ARBORICULTURAL TREE
SERVICES PTY LTD

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Tree Risk Assessment Report

Prepared for;

Mrs. J. Brown

55 Tasman Rd
Avalon Beach
NSW 2107

October 2019

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1. Introduction

This Tree Risk Assessment has been requested by Mrs. Brown (Tree owners / guardian) who have requested my professional opinion on the condition and health of one *Eucalyptus robusta* (subject tree) located and growing within the western front property garden entrance of 55 Tasman Rd. Avalon. Beach. NSW 2107

2. Scope

This report is only concerned with;
Assessing the health and structural condition of 1 x *Eucalyptus robusta* tree.
The structural assessment and structural integrity from the subject tree upon any fixed property structure has not been undertaken as this is beyond the field of my expertise. Clearly visual botanical structural conflict damage was photographed, noted and detailed within this report.

This report follows the guidelines within the Northern Beaches Council - Pittwater 21 - Development Control Plan (Pittwater 21DCP 2015), Local Environmental Plan (2015).

3. Discussion

The following narrative serves as a brief discussion on tree risk assessments to inform on some of the considerations required within the context of this assessment.

Concepts of Tree Risk

3.1. Health versus Structure

A brief discussion on tree health and structure is warranted here. The individual components of a tree provide unique and integrated support to maintain a tree's system. Each component's structure and functions are complex in nature. Three roles of wood as one of these components is to provide a transportation system for water and nutrients throughout the tree, storage of starches for later use and a support system for the whole tree.
Sapwood, the outer circle of annual rings, is comprised of living tissue and primarily provides the transportation system and support. Heartwood, the interior annual rings of the tree, is comprised of dead tissue and provides the main support system for the tree.
As decay deteriorates the interior of the tree, its structural integrity is compromised. At the same time, the sapwood may still be fully functioning providing water and nutrients to the system. In essence, a tree can appear healthy yet be structurally unsound.

3.2. Defects Associated with the Trees

There are three issues of significance associated with the two trees in question.

a) Decay – Process of degradation of wood by microorganisms and fungus. (Australian Standard 2007, p. 6)
Decay, in the context of a tree, is a deterioration of wood fibre caused by decay organisms. The decay process is realized in stages, from early discoloration to cellular breakdown and eventual formation of a cavity.
A tree can exhibit all stages at the same time. Types of decay can be separated into those that undermine the cellulose, which reduces bending strength, or undermines the lignin, which reduces compressive strength. Any form of decay reduces a trees structural integrity. The presence of decay does not necessarily mean a tree has a high risk of failure. The extent of decay and additional contributing defects greatly affect risk determination.

b) **Strength Retention Formula** – The arboricultural profession has relied on a number of strength retention formulas to assist in determining the risk associated with decay. The most common formula in use was devised by Klaus Mattheck 'The Body Language of Trees' (Mattheck and Breloer, 1994) and is presented as t/r, where t is the thickness of sound wood and r is the radius of the part being measured. Commonly, a **figure of 30 to 35 percent** for full crown trees is considered a threshold for raising concerns about the integrity of the tree. Numbers below this threshold are an indicator of increasing risk.

These types of formulas have allowed the profession to better understand that decay can be present to a limited extent and structural integrity may be minimally compromised. They have also informed our understanding that a tree that can maintain a healthy cylinder of solid wood, without exceeding strength limits, could also be structurally stable. Complicating factors that certainly compromise this system are associated with the range of mechanical differences between species, irregular decay patterns and additional defects. Any strength loss formulas within this report are used as a guide only.

Note: Many trees have variable canopy and trunk loadings and are often not symmetrical and not 'Centralised'. Tree's often produce reaction strengthening wood to compensate for a weakness within its structure. All variable biotic and abiotic conditions have been taken into account in determining the likelihood of failure and Risk Rating as detailed within this report.

C) The most common forms of structural tree defects are:-
Wounds to the trunk and branches;
Damage to roots or disturbance of soil;
Decay within trunks, branches or roots;
Cracks, splits and bulges;
Excessive leans or branch end-weight.
Weak branch attachments and included bark (where the bark of two stems is caught between the two growing stems forming an inherently weak attachment);
Deadwood and hanging branches.

Cracks and Stress - Trees experience two forms of loading. Static loading is constant and is typically conveyed as the stress experienced by a tree from gravity. In other words, the tree must counter the effects of supporting itself while standing. External loading, such as wind, snow, etc. fluctuate over time and effect different parts of the tree at different times and intensities. Trees are adaptive structures that react to both stresses over time by developing reaction wood and adding girth.
Cracks are forms of structural failure. They occur when demands on the tree from stresses exceed the capacity to withstand the loading. Cracks are one of the key factors that compromise efforts by the tree to counter the effects of stresses. Trees require time, measured in years and decades, to react to both static and external stresses. Cracks disrupt this function by compromising the trees ability to respond quickly.

3.3. Assignment of Risk

Current concepts of risk centre on determining the likelihood of a tree part to fail (hazard) and the likelihood of the part then striking a target (risk). The likelihood of failure is determined by numerous variables and can include species, defects, reaction wood, environmental factors, loading, etc. The likelihood of striking a target is mainly determined by occupancy rates, direction of failure and protection factors. The final element of a tree risk assessment is determining consequences. Matrix 1, called the "Likelihood Matrix" provides a likelihood outcome (unlikely to very likely) based on combining the potential of a tree part failing and the potential of that same part then impacting a target.

Matrix 1 – Likelihood matrix (2013 ISA Tree Risk Assessment Manual).

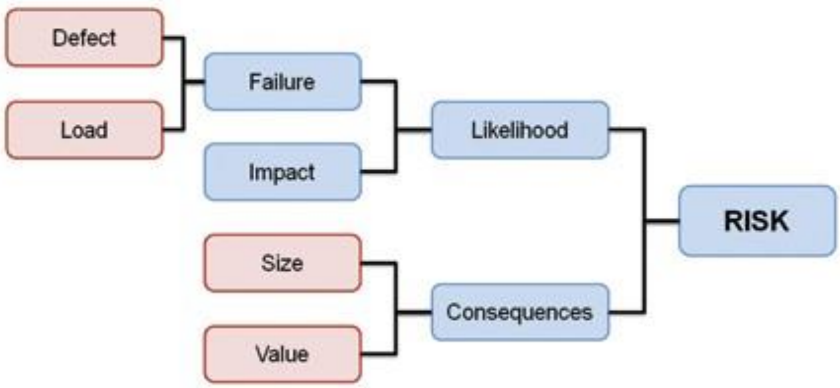
Likelihood of Failure (Tree part)	**Likelihood of Impacting Target**			
	Very Low	**Low**	**Medium**	**High**
Imminent	Unlikely	Somewhat likely	Likely	Very likely
Probable	Unlikely	Unlikely	Somewhat likely	Likely
Possible	Unlikely	Unlikely	Unlikely	Somewhat likely
Improbable	Unlikely	Unlikely	Unlikely	Unlikely

Matrix 2, called the "Risk Matrix" provides a risk outcome (low to extreme) based on combining the results from the likelihood matrix and the consequences if the likelihood of the event were to occur.

Matrix 2 – Risk rating matrix (2013 ISA Tree Risk Assessment Manual).

Likelihood of Failure and Impact	**Consequences**			
	Negligible	**Minor**	**Significant**	**Severe**
Very likely	Low	Moderate	High	Extreme
Likely	Low	Moderate	High	High
Somewhat likely	Low	Low	Moderate	Moderate
Unlikely	Low	Low	Low	Low

Flow Chart indicating categories used to determine risk.



4. Methodology

4.1 The method for Tree Risk Assessment used in this report is that which is outlined by the **International Society of Arboriculture (ISA) in their Best Management Practices – Tree Risk Assessment 2011.** This is a companion publication to the American Standard ANSI A300 Part 9: Tree, Shrub and Other Woody Plant Material management – Standard Practices (Tree Risk Assessment a. Tree Structure Assessment).

This method uses a matrix based, qualitative approach to risk assessment.
The assessment of the subject tree was based on a "Level 2" tree assessment;

Escalated to an advanced "level 3" scientific decay analysis assessment of the subject tree's structural 'bark included' co-dominant trunk stem(s) (SS) 0.8m agl.

A "level 2" assessment involves:-

A detailed visual inspection of the tree and its surrounding site and a synthesis of the information collected. The tree risk assessor walked completely around the tree looking at the buttress roots, trunk and branches.
Review of the trees condition using tools, where necessary, such as binoculars, hand lenses, a nylon sounding mallet, probes and a small shovel or trowel to expose root collars.

A review of the target area and the components of the tree most likely to fail.

4.2 Assessment of whether a "Level 3" or "advanced" assessment is warranted which may entail aerial, internal decay investigative techniques or tree root inspections would be based upon external visual inspection.

Recommendation of level 3 scientific decay investigation would be based upon visual inspection, probing of cavity and acoustic invariants produced from hitting parts of trunk / stem with sounding mallet upon sound and decayed wood / hollow.

Recommendation of a level 3 aerial inspection would be based upon a visual structural fault / decay cavity / poor attachment point visibly located up in the tree canopy but out of reach for inspection from ground level. Canopy areas with decay wounds, cavities or displaying pathogenic activity may also require scientific decay investigation.

Recommendation of a tree root inspection would be based upon visual condition of the tree root plate / exposed lateral tree roots at ground level.

The risk rating guides the arborist in determining the action to be taken and in prioritizing the pruning or removal of high risk trees. **In the assessment** and determination of trunk, structural stem (SS) and or order branch (OB) failure of the subject tree the **Mattheck and Breloer 'The Body Language of Trees' 1994 theories** for strength loss has been considered **and more importantly** interpretation of the subject tree's **actual visual body language** in determining the **likelihood of failure** of defective tree parts.

4.3 Landscape Significance & Retention Value

The methodology used in determining the subject tree's landscape significance has been assessed using;

Significance of a Tree, Assessment Rating System* (IACA 2010) – S.T.A.R.S. ©

Site aerial view and subject tree.

5. Data Collection

Visual tree assessment (VTA)[1] and scientific decay analysis was conducted from;

(i) 0.8m agl with use of Sonic PiCUS tomography (SoT), Electric Resistance Tomography (ERT) and wood confirmation resistance tests using an IML PD500 resi'. Other specific tree date was recorded on a digital notebook and photographs taken using a digital camera.

6. Documents Provided.

No documents were provided.

7. Site Visits

Site Visits: 11/9/2019
Time: 9.30am - 12.30pm
Weather condition: Fine
Present: Mr. Graham Brooks. Consulting Arborist.
Analysis Conducted: Visual tree assessment (VTA). Level 2 basic tree risk assessment. Escalated to advanced level 3 scientific decay analysis Sonic PiCUS Tomography (SoT), Electric Resistance Tomography (ERT) and confirmation resistance testing upon the subject tree's co-dominant 'bark included' Structural Stem 0.08m agl. Observations of botanical defects. Collection of data.

[1] VTA: Visual Tree Assessment. A systematic methodology identifying tree characteristics and hazard potential. Recognised by International Society of Arboriculture.

8. Condition & Assessment of the subject tree.

Photograph Set 1. Subject tree and previously recent failure of 1st order co-dominant structural stem.

Note: Failure of 1st order structural stem has resulted in an asymmetrical canopy with altered architecture and disruption of wind damping effects – Remaining two co-dominant structural stems are pre-disposed to failure.

Photograph 2. Subject tree – Displaying poor architecture.

Photograph 3. (c) Scientific Decay Sonic PiCUS tomogram (SoT) annotated into 'bark included' co-dominant structural stem.

Tree Inventory / Schedule & SULE Category

Tree No	Genus / Species	Common Name Origin	DBH 1.4m above ground level cm	D at Base (above buttress) cm	Height m	Spread m	Vigor	Cond -ition	Canopy Loading	ULE	Sig Rating S.TA.R.S	Recommendations / Comments
1	*Eucalyptus robusta*	Swamp mahogany Australia	TT 107	124	17	N12.4 S4.8 E8.4 W5.5	G	P	1OSS S= S IOSS N= N	R	Priority for Removal	**Removal of hazardous subject tree.** Compromised tree stability. Tree instability –'Bark included' decayed co-dominant attachment union. Active internal crack/s formation. Internal decay pathogens – including termites. **Targets**= Residential property, roadway, public foot path recreational areas and electrical cables. **Risk Rating = High** **Residual Risk Rating= High**

Tree Height: Height was estimated and recorded in meters. **Tree Trunk Diameter:** Tree trunk diameter at 1.4 meters above ground level was measured using a tape measure and recorded in meters. **Tree Canopy Spread:** Canopy spread was estimated and recorded in meters. **Vigor:** Good (G), Fair (F), Poor (P). **Condition:** Good (G), Fair (F), Poor (P) Safe **Useful Life Expectancy: ULE.** A pre- planning / Development tree assessment methodology developed by Jeremy Barrell. England 1996 SULE is an acronym for Safe Useful Life Expectancy, which refers to the length of time an arborist assesses an individual tree, can be retained with an acceptable level of risk based upon the information available at the time of inspection. SULE ratings are LONG (retainable for 40 years or more with an acceptable level of risk), Medium (retainable for 15 to 40 years), Short (retainable for 5 to 15 years) and Removal (trees which should be removed immediately due to imminent hazard or within the next five years).

