managing
trees in the
urban
landscape

Brownhill Creek Recreation Park

Kaurna shelter tree management plan

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Introduction

Following instructions from Ron Bellchambers, Community Liaison Officer with the Brownhill Creek Association Inc. I visited Brownhill Creek Recreation Park on the 3rd of May 2018.

I attended an onsite meeting with stakeholders at the Kaurna shelter tree to discuss recent trenching damage and likely potential effects on the tree.

I previously visited this site to discuss and assess the same tree in 2011, preparing a management plan for the tree and its immediate environs for the Fiends of Brownhill Creek Recreation Park.

Brief

- Assess the Kaurna shelter tree for potential impacts caused by the adjacent unauthorized trenching.
- Undertaken chlorophyll fluorescence testing of the foliage to determine the underlying health and vitality levels of the tree.
- Review and modify as required the existing management plan taking into consideration the recent damage to the trees root system and growing environment.

Observations

Site visit

I conducted an assessment of the subject tree on the 3rd of May 2018.

I had good access to the tree in question. All observations were visual from ground level[i]. All dimensions marked (~) are estimates.

The weather at the time of my visit was overcast with occasional showers resulting in average visibility and poor conditions for photography.

Site description

Brownhill Creek Recreation Park is situated in the foothills of the Mt Lofty Ranges, in the City of Mitcham. The park covers an area of approximately 52 hectares and operates as a multi-use recreational park with historical and scenic qualities.

The park comprises a steep sided valley, with Brownhill Creek meandering across the narrow valley floor. Various facilities, including a bitumen road and caravan park lease within the reserve.

The natural vegetation of the park has largely been cleared. Remnant vegetation of mature and senescent River red gums – *Eucalyptus camaldulensis* occurs sporadically along the creek, while *Eucalyptus leucoxylon* - South Australian blue gum are present in places within woodland on the slopes (this vegetation may be outside of park boundaries).

Brownhill Creek Recreation Park - Kaurna shelter tree management plan. May 2018.

There are 17 remnant *Eucalyptus camaldulensis* in the Park. Fourteen of these are living and 1 has collapsed. The remaining 2 are standing dead trees. (Information supplied by David Wagner 2011)

The site has in the past been dominated in some areas by introduced plants; most notably woody weed species such as Willow, Poplar, Ash and Olives.

Selected areas of the park have been cleared woody weed species.

Numerous exotic and native trees have been planted in the past within the park for ornamental purposes.

Some of these trees provide significant amenity and character values to the locality.

An image of the Kaurna Shelter tree taken in the 1890's.

Standing on the edge of Brownhill Creek, the Kaurna shelter tree remains largely surrounded by woody weeds. The recent trenching (2018) occurs immediately behind the bunting in the above image.

Findings

Location

The Kaurna shelter tree is located 50m south east of the tennis courts and 30m south west of the entrance roadway, on the eastern edge of Brownhill Creek.

Tree data

Height	19.3m
Crown spread	~9m north, 6m south, 8m east & 8m west.
Trunk circumference 1m above ground level	10.8m.
Trunk diameter at 1.4m (DBH)[ii]	2.64m
Tree protection zone radius (TPZ)[iii]	15m (Maximum under AS 4970)
Structural root zone radius (SRZ)[iv]	4.0m
Estimated Age	350-400 years (within senescent phase)[v]

Health

Foliage colour	Normal
Foliage density	Relatively sparse (somewhat variable)
Foliage distribution	Relatively even where foliage occurs. Some concentration toward branch extremities. Sporadic areas of epicormic regrowth on the lower trunk and branches.
Die-back - presence and extent	Minor – historic
Dead branches	Several large diameter historical failure stubs. Many small dead branch stubs.
Presence of pests and diseases.	Minor sucking insect damage to foliage (*Cadiaspinor retator* – River Red Gum Basket Lerp). Signs of old borer damage to main stem. Minor new wood borer damage to trunk. Phomopsis galls[vi] on main stem and larger primary branches.
Sap/kino exudate – extent and location.	Minor – associated with borer damage
Termites/bees – extent and location	None noted
Chlorophyll Fluorescence[vii]	Testing of the foliage indicates the underlying status of tree health is at the top of the expected range for a healthy tree; Fv/Fm range <.25 (plant likely to die) to .85 (a healthy plant for the species). The average Fv/Fm[viii] value determined for the Kaurna Shelter Tree is .85.

Recent trenching near the Kaurna shelter tree. Fortunately no major root damage has been inflicted by this process. It is unlikely there will be any ongoing health consequences associated with the trenching.

