Asset Management Plan

Transmission Lines Support Structures Foundations

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Responsibilities

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

The approval of this document is the responsibility of the General Manager, Strategic Asset Management.

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

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

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Reference documents

R954721 – TasNetworks Strategic Asset Management Plan

R40766 – TasNetworks Asset Management Policy

R909655 – TasNetworks Risk Management Framework

Record of revisions

Revision	Details	Date
4.0	Revised document structure into new template Updated tables throughout document Updated risk assessment	31/10/2017
8.0	Revised document structure into new template Updated tables throughout document Updated risk assessment	22/12/2022

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1. Purpose

The purpose of this document is to describe for transmission lines support structures foundations 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.
- Forecast CAPEX and OPEX, including the basis upon which these forecasts are derived.

2. Scope

This document covers all transmission line support structure foundations, including, but not limited to the following types:

- directly embedded steel;
- steel reinforced concrete; and
- rock bolts and wall anchors.

Wood and steel poles that have been directly buried do not incorporate a foundation, and hence asset management issues pertaining to these poles have been addressed within the Transmission Line Support Structure Asset Management Plan.

This asset management plan excludes foundations associated with assets located in substations or switching stations.

3. Management strategy and objectives

This asset management plan has been developed to align with both TasNetworks' Asset Management Policy and Strategic Objectives. This management plan describes the asset management strategies and programs developed to manage the transmission line support structure foundations, with the aim of achieving these objectives.

For these assets the management strategy focuses on the following objectives:

- Safety will continue to be our top priority and we will continue to ensure that our safety performance continues to improve.
- 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.
- Cost performance will be improved through prioritisation and efficiency improvements that enable us provide predictable and lowest sustainable pricing to our customers.
- 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.

4. Description of the asset portfolio

Foundations are the base upon which transmission line support structures and associated stay wires are erected or attached.

Foundations include all structures that are set in the ground, to which the transmission line support structure is attached, and provide the necessary strength to withstand all applied loads. Foundations include corrosion protection systems (anodes), stay wire anchors and earthing systems. The maintenance of foundations is imperative for the sustained integrity of the transmission line.

Due largely to the evolution of the network over a considerable number of years, TasNetworks has utilised a variety of transmission line foundations. These fall within the following categories:

- directly embedded steel;
- steel reinforced concrete; and
- rock bolts and wall anchors.

In general, structures and their associated foundations have been designed to a range of standards over the last 90 years. Structures and foundations built since the mid-1960s were designed in accordance with ASTM/ASCE and Australian Standards. Prior to 2010, structures and foundations were also designed in accordance with “ENA C(b)1-2006 Guidelines for the design of overhead distribution and transmission lines”. In 2010 this guideline was superseded by “AS/NZS 7000:2010 - Overhead line design – Detailed procedures”, and updated in 2016 to “AS/NZS 7000:2016 - Overhead line design – Detailed procedures”.

4.1 Transmission line support structure foundation types

4.1.1 Foundation asset specification

TasNetworks owns and maintains 7,726 support structures on its transmission system. Each support structure will have one or more foundations (with the majority of structures having four foundations) associated with it. As shown in Table 1, due to the prevailing standards at the time of construction most foundations associated with these structures consist of buried steel.

Table 1: Foundation types and anodes within TasNetworks

Foundation Type	Number	Percentage
Concrete	2,194	8
Concrete / Steel	335	1
Directly buried steel	25,238	91
Total:	27,767	100
Anodes installed	2,800	

4.1.2 Directly buried steel

TasNetworks’ Transmission Line Construction Standard specifies that new foundations will generally be a concrete type, with directly buried steel foundations only permitted where specifically required.

However, until recently TasNetworks has predominantly utilised directly buried steel foundations of a number of differing designs, including:

- grillage;
- mini grillage;
- tray; and
- plate.

While each is different, the underlying design principle remains the same; to provide a horizontal surface which provides sufficient weight of overlying soil to counteract the uplift load from the support structure leg to which the foundation is attached. This arrangement also provides sufficient bearing on the underlying soil to counteract the corresponding compressive load on the adjacent leg.

The moisture content, acidity, and level of aeration within the soil will cause the initial deterioration of the zinc galvanising layer associated with a steel foundation, eventually escalating to corrosion and pitting of the steel foundation itself. This corrosion is more prevalent near the surface at the air/soil interface, down to a depth of approximately 600mm.

It has been commonly observed that after 20 years of service, corrosion is at a stage that may require attention. Because foundations are buried, a definitive condition assessment requires excavation of the transmission tower legs which is not always practicable.

Other infrastructure, such as cables or steel pipes, may be installed in the vicinity of transmission line support structure foundations. At these locations it is possible for galvanic corrosion to occur, causing degradation in underground structural material on TasNetworks' directly buried steel foundations.

To mitigate the effects of advanced corrosion, TasNetworks typically refurbishes or augment the foundation using one of the following remedial processes:

- leg and/or grillage replacement;
- application of bitumen tape ('Denso'); and/or
- installation of sacrificial anodes.

It should also be noted that shear plates installed on tower legs provide additional uplift capability in addition to their main duty of providing horizontal restrain and must not be exposed above ground level. Erosion, track work, farming and machinery activity, as well as animal activity, can remove this cover.

Weather resistant steel (WRS) structure foundations are constructed differently to those used for mild steel structures, consisting of a galvanised mild steel grillage, connected to a galvanised WRS section crossing the air/soil interface, which in turn is connected to WRS members for the remainder of the structure. The galvanised WRS section located at the air/soil interface requires treatment prior to installation, normally consisting of a two-pack coating of epoxy paint and taping of member edges to ensure the coating is not chipped or cracked during installation. It is particularly important for WRS structures to ensure that the steel galvanising extends above the surface level, and to also ensure it is maintained free of vegetation and debris at ground level.