At the time of assessment it was evident:
The subject tree grew dominantly within the landscape setting.
The subject tree was considered to provide medium wildlife habitat value. No active nest sites were visibly evident. The subject tree was found to be asymmetrical in form with poor architecture due to previously failed 1st order co-dominant structural stem eastern quadrant.

Visual vitality indicators were considered fair.
Condition was considered poor with multiple defective tree parts, decay indicators and visible pathogens. The canopy loading was; 1st OSS North = North, 1st OSS south = South.

Scientific decay analysis **identified an internal decaying 'bark included' cracked structurally compromised co-dominant union attachment 0.8m agl.**– Refer SoT & ERT below in section 9.

An open decay cavity was visibly identified upon the eastern attachment (previously failed) co-dominant 1st OSS – Visible columnar decay into lower basal 'bark included' co-dominant structural stem.

The crown density was at 50% compared to that idealized for the genus and species when in good condition, of normal vigor and architecture.

Evident botanical visual defects.

History of Failures;
Yes – Codominant 1st OSS western quadrant. Numerous 3-4th order branches mid to high canopy.

Recent pruning events consisted off;

- None

Historic pruning events consisted off;

- 2nd – 3rd order low canopy branches for pedestrian clearance.

Abiotic Impacts within Tree Protection Zone comprising; none.

Resonance soundings of structural stem agl indicated internal columnar decay.

Response growth development upon the subject tree;

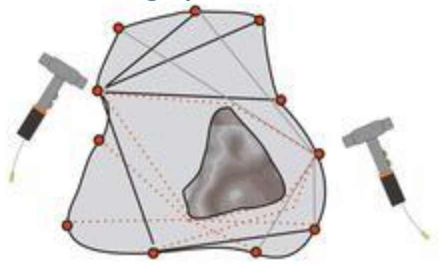
- Fair buttress root formation.

The target areas included; Residential property, recreational areas, motorist roadway / pedestrian footpaths and electrical cables.

No other botanical abnormalities were evident.

9. Picus Sonic Tomograph (SoT), Electric Resistance Tomograph (ERT) and Confirmation Resistance Testing.

Operational theory of the PiCUS Sonic Tomograph



The PiCUS Tomograph measures the velocity of sound waves in wood in order to detect decay and cavities in standing trees non-invasively. The acoustic velocity depends on the modulus of elasticity and the density of the wood itself. Most damage and disease causes fractures, cavities, or rot and reduces the wood's elasticity and density. The sketch displays the basic working principle, in that sound waves cannot take a direct path through the wood (red dotted line) if there is a cavity between the transmitter and receiver.

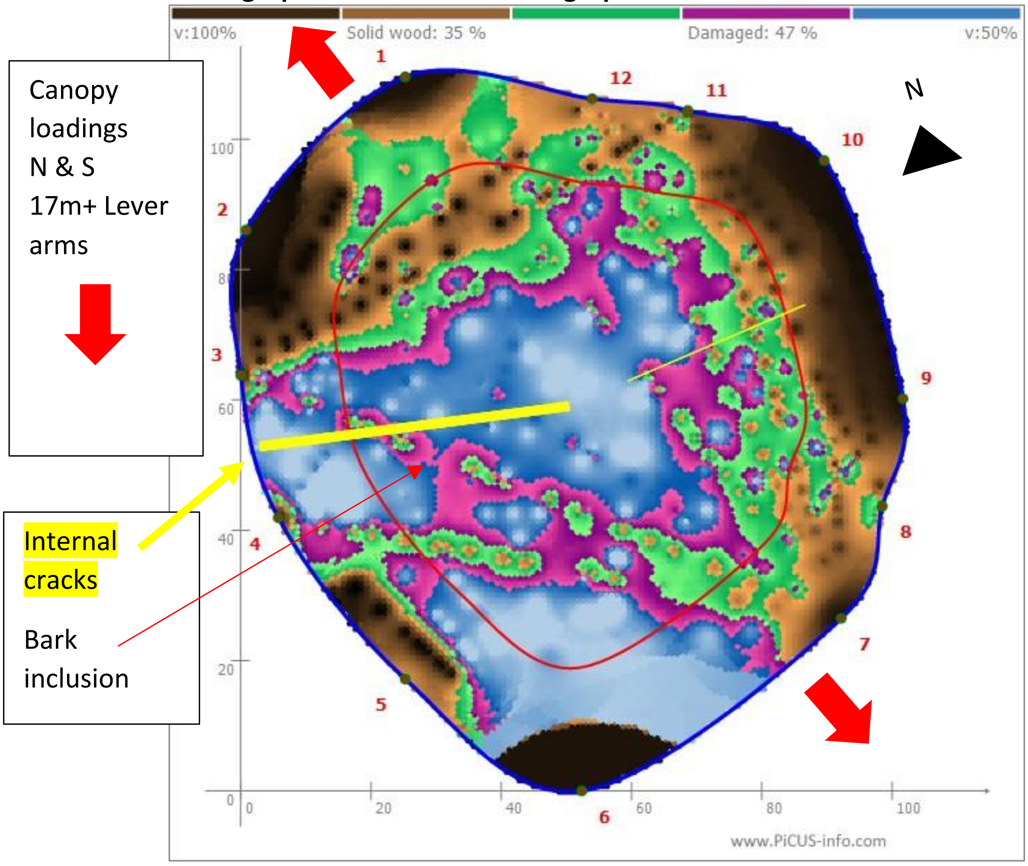
The acoustic waves are created manually with a little hammer, sonic sensors (receivers) record the signals. Little pins are used for coupling the sensors to the wood. Number and positions of the test points are critical to the accuracy of the scan.

By using both acoustic travel-time information and geometry data of the measuring level the software calculates tomograms that show the apparent sonic velocities, the so called sonic tomograms acoustic tomograms. The speed of sound in wood correlates with wood quality and is therefore a measure for the breaking safety of the trunk. The PiCUS sonic tomogram shows the residual wall thickness.

<u>Basal Defect 1 - Sonic PiCUS Tomograph (SoT) Test of Subject Tree</u>

A sonic PiCUS tomograph test was undertaken upon the subject tree's co-dominant 'bark included' 1st Order structural stem attachment union 0.8m agl

Photograph of PiCUS sonic tomograph test. Co-dominant structural basal stem 0.8m agl



To display different acoustic conductivity of wood, the PiCUS program uses set colours, assigning one colour to each point of the tomograph.

Areas of high velocity are represented in **black** or dark brown. **(Sound wood)**

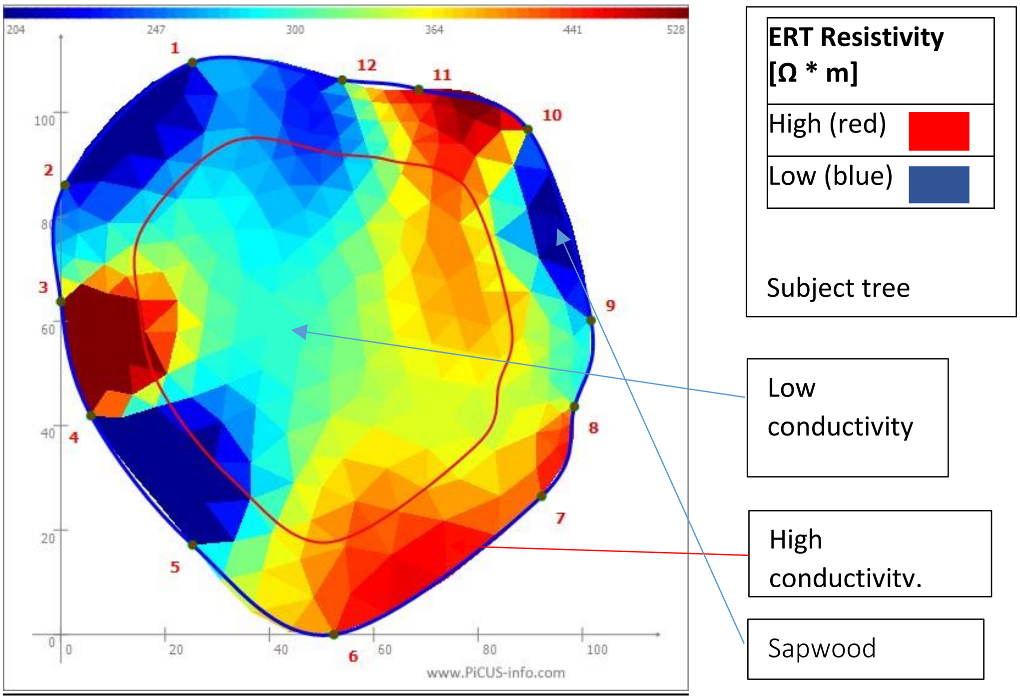
Areas of low velocity appear in **violet**, **white or** blue, and these are the areas that indicate problems. Those colours do not mean that there is a cavity, it just mean that the acoustic waves travel slowest in that area.

Green areas mark those sections which could not be classified as being either fast or slow, and these areas must be interpreted together with the overall damage.

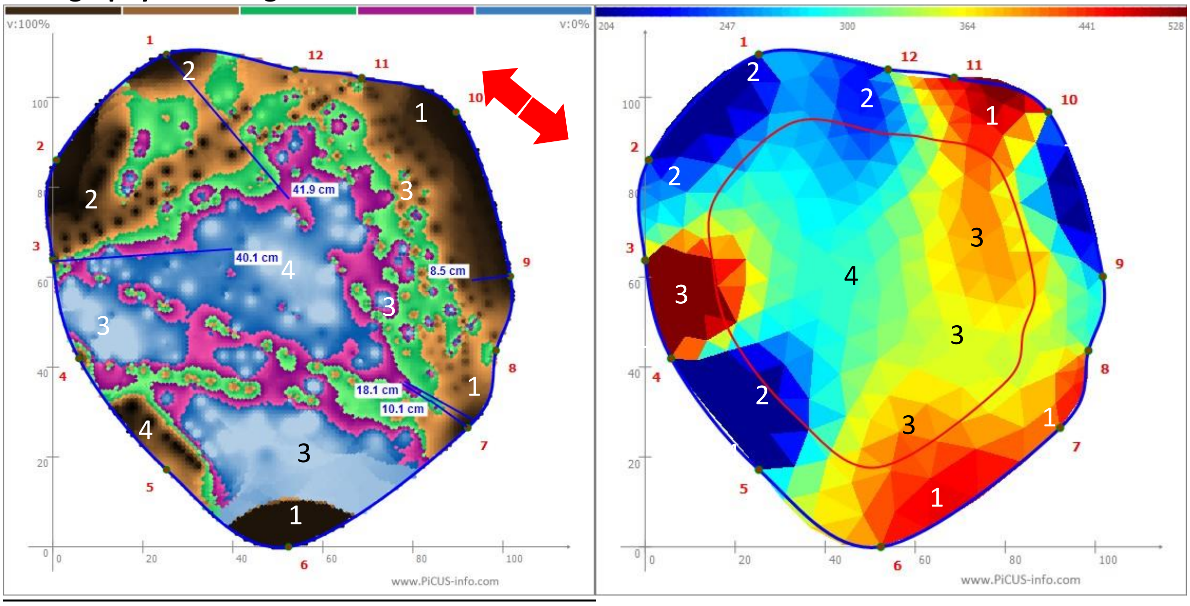
The colour scale (**black**, brown, **green**, **violet**, **blue**, **white**) ranges from 100% velocity (**brown**) to the slowest velocity (**blue**).

<u>Electric Resistance Tomograph Test of the Subject Tree</u>

Photograph **of PiCUS electric resistance tomograph test taken at 0.8m agl basal SS.**



Combined analysis of SoT and ERT with Confirmation wood resistance tests annotated into SoT tomography – 0.8m agl.