Structure

Soil level.	The root crown has developed under the influence of tree's position and site changes (floods, erosion, silt deposition) over the life of the tree. An exposed woody structural root to the east continues to be scalped by turf mowing operations. The dominant portions of root crown extend to the north, south and east, likely connecting to large diameter woody roots to provide primary anchoring and stability functions for the tree. There are no obvious indications of structural roots to the south.
Trunk buttress	The lower trunk consists of a segmented hollow shell of varying thicknesses and large openings. Most of the western half of the lower trunk buttress has decayed away or been burnt out. Only a thin sliver of the original trunk remains. Vandalism and ongoing decay have reduced the size and thickness of this section to the point where it is unlikely to be playing a supportive role. The remaining sections of the buttress contain areas that are thin walled, or decaying, with minor openings to the hollow centre. Growth over these areas continues to add new wood, potentially increasing structural strength through adaptive[ix] growth processes. There are no signs that the tree is unstable at ground level.
Trunk	The single trunk rising above the buttress terminates at an old failure ~10m above ground level. The trunk is hollow through the majority of its length. A layer of new wood overlays a central decaying and/or hollowing core. Open hollows associated with past failures are present at various points.
Crown	Upright, irregular, sparsely branched. Bias to west as a result of past branch failures and prevailing winds.
Branch/stem taper	Branch taper is variable. The majority of the small diameter branches are poorly tapered. The remaining branches have reduced taper, improving marginally with increasing diameter.
History of branch/stem failure	The tree has an ongoing branch and stem failure history; · 2 x ~500mm diameter primary branches over the creek. · 1 x ~400mm stem failure over the park at 10m. · 7 x 200-300mm diameter primary branch failures from throughout the crown. · Numerous smaller branch failures <100mm diameter from all parts of the crown. There have been no recent failures of note.

Legal status

The Kaurna shelter tree is currently protected by the *Native Vegetation Act 1991.*

Part 4—Application of Act

(1) Subject to this section, this Act applies to the whole of the State.

(2) This act applies in those parts of the Hundreds of Adelaide, Munno Para, Noarlunga and Yatala

(a) that are within the zone designated as the Metropolitan Open Space System or Hills Face Zone by a Development Plan or Development Plans under the Development Act 1993;

Consultation with the City of Mitcham and the Native Vegetation Council regarding protections described in my previous report provided under the *Development Act 1993* for Significant or Regulated trees have been found to not apply as follows;

As a result of the above status under the *Native Vegetation Act 1991* the Kaurna shelter tree is not protected by the *Development Act 1993.*

The *Development Regulations 2008*;

6A—Regulated and significant trees;

(1) Subject to this regulation, the following are declared to constitute classes of regulated trees for the purposes of paragraph (a) of the definition of regulated tree in section 4(1) of the Act, namely trees within the designated area under subregulation (3) that have a trunk with a circumference of 2 metres or more or, in the case of trees with multiple trunks, that have trunks with a total circumference of 2 metres or more and an average circumference of 625 millimetres or more, measured at a point 1 metre above natural ground level.

(2) Subject to this regulation—

(a) a prescribed criterion for the purposes of paragraph (b) of the definition of significant tree in section 4(1) of the Act is that a regulated tree under subregulation (1) has a trunk with a circumference of 3 metres or more or, in the case of a tree with multiple trunks, has trunks with a total circumference of 3 metres or more and an average circumference of 625 millimetres or more, measured at a point 1 metre above natural ground level; and

(b) regulated trees under subregulation (1) that are within the prescribed criterion under paragraph (a) are to be taken to be significant trees for the purposes of the Act.

(5) Subregulations (1) and (2) do not apply—

(d) to a tree that may not be cleared without the consent of the Native Vegetation Council under the Native Vegetation Act 1991.

Define size of the growing environment

TPZ radius as per AS 4970 - 2009 'Protection of trees on development sites'	15m (Maximum value under this system)
As determined by trunk diameter and topography	30m radius. (~12 x DBH @ 1.4m)

Assess environmental values

Species biodiversity value	*Eucalyptus camaldulensis* is the most biologically diverse endemic tree species in SA, directly supporting over 100 species of insects and small animals[x].
Presence and number of existing hollows/habitats	Four hollows occur on the western side of the tree, all with moderate to large openings @ ~5m, ~8m, ~9m, & ~11m above ground level. Another large hollow occurs at ~7m to the north on the main stem.

Growing environment

Position	Top of eastern creek bank adjacent to a creek flat.
Soil type	Variable: Alluvial loams generally. Soil to east is loam to varying depths, overlying layers of compacted crushed rock and imported soils to varying depths.
Surrounding land use	Passive recreational
Drainage	No obvious issues
Soil compaction/bulk density[xi]	Moderate levels of soil compaction in the area immediately around the base of the tree (resulting from pedestrian visitation). Assumed higher levels of soil compaction to the east in the zone affected by the gravel layer and vehicle movement. The soil profile to the north east of the tree has been partly revealed by recent trenching. The site contains pockets of buried waste materials and gravels.
Presence of surface coverings & adjacent infrastructure	Impervious gravel and crushed rock layers installed in places to the east of the tree are likely to impede water and oxygen movement into the soil.
Signs of site disturbance within the growing environment	An old concrete and brick pad occurs ~8m north of the tree. Soil levels within the creek appear approximately 2m higher than indicated in images taken of the site 120 years ago. The near total clearance of slopes and hilltops in the area following settlement would have resulted in large volumes silt moving into and flowing through the Brownhill Creek system. Excavated materials exposed by recent trenching past the tree contain imported fill and waste overlying local silt.

Image 5: The large expanse of turf east of the tree degrades the quality of the growing environment.

A compacted gravel layer beneath the turf is likely to be impervious in places. The gravel layer is visible here where an eroded central pathway is exposed.

Image above: The trenching revealed layers of imported gravel and soil and well as buried debris within the root zone east of the tree.

