actual	$4,475,770	$3,175,002	$2,666,516	$ -	$ -

Figure 16 Expenditure profile (Capex) over previous, current and future regulatory periods



TasNetworks' makes a concerted effort to prepare a considered deliverability strategy based on the planned operational and capital programs of work for distribution network assets. A number of factors contribute to the successful delivery of the program of work. These factors are utilised as inputs to prioritise and optimise the program of work and to ensure sustainable and efficient delivery is maintained. This program of work prioritisation and optimisation can impact delivery of individual work programs in favour of delivery of other programs. Factors considered include:

- Customer-driven work we must address under the National Electricity Customer Framework (NECF).
- Priority defects identified through inspection and routine maintenance activities.
- Identified asset risks as they relate to safety, the environment and the reliability of the electrical system.
- Adverse impacts of severe storms and bushfire events.

- System outage constraints.
- Changes to individual project or program delivery strategy.
- Size and capability of its workforce.
- Support from external contract resources and supplementary service provision.
- Long lead equipment and materials issues.
- Resolution of specific technical and functional requirement issues.
- Complex design/construct projects with long lead times.
- Approvals, land acquisition or wayleaves; and
- Access issues.

Specific to this asset management plan these factors have resulted in the delayed delivery of the operational and capital programs of work.

18 Related standards and documentation

The following documents have been used to either in the development of this management plan, or provide supporting information to it:

1. Australian Standard AS2067 Substations and High Voltage Installations exceeding 1 kV a.c
2. ENA EG 0 Power System Earthing Guide
3. TasNetworks Annual Distribution Performance Report 2013-2014 (R49306)
4. ENA DOC 007 -2006 Specification for pole mounting distribution transformers
5. ENA DOC 18-2008 The Interim Guidelines for Fire Protection of Electricity Substations
6. Australian Energy Regulator's (AER's) Service Standards Guideline
7. Peterson, A. and Austin, P., "Impact of recent transformer failures and fires – Australian and New Zealand experience"
8. Australian and New Zealand Environment and Conservation Council (ANZECC) Polychlorinated Biphenyls Management Plan
9. Tasmanian Environmental Management and Pollution Control Act 1994
10. NEPM standards Act

19 Appendix A – summary of programs and risk

Description	Work Category	Risk Level	Driver	Expenditure Type	Residual Risk	12/13	13/14	14/15	15/16	16/17
OH Transformers Inspection & Monitoring (Earthing)	AIOTX	High	Regulatory	Opex	Medium	$20k	$87k	$90k	$516k	$516k
Oil Management	AROIL	Very High	Regulatory	Opex	Low	$643k	$746k	$766k	$678k	$680k
Replace Transformers	RETXL	Medium	Reliability	Capex	Medium	$4.4m	$3.1m	$2.5m	$2.1m	$3m
Replace Transformer Earthing	RETXE	High	Regulatory	Capex	Low	$30k	$0	$15k	$175k	$180k
Replace Transformer H-pole Structures	RETXH	Medium	Safety	Capex	Medium	$33k	$84k	$182k	$165k	$165k