Defect 1 - ERT type 1 Decision Table

SoT – Sonic Velocity [m/s]	ERT Resistivity [Ω * m]	Wood status	# in Tomogram
High (brown)	High (red)	Sound wood	(1)
High (brown)	Low (blue)	Still safe, but early decay	(2)
Low (blue/purple)	High (red)	Cavity / crack / dead decay	(3)
Low (blue/purple)	Low (blue)	Decay	(4)

Interpretation.

Evident large volume of decay (3, 4) with increasing incipient wood (2) within shell wall.
Minor anomaly of SoT data at MP3 with greater sound wood volume. **Causation;** Internal cracks.
Evident decay within location of 'included bark union'.

Likelihood of failure Co-dominate structural stem 0.8m agl = **Probable**
(ISA Likelihood matrix 1)

10. Risk Rating

Risk Rating
Matrix 1 – Likelihood matrix (2013 ISA Tree Risk Assessment Manual).

Predominant Tree Hazard Part. Co-dominant 'Bark included' Structural Stem(s)

Likelihood of Failure	**Likelihood of Impacting Target**			
	Very Low	**Low**	**Medium**	**High**
Imminent	Unlikely	Somewhat likely	Likely	Very likely
Probable	Unlikely	Unlikely	Somewhat likely	Likely
Possible	Unlikely	Unlikely	Unlikely	Somewhat likely
Improbable	Unlikely	Unlikely	Unlikely	Unlikely

Matrix 2 – Risk Rating Matrix. (2013 ISA Tree Risk Assessment Manual).

Likelihood of Failure and Impact	**Consequences**			
	Negligible	**Minor**	**Significant**	**Severe**
Very likely	Low	Moderate	High	Extreme
Likely	Low	Moderate	High	**High**
Somewhat likely	Low	Low	Moderate	Moderate
Unlikely	Low	Low	Low	Low

Residual Risk Rating.

Likelihood of Failure and Impact	**Consequences**			
	Negligible	**Minor**	**Significant**	**Severe**
Very likely	Low	Moderate	High	Extreme
Likely	Low	Moderate	High	**High**
Somewhat likely	Low	Low	Moderate	Moderate
Unlikely	Low	Low	Low	Low

Categorised Residual Risk Rating Subject Tree = HIGH RISK

11. Recommendations.

The subject tree has been categorised under the IACA Tree Retention Value (S.T.A.R.S) as ‘Priority for Removal’. The categorised residual risk rating was **HIGH.**

Arboricultural management.

- Removal of HIGH RISK TREE
- Replacement planting with 1 x 100ltr Angophora costata

Yours faithfully,

Arboricultural Tree Services Pty Ltd

Graham Brooks dip arb

Managing director. Arboriculture Australia Consulting Arborist No: 1983

ISA TRAQ Certified Arborist 2014-2019

Member of ISA & Arb’ Australia.

ISA Mem No: 173140

Appendix 1 – Significance of a Tree, Assessment Rating System* (IACA 2010) – S.T.A.R.S. ©

The landscape significance of a tree is an essential criterion to establish the importance that a particular tree may have on a site. However, rating the significance of a tree becomes subjective and difficult to ascertain in a consistent and repetitive fashion due to assessor bias. It is therefore necessary to have a rating system utilising structured qualitative criteria to assist in determining the retention value for a tree. To assist this process all definitions for terms used in the *Tree Significance - Assessment Criteria* and *Tree Retention Value - Priority Matrix*, are taken from the IACA Dictionary for Managing Trees in Urban Environments 2009.

This rating system will assist in the planning processes for proposed works, above and below ground where trees are to be retained on or adjacent a development site. The system uses a scale of *High*, *Medium* and *Low* significance in the landscape. Once the landscape significance of an individual tree has been defined, the retention value can be determined. An example of its use in an Arboricultural report is shown as Appendix A.

Tree Significance - Assessment Criteria

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High Significance in landscape

- The tree is in *Good condition* and *Good vigor*;
- The tree has a form typical for the species;
- The tree is a remnant or is a planted locally indigenous specimen and/or is rare or uncommon in the local area or of botanical interest or of substantial age;
- The tree is listed as a Heritage Item, Threatened Species or part of an Endangered ecological community or listed on Councils significant Tree Register;
- The tree is visually prominent and visible from a considerable distance when viewed from most directions within the landscape due to its size and scale and makes a positive contribution to the local amenity;
- The tree supports social and cultural sentiments or spiritual associations, reflected by the broader population or community group or has commemorative values;
- The tree's growth is unrestricted by above and below ground influences, supporting its ability to reach dimensions typical for the taxa *in situ* - tree is appropriate to the site conditions.

Medium Significance in landscape

- The tree is in *Fair-Good condition* and *Good* or *Low vigor;*
- The tree has form typical or atypical of the species;
- The tree is a planted locally indigenous or a common species with its taxa commonly planted in the local area
- The tree is visible from surrounding properties, although not visually prominent as partially obstructed by other vegetation or buildings when viewed from the street,
- The tree provides a fair contribution to the visual character and amenity of the local area,
- The tree's growth is moderately restricted by above or below ground influences, reducing its ability to reach dimensions typical for the taxa *in situ*.

- Low Significance in landscape

- The tree is in fair-poor condition and good or low vigor;
- The tree has form atypical of the species;
- The tree is not visible or is partly visible from surrounding properties as obstructed by other vegetation or buildings,
- The tree provides a minor contribution or has a negative impact on the visual character and amenity of the local area,
- The tree is a young specimen which may or may not have reached dimension to be protected by local Tree Preservation orders or similar protection mechanisms and can easily be replaced with a suitable specimen,
- The tree's growth is severely restricted by above or below ground influences, unlikely to reach dimensions typical for the taxa *in situ* - tree is inappropriate to the site conditions,
- The tree is listed as exempt under the provisions of the local Council Tree Preservation Order or similar protection mechanisms,
- The tree has a wound or defect that has potential to become structurally unsound.

Environmental Pest / Noxious Weed Species

- The tree is an Environmental Pest Species due to its invasiveness or poisonous/ allergenic properties,
- The tree is a declared noxious weed by legislation.

Hazardous/Irreversible Decline

- The tree is structurally unsound and/or unstable and is considered potentially dangerous,
- The tree is dead, or is in irreversible decline, or has the potential to fail or collapse in full or part in the immediate to short term.

The tree is to have a minimum of three (3) criteria in a category to be classified in that group.

Note: The assessment criteria are for individual trees only, however, can be applied to a monocultural stand in its entirety e.g. hedge.

Institute of Australian Consulting Arboriculturists (IACA 2010), *IACA Significance of a Tree, Assessment Rating System (STARS)*, www.iaca.org.au

In the development of this document IACA acknowledges the contribution and original concept of the Footprint Green Tree Significance & Retention Value Matrix, developed by Footprint Green Pty Ltd in June 2001

Tree Retention Value - Priority Matrix

	Significance in Landscape				
Estimated Life			Low	Environmental Pest / Noxious Weed Species	Hazardous / Irreversible Decline
Long >40 years	Priority for		Consider for	Consider for	Priority for
Medium 15-40 years					
Short <1-15 years					
Dead					

Legend for Matrix Assessment	
Priority for Retention	These trees are considered important for retention and should be retained and protected. Design modification or re-location of building/s should be considered to accommodate the setbacks as prescribed by the Australian Standard AS4970 *Protection of trees on development sites*. Tree sensitive construction measures should be implemented if works are to proceed within the Tree Protection Zone (e.g. use of pier and beam footings).
Consider for Retention	These trees may be retained and protected. These are considered less critical; however their retention should remain a priority with removal considered only if adversely affecting the proposed works and other alternatives have been considered and exhausted.
Consider for Removal	These trees are not considered important for retention, nor require special works or design
Priority for Removal	These trees are considered hazardous

*IACA 2010, *IACA Significance of a Tree, Assessment Rating System (STARS)*, Institute of Australian Consulting Arboriculturists,

www.iaca.org.au

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Appendix 2

Resistograph Terminology and Interpretation

IML Resistograph Testing Standard, Procedures & Audit
IML Australia © 2013

Safe Work method Statement: Attached.

PPE – Personal protection equipment:
(as per attached safe Work Method Statement)
- Ear protection
- Approved safety footwear
- Safety glasses/visors
- Reflective jacket/clothing

Pre Resi Test Checks:
- Ensure batteries are fully charged
- Enter correct ID number on Resi
- Enter the right Feed Speed for the particular species (if unsure, always start with a lower speed – 1 or 2)

– ideal is close to 40% amplitude
- Check and record Cardinal Direction
- Measure and record the height of Measurement
- Ensure needle exit is clean and free of sap etc.
- Ensure a steady and comfortable Position
- Check correct feed speed and RPM for the job

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Resistograph Methodology: IML PD-400
The Resistograph inserts a 1.4 mm needle (drill bit) into the tree to measure the resistant's of wood. The measurement is then transferred electronically to a graph that clearly shows various stages of decay, as well as white rot, brown rot, termites etc.

The more resistance in the tested area, the higher is the amplitude in the graph and therefore shows sound wood.
If the amplitude drops below a certain level (in reference to good wood) then an experienced operator can determine the extent and stages of decay.
The "***decay analysing software***" helps to show the sound wood and decay clearly by the red and green markings. This ensures easy to understand reports.

This method does NOT harm the tree! (*C. Mattheck*)

Resi Testing Procedure:
Ensure all operation is carried out in accordance with the relevant Safe Work Method Statement

The Resi tests should be conducted on the most likely area where decay or defect is suspected.

Therefore, a VTA (Visual Tree Assessment) is imperative before commencing any testing.
The operator is looking for general health, wounds, swelling, included bark, fungi and any other obvious or less obvious signs.
- After pressing the Red Start Button at the rear of the Resi it is imperative to maintain weight and pressure during the entire drilling procedure
- It is recommended not to exceed more than 6 cm of hollow to prevent needle deviation (better to measure the amount of sound wood)
- After needle retraction check Needle Check and ensure that the measurement was stored correctly (Resi will indicate this)
- Write down comments and observations on this particular test drill in reference to the ID number
- Conduct as many or few measurements necessary to form an informed opinion on the inside state of the particular tree
- After conclusive testing, ensure the Resi is being carefully laid back into the padded hard case
- Ensure drilling needle is always clean and sharp

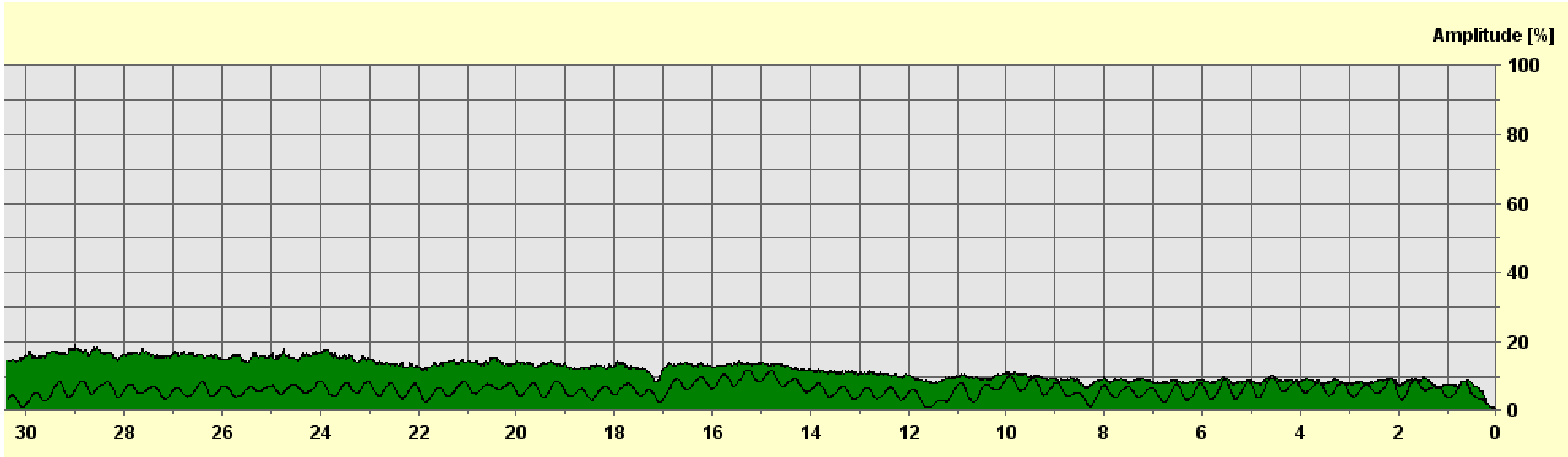
Conduct as many of few Resi test's necessary to give the operator a clear understanding of the inside state of the tree. – There is no direct rule as to how many test's should be undertaken on a tree. Four test's (one on each cardinal direction) on the same level provides a reasonable "picture".