Assess risks

Site use/occupancy	Mobile pedestrians walking through the park. Mobile and stationary persons recreating in the adjacent area. Overflow from persons using adjacent facilities (Tennis court, Picnic tables) Persons specifically visiting the tree.
Conduct VTA[xii]	The tree has an extensive branch and stem failure history. Few remaining live limbs occur over the highest use zone. A number of dead branches occur over the turf area. There are no obvious signs of instability or abnormality. Reduced branch taper, over-extension and exposure during storms have all played some part in the previous high incidence of branch failures. There are no obvious indications the previous failures are related to sudden branch failure[xiii]. Branch failure is most likely to occur during storm conditions when occupancy levels are likely to be reduced. Overall tree condition is fair.
Conduct a risk assessment QTRA[xiv] (valid for 12 months)	Target value x size of part (110mm-250mm diameter) x Probability of failure = Risk of harm = 1/500,000. Based on my assessment the risk of harm posed by this tree is substantially below the threshold for action of 1/10,000.

Image above: The ~250mm diameter branch overhanging the turf area to the north is the largest branch most likely to fail into the target zone. The QTRA assessment conducted on this tree indicates the risk posed by this branch is low. No action can be justified at this time to further mitigate and already low risk. NOTE: significant changes to site occupancy levels may increase the risk of harm posed by the tree.

Historical context

Pre-European historical indicators	The subject tree is reported to be a shelter tree for the Kaurna people. There is an information void surrounding the aboriginal history of occupation on the site. Many references are made in relevant literature as to the use of the tree as an aboriginal shelter tree but as far as I can ascertain there are no archaeological studies or other evidence to confirm the nature and extent of use. The absence of a museum facility in SA until 1856 meant that many aboriginal artefacts from this period went to museums overseas. Non-aboriginals are also likely to have camped in the tree.
Post settlement historical indicators	There is a long history of settlement and use of the surrounding area. A dammed body of water existed at the site adjacent to the tree as part of a series of dams on Brownhill Creek. Some of these dams were used for bathing. The dams within the creek were removed in the early 20th Century.

Threats to viability

Site use	Visitor pressure and existing site uses are contributing to a deterioration of the growing environment around the shelter tree. Current unsuitable management practices within the growing environment include the cultivation of turf and root scalping via mowing operations.
Contamination of growing environment	Potential exists for contamination of creek water with excessive quantities of nutrients and a range of other toxins and pollutants via runoff from the surrounding land. Cyclic leaf debris from exotic tree and weed species will be reducing water quality and adding to weed issues. Existing soil/site contamination (buried materials) occur within the growing environment.
Soil compaction	Soil compaction is an ongoing factor limiting tree root growth and development. Soil compaction and changing soil conditions prevent the development and maintenance of a healthy population of mycorrhizae.[xv] The associations formed between tree root systems and mycorrhizae are essential for healthy root function and tree growth.
Weed species	The growth of woody, perennial or annual weed species pose a continuous threat to the future viability of all native vegetation along Brownhill Creek. All species of non-indigenous plants compete with native plants for resources (space, light, water and nutrients) to varying degrees depending on the nature of the plants involved. Exotic plants may change the nature of the growing environment by increasing nutrient levels in the soil and/or water to harmful levels, or through allelopathy,[xvi] e.g., ground cover weed species such as Soursob - *Oxalis pes-caprae* are commonly found within the root zones of trees and other native species in decline. In my experience there is a link (probable allelopathy) between the presence of many common weed species and the decline of many native species, including trees.

Threats to viability (continued)

Fire	Trees with significant hollow development are vulnerable to the effects of fire. If fire becomes established within the hollows it can be extremely difficult to extinguish. The effects of uncontrolled fire may result in whole or partial tree failure.
Pests & diseases	The potential for harm from the introduction soil borne diseases, i.e., *Armillaria spp.* Honey fungus, *Phytophthora spp*., or other pathogens remains ever-present. There are a wide range of disease and insect pests that could potentially harm native vegetation in Australia. New pests and diseases continue to enter the country almost every year despite quarantine restrictions.
Animals	No obvious signs of pressure from grazing animals such as Koalas or Possums were noted in the tree.
Change/development	The recent unauthorized trenching past the Kaurna shelter tree provide a clear indication that threats from development or change are always present. The full extent of change planned for the area around the shelter tree not known. The recently installed electrical trench has potential to facilitate higher site use levels and changes in the nature of site use in the vicinity of the tree, e.g. vehicles.

Conclusions

- The Kaurna shelter tree - *Eucalyptus camaldulensis* is protected by the Native Vegetation Act 1991.
- The tree is in average health and has moderate levels of vitality. Underlying health indicators are good based on CF testing of the foliage. Visually the tree has improved since the last assessment in 2011. Pest and disease levels will continue to fluctuate with the seasons. There are no indicators to suggest pest or disease issues are a significant problem for the tree.
- Tree form has been shaped by a combination of inherited genetic traits, site use within the immediate locality and the influence of the surrounding environment.
- The trees position on the creek bank likely determined the configuration of the woody root system. Later wounding inflicted during times of flooding, or caused by wood boring insects at times of stress, or by fire, would have shaped the lower trunk as it exists today.
- Extensive hollowing of the buttress, trunk and branches followed initial branch failures wounding and decay, developing over the life of the tree. Fire is the most likely reason the western section of the lower trunk buttress is missing. Despite these issues, adaptive growth continues to provide a stable main structure.
- There are a wide range of threats with potential to influence the future prospects for the Kaurna shelter tree. They include;
    - The combined effect of woody weeds, other weed species and turf. These plants all compete with the tree for space and resources. They do not contribute anything back to the tree.
    - Soil and water contamination of root environment by existing and potential pollutants.
    - Soil compaction and erosion of the area associated with past and present site use and management.
    - Fire.
    - The introduction of new pests or diseases.
    - Uncontrolled increased site use.
    - Change or development has potential to diminish the size or the quality of the growing environment.
    - Change may also increase site occupancy with potential consequences for risk management
    - Inaction.