A selection of typical directly buried steel foundations is shown in the following figures.

Figure 1: Grillage steel foundation example

Figure 2: Mini-grillage steel foundation example

Figure 3: Steel plate foundation example

4.1.3 Steel reinforced concrete – mass or pier/pile

In recent times it has been found that the most efficient transmission line designs with the lowest life cycle cost have normally been those utilising steel reinforced concrete foundations. For this reason, over the last twenty years the number of concrete foundations installed by TasNetworks has increased markedly and TasNetworks' Transmission Line Construction Standard specifies that new foundations will generally be of the concrete type, with directly buried steel foundations only permitted where specifically required.

Concrete foundations offer a number of advantages over grillage foundations, requiring minimal maintenance for at least the first twenty years of life. Unlike grillage foundations, there is no air/soil interface at which corrosion can occur, normally resulting in significantly better asset condition after the same service life.

Despite these advantages, there are a number of asset management considerations that must be considered when utilising concrete foundations:

- for some support structures the cost of utilising concrete foundations is prohibitively expensive due to the scale of the excavation, reinforcing requirements, and volume of concrete required to provide an acceptable level of strength;
- moisture ingress at the concrete/steel interface will result in corrosion of the reinforcing steel and eventual loss of foundation strength. This can be prevented by ensuring:
  - the concrete/steel interface is adequately sealed;
  - any developing concrete cracks are sealed; the area around concrete foundations is maintained clear of vegetation and drainage is adequate to prevent pooling of water;
  - the points of entry of support steel into concrete collars or 'chimneys' where moisture flows down the leg into the concrete are adequately sealed; and
  - any mortar/grout used under base plates is in good condition;
- if insufficient fly ash is utilised within the concrete mix then foundation strength can be compromised (aggregates in the vicinity of the Gordon–Chapel Street 220 kV transmission line have previously been seen to cause problems if additional fly ash is not added to the concrete mix); and
- earthing systems in the vicinity of concrete foundations must be maintained to ensure their continuity and correct function.

As TasNetworks' population of concrete foundations is relatively young, there has been no requirement to implement any condition monitoring regimes beyond visual inspections. However, as these foundations have started to reach twenty years of service life TasNetworks will need to consider the development and implementation of a condition monitoring regime for these assets.

Figure 4: Example of reinforcing steel in concrete foundation

4.1.4 Rock bolted or wall anchor support

Steel rock bolts and wall anchors are used to terminate spans of transmission conductor and/or to provide stay anchor points for tower structures. These usually exist in deep valleys and are subject to high levels of moisture through water spray from power stations and rain, and minimal sunshine, particularly in winter.

These factors result in corrosion being the most prevalent form of condition deterioration for these assets.

4.1.5 Anodes

Depending on the location and type of support structure, the installation of sacrificial anodes can be the most cost effective form of life extension for directly buried steel foundations. Typically, this has been found to be most applicable to large 220 kV support structures, and would usually consist of two anodes attached to opposing support structure legs (i.e. legs 1 and 3, or legs 2 and 4). In some particularly corrosive areas up to three anodes may be used.

TasNetworks utilises magnesium anodes designed in accordance with Australian standards, sized for a life of 10 to 15 years. New anodes are normally assessed six months after installation to determine the rate of anode consumption, normally resulting in the insertion of regulating resistors to adjust the rate of consumption to an appropriate level for the remaining life of the anode. The ongoing condition of anodes or directly buried steel foundations is determined through half-cell tests.

Anodes must be regularly monitored to ensure they are still active and connected to the foundation.

4.1.6 Foundation earthing systems

TasNetworks installs earthing systems at all transmission line support structures, ensuring compliance with requirements specified in the Transmission Line Construction Standard.

Structure footings provide a ground path for fault currents in the transmission line arising from system faults and/or lightning. Poor earthing will:

- increase the risk of back-flashovers at EHV insulators under lightning conditions;

- reduce the level of fault current detected by protection relays at the substation, possibly resulting in delayed protection operation; and
- increase step and touch potentials at support structures, increasing the risk to safety of the public and maintenance personnel.

Therefore, it very important that footing earth resistances are maintained at acceptable levels as defined within the standard.

In some locations, due to the local geology it may not be possible to achieve low enough earthing resistances at individual support structures. In these circumstances it may be necessary to install what is commonly known as a counterpoise system, where a Copperweld conductor is installed below ground, joining numerous support structures and creating a continuous earth. These systems typically attempt to achieve a tower earth resistance less than 10Ω wherever possible. Where a tower footing resistance of 10Ω cannot be achieved at a single tower, an average footing resistance of 10Ω across five consecutive towers may be approved by TasNetworks.

TasNetworks has one such counter-poise system, installed on the Gordon–Chapel Street 220 kV transmission line between Gordon Power Station and Tower 127 at Maydena. Through anecdotal evidence it is known that some sections of the counterpoise system have been inadvertently dug up by forestry and other personnel, however these events occurred some time ago and exact locations were not been recorded. Regardless, the effectiveness of the counterpoise system was tested in 2001 and found to still result in a sufficiently low earth resistance.

4.2 Age profile

TasNetworks' transmission line support structures are among the oldest transmission line support structures in Australia. Although age is not a definitive indicator of foundation life expectancy, it does provide an indication of the condition of TasNetworks' foundation population, and can identify those foundations requiring more comprehensive condition monitoring and testing activities. It is considered likely that the associated foundations that are advanced in age will exhibit an increase in deterioration.

Where available, foundation age is recorded in WASP for each foundation. Where this is unavailable, the age of the support structure has been used, as the foundation and support structure are normally installed at the same time.