3/6

Resi PD Speed:

There are 5 feed speed and various needle speed settings available.
- For hard and tropical wood a needle speed of 5000 RPM is recommended
- The harder the wood, the higher the RPM and the lower the feed speed!
- Try to achieve an average drill graph amplitude of around 40 to 60%

Feed Speed # 1 @ 25 cm per minute
Feed Speed # 5 @ 250 cm per minute
Tip: Use 5000 RPM for wood with excessive sap.



Feed Speed # 1 @ 25 cm per minute
Tip: Use 5000 RPM for wood with excessive sap.
Direction:
The software asks for cardinal direction: drilling towards
Example: Drilling direction: North – then the operator drills on the southern trunk.

4/6

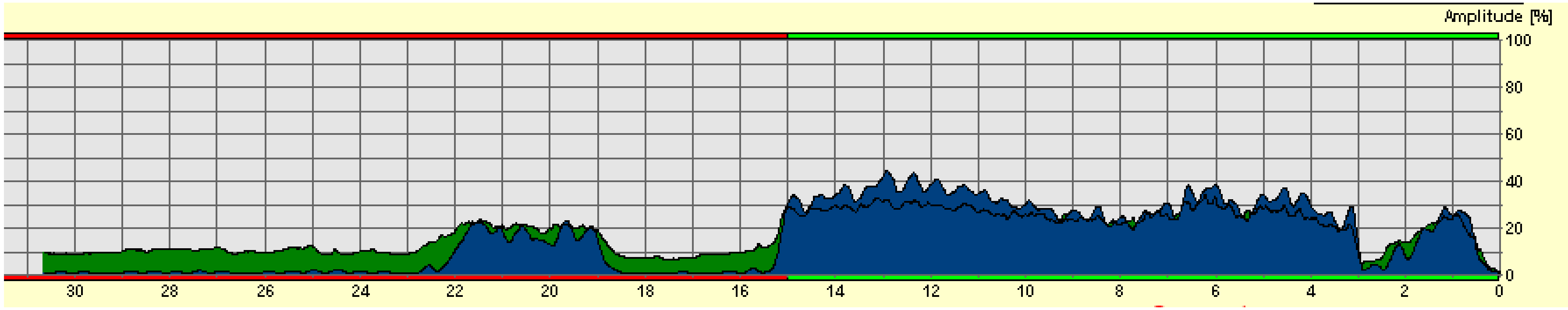
Test & Graph interpretation:
As the Resistograph delivers a “relative” measurement, the results are shown in a graph. Basically the higher the amplitude of the graph, the more resistance, therefore the more sound. A low amplitude in the graph or a sudden fall in amplitude indicates decay or hollow. The spikes visible in a sound wood graph indicate growth rings (depending on species – i.e. pine species show distinct growth rings)

Amplitude of Graph:
Amplitude is shown in percentage and divided into 10 sections each section representing 10 %

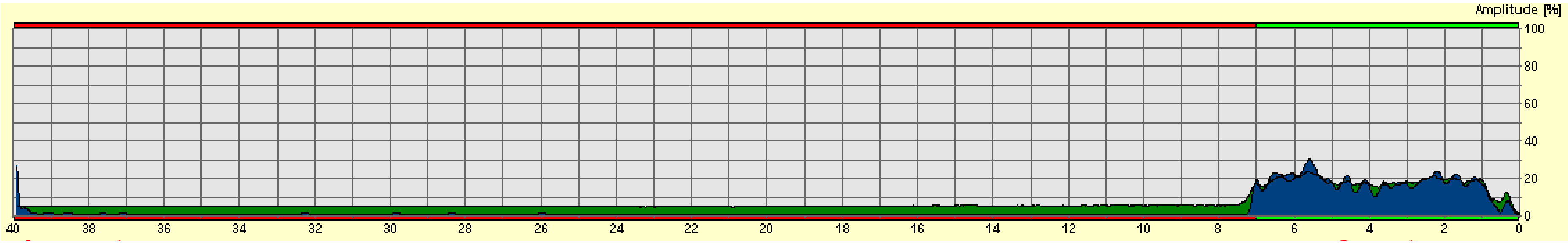
Various stages of decay and incipient wood (changing wood)
The test can show various stages of decay and incipient wood (changing wood) depending on the position, speed and amplitude of the test graph.
- Graph amplitude below 10 % usually indicates significant decay (very soft) or hollow
- Graph amplitude between 10% and 20% could mean incipient (changing wood) – no structural strength!

This is on the assumption that the average amplitude of the reference test drill is between 40% and 55%

This test graph example shows a sound Silky Oak (*Grevillia robusta*)
Average amplitude around 40%



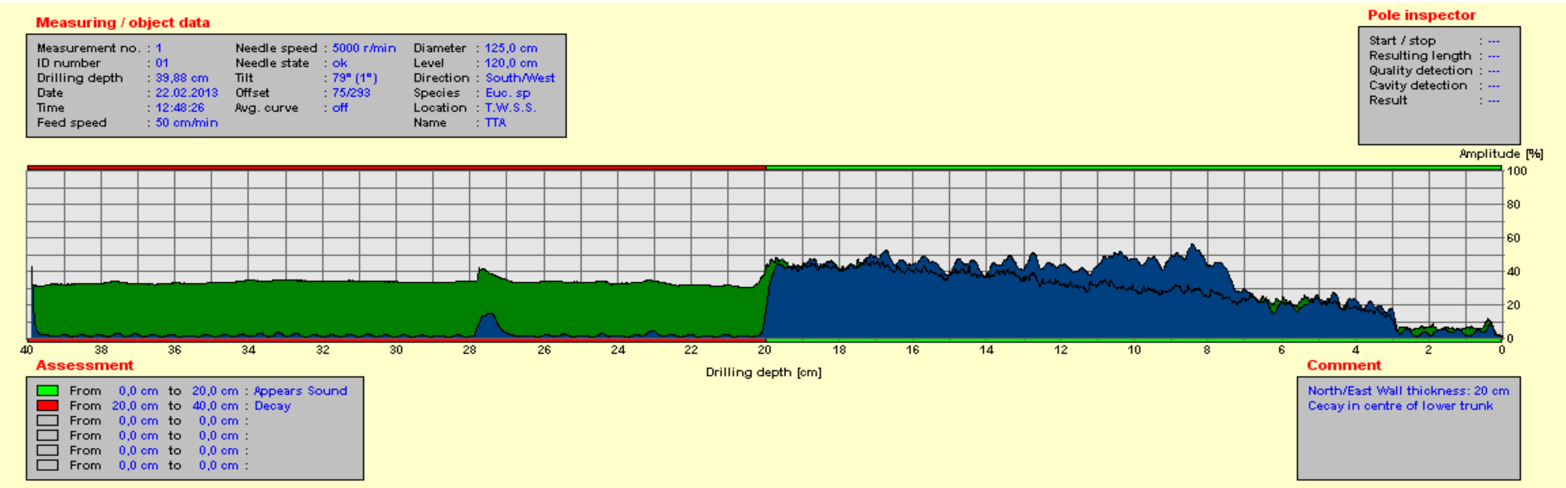
This test graph example shows decay in a pine species from 15 cm and “free floating wood” at 19 to 22 cm. Please note: “Free Floating” wood is not structurally sound!



This test graph example shows significant decay leaving 7 cm wall thickness

Reference Test Drill:
To confirm unclear graph and test measurement to the operator, a "reference test" is recommended.
The reference test is conducted on the likeliest sound areas of the tree. i.e. sound buttress or muscle on tension side of the tree.

Feed Curve vs. Drilling Curve (PD- Series & Feed Module only)
The high Amplitude in the graph showing "Shaft Friction" can be often mistaken for sound wood. The amplitude continues to increase in the graph due to shaft friction on the needle. Therefore decay is often only a slight drop in amplitude.



This graph example indicates decay from 20 cm onwards (blue = feed curve – green = drill curve)
For further reference we recommend: Basic Decay Detection Manual ISBN 0-646-46859-6 by P.Blank –
or contact: imlaustralia@bigpond.com

6/6

Tree management program according to test results and findings:
If no decay is found on the most likely area and the operator is satisfied with the testing a normal "monitor" program would prevail.

Various stages and size of Decay or Hollow:
- Large area of total decay or hollow (amplitude well below 10%) – Immediate action, depending on target area and species!

- Medium size are of total decay or hollow (amplitude well below 10%) – Discretionary action, depending on target area and species!

- Large area of incipient wood (classed as decay due to no structural strength) – Discretionary action, depending on target area and species!

- The recommended action undertaken by the relevant authority or individual on any smaller percentage in size and decay stages is again discretionary depending on target area and species.

Example: A 30% decayed main trunk of a known structural unsound species situated in a children's playground is obviously of higher priority then a 50% decayed tree in a field with little or no traffic/targets.

Appropriate action in reference to the findings is mostly up to the individual laws and guidelines.
Removal, weight & crown reduction, limb removal or monitor.
Watch the **Reaction zone!**

If there is a definite spike, this means that the tree is creating a barrier and the tree is doing something about it to prevent further decay infestation.

If it is only a gradual graph drop and no definite reaction (barrier) zone then this shows the different stages of decay and the tree is not able to compartmentalise.
Therefore it is advisable to test again in 12 month time to quantify the extend and speed of possible spreading decay.

6/6

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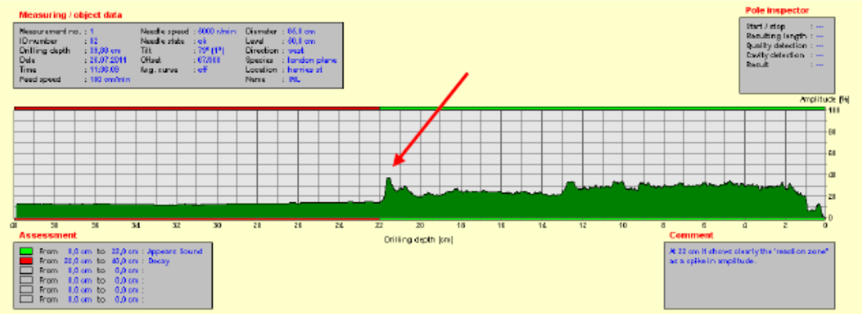


This graph example shows clearly the reaction (barrier) zone before the decay zone at 21.5 cm manifested as a spike in amplitude.

Appendix 3

PiCUS Tree Tomography Methods at a Glance

1. Overview

Currently there are two tomographic methods available for trees: Sonic Tomography (SoT) and Electric Resistance Tomography (ERT). Both methods use different physical ideas and thus, do show different information of the tree. SoT gives information about the integrity of the mechanical structure of the wood while ERT shows – so to say – “chemical” information.

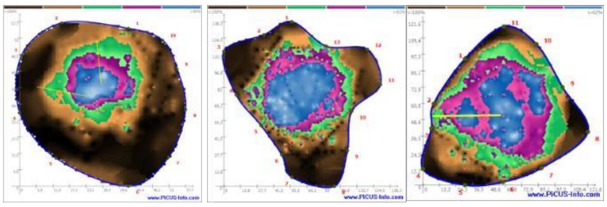
Both methods do have advantages and limitations. SoT for instance suffers from cracks in the tree that do interfere with the acoustic waves sent through the trunk.

Combining both SoT and ERT method we can overcome those limits and derive more and better conclusions about the tree. In particular it is possible to:

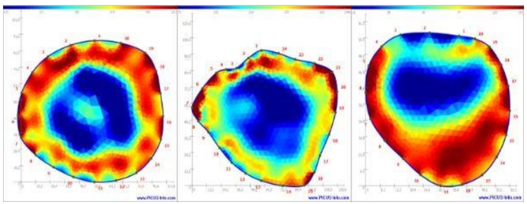
- Finding out about the **type of a defect**: what are we looking at in the tomogram: is it a hollow, or decay or just a crack?
- What **stage of decay** is in the tree: incipient or advanced or old?

 Measuring the **size of the defect more precisely**. Detect **decay below ground level**
 Avoid wrong conclusions!

This document briefly describes how SoT and ERT work on trees and how the results can be understood.