- Based on my VTA and QTRA assessments of the tree and surrounding site use, the risk of harm associated with branch failure by this tree is below the acceptable threshold at 1/500,000. No action is required to further reduce this risk
- The Kaurna shelter tree retains the capacity to respond to improved conditions.
    - The level of protection provided to the tree to minimise harm from potential threats needs to be improved.
    - Improvements to the quality of the immediate growing environment can maintain and improve tree condition over time in the short to medium term.
    - The long term viability of the Kaurna shelter tree is dependent on consistent good quality management as well as the provision of a functioning surrounding habitat linking Brownhill Creek to a wider biologically diverse natural landscape comprising local native plant animal and invertebrate species.

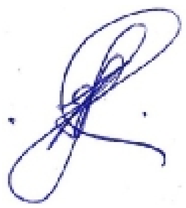
Recommendations

Action	Priority	Duration
1. Determine the size and shape of the management area		
· Ideally the management of and improvements to the growing environment would occur in a linear manner as part of an overall strategy to improve and revegetate Brownhill Creek. · The management zone for the Kaurna shelter tree must include the creek and the adjacent banks. · The width and length of the initial management zone area will be determined by existing constraints and available resources. · Ideally the management zone would extend out to incorporate adjacent revegetation zones or existing native vegetation zones where these areas occur. · Ideally where this zone incorporates important remnant trees such as the 'Kaurna shelter tree' or the 'Monarch of the Glen' the width of the zone would take the requirements of the individual trees into account. · The width of the zone extending east of the Kaurna shelter tree should be no less than 8m (preferably 12m). · In the short term the management zone should extend 30m upstream and downstream from the tree. · This area upstream and downstream should be extended as resources allow.	High	Year 1
2. Control woody weeds		
· Remove all woody weeds (Ash, Willow etc) within the management zone on both sides of the creek. · The removal processes must ensure existing native vegetation being retained and the surrounding growing environment are protected and preserved as best possible throughout the clearance process.	High	Year 1
3. Control annual & perennial weeds		
· Control using herbicides or physically remove ground cover weed species within the revegetation zone prior to planting the site using methods best suited to each species being eradicated. · Particular attention should be made to controlling weed species that spread via underground rhizomes, corms, bulbs etc., e.g., Kikuyu, Couch grass, Soursob, Watsonia, etc. These plants can seriously hamper or prevent the establishment of habitat.	High	Year 1
4. Control turf		
· Kill the turf grass adjacent to the management area using glyphosate at recommended rates at least 8 weeks prior to ripping treatment.	High	Year 1

5. Improve the growing environment		
· Reduce soil compaction and aerate the soil east of the Kaurna shelter tree. · Use a ripping tine to break through compacted soil and gravel layers to a depth of ~500mm. Ripping must occur in a radial pattern extending away from the tree. This process is best completed when the soil is relatively dry. · Ripping lines 500mm apart should start immediately east of the recently excavated trench, cover the management area out to 12m radius. · This process should be undertaken with an arborist present. · Apply a 75-100mm thick layer or organic mulch[xvii] to the upper bank portion of the management zone.	Medium	Year 1
6. Create habitat/enhance biodiversity		
· Densely plant the management zone with local endemic ground cover, shrub and tree species with the intent of re-establishing a biodiverse multilayered habitat. · Use tree guards/shelters to protect young plants & improve establishment success rates.	High	Year 1
7. Maintain the management area		
· Monitor plantings and management requirements		Monthly
· Control annual and perennial weed regrowth · Control woody weed regrowth. · Manage/remove tree shelters as required. · Replant areas where establishment rates are unacceptable.		As required
8. Ongoing Kaurna shelter tree management		
· Prepare a plan to minimise the threat fire poses to the tree. The plan should have an early intervention strategy to extinguish a well-established fire within the hollow portions of the tree and keep it extinguished (they often re-ignite).	High	As funds allow
· Install a raised boardwalk around the base of the tree to protect the tree and reduce the impact of visitation. A boardwalk would also improve the visitor experience. · Install interpretive signage.	Medium	As funds allow.
· Trees are complex dynamic organisms that are subject to change. Assess tree health, risk and management requirements.	Medium	Biannual - ongoing

8. Ongoing Kaurna shelter tree management (cont.)		
· Increase the size of the management zone, repeating points 1-7 in conjunction with a wider plan to protect and enhance the entire Brownhill Creek system.	Medium	As funds allow - ongoing
· Update the management plan for the tree and the park	Medium	As required

If you have any further queries regarding the information contained in this report please feel free to contact me.