Figure 5: Age profile of structures

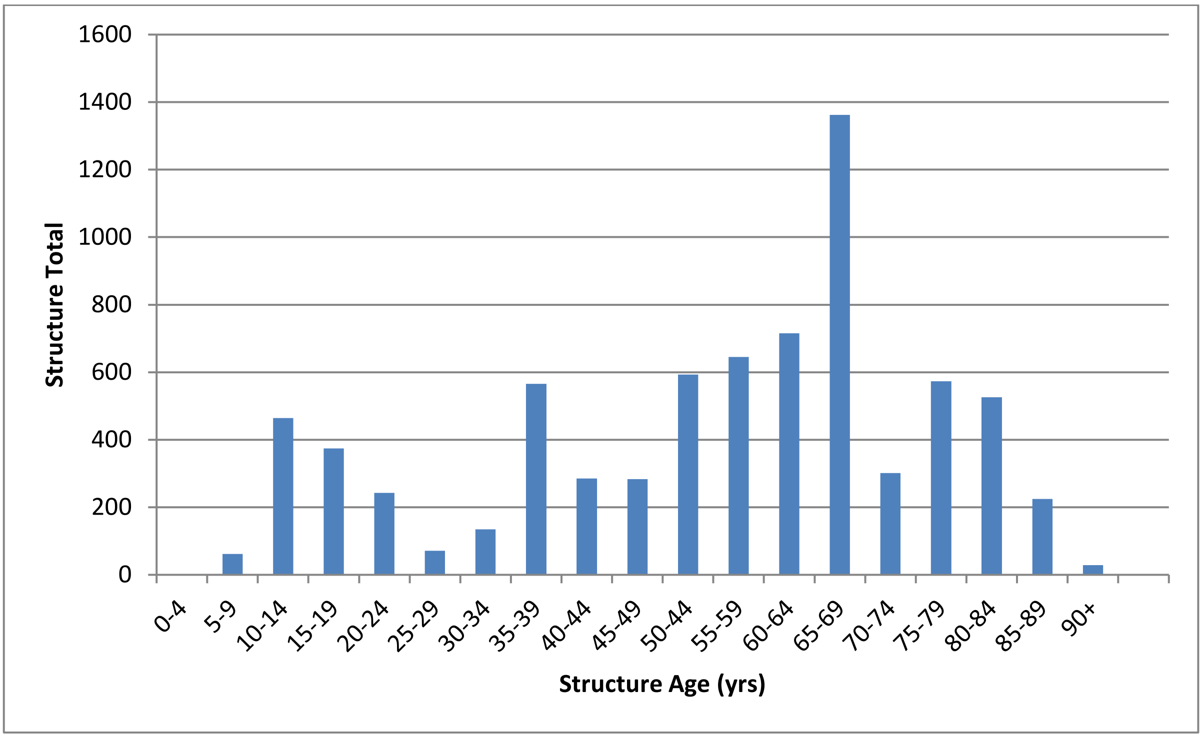

Table 2 below summarises the range in foundation ages.

Table 2: Ranges in foundation age

Foundation Type	Minimum Age	Maximum Age
Concrete	2	47
Concrete / Steel	1	26
Directly buried steel	1	96

4.2.1 Anodes

Magnesium anodes are a consumable item, and are sized to give between 10 and 15 years life.

4.2.2 Earthing Systems

The earthing system associated with a particular structure will normally be installed at the same time as the structure, and hence the age profile of TasNetworks' earthing systems is similar to that for support structures.

TasNetworks' only counterpoise system, located on the Gordon–Chapel Street 220 kV transmission line, was installed in 1975.

4.3 Special operational and design issues

4.3.1 Operational issues

Augmentation of transmission line support structures will normally result in an increase in mechanical loads experienced by the tower foundations. To continue to meet the requirements of AS/NZ 7000:2010 it is often necessary to review the foundation capacity as part of the augmentation works and undertake subsequent modifications to increase its strength.

TasNetworks will continue to undertake these design checks as required, and incorporate any remedial works into the scope of the associate capital project.

4.3.2 Design issues

4.3.2.1 Geotechnical investigations

Two important criteria to be considered when designing and installing foundations are soil type and soil stability. Historically, geotechnical investigations were not carried out at each individual tower site and over the years a small number of tower foundations have been installed in locations that have resulted in landslip occurring. This may have been exacerbated by environmental factors that were not present during the design stage.

4.3.2.2 Sinkholes

In the Railton area an issue has been identified where grillage foundations have been installed in an area where the underlying limestone is subject to sinkhole activity. In these locations TasNetworks has had to invest in concrete foundations that are significantly larger and stronger than those typically used across the network. TasNetworks will continue to monitor geological conditions as part of routine inspections for existing transmission lines, and as part of the design process for new transmission lines, ensuring that the risk of sinkholes or other geological anomalies is sufficiently mitigated.

4.3.2.3 Induced corrosion from other infrastructure

Other infrastructure, such as cables or steel pipes, may be installed in the vicinity of a transmission line support structure. At these locations it is possible for galvanic corrosion to occur, causing a degradation in underground structural material on either TasNetworks' or the third party's assets.

In these locations cathodic protection may be required to inhibit this process.

As an example, accelerated corrosion of direct buried steel foundations has been observed in the Port Latta and George Town areas where steel pipelines have been installed in the vicinity of transmission lines. Anodes have been installed at these locations to provide ongoing cathodic protection for these assets.

At Smithton Substation a similar issue has emerged. To obtain adequate earthing it has been necessary to install additional earthing at towers T282 to T287 in the form of a buried copper loop connected to the overhead optical fibre ground wire. The use of copper earth leads has created an undesirable electrolytic cell at each of the towers, resulting in accelerated corrosion of the tower legs as they are effectively acting as sacrificial anodes.