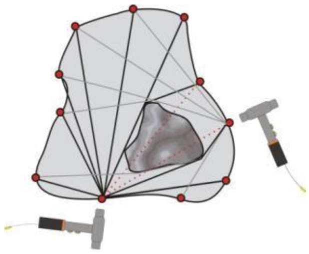
Sonic Tomograms

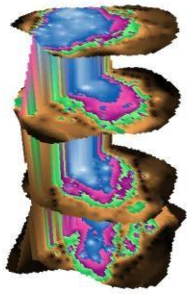


Electric Resistance Tomograms

2. Sonic Tomography (SoT)

Sonic Tomographs are instruments that detect decay and cavities in standing trees noninvasively. The instruments measure the velocity of sound waves in wood. The acoustic velocity depends on the modulus of elasticity and the density of the wood itself. Most damage and disease causes fractures, cavities, or rot and reduces the wood's elasticity and density.

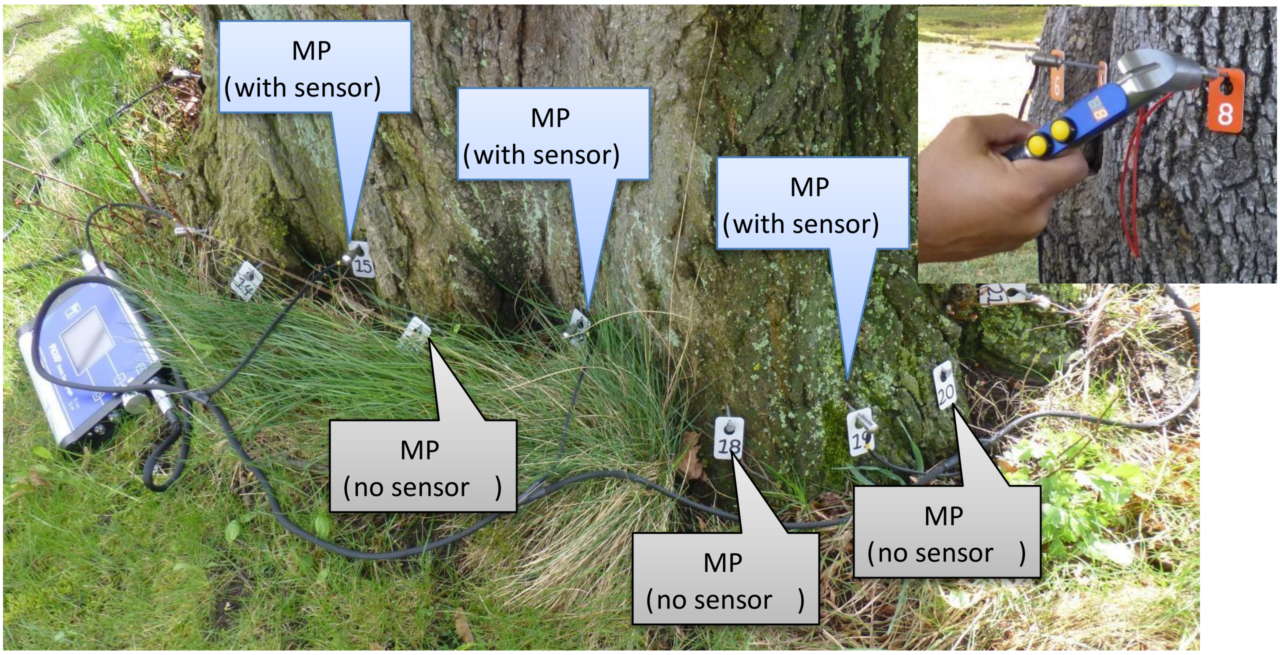




The sketch displays the basic working principle, in that sound waves cannot take a direct path through the wood (red dotted line) if there is a cavity between the transmitter and receiver.

The acoustic waves are created manually with a little hammer, sonic sensors (receivers) record the signals. Little pins are used for coupling the sensors to the wood. Number and positions of the test points are critical to the accuracy of the scan.

The PiCUS technology differentiates between sensors and measuring points (MP). A MP is a simple nail. For a PiCUS scan a virtually unlimited number of measuring points (nails) can be used because of that technology. The photo below shows a setup of 12 sensors on 24 MP. The electronic hammer can create sonic signals on all 24 MP!



PiCUS 3 on a *tilia cordata* tree

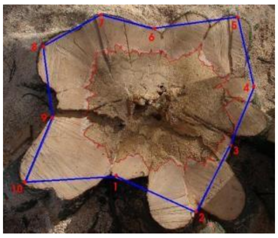
2.1. How to record a sonic tomogram

Taking sonic measurements involves four basic steps:

1. Determine the level, number and positions of measuring points

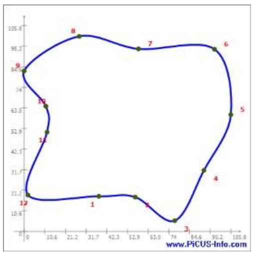
Care must be taken when selecting the level of tomography and the locations of the measuring points (MP). Inappropriate MP locations may lead to inaccurate tomograms.

2. Measure the geometry of the tree at the level you are working at



Cross section of a tree and electronic calipers to program

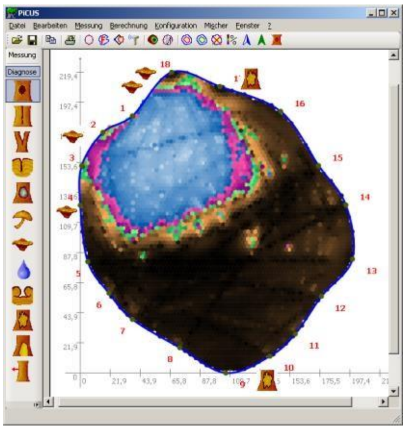
Using Triangulation method that measurement in PC



Graphic representation of measure positions of all MP

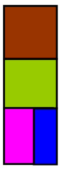
3. Take the sonic measurements

Each measuring point (nail) is tapped with the electronic hammer in order to create sonic waves.



4. Calculate the tomogram, Interpretation

The tomograph main unit itself or the PC calculates the sonic tomogram when all readings have been taken. The tomogram shows the relative and apparent ability of the wood to transmit acoustic waves. Different colours display the various properties of the wood:



Areas of good wood, where the fastest velocities can be found, are represented in (dark) browns. The meaning of green varies according to the defect. It often describes the distance between healthy and damaged wood, but can also indicate early fungus infection. Violets and blues represent damaged areas.

2.2. Advantages of the PiCUS Tomograph

 Extremely **quick tapping**

- **Less cables**: sensors are assembled to a sensor-cable-harness **Unlimited number of measuring points**: 10, ... 15, … 20, … 50
- **Sensors are small** land light-weight: pins are not deep in the wood. Pin diameter < 3 mm!
- **No special pins needed**, regular nails from hardware store work well. No extra after-sales costs!!!
- New **compact system design**: just one main control unit, no extra sensor-supply boxes

- **Low weight** of the tomograph, approx. 4 kg only! All gear fits into a small shoulder bag if needed. Ruggedized transportation case is supplied.
- **NO PC** needed in the field. Can operate the entire tomography scan with or without PC
- Preview sonic tomogram shown on screen on-site
- **Three-point-measurements** (no PC needed) to quick-test the tree to help to decide whether a full tomogram is needed
- Main control unit saves scans on non-volatile memory.

 Inbuilt GPS

- Inbuilt semi-automatic **tree height measurement**
- **Precise and fast geometry** of any tree using triangulation functions and PiCUS caliper

Left: Tomography in rain – the operator needs to be protected. The sensors? Not so much.
Middle: Tomography in the tropics in Panama. Right:
Ruggedized transportation case.

3. Electric Resistance Tomography (ERT)

Electrical Resistance Tomographs using electric current/voltage to examine the tree. The resulting measurements are displayed in a two-dimensional map showing the apparent electrical resistance of the wood, called an *Electrical Resistance Tomogram* (ERT).

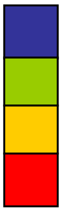
The electric resistance of the wood is influenced most of all by the

- water content
- chemical elements which change according to the status of wood and
- cell structure: reaction wood or roots do have different resistances compared to "normal wood"

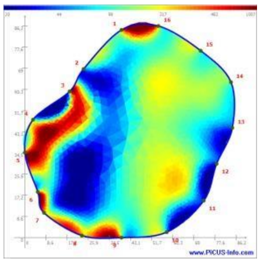
When used in **combination with a Sonic Tomograph**, an ERT offers you more information about the tree:

- distinguish between different types of damage (for instance crack/cavity vs. decay) in many cases
- detect early stages of decay
- get information about areas above or below the measuring level. This is interesting for analysing root decay problems.

In order to analyse an ERT, the operator will need knowledge about the specific type of tree species. **Each species has its own typical resistance** (water/moisture) **distribution**. The ERT are coded with rainbow colours:

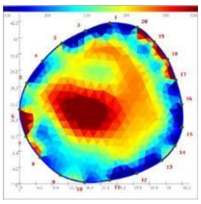


Blues indicate areas of low resistance (high water content, etc.)
Greens and yellows show increasing resistance
Red colours indicate areas of high resistance (lower water content, etc.)

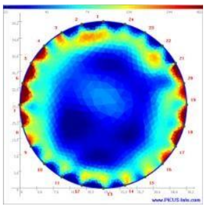


How to read resistance tomograms

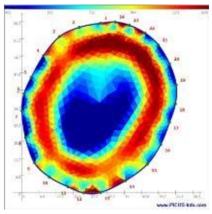
The main aspect of interpreting ERTs is the distribution of high and low conductive areas. You are looking to see where high resistance is and where low resistance is. This information needs to be compared with the normal resistance distribution in sound trees of this particular species. The interpretation of the ERT is most accurate when done in combination with the SoT. So far we have identified **three types of typical resistivity distributions** in trees.



ERT type 1



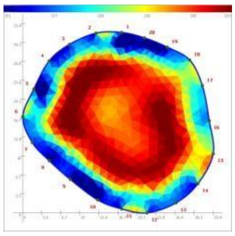
ERT Type 2



ERT Type 3

The table below shows general rules of interpretation for *ERT Type 1* trees. *ERT Type 1* trees usually have lower resistance (blue in ERT) in the sapwood on the edge and high resistance in the heartwood (red in ERT) in the centre:

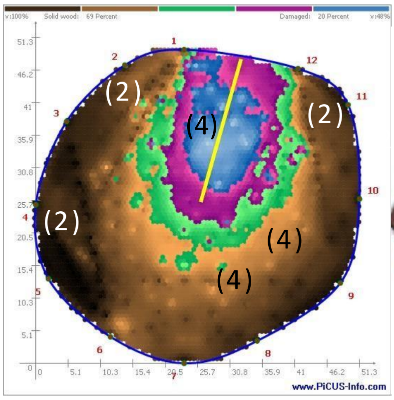
The table helps to evaluate the **centre** of the tree

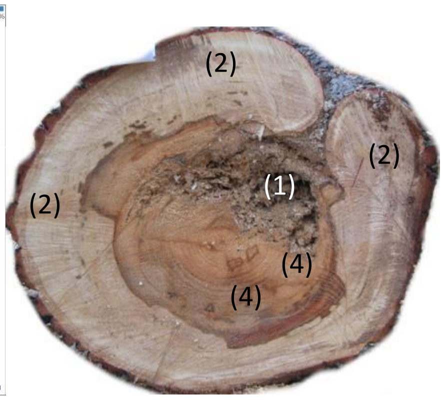


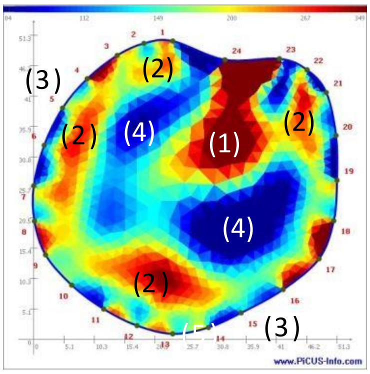
SoT **Sonic velocity [m/s]**	ERT **Resistivity [Ω*m]**	**Conclusion**
High (brown)	High (red)	Healthy
High (brown)	Low (blue)	Still safe, but early decay
Low (blue/violet)	High (red)	Cavity / dead decay
Low (blue/violet)	Low (blue)	Active decay

3.1. Example 1: Different stages of decay

The example shows a Linden tree with decay and cavity. Linden trees belong to ERT type 1. Areas shown in brown colours show high sonic velocity (= sound wood), areas in blue/purple show decay or the cavity.