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Appendix 1 – Qualifications

I have based this report on my education, experience, ongoing training, site observations and the information provided to me. I have 38 years' experience in the field of arboriculture. A summary of my qualifications includes:

- Advanced Certificate of Amenity Horticulture. Brookway Park. SA (1984)
- Advanced Certificate of Arboriculture. VCAH, Burnley Vic. - Dux (1994)
  - Awarded the Burnley prize for Arboriculture.
  - Awarded the Arbor Co prize for outstanding achievement in Arboriculture.
- Advanced Diploma of Horticulture - Arboriculture. Hortus Australia (1999).
- ISA Certified Arborist - International Society of Arboriculture. AU-0001. I have maintained Continuing Professional Development with this certification.
- Tree Risk Assessment Qualification - International Society of Arboriculture (2013)
- I am a registered consulting arborist with Arboriculture Australia. I have maintained Continuing Professional Development with this certification.
- Australian Arborist Industry License - Tier 1 License no. AL1117   Exp. 31/12/18.

Endnotes

[i] A visual tree assessment (VTA) is an analytical process undertaken by a qualified Arborist or other suitably trained person to determine the structural soundness of a tree. Biological and mechanical components of trees are assessed, including tree health; presence of pests and diseases, die-back, foliage density and distribution, and vitality; growth rate, wound wood development, capacity to respond to improved conditions. Mechanical components include trunk lean, crown bias, bark inclusions, wounds, hollowing, trunk bulges, ribs, cracks, branch form, failure history, pruning history, condition of trunk flare, and other existing defects. All these factors are examined to determine if internal weaknesses may be present. If abnormalities are detected, we may conduct further investigations using a range of tools. These include sounding mallets, long thin drill bits, Resistograph, Sonic Tomograph, Air spade and other tools as required. Ref: Mattheck. Claus & Breloer, Helga. *The Body Language of Trees. A Handbook for Failure Analysis*. Department of the Environment. London 1997.

[ii] Diameter at Breast Height (DBH) is the diameter of the trunk measured at breast height. This measurement is taken at 1.40m above ground level. (Refer to appendix A of the standard for variations on measuring DBH) This is the nominal point measured to determine Tree Protection Zones using the Australia Standard method AS 4970-2009 *Protection of trees on development sites*. When calculating a DBH for a tree with multiple trunks, the combined DBH do not accurately represent the root volume or area and the TPZ becomes exaggerated. Combining DBH in the following formula results in a revised total DBH that better represents the total stem cross sectional area as if it were 1 stem. From this a more proportional TPZ can then be calculated.

$$\text{Combined DBH} = \sqrt{(A^2 + B^2 + C^2 \text{ etc.})}$$

(A, B and C etc. are the DBH of each individual stem)

[iii] The Tree Protection Zone (TPZ) radius is calculated by multiplying the trunk diameter at 1.4m by a factor of 12. The radius is measured from the centre of the trunk at ground level. A TPZ should not be less than 2m nor greater than 15m (except where crown protection is required). This method is outlined in the Australian Standard AS 4970 – 2009 Protection of trees on development sites.

[iv] The Structural Root Zone (SRZ) is the area around the base of a tree required for the tree's stability in the ground. The woody root growth and soil cohesion in this area are necessary to hold a tree upright. The SRZ is nominally circular with the trunk at its centre and is expressed as a radius in metres. This zone considers the tree's structural stability only, not the root zone required for the tree's vigour and long-term viability, which will usually be a much larger area. There are many factors that affect the size of the SRZ (e.g. tree height, crown area, soil type, soil moisture). The SRZ may also be influenced by natural or built structures, such as rocks and footings. An indicative SRZ radius can be determined from the following formula. Root investigations may provide more information on the extent of these roots. From AS 4970-2009 *Protection of Trees on Development Sites.*

$$\text{SRZ radius} = (D \times 50)^{0.42} \times 0.64$$

(D= trunk diameter in metres when measured above the root buttress)

Any work within the SRZ should be avoided. Where no alternative exists, the work must be supervised by a qualified Arborist and approved by Local Council. Tree removal may be required depending upon the size and number of roots affected.

[v] A tree of an advanced old age, or over-mature, leading towards death. The senescent phase in the life of *Eucalyptus camaldulensis* can be very long under the right conditions, i.e., 100-200 years, possibly more.

[vi] Phomopsis Galls- Various sized warty growths on the trunk and lower limbs of species such as *Eucalyptus camaldulensis* and others. Such galls slowly increase in size and number in susceptible trees.

Research into this problem reveals that there are numerous causes of galls and little reliable information exists. Generally speaking, galls are said to be growth abnormalities that can be caused by bacteria, fungi, insects, etc.

One particular gall known as the Phomopsis Gall, (*Reference: Sinclair, Lyon & Johnston. Diseases of trees and shrubs. Cornell University Press. 1987. p146-147)* caused by fungi in the genus Phomopsis) has features matching those found in this tree. Phomopsis appears to lack host specificity and hence is noted in the literature as affecting numerous tree and plant species.

The disease appears as a cluster of nodes pressed tightly together forming a roughened dark clump on the surface of the trunk or branch. Beneath the bark each nodule consists of disorganized heartwood. Galls can be anywhere in size from a few mm's to 40cm's or more across, depending upon the species of tree and location on the plant. Most galls are bulging rounded protrusions. The largest ones are hemispherical protrusions on the lower trunk. The galls can also occur in groups, forming raised ridges or other unusual shapes. Where these groups and lines of nodes occur at the base of a limb it can lead to a general loss of vitality and there is a possibly of stem death should the gall girdle the stem.

Interestingly, galls can affect one tree and not another of the same species adjacent to it. The reason for this is unknown, however from observation; most affected trees are in disturbed environments and have been stressed by prior root damage, heavy pruning or other trauma.