To address this and prevent further deterioration of the support structure foundations, TasNetworks has installed magnesium anodes at each of the towers. However this solution does not address the root cause and will be costly to maintain. The earthing design that has contributed to this issue should be reviewed to determine whether there is an alternative design that can still provide adequate substation earthing, while also removing the requirement for the ongoing use of anodes at each of these towers.

4.3.2.4 Lightning

A number of fault outages due to lightning in the west and north west regions of the State in recent years has raised concerns regarding the effectiveness of TasNetworks earthing.

Subsequent earthing system resistivity tests at three locations on the west coast and in the north west of the State, known to be prevalent to lightning strikes found that the earthing impedance on a number of structures is well above 50Ω.

TasNetworks Transmission Line Construction Standard specifies that TasNetworks should achieve earthing impedance values of 10Ω or less at each structure, and hence there may be an elevated risk of back flashover at these locations. After a successful trial of reducing the earthing impedance on a support structure known to be in difficult ground, a program of earthing improvements was rolled out on a number of exposed towers within the transmission network in the 2014-19 regulatory control period. Beyond this improved earthing will be determined on a circuit reliability basis.

TasNetworks records footing resistance values for all new support structures. To provide a more comprehensive asset condition profile, TasNetworks is currently evaluating the most effective way of incorporating footing impedance tests into its asset inspection and testing regimes for foundations. In addition to this, TasNetworks also reviews fault outages to identify any emerging failure modes that may be attributable to, or exacerbated by inadequate earthing systems.

5. Associated risk

5.1 Risk management framework

TasNetworks has developed a Risk Management Framework for the purposes of assessing and managing its business risks, and for ensuring a consistent and structured approach for the management of risk is applied.

An assessment of the risks associated with the support structure foundations has been undertaken in accordance with the Risk Management Framework.

The quantification of risk is supported by the Health Based Risk Management (HBRM) framework. This approach allows the risks of individual assets to be quantified against the defined assessment.

Due to the level of risk identified in some of the assessment criteria a requirement to actively manage these risks has been identified.

5.2 Asset risks

The following areas have been identified as risk areas in the management of transmission line support structure foundations.

5.2.1 Unidentified degradation of support structure foundations

A significant degradation of a support structure foundation has the potential to cause a transmission line failure. The consequence of such an event may include injuries, fatalities and a transmission line outage. The failure may be due to steel corrosion or reduction in the strength of a concrete foundation. TasNetworks undertake regular full condition assessment of structures on a periodic basis and ground inspection annually. Where required, assessment of the load bearing and uplift capacity of existing foundations is undertaken. Anodes may be installed to address corrosion or foundations may be required to be refurbished or replaced. Anodes corrosion rates present an additional risk where the anode has corroded more quickly than planned for, or is no longer connected to the foundation resulting in degradation of the steel foundation.

5.2.2 Deterioration and failure of earthing systems

The transmission line foundation earthing systems enable energy associated with system faults or lightning strikes to be dissipated safely and with minimal potential damage to the transmission line. Over time the earthing system can become corroded or damaged and connections broken. Deterioration and failure of the earthing system could cause unsafe step and touch potentials under fault conditions. This results in a high safety and people risk ranking. TasNetworks mitigation strategy is to inspect, test and repair earthing systems where evidence of deterioration is identified.

5.2.3 Induced corrosion form surrounding infrastructure

Assets buried in the vicinity of TasNetworks' support structure foundation can cause accelerated degradation of the foundation.

5.2.4 Transmission line augmentation

Overtime there may be a requirement for additional loads to be added to existing transmission lines, such as OPGW, or for a line to be augmented. When this occurs there is an obligation for an assessment for compliance against the latest transmission line standards and codes, including AS7000. There is a risk that the existing foundations may not be compliant and therefore additional refurbishment or replacement of assets is required. This would result in additional unplanned financial costs being imposed on TasNetworks and therefore is considered a high risk ranking based on the potential financial impact.

5.2.5 Extreme weather events (climate change)

Climate change and an increase in extreme weather events (wind or microburst) beyond the current design capabilities of the support structure foundation resulting in a fallen support structure and death or serious injury, loss of supply to customer load or a bushfire as a result of fallen conductors.

5.3 Summary of risk

Table 3 summarises the transmission line support structure foundations risks, their mitigation strategy and residual risk levels.

Table 3: Summary of asset risks

Risk Identification		**Risk Analysis (Inherent)**				
Risk	**Risk Description**	**Category**	**Likelihood**	**Consequence**	**Risk Rank**	**Treatment Plan Yes / No**
Unidentified degradation of support structure foundation	Transmission line support structure foundations have a defined design life based on assumptions of loss of strength due to corrosion. Corrosion rates will vary and condition must be monitored. If allowed to progress unchecked, the transmission line support structure foundation will fail resulting in a fallen support structure, death or serious injury, loss of supply to customer load or a bushfire as a result of fallen conductors.	Safety and People	Rare	Severe	Medium	Yes
		Financial	Rare	Minor	Low	
		Customer	Rare	Moderate	Low	
		Regulatory Compliance	Rare	Minor	Low	
		Network Performance	Rare	Moderate	Low	
		Reputation	Rare	Moderate	Low	
		Environment & Community	Rare	Severe	Medium	
Deterioration and failure of earthing systems	Poor earthing systems will prevent the effective dissipation of energy associated with system faults and lightning strikes, and may alter step and touch potentials to unsafe levels resulting in death or serious injury, line outages and loss of supply.	Safety and People	Rare	Severe	Medium	Yes
		Financial	Unlikely	Minor	Low	
		Customer	Unlikely	Moderate	Medium	
		Regulatory Compliance	Unlikely	Minor	Low	
		Network Performance	Possible	Moderate	Medium	
		Reputation	Possible	Minor	Low	
		Environment & Community	Unlikely	Negligible	Low	