(3)

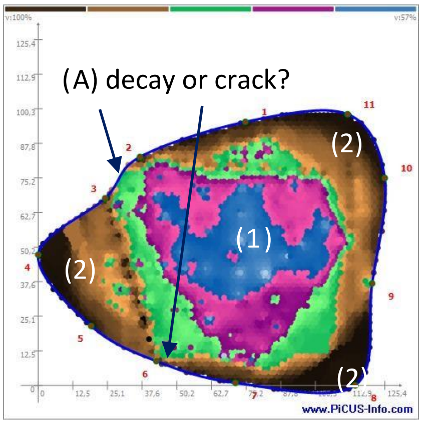
Sonic Tomogram (SoT) Photo of cross section Electric resistance tomogram

(1) Low V*) and high R*): Cavity, or dead dry wood
(2) High V and medium R: sound wood
(3) Low R at the very edge: normal sapwood.
(4) Medium V and Low R: active decay but wood is still relatively dense

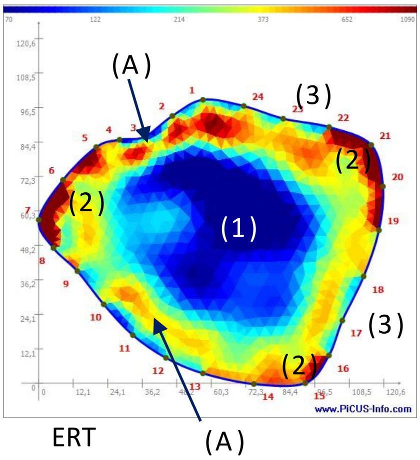
*) V = velocity, R = Resistance

3.2. Example 2: decay or crack?

The example shows a *castanea sativa* in Rostock. The SoT seems to show that the left part of the tree is separated from the right part. What is the reason for the separation – decay breaking through or just a bark inclusion (crack) at positions (A)?



SoT



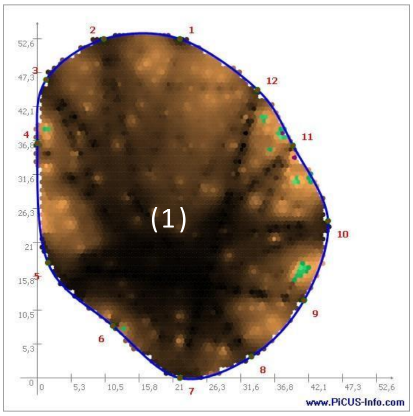
ERT

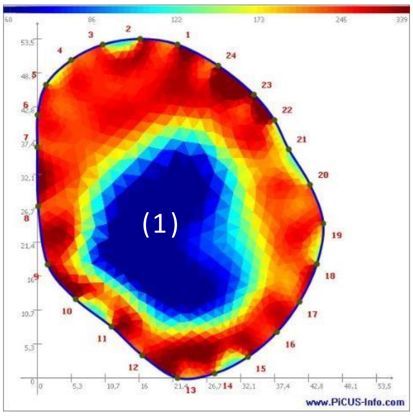
(1) Low V*) and low R*): advanced wet
(2) High V and high R: sound wood
(3) Low R at the very edge: normal sapwood.

The wood near (A) does not transmit acoustic waves well. But the material has a high R.
Thus, there is no decay! It is a “regular” bark inclusion!
The ERT shows the size of the defect more precisely than the SoT due to the bark inclusions. All red/yellow area will be good material! The defect is a little smaller than the SoT shows.

3.3. Example 3: incipient decay

The SoT of the linden tree in this example does not show a problem. However, the electric resistance of the wood is already changed due to incipient decay like the ERT proves.





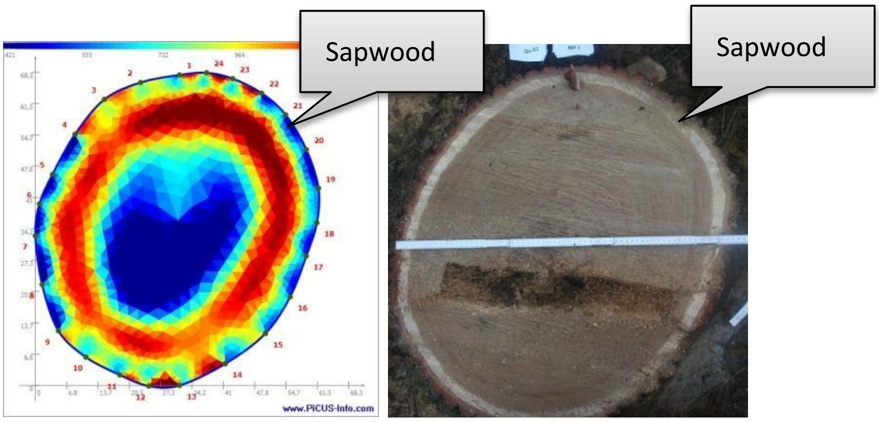
SoT ERT

(1) High V*) and low R*): still good sonic propagation but wet! Incipient decay.

*) V = velocity, R = Resistance

3.4. Example 4: Detecting hardwood/sapwood using ERT

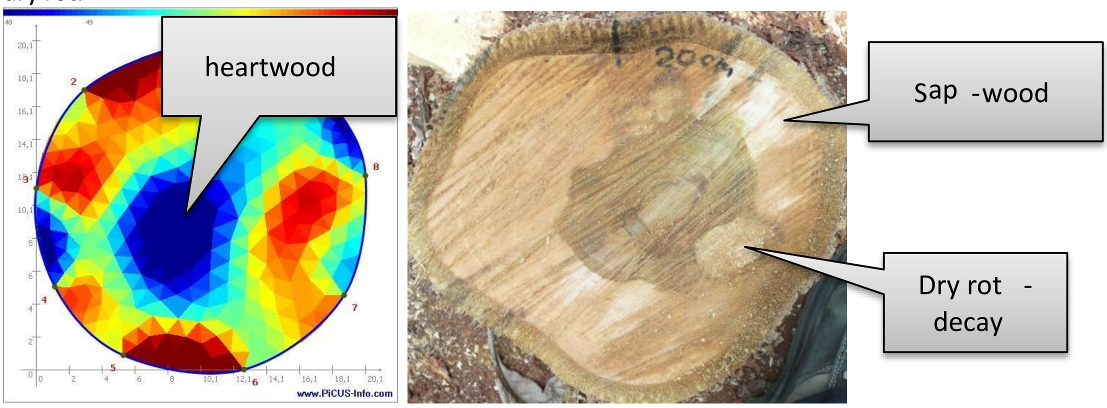
Some tree species develop a distinct sapwood area. If the resistance of the sapwood is different from the rest of the tree then the ERT can measure the thickness of that layer. The example shows an oak (*quercus robur*).



ERT (120 cm above ground) S tump (20 cm)

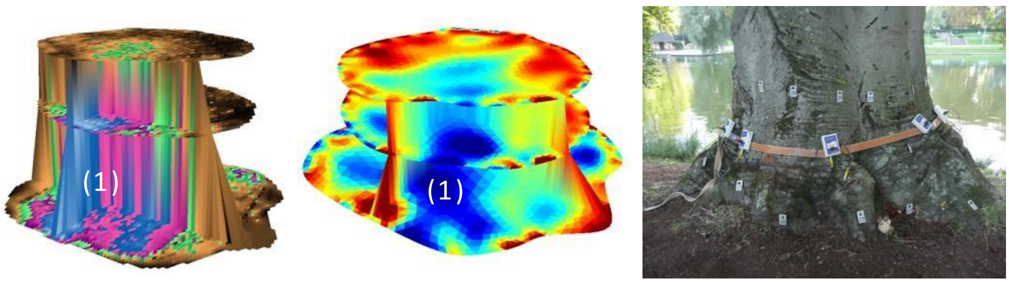
3.5. Example 5: Detecting hardwood/sapwood in teak (tektona grandis)

Teak wood develops a distinct heartwood, which is the most valuable part of the wood. The electric resistance of that heartwood is apparently low. The example shows a teak tree in Mexico that is developing a dangerous dry rot.



4. 3D Scans

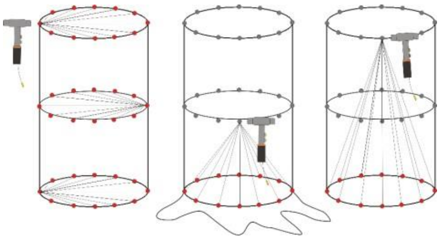
The most accurate way of getting 3D information of trees is to record several levels and calculate the 3D image of the tree. The example below shows a beech tree with *ganoderma* infection. The SoT shows little damage in the 3ed level, but the blue colour in the ERT (low resistance) indicates wet material – an early stage of the fungus.



SoT ERT

(1) Slow V + low R = active fungus

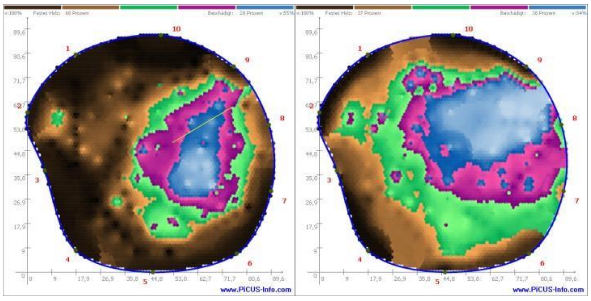
The sketches below show options to record 3D acoustic data. Red dots represent sonic sensors, grey dots are the measuring points - "just" nails. Because of the unlimited number of measuring points (the nails) – the data can be collected in many different configurations.



Data collection options for sonic scans.

5. Timelines

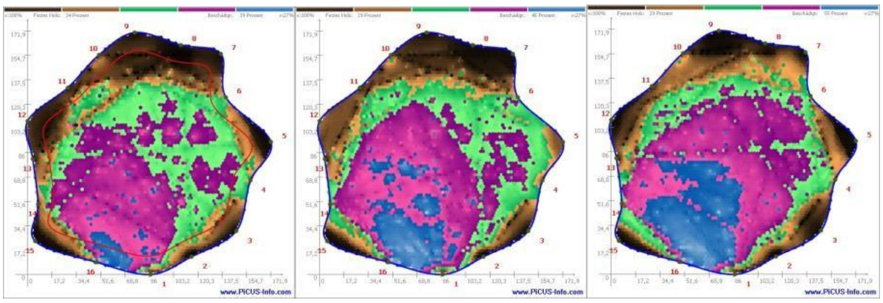
Trees can be tomographed every couple of years to find out about the progress of a decay. When doing so it is important to use the same MP-positions all the time.



The example shows the progress of a fungus infection in a beech tree. The tree was tested in 2007 and in 2011.

The fast progression of the decay does not inspire confidence about the future of that tree.

SoT 2007 20110



Tomograms of an oak. The size of the damaged area seems to stay constant. Apparently the tree did find a way to stop the fungus growing into good wood.

SoT 2006 2008 2010

6. Contact information

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e-mail : lothar.goecke@argus-electronic.de

www.argus-electronic.de

Appendix 4 Glossary of Terminology

Age Most trees have a stable biomass for the major proportion of their life. The estimation of the age of a tree is based on the knowledge of the expected lifespan of the taxa in situ divided into three distinct stages of measurable biomass, when the exact age of the tree from its date of cultivation or planting is unknown and can be categorized as *Young*, *Mature* and *Over-mature* (British Standards 1991, p. 13, Harris *et al*, 2004, p. 262).

Young Tree aged less than <20% of life expectancy, *in situ*.

Mature Tree aged 20-80% of life expectancy, *in situ*.

Over-mature Tree aged greater than >80% of life expectancy, *in situ,* or *senescent* with or without reduced *vigour*, and declining gradually or rapidly but irreversibly to death.

Condition of Trees

Condition A tree's *crown form* and growth habit, as modified by its *environment* (aspect, suppression by other trees, soils), the *stability* and *viability* of the *root plate*, trunk and structural branches (first (1st) and possibly second (2nd) order branches), including structural defects such as wounds, cavities or hollows, *crooked* trunk or weak trunk/branch junctions and the effects of predation by pests and diseases. These may not be directly connected with *vigour* and it is possible for a tree to be of *normal vigour* but in *poor condition*. Condition can be categorized as *Good Condition*, *Fair Condition*, *Poor Condition* and *Dead*.

Good Condition Tree is of good habit, with *crown form* not severely restricted for space and light, physically free from the adverse effects of *predation* by pests and diseases, obvious instability or structural weaknesses, fungal, bacterial or insect infestation and is expected to continue to live in much the same condition as at the time of inspection provided conditions around it for its basic survival do not alter greatly. This may be independent from, or contributed to by vigor.