The disease cycle has not been studied. Documented accounts of *Phomopsis* are from observation and as a result of studying other diseases. The mode of transmission is unknown.

Galls of the lower trunk may be used by termites where present. Gall sites have been used by termites as pathways on which they create flight exit holes from deeper galleries within the trunk or stem.

This gives rise to the possibility that the growth of a Phomopsis galls weakens the trunk tissue behind it, providing an access point for insects and/or disease. I have noted flight exit holes in termite affected *Eucalyptus camaldulensis* without these galls, indicating the relationship is by no means exclusive.

The long term impact of Phomopsis galls in the tree is unknown beyond inducing a general reduction in the overall condition of the tree in concert with other adverse cultural factors and pests/diseases.

[vii] *Chlorophyll Fluorescence* (CF). A wide range of urban stresses including soil compaction, de-oxygenation, drought or pollution affect the biology of trees in various ways, limiting photosynthesis through reductions in water and nutrient uptake. This affects the level of available carbohydrates, limiting growth and protection. Visible symptoms of stress can include leaf chlorosis, wilting, dieback and ultimately death. The early recognition and identification of the cause/s of these symptoms is essential if corrective action is to be taken in reducing plant stress before serious damage occurs.

The level of photosynthetic activity within the leaf surface provides a link between the plants internal biology and external stresses. The CF meter (Handy PEA*)* provides Arborists with a tool capable of detecting and isolating the cause of these stresses even before visible symptoms appear. The efficiency of Chlorophyll within the leaf is reduced by stresses, with this change being detected through variations in the quantity, quality and timing of reflected light (Leaf fluorescence). Each type of stress is known to affect different parts of the photosynthetic process, giving it a particular and unique 'signature' within the 56 parameters measured by the Handy PEA. It is possible for this data to then be matched against known signatures for particular stresses to provide specific diagnosis for specific issues.

The Handy PEA also provides a measure of plant vitality and future potential, shown as the Fv/Fm range <.25 (plant likely to die) to .85 (a healthy plant for the species). The use of CF data by Arborists improves tree health diagnosis and assists the targeting and monitoring of tree health care measures.

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[viii] The Handy PEA provides a measure of plant vitality and future potential, shown as the Fv/Fm range <.25 (plant likely to die) to .85 (a healthy plant for the species). The use of CF data by Arborists improves tree health diagnosis and assists the targeting and monitoring of tree health care measures. Kaurna Shelter tree data below;

Hansatech Instruments Ltd Handy PEA Data PEA Plus Version: 1.10

Brownhill Creek Kaurna Shelter Tree: 10 leaf samples were each tested at 3 different dark adaption intervals to determine the highest value that could be obtained.

Record No	Light	Date	Dark Adapt	Fo	Fm	Fv/Fm	Fv/Fo	Vj	Vi	Sm	N	Dark adaption time	Average values
1	1500	11/05/2018	30	296	1995	0.852	5.74	0.2766	0.6257	49.5258	40.3934	30 mins	0.8554
2	1500	11/05/2018	30	329	2343	0.86	6.122	0.3083	0.7443	36.4731	31.1284	60 mins	0.8541
3	1500	11/05/2018	30	314	2325	0.865	6.404	0.3013	0.7315	38.8656	31.426	90 mins	0.8529
4	1500	11/05/2018	30	313	2303	0.864	6.358	0.2759	0.7065	40.879	32.7628		
5	1500	11/05/2018	30	308	2140	0.856	5.948	0.327	0.7631	35.4489	32.3518		
6	1500	11/05/2018	30	312	2059	0.848	5.599	0.2948	0.6657	44.8318	38.8833		
7	1500	11/05/2018	30	303	2134	0.858	6.043	0.2649	0.6559	45.5734	36.0203		
8	1500	11/05/2018	30	277	1757	0.842	5.343	0.2676	0.5736	66.7309	52.2388		
9	1500	11/05/2018	30	312	2132	0.854	5.833	0.2841	0.7198	38.3312	29.9038		
10	1500	11/05/2018	30	326	2241	0.855	5.874	0.2982	0.7238	37.6893	31.0227		
11	1500	11/05/2018	60	303	2021	0.85	5.67	0.287	0.6321	47.6033	40.2326		
12	1500	11/05/2018	60	340	2411	0.859	6.091	0.3235	0.762	34.3746	30.9542		
13	1500	11/05/2018	60	321	2368	0.864	6.377	0.3141	0.7494	36.4037	31.1385		
14	1500	11/05/2018	60	325	2386	0.864	6.342	0.2882	0.722	38.6943	32.7881		
15	1500	11/05/2018	60	317	2170	0.854	5.845	0.3389	0.775	32.8773	30.3644		
16	1500	11/05/2018	60	320	2081	0.846	5.503	0.3049	0.6729	41.7023	36.4992		
17	1500	11/05/2018	60	311	2168	0.857	5.971	0.2687	0.6629	45.1217	37.074		
18	1500	11/05/2018	60	285	1789	0.841	5.277	0.2719	0.5811	66.3386	54.0657		
19	1500	11/05/2018	60	321	2186	0.853	5.81	0.296	0.734	35.2911	29.4092		
20	1500	11/05/2018	60	332	2257	0.853	5.798	0.3143	0.7403	35.7665	30.7415		
21	1500	11/05/2018	90	309	2046	0.849	5.621	0.2861	0.6344	46.5065	40.5489		
22	1500	11/05/2018	90	348	2421	0.856	5.957	0.3362	0.7776	31.5739	29.5958		
23	1500	11/05/2018	90	325	2375	0.863	6.308	0.3176	0.7551	35.4088	30.4592		
24	1500	11/05/2018	90	330	2408	0.863	6.297	0.2907	0.7291	37.0262	32.0812		
25	1500	11/05/2018	90	315	2158	0.854	5.851	0.3413	0.7813	32.6097	30.415		
26	1500	11/05/2018	90	322	2096	0.846	5.509	0.3083	0.6764	41.1222	36.8371		
27	1500	11/05/2018	90	312	2167	0.856	5.946	0.2679	0.6647	43.0469	36.0889		
28	1500	11/05/2018	90	288	1793	0.839	5.226	0.2771	0.5874	64.9784	55.0577		
29	1500	11/05/2018	90	324	2189	0.852	5.756	0.2981	0.7416	33.9595	28.5032		
30	1500	11/05/2018	90	336	2256	0.851	5.714	0.3156	0.749	34.3567	30.2369		