Risk Identification		**Risk Analysis (Inherent)**				
Risk	**Risk Description**	**Category**	**Likelihood**	**Consequence**	**Risk Rank**	**Treatment Plan Yes / No**
Induced corrosion form surrounding infrastructure	Assets buried in the vicinity of TasNetworks' support structure foundation can cause accelerated degradation of the foundation.	Safety and People	Rare	Minor	Low	Yes
		Financial	Possible	Minor	Low	
		Customer	Rare	Moderate	Low	
		Regulatory Compliance	Rare	Minor	Low	
		Network Performance	Rare	Negligible	Low	
		Reputation	Unlikely	Moderate	Low	
		Environment & Community	Rare	Negligible	Low	
Transmission line augmentation	Prevailing regulation requires that any change in the operation of support structure foundations brings about an obligation to modify the support structure to meet present day requirements. Where new loads are imposed (e.g. OPGW stringing) the structure must be reassessed to prevent potential failure. Failure to reassess structural load changes may result in a fallen support structure and death or serious injury, loss of supply to customer load or a bushfire as a result of fallen conductors.	Safety and People	Rare	Severe	Low	Yes
		Financial	Rare	Minor	Low	
		Customer	Rare	Moderate	Low	
		Regulatory Compliance	Rare	Minor	Low	
		Network Performance	Rare	Negligible	Low	
		Reputation	Rare	Moderate	Low	
		Environment & Community	Rare	Severe	Medium	

Risk Identification		**Risk Analysis (Inherent)**				
Risk	**Risk Description**	**Category**	**Likelihood**	**Consequence**	**Risk Rank**	**Treatment Plan Yes / No**
Extreme weather events	Extreme weather event (wind or microburst) beyond the design capabilities of the support structure foundation resulting in a fallen support structure and death or serious injury, loss of supply to customer load or a bushfire as a result of fallen conductors.	Safety and People	Rare	Severe	Medium	Yes
		Financial	Rare	Minor	Low	
		Customer	Rare	Moderate	Low	
		Regulatory Compliance	Rare	Minor	Low	
		Network Performance	Rare	Moderate	Low	
		Reputation	Rare	Moderate	Low	
		Environment & Community	Rare	Severe	Medium	

6. Whole of life management plan

6.1 Maintenance strategy

The good performance of transmission line support structure foundations is partially achieved through the implementation of a programmed condition assessment regime and resulting asset management activities such as asset refurbishment or replacement.

As transmission line support structure foundations age, different life cycle issues and failure modes arise and must be captured in the preventative and corrective practices. Table 4 provides a summary of the life cycle issues applicable to support structure foundations.

Table 4: Life cycle issues

Type of support structure foundation	Issue
All	TasNetworks' transmission line support structures are among the oldest transmission line support structures in Australia and it is likely that the associated foundations will exhibit an increase in deterioration. Other infrastructure, such as cables or steel pipes, may be installed in the vicinity of transmission line support structure foundations. At these locations it is possible for galvanic corrosion to occur, causing a degradation in underground structural material on either TasNetworks' or the third party's assets. To support TasNetworks' medium and long term vision, it may be necessary for transmission lines to be either augmented or decommissioned. Where this occurs it is important that TasNetworks consider the requirements of new and more onerous design standards to ensure that compliance is maintained.
Directly buried steel	Moisture content, acidity, and the level of aeration within the soil will cause deterioration of the zinc galvanising layer associated with a steel foundation, eventually escalating to corrosion and pitting of the steel foundation. This corrosion is more prevalent near the surface at the air/soil interface, down to a depth of approximately 600mm.
Concrete	Moisture ingress at the concrete/steel interface will result in corrosion of reinforcing steel and eventual loss of foundation strength. If insufficient fly ash is utilised within the concrete mix then foundation strength can be compromised.
Anodes	The use of incorrect regulating resistors can result in anode consumption that is either too fast or too slow, increasing lifecycle cost or increasing the risk of foundation deterioration respectively.
Earthing systems	In some locations, due to the local geology it may not be possible to achieve low enough earthing resistances at individual support structures.

6.1.1 Foundation condition monitoring activities

Support structure foundation condition is predominantly determined by local geological conditions, i.e. soil type, local soil and rock stability and the situation of surface drainage and near surface ground water.

Due to their short service life, internal corrosion or degradation of concrete foundations is rare and hence these foundations are only inspected visually for failure modes such as cracking, movement or erosion. There is no testing regime for these foundations however as the service life increases TasNetworks will need to investigate other inspection and testing regimes.

Past experience has shown it is undesirable to excavate foundations as a primary means of condition assessment, as the disturbance of the soil and exposure to atmosphere promotes accelerated corrosion.

For this reason, the half-cell electrical test has been developed and refined for use on directly buried steel foundations. This test methodology does not require excavation of surrounding material for the assessment to occur. Calibration of the test does require periodic exposure of actual foundation condition (to check validity of the readings) however this is kept to a minimum.

In addition, TasNetworks has established a contract with an external corrosion management contractor to perform 'risk integrity' tests of directly buried steel foundations. A risk integrity test provides a comprehensive profile of the foundation and the surrounding soil and includes, but is not limited to the following activities:

- half-cell test;
- resistivity measurements;
- sulphide measurements;
- ph measurements;
- extraction of soil core samples; and
- inspection of geographical features that may impact on foundation integrity.