Fair Condition Tree is of good habit or *misshapen*, a form not severely restricted for space and light, has some physical indication of *decline* due to the early effects of *predation* by pests and diseases, fungal, bacterial, or insect infestation, or has suffered physical injury to itself that may be contributing to instability or structural weaknesses, or is faltering due to the modification of the *environment* essential for its basic survival. Such a tree may recover with remedial works where appropriate, or without intervention may stabilise or improve over time, or in response to the implementation of beneficial changes to its local environment. This may be independent from, or contributed to by vigor.

Poor Condition Tree is of good habit or *misshapen*, a form that may be severely restricted for space and light, exhibits symptoms of advanced and *irreversible decline* such as fungal, or bacterial infestation, major die-back in the branch and *foliage crown*, *structural deterioration* from insect damage e.g. termite infestation, or storm damage or lightning strike, ring barking from borer activity in the trunk, root damage or instability of the tree, or damage from physical wounding impacts or abrasion, or from altered local environmental conditions and has been unable to adapt to such changes and may decline further to death regardless of remedial works or other modifications to the local *environment* that would normally be sufficient to provide for its basic survival if in *good* to *fair* condition. Deterioration physically, often characterised by a gradual and continuous reduction in vigor but may be independent of a change in vigor, but characterised by a proportionate increase in susceptibility to, and *predation* by pests and diseases against which the tree cannot be sustained. Such conditions may also be evident in trees of advanced senescence due to normal phenological processes, without modifications to the growing environment or physical damage having been inflicted upon the tree. This may be independent from, or contributed to by vigor.

Moribund Advanced state of decline, dying or nearly dead.

Dead Tree is no longer capable of performing any of the following processes or is exhibiting any of the following symptoms;
Processes
Photosynthesis via its foliage crown (as indicated by the presence of moist, green or other coloured leaves);
Osmosis (the ability of the root system to take up water);
Turgidity (the ability of the plant to sustain moisture pressure in its cells);
Epicormic shoots or *epicormic strands* in Eucalypts (the production of new shoots as a response to stress, generated from latent or adventitious buds or from a *lignotuber*);
Symptoms
Permanent leaf loss;
Permanent wilting (the loss of turgidity which is marked by desiccation of stems leaves and roots);
Abscission of the *epidermis* (bark desiccates and peels off to the beginning of the sapwood)

Branch

Branch An elongated woody structure arising initially from the trunk to support leaves, flowers, fruit and the development of other branches. A branch may itself fork and continue to divide many times as successive *orders of branches* with the length and taper decreasing incrementally to the *outer extremity* of the *crown*. These may develop initially as a gradually tapering continuation of the *trunk* with minimal division as in a *young* tree or a tree of *excurrent habit*, or in a *sapling*, or may arise where the trunk terminates at or some distance from the *root crown*, dividing into *first order branches* to form and support the *foliage crown*. In an *acaulescent* tree, branches arise at or near the *root crown*. Similarly branches may arise from a *sprout mass* from damaged *roots*, *branches* or *trunk*.

Orders of branches The marked divisions between successively smaller branches (James 2003, p. 168) commencing at the initial division where the trunk terminates on a *deliquescent* tree or from *lateral* branches on an *excurrent* tree. Successive branching is generally characterised by a gradual reduction in branch diameters at each division, and each gradation from the trunk can be categorised numerically, e.g. first order, second order, third order etc. (See Figure 21.)

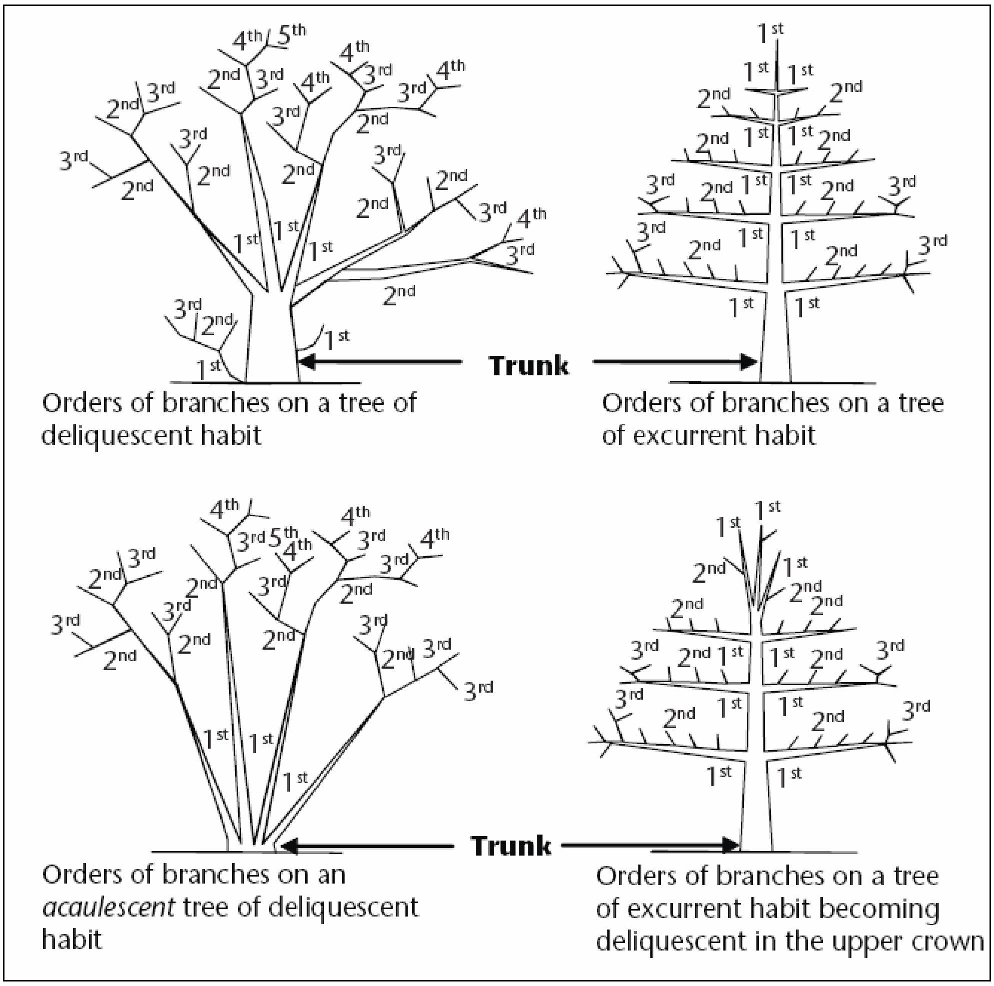

Figure 21 Orders of branches

Crown

Canopy 1. Of multiple trees, the convergence, or merging in full or part, of the crowns of two or more trees due to their proximity, or where competition for light and space available in a forest environment is limited as each tree develops forming a continuous layer
of foliage. 2. Used as a plural for crown. 3. Sometimes synonymously used for crown (USA).

Crown Of an individual tree all the parts arising above the trunk where it terminates by its division forming branches, e.g. the branches, leaves, flowers and fruit; or the total amount of foliage supported by the branches. The crown of any tree can be divided vertically into three sections and can be categorised as *lower crown*, *mid crown* and *upper crown* (Figure 8). For a *leaning* tree these can be divided evenly into crown sections of one-third from the *base* to *apex*. The volume of a crown can be categorised as the *inner crown*, *outer crown* and *outer extremity of crown* (Figure 9).

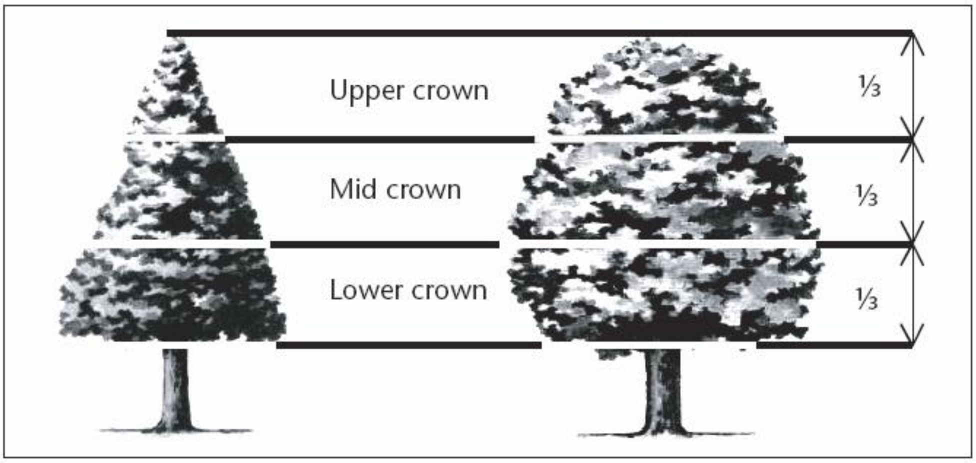

Figure 8 Sections of crown.

Lower crown The *proximal* or lowest section of a crown when divided vertically into one-third (⅓) increments. See also *Crown*, *Mid crown* and *Upper crown*.

Mid crown The middle section of a crown when divided vertically into one-third (⅓) increments. See also *Crown*, *Lower crown* and *Upper crown*.

Upper crown The *distal* or highest section of a crown when divided vertically into one-third (⅓) increments. See also *Crown*, *Mid crown* and *Lower crown*.

Deadwood

Deadwood Dead branches within a tree's crown and considered quantitatively as separate to *crown cover* and can be categorised as *Small Deadwood* and *Large Deadwood* according to diameter, length and subsequent *risk* potential. The amount of dead branches on a tree can be categorized as *Low Volume Deadwood*, *Medium Volume Deadwood* and *High Volume Deadwood*. See also *Dieback.* **Dead wooding** Removing of dead branches by *pruning*. Such pruning may assist in the prevention of the spread of *decay* from *dieback* or for reasons of safety near an identifiable target.

Small Deadwood A dead branch up to 10mm diameter and usually <2 metres long, generally considered of low *risk* potential. **Large Deadwood** A dead branch >10mm diameter and usually >2 metres long, generally considered of high *risk* potential.

High Volume Deadwood High Volume Deadwood Where >10 dead branches occur that may require *removal*.

Medium Volume Deadwood Where 5-10 dead branches occur that may require *removal*.

Low Volume Deadwood Where <5 dead branches occur that may require *removal*.

Dieback

Dieback The death of some areas of the *crown*. Symptoms are leaf drop, bare twigs, dead branches and tree death, respectively. This can be caused by root damage, root disease, bacterial or fungal canker, severe bark damage, intensive grazing by insects, *abrupt changes* in growth conditions, drought, water-logging or over-maturity. Dieback often implies reduced *resistance, stress* or *decline* which may be temporary. Dieback can be categorized as *Low Volume Dieback*, *Medium Volume Dieback* and *High Volume Dieback*.

High Volume Dieback Where >50% of the *crown cover* has died.

Medium Volume Dieback Where 10-50% of the *crown cover* has died.

Low Volume Dieback Where <10% of the *crown cover* has died. See also *Dieback*, *High Volume Dieback* and *Medium Volume Dieback*.

Epicormic shoots

Epicormic Shoots Juvenile shoots produced at branches or trunk from *epicormic strands* in some Eucalypts (Burrows 2002, pp. 111-131) or sprouts produced from dormant or latent buds concealed beneath the bark in some trees. Production can be triggered by fire, pruning, wounding, or root damage but may also be as a result of *stress* or *decline*. Epicormic shoots can be categorized as *Low Volume Epicormic Shoots*, *Medium Volume Epicormic Shoots* and *High Volume Epicormic Shoots*.

High Volume Epicormic Shoots Where >50% of the *crown cover* is comprised of live *epicormic shoots*.

Medium Volume Epicormic Shoots Where 10-50% of the *crown cover* is comprised of live *epicormic shoots*.

Low Volume Epicormic Shoots Where <10% of the c*rown cover* is comprised of live *epicormic shoots*.

General Terms

Cavity A usually shallow void often localized initiated by a *wound* and subsequent *decay* within the trunk, branches or roots, or beneath bark, and may be enclosed or have one or more opening.

Decay Process of degradation of wood by microorganisms (Australian Standard 2007, p. 6) and fungus.

Hazard The threat of danger to people or property from a tree or tree part resulting from changes in the physical condition, growing environment, or existing physical attributes of the tree, e.g. included bark, soil erosion, or thorns or poisonous parts, respectively.