[ix] Tree growth is adaptive, influenced by the loads, environment and availability of essential resources. Response growth, a form of adaption, is the production of new wood in response to damage or additional loads to compensate for higher strain (deformation) in outermost fibres; it includes reaction wood, flexure wood & wound wood.

[x] Dr John T. Jennings. Senior Lecturer. Ecology & Evolutionary Biology. School of Earth & Environmental Sciences. G15d Darling Building. The University of Adelaide SA. Presentation to the South Australian Society of Arboriculture. 12/05/07.

[xi] Apart from the actual removal of roots during excavation or trenching, soil compaction is one of the major causes of root damage on development sites. Compaction is defined as the loss of major pore spaces (macropores) within the soil with a net loss of total pore space. Macropores are essential for the exchange of gases between the soil air and the atmosphere (aeration) and the removal of excess water from the soil (drainage).

Compaction results from loads or stress forces applied to the soil as well as shear forces. Both foot traffic and vehicle traffic exerts both forces on soils. Vehicle traffic may cause significant compaction at depths of 150-200mm (the area in which most absorbing roots are located). The degree of compaction will depend on the weight of vehicles, number of movements, soil moisture levels and clay content. Soil handling, stockpiling and transporting also tend to lead to the breakdown of soil structure and thus compaction. Vibration as a result of frequent traffic or adjacent construction activities will also compact soils.

The effects of compaction include –

- Reduced aeration (oxygen levels decrease and carbon dioxide concentration increases to perhaps toxic levels);
- Low oxygen levels discourage root growth and thus the uptake of water and nutrients;
- Reduced infiltration of water into the soil, and more run-off;
- Increased run-off increases soil losses by erosion;
- Low oxygen levels also lead to chemical changes in the soil with can lead to reduced availability of some plant nutrients; and
- The reduction in the number and diversity of beneficial soil organisms(including mycorrhizal fungi);

Soil compaction is measured as bulk density. Bulk density is the soils dry weight divided by its volume. This figure gives an indication of the soils physical properties and its suitability for root growth. Bulk density should not exceed 80-85% depending upon the soil texture. Heavy clay soils are particularly prone to soil compaction and high bulk densities and so may restrict, limit or prevent root growth depending on the extent of compaction.

[xii] A visual tree assessment (VTA) is an analytical process undertaken by a qualified Arborist or other suitably trained person to determine the structural soundness of a tree. Biological and mechanical components of trees are assessed, including tree health; presence of pests and diseases, die-back, foliage density and distribution, and vitality; growth rate, wound wood development and the trees capacity to respond to improved conditions. Mechanical components include trunk lean, crown bias, bark inclusions, wounds, hollowing, trunk bulges, ribs, cracks, branch form, failure history, pruning history, condition of trunk flare, and other existing defects. All these factors are examined to determine if internal weaknesses or abnormalities may be present. If abnormalities are detected, we may conduct further investigations using a range of tools. These include soft faced sounding mallets, long thin drill bits, Resistograph, Sonic Tomograph, Air spade and other tools as required. Ref: Mattheck. Claus & Breloer, Helga. *The Body Language of Trees. A Handbook for Failure Analysis*. Department of the Environment. London 1997.

[xiii] Sudden Branch Failure (SBF) is a common feature of many species of Eucalypts and other native trees, including Araucaria and Ficus sp. It can also affect exotic trees such as Elms, Beech, Chestnuts, Poplars and others.

This phenomenon almost always affects limbs held in a horizontal or near horizontal plane, or where limbs held at higher angles are affected by internal defects and adaptive growth processes are not functioning. To the best of my knowledge vertical and near vertical limbs do not fail in this way.

Predisposing factors to SBF include:

- A genetic predisposition to SBF. Affected trees often suffer repeated failures of this type.
- A low angle of branch orientation.
- An absence of or reduced taper over the length of the limb.
- Increased exposure: Branches that extend beyond the main crown, or that have been recently exposed by the removal of adjacent trees or structures, or where adjacent limbs have already failed have a higher likelihood of failure.
- Long limbs have a higher likelihood of failure than shorter limbs.
- Lateral branch distribution: A concentration of lateral branches toward the end of the limb increases wind forces acting on the branch during strong winds.
- The removal of lower laterals from a branch adversely affects limb stability, 'lion's tailing'.
- Being of a species with a known potential to shed limbs without warning in still air.