A risk integrity test only needs to be completed once at each site, after which half-cell testing will be the only ongoing test requirement. Hence, TasNetworks is currently implementing a program whereby risk integrity tests are completed for the entire tower foundation population. This program focuses on critical circuits such as 220 kV transmission lines and transmission lines with the greatest service life.

As TasNetworks' population of concrete foundations approaches a service life of 20 years it will be necessary for TasNetworks' to implement condition monitoring activities specific to these assets. It is anticipated that the risk integrity test methodology will be modified and applied to these assets.

6.1.1.1 Directly buried steel foundations

Copper/copper sulphate half-cell tests are performed on all directly buried steel foundations that are more than 20 years old, where a coating has not previously been applied to inhibit the corrosion process (e.g. denso tape or paint). Retesting is necessary every five years after the initial test.

These foundations will fall into one of the three following zones of operation:

- < -850mV: New anode or galvanised steel leg. Foundation is fully protected from corrosion. Will normally correspond with a current flow of less than 20mA.
- -850mV to -550mV: Anode and/or steel galvanising is being consumed. Foundation is fully protected from corrosion.
- -550mV to 0mV: Anode and/or galvanising has been totally consumed. Foundation is experiencing corrosion.

While half-cell results will indicate if zinc or steel corrosion is occurring, they cannot reliably indicate the degree of corrosion activity. To verify these results TasNetworks will normally excavate a small number of sites (<5 per cent) and perform a visual inspection to determine the actual level of remaining zinc galvanising.

For those foundations where a coating has been used to inhibit the corrosion process, TasNetworks will perform targeted excavations to visually assess the level of corrosion and remaining zinc galvanising. Again, this will normally be undertaken on a small number of support structures distributed along the transmission line of interest.

Foundation excavations will always be a necessity to facilitate the inspection of directly buried steel foundations, however it should be noted that these excavations will disturb the corrosion process occurring within the foundation micro-environment. This disturbance may actually result in an acceleration of corrosion due to the aeration of the soil and is also likely to result in a step change in half-cell reading for any future tests. Despite this, the benefits of performing the visual inspection outweigh the potential for accelerated corrosion.

6.1.1.2 Steel reinforced concrete foundations

TasNetworks does not currently employ any specific condition monitoring activities for steel reinforced concrete foundations. This has been a deliberate strategy given that the majority of these foundations have been in service for less than 20 years.

TasNetworks is currently assessing the range of condition monitoring activities that could be applied to concrete foundations as they approach and exceed 20 years of service life.

6.1.1.3 Rock bolted or wall anchor support foundations

TasNetworks does not currently employ any specific condition monitoring activities for rock bolted or wall anchor support foundations.

6.1.1.4 Anodes

TasNetworks' inspection and condition monitoring regimes have identified that anode deterioration is occurring at a number of transmission line structure foundations and that anode replacement is necessary.

Similar to directly buried steel foundations, remaining anode life can be ascertained through half-cell testing, with anodes falling into one of the three following zones of operation:

- < -850mV: New anode or galvanised steel leg. Foundation is fully protected from corrosion.
- -850mV to -550mV: Anode and/or steel galvanising is being consumed. Foundation is fully protected from corrosion.
- -550mV to 0mV: Anode and/or galvanising has been totally consumed. Foundation is experiencing corrosion.

The historical rate of change in measured half-cell voltage provides TasNetworks an opportunity to plan for anode replacement.

6.1.1.5 Earthing systems

A number of fault outages due to lightning in the west and north west regions of the State has raised concerns regarding the effectiveness of TasNetworks' earthing.

Subsequent earthing system resistivity tests on a number of transmission lines on the west coast and in the north west of the State, known to be prevalent to lightning strikes found that the earth resistivity on a significant number of geographically exposed structures was well above 10Ω.

TasNetworks' Transmission Line Construction Standard specifies that TasNetworks should achieve earth resistivity values of 10Ω or less at each structure, and hence there may be an elevated risk of back flashover at these locations. Sites of repeated back flash can be risk mitigated by upgrading footing earthing.

6.2 Preventive and corrective maintenance (OPEX)

6.2.1 Preventative maintenance

Preventive maintenance is, by its nature, a planned and scheduled maintenance activity that is completed to a predetermined scope, and consists of:

- Condition assessment - the routine inspection, testing and monitoring of assets to ascertain their condition.
- Maintenance (routine and condition based) - assets are maintained either on predetermined frequency basis (time-based) or in response to findings arising from condition assessment activities.

TasNetworks has adopted internationally recognised procedures for the assessment and maintenance of its transmission line support structure foundations. Condition assessments by air and by ground each have their merits which must be balanced to achieve an optimum level of cost effectiveness and overall outcomes efficiency.

After consideration of the many factors applying to Tasmania's geography, climatic conditions and the history of known deterioration of transmission line support structure foundations in this environment, TasNetworks' has adopted the preventive maintenance strategies summarised in Table 5.

6.2.2 Corrective maintenance

In the event of a fault condition, TasNetworks will arrange for corrective maintenance to occur to either replace the asset, or undertake other activities to restore the asset to an appropriate level of service.

6.2.3 Routine maintenance versus non routine maintenance

Transmission line foundation failures may cause serious or catastrophic damage to a transmission line causing transmission outages and a real risk to the public and surrounding infrastructure. Whilst these assets have a low unit value, the failure of a foundation could cause significant damage to a transmission line so a preventative corrective maintenance program represents a cost effective alternative to a reactive corrective maintenance program.

6.2.4 Refurbishment

Transmission line foundations, anodes and earthing systems are generally not considered suitable for redeployment back into the network when a transmission line is decommissioned. However in some cases transmission line foundations may be able to be refurbished in situ.

6.2.5 Summary of Opex expenditure

Table 5: Summary of Opex programs and expenditure

Project/Program	Func. Area	Program Data										
		Financial year	**FY22**	**FY23**	**FY24**	**FY25**	**FY26**	**FY27**	**FY28**	**FY29**	**FY30**	**FY31**
Transmission Line Routine Inspections	PMTRI	**Expenditure ($m)**	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45
Transmission Line Support Structure Foundation Preventative Maintenance	PMFND	**Expenditure ($m)**	0.30	0.41	0.43	0.28	0.25	0.30	0.41	0.43	0.28	0.25

6.3 Reliability and quality maintained (CAPEX)

The cost of asset replacement activities that meet the capitalisation requirements outlined within TasNetworks' Asset Accounting Standard can be capitalised. These capital projects are detailed below.

Asset replacement activities not meeting these requirements will be undertaken as operational expenditure.

6.3.1 Planned asset replacement versus reactive asset replacement

Similarly to Section 6.2.3, a reactive replacement does not represent an attractive alternative to a planned renewal activity. Transmission lines predominately connect generators to the network or supply major customers or population areas with high reliability requirements. Also reactive replacements are generally more expensive, incurring overtime, potential outage penalties and additional repair costs to structures and nearby infrastructure.

Replacement is generally only preferred when this is a more economic proposition compared to ongoing maintenance costs over the estimated remaining service life of the asset. These are identified from the maintenance and inspections activities and feed into the list of proposed capital expenditure projects for prioritisation.

6.3.2 Non network solutions

Transmission line foundations support the transmission line tower structure. As such any potential non-network solution would need to provide an alternative to the entire transmission line as a system rather than any specific solution which addresses only the transmission line foundations.

6.3.3 Network augmentation impacts

TasNetworks' requirements for developing the power transmission system are principally driven by five elements:

- Demand forecasts
- New customer connection requests
- New generation requests
- Network performance requirements
- National electricity rules (NER) compliance

Installation of new foundations would be required as part of any transmission line development as a result of a network augmentation requirement.

6.3.4 Foundation refurbishment and replacement program

As a result of test results, defects and other condition information, and bearing in mind fleet management considerations, the transmission line foundation replacement program expects to replace approximately 50 support structure foundations annually during the 2024-29 regulatory control period.

6.3.5 Support structure anode installation and renewals

As a result of test results, defects and other condition information, and bearing in mind fleet management considerations, the transmission line anode installation renewal program expects to ramp up as anodes require renewal on existing support structures and an aging transmission base may require the installation of anodes to extend the life of support structures where presently no anodes are installed.

6.3.6 Details of future Capex projects/programs

Table 6: Program/project details

Project/Program description	Functional area	HBRM Document Id. (IES)
Transmission Line Support Structure Foundation Renewal Program	RENTL	PRJ000641
Transmission Line Support Structure Foundation Anode Renewal Program	RENTL	PRJ000739

6.4 Spares management

TasNetworks' maintains appropriate levels of asset spares for emergency response and other activities as defined within the System Spares Policy R517373.

6.5 End of life management

Disposal of any transmission line support structure foundations will be done in accordance with the relevant standards and procedures.

7. Related standards and documentation

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

TasNetworks documents:

1. TNM-GS-809-510-05 - Transmission line defect prioritisation standard (draft)
2. R517373 System Spares Policy

Technical requirements for new foundations and anodes are detailed in the following standards/specifications:

3. R1037048 Transmission Line Design Standard
4. R1047190 Transmission Line Normative to the Design Standard
5. R2079583 Transmission Construction Standard
6. D04/10170 Transport and Use of Chemicals
7. D05/44571 Excavation Standard

Other standards and documents:

8. AS7000:2016 – Overhead line design – Detailed procedures
9. AS 2832.1-5 Cathodic Protection of Metals (2015, 2003, 2005, 2006, 2008)

Appendix A – Transmission line support structure foundation risk analysis

RISK IDENTIFICATION		RISK ANALYSIS				RISK MITIGATION	
Risk	**Detailed Risk**	**Category**	**Likelihood**	**Consequence**	**Risk Rank**	**Mitigating Action(s)**	**Residual Risk Rating**
Unidentified degradation of support structure foundation	Transmission line support structure foundations have a defined design life based on assumptions of loss of strength due to corrosion. Corrosion rates will vary and condition must be monitored. If allowed to progress unchecked, the transmission line support structure foundation will fail resulting in a fallen support structure, death or serious injury, loss of supply to customer load or a bushfire as a result of fallen conductors.	Safety and People	Rare	Severe	Medium	• Perform full condition assessment of structures on a periodic basis and ground inspection annually. • Continued implementation of the foundation risk integrity testing regime. • Where required, confirm load bearing and uplift capacity of existing foundations. • Asset refurbishment or replacement as required.	Medium
		Financial	Rare	Minor	Low		Low
		Customer	Rare	Moderate	Low		Low
		Regulatory Compliance	Rare	Minor	Low		Low
		Network Performance	Rare	Moderate	Low		Low
		Reputation	Rare	Moderate	Low		Low
		Environment & Community	Rare	Severe	Medium		Medium
Deterioration and failure of earthing systems.	Poor earthing systems will prevent the effective dissipation of energy associated with system faults and lightning strikes, and may alter step and touch potentials to unsafe levels resulting in death or serious injury, line outages and loss of supply.	Safety and People	Rare	Severe	Medium	• Inspect and test on a periodic basis and repair earthing systems back to specified levels.	Medium
		Financial	Unlikely	Minor	Low		Low
		Customer	Unlikely	Moderate	Medium		Low
		Regulatory Compliance	Unlikely	Minor	Low		Low
		Network Performance	Possible	Moderate	Medium		Low
		Reputation	Possible	Minor	Low		Low
		Environment & Community	Unlikely	Negligible	Low		Low
Induced corrosion form surrounding infrastructure	Assets buried in the vicinity of TasNetworks' support structure foundation can cause accelerated degradation of the foundation.	Safety and People	Rare	Minor	Low	• Perform full condition assessment of structures on a periodic basis and ground inspection annually. • Work with the asset owner(s) to remove or substitute the infrastructure. If this is not possible then anode installation may be necessary. Inspect, test and replace anode systems on a periodic basis.	Low
		Financial	Possible	Minor	Low		Low
		Customer	Rare	Moderate	Low		Low
		Regulatory Compliance	Rare	Minor	Low		Low
		Network Performance	Rare	Negligible	Low		Low
		Reputation	Unlikely	Moderate	Low		Low
		Environment & Community	Rare	Negligible	Low		Low

RISK IDENTIFICATION		RISK ANALYSIS				RISK MITIGATION	
Risk	**Detailed Risk**	**Category**	**Likelihood**	**Consequence**	**Risk Rank**	**Mitigating Action(s)**	**Residual Risk Rating**
Transmission line augmentation	Prevailing regulation requires that any change in the operation of support structure foundations brings about an obligation to modify the support structure to meet present day requirements. Where new loads are imposed (e.g. OPGW stringing) the structure must be reassessed to prevent potential failure. Failure to reassess structural load changes may result in a fallen support structure and death or serious injury, loss of supply to customer load or a bushfire as a result of fallen conductors.	Safety and People	Rare	Severe	Low	• Assess all structural changes to support structures for compliance against AS7000. If required, modify or replace the support structure to bring it up to the required standard.	Low
		Financial	Rare	Minor	Low		Low
		Customer	Rare	Moderate	Low		Low
		Regulatory Compliance	Rare	Minor	Low		Low
		Network Performance	Rare	Negligible	Low		Low
		Reputation	Rare	Moderate	Low		Low
		Environment & Community	Rare	Severe	Medium		Low
Extreme weather events	Extreme weather event (wind or microburst) beyond the design capabilities of the support structure foundation resulting in a fallen support structure and death or serious injury, loss of supply to customer load or a bushfire as a result of fallen conductors.	Safety and People	Rare	Severe	Medium	• Monitor weather pattern trends in Australia to determine any potential change to likelihood of extreme weather events. • Ensure any foundation renewals take future weather changes into consideration during design.	Medium
		Financial	Rare	Minor	Low		Low
		Customer	Rare	Moderate	Low		Low
		Regulatory Compliance	Rare	Minor	Low		Low
		Network Performance	Rare	Moderate	Low		Low
		Reputation	Rare	Moderate	Low		Low
		Environment & Community	Rare	Severe	Medium		Medium

Appendix B – Support structure foundations inspection and test strategies

Foundation type	Strategy	Frequency	Description
Directly buried steel	Methodical inspection	3 year cycle	• A detailed condition assessment is conducted utilising a helicopter (approximately 33 per cent of total structures per year). Use of the aerial inspection is an efficient way of identifying foundations which have been subjected to erosion, land slip which brings the integrity of the foundation into question. • Effective for approximately 97 per cent of the transmission line population over the 3 year period. The remainder is subject to a ground based condition assessment.
			• A detailed ground based condition assessment is conducted at individual structures. • Applies to approximately 3 per cent of total structures over the 3 year period. • Only applicable where 'no-fly' areas prevent the use of a helicopter.
	Ground based	Annual	• A visual inspection aimed at identifying obvious defects that could impair the electrical or structural integrity of the transmission line. • The soil interface and foundation ground cover will be inspected, with repairs carried out if necessary. • Any defects are reported. • Applies to the structures that did not receive a 'methodical' inspection (e.g. 67 per cent of total structures).
	Risk integrity test	Programmatic	• A series of soil and foundation tests resulting in a prediction of remaining asset life. • The foundations of approximately 300 structures are tested per year, on structures that have been in service 20 years or longer. • A risk integrity test is only required to be completed only once per structure in its lifetime. • Assets in poor condition are either refurbished, replaced or anodes are installed. • The completion of a risk integrity test negates the requirement for a separate half-cell test (due to the risk integrity test incorporating a half-cell test).
	Half-cell test	6 year cycle	• Perform half-cell tests on approximately 16 per cent of foundations that have been in service for 20 years or longer, to determine remaining galvanising and provide data to corrosion experts so that they can advise remedial work required. • Half-cell tests will be performed on the same structures that undergo a methodical inspection each year, but at different times in the year due to the differing test resources required.

Foundation type	Strategy	Frequency	Description
Concrete foundations, rock bolts and wall anchors	Methodical inspection	3 year cycle	• A detailed condition assessment is conducted utilising a helicopter (approximately 33 per cent of total structures per year). • Effective for approximately 97 per cent of the transmission line population over the 3 year period. The remainder is subject to a climbing condition assessment.
			• A detailed condition assessment is conducted by climbing individual structures. • Applies to approximately 3 per cent of total structures over the 3 year period. • Only applicable where 'no-fly' areas prevent the use of a helicopter.
Earthing systems	Testing	12 year cycle	• Undertake testing of support structure earthing systems on 8 per cent of structures, for all sites where opportunistic tests (e.g. during commissioning activities or protection studies) have not been possible. This is a one-off test to establish base line readings of footing resistances.
General	Inspection / testing	As required	• Where other infrastructure interacts with support structure foundations, location specific monitoring and maintenance plans will be developed in consultation with other owners of the infrastructure.