Included bark 1. The bark on the inner side of the *branch union*, or is within a concave *crotch* that is unable to be lost from the tree and accumulates or is trapped by *acutely divergent* branches forming a *compression fork*. 2. Growth of bark at the interface of two or more branches on the inner side of a branch union or in the crotch where each branch forms a branch collar and the collars roll past one another without forming a graft where no one collar is able to subsume the other. Risk of failure is worsened in some taxa where branching is *acutely divergent* or *acutely convergent* and ascending or erect.

Hollow A large void initiated by a *wound* forming a *cavity* in the trunk, branches or roots and usually increased over time by *decay* or other contributing factors, e.g. fire, or fauna such as birds or insects e.g. ants or termites. A hollow can be categorized as an *Ascending Hollow* or a *Descending Hollow*.

Risk The random or potentially foreseeable possibility of an episode causing harm or damage.

Visual Tree Assessment (VTA) A visual inspection of a tree from the ground based on the principle that, when a tree exhibits apparently superfluous material in its shape, this represents repair structures to rectify *defects* or to reinforce weak areas in accordance with the *Axiom of Uniform Stress* (Mattheck & Breloer 1994, pp. 12-13, 145). Such assessments should only be undertaken by suitably competent practitioners.

Leaning Trees

Leaning A tree where the *trunk* grows or moves away from upright. A lean may occur anywhere along the *trunk* influenced by a number of contributing factors e.g. genetically predetermined characteristics, competition for space or light, prevailing winds, aspect, slope, or other factors. A *leaning* tree may maintain a *static lean* or display an increasingly *progressive lean* over time and may be hazardous and prone to *failure* and *collapse*. The degrees of leaning can be categorized as *Slightly Leaning*, *Moderately Leaning*, *Severely Leaning* and *Critically Leaning*.

Slightly Leaning A leaning tree where the trunk is growing at an angle within 0^{o}-15^{o} from upright.

Moderately Leaning A leaning tree where the trunk is growing at an angle within 15^{o}-30^{o} from upright.

Severely Leaning A leaning tree where the trunk is growing at an angle within 30^{o}-45^{o} from upright.

Critically Leaning A leaning tree where the trunk is growing at an angle greater than >45^{o} from upright.

Progressively Leaning A tree where the degree of *leaning* appears to be increasing over time.

Static Leaning A leaning tree whose lean appears to have stabilized over time.

Periods of Time

Periods of Time The life span of a tree in the urban environment may often be reduced by the influences of encroachment and the dynamics of the environment and can be categorized as *Immediate*, *Short Term*, *Medium Term* and *Long Term*.

Immediate An *episode* or occurrence, likely to happen within a twenty-four (24) hour period, e.g. tree failure or collapse in full or part posing an imminent danger.

Short Term A period of time less than <1 – 15 years.

Medium Term A period of time 15 – 40 years.

Long Term A period of time greater than >40 years.

Trunk

Trunk A single stem extending from the *root crown* to support or elevate the *crown*, terminating where it divides into separate *stems* forming *first order branches*. A trunk may be evident at or near ground or be absent in *acaulescent* trees of *deliquescent* habit, or may be continuous in trees of *excurrent* habit. The trunk of any *caulescent* tree can be divided vertically into three (3) sections and can be categorized as *Lower Trunk*, *Mid Trunk* and *Upper Trunk*. For a *leaning* tree these may be divided evenly into sections of one third along the trunk.

Acaulescent A *trunkless* tree or tree growth forming a very short *trunk*. See also *Caulescent.* (See Fig. 21)

Caulescent Tree grows to form a *trunk*. See also *Acaulescent*. (See Fig. 21)

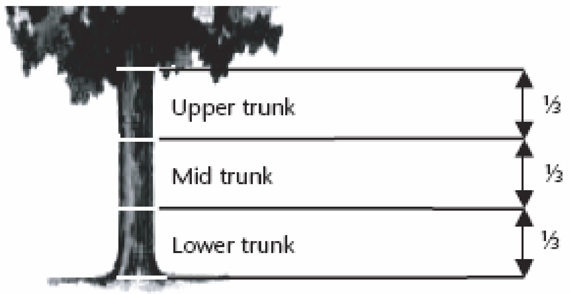

Figure 28 Trunk sections.

Lower trunk Lowest, or *proximal* section of a trunk when divided into one-third (⅓) increments along its *axis*. See also *Trunk*, *Mid trunk* and *Upper trunk*.

Mid trunk A middle section of a trunk when divided into one-third (⅓) increments along its *axis*. See also *Trunk*, *Lower trunk* and *Upper trunk*.

Upper trunk Highest, or *distal* section of a trunk when divided into one-third (⅓) increments along its *axis*. See also *Trunk*, *Lower trunk* and *Mid trunk*.

Vigour

Vigor Ability of a tree to sustain its life processes. This is independent of the *condition* of a tree but may impact upon it. Vigor can appear to alter rapidly with change of seasons (seasonality) e.g. *dormant*, deciduous or semi-deciduous trees. Vigor can be categorized as *Normal Vigor, High Vigor*, *Low Vigor* and *Dormant Tree Vigor*.

Normal Vigor **Ability of a tree to maintain and sustain its life processes. This may be evident by the *typical* growth of leaves, *crown cover* and *crown density*, branches, roots and trunk and *resistance* to *predation*. This is independent of the *condition* of a tree but may impact upon it, and especially the ability of a tree to sustain itself against predation.**

High Vigor *Accelerated growth* of a tree due to incidental or deliberate artificial changes to its growing *environment* that are seemingly beneficial, but may result in *premature aging* or failure if the favorable conditions cease, or promote *prolonged senescence* if the favorable conditions remain, e.g. water from a leaking pipe; water and nutrients from a leaking or disrupted sewer pipe; nutrients from animal waste, a tree growing next to a chicken coop, or a stock feed lot, or a regularly used stockyard; a tree subject to a stringent watering and fertilising program; or some trees may achieve an extended lifespan from continuous *pollarding* practices over the life of the tree. Low Vigor Reduced ability of a tree to sustain its life processes. This may be evident by the *atypical* growth of leaves, reduced *crown cover* and reduced *crown density*, branches, roots and trunk, and a deterioration of their functions with reduced *resistance* to *predation*. This is independent of the *condition* of a tree but may impact upon it, and especially the ability of a tree to sustain itself against predation.

Symmetry

Symmetry Balance within a *crown,* or *root plate,* above or below the *axis* of the trunk of branch and foliage, and root distribution respectively and can be categorized as *Asymmetrical* and *Symmetrical*.

Asymmetrical Imbalance within a crown, where there is an uneven distribution of branches and the foliage *crown* or *root plate* around the vertical *axis* of the trunk. This may be due to *Crown Form Co dominant* or *Crown From* Suppressed as a result of natural restrictions e.g. from buildings, or from competition for space and light with other trees, or from exposure to wind, or artificially caused by pruning for clearance of roads, buildings or power lines. An example of an expression of this may be, crown asymmetrical, bias to west.

Symmetrical Balance within a crown, where there is an even distribution of branches and the *foliage crown* around the vertical *axis* of the trunk. This usually applies to trees of *Crown Form Dominant* or *Crown Form Forest*. An example of an expression of this may be crown symmetrical.

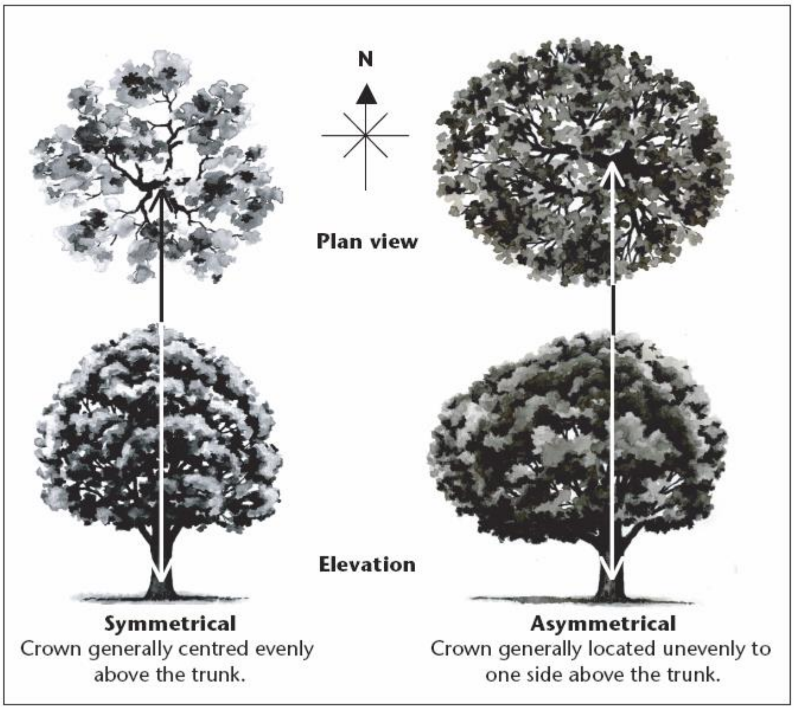

Figure 27 Symmetry within crown

Roots

First Order Roots (FOR) Initial woody roots arising from the *root crown* at the base of the *trunk*, or as an *adventitious root mass* for structural support and *stability*. Woody roots may be buttressed and divided as a marked gradation, gradually tapering and continuous or tapering rapidly at a short distance from the root crown. Depending on soil type these roots may descend initially and not be evident at the root crown, or become buried by changes in soil levels. Trees may develop 4-11 (Perry 1982, pp. 197-221), or more first order roots which may radiate from the trunk with a relatively even distribution, or be prominent on a particular aspect, dependent upon physical characteristics e.g. leaning trunk, *asymmetrical* crown; and constraints within the growing *environment* from topography e.g. slope, soil depth, rocky outcrops, exposure to predominant wind, soil moisture, depth of *water table* etc.

Orders of Roots The marked divisions between woody roots, commencing at the initial division from the base of the trunk, at the *root crown* where successive branching is generally characterised by a gradual reduction in root diameters and each gradation from the trunk and can be categorized numerically, e.g. *first order roots*, second order roots, third order roots etc. Roots may not always be evident at the *root crown* and this may be dependent on species, age class and the growing environment. Palms at maturity may form an adventitious root mass.

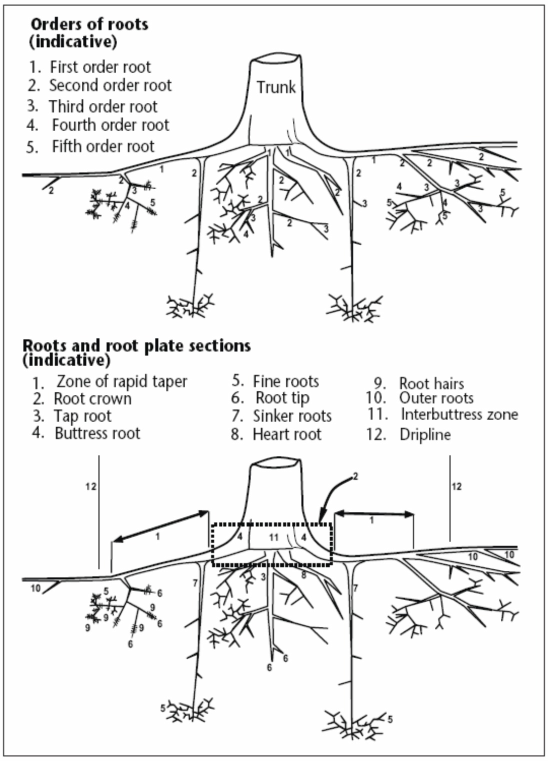

Figure 22 Orders of Roots

Root Plate The entire root system of a tree generally occupying the top 300-600mm of soil including roots at or above ground and may extend laterally for distances exceeding twice the height of the tree (Perry 1982, pp. 197-221). Development and extent is dependent on water availability, soil type, *soil depth* and the physical characteristics of the surrounding landscape.

Root Crown Roots arising at the base of a trunk.
Zone of Rapid Taper The area in the *root plate* where the diameter of *structural roots* reduces substantially over a short distance from the *trunk.* Considered to be the minimum radial distance to provide structural support and *root plate* stability. See also *Structural Root Zone (SRZ)*.
Structural Roots Roots supporting the infrastructure of the *root plate* providing strength and *stability* to the tree. Such roots may taper rapidly at short distances from the *root crown* or become large and woody as with gymnosperms and dicotyledonous angiosperms and are usually 1st and 2nd order roots, or