Defects such as animal wounds or internal decay do not have to be present, though when they are they may exacerbate the likelihood of SBF.

SBF require an initiating defect, usually one or more internal cracks. These cracks occur when the above predisposing factors culminate in excessive limb movement during high winds. Large movements act against the trees normal growth stresses, i.e., when a branch normally accustomed to resisting gravity is forced strongly upwards or sideways.

Affected limbs may not fail at the time of the damage. Instead the excessive movement can result in affected limbs sustaining one or more fine cracks and/or the creation of radial compression wounds at or near the base of the branch.

I have viewed the signs of such damage in limbs affected by SBF on hundreds of occasions. They are manifest by dark staining and the presence of Phenols over a portion of the failed surface, indicating a barrier zone has been activated by wounding prior to failure. In eucalypts, the staining indicates the production of Polyphenols. These protective chemicals produce a strong barrier against decay and insect damage, but are also structurally weak. Their production is a part of the CODIT process. (Compartmentalization Of Decay In Trees)

Cracks and staining found in failed limbs are often accompanied by a flat fracture surface that I have assumed to be associated with wood compression injury. This damage always occurs within the upper half of the limb failure surface.

The timing of failure in affected limbs is difficult to predict and can be from days to months or longer. Failure may not occur from the affected area at all. The development of a barrier zone at the point of wounding appears to weaken the limb over time as phenolic chemicals build up within and around the wound. Eventually the weight of the limb may be too great to be supported by the cracked section and failure with little or no warning may occur.

The mechanisms involved in SBF are complex and not well understood. The limited research available suggests a build-up of plant growth regulators and ethylene gas in the wood due to moisture stress may also be triggering factors. These chemicals may weaken the bonds giving wood its strength.

High air temperature and elevated levels of moisture stress are also common conditions affecting the frequency of SBF. Hence SBF is more prevalent in summer.

Drought and extreme heat bring about changes in the moisture content of wood, causing sudden alterations in the distribution of stresses due to differential shrinkage. These changes disturb the normal longitudinal pre-stressing of wood in lateral limbs. The levels of available energy in the tree and local tissue moisture content interact with other factors in a manner that is not yet completely understood.

There is a general consensus amongst Arborists that some individual trees are more prone to SBF than others of the same species found in the same growing conditions, suggesting genetic influences play a major part in susceptibility to SBF.

Expert advice and well targeted pruning can significantly reduce the likelihood of SBF where tree structure accommodates acceptable limb reductions. Pruning to minimise the likelihood of SBF should comply with the Australian Standard AS 4373 – 2007 *Pruning of amenity trees*. Such work should also deliver an aesthetically pleasing tree. The health of the tree should also be unaffected by the extent of pruning.

[xiv] Quantified Tree Risk Assessment (QTRA) provides a framework for determining the risk of harm from tree failure, whether it is a branch or whole tree failure. (Version 5.2/16) The method assesses three components of tree failure risk; Target value, Probability of failure and Impact potential. A numerical range is applied to each of these components of risk. The value or probability of each component is then multiplied to determine a risk of harm. As we are constantly exposed to risk there must be a level to determine when the risk is acceptable or unacceptable. It is generally agreed that an acceptable limit of risk is 1/10,000 (British Medical Association, Health and Safety Executive UK). I am a trained and licensed user of this system (License number 769). For further information on this methodology refer to www.qtra.co.uk

[xv] A mycorrhiza is a combination of a fungus and plant roots developing a symbiotic or weakly pathogenic association. There are a number of types that form close, long-term relationships using a variety of different mechanisms.

Approximately, 95% of vascular plants belong to genera that form mycorrhizal relationships. It is likely that 80% of plant species associate with mycorrhizal fungi. In most cases, the symbiotic relationship between host plants and the mycorrhizal fungus is mutualistic, or mutually beneficial.

Mycorrhizal fungi increase the number of short roots and the total surface area of the root system, increasing efficiencies. The enhanced root system adds significantly to the plants ability to gather water & nutrients from the soil through the actions of the fungus. In exchange, the plant feeds the fungus sugars it produces during photosynthesis. Thus, the relationship is beneficial to both. The plant receives more nutrients than it could on its own, and the fungus gets the food it needs for energy.

The fungus may also provide a barrier to other pathogenic fungi that might adversely affect plant roots. The plants increased capacity to assimilate vital resources may increase the plants tolerance to drought and other stress factors.

The conditions that favour the growth of Mycorrhizal fungi and plant associations are typically those that would be found to exist in natural or unmodified environments. Factors that will reduce the growth of mycorrhizae include increased soil bulk densities, low organic matter content, poor drainage, disturbed profiles, impervious surface coverings and reduced biodiversity.

[xvi] The release of chemicals from a plant that are detrimental to other nearby plants by inhibiting their growth, including its own progeny, to reduce competition, e.g. from Pinus spp., Casuarina spp., Cinnamomum camphora, Eucalyptus spp., etc.

[xvii] Mulches provide a range of benefits to trees including adding organic matter to the soil, adding minerals and nutrients, help to improve soil moisture retention, encourage beneficial soil micro-organisms, reduce soil compaction levels, buffer soil pH and help to suppress weeds. Mulches should be organic in origin, contain a mixture of coarse and fine particles and should be slightly aged. Mulches should be 75-100mm thick and applied out to the drip line of trees or further if possible. Mulches should be topped up every 1-2 years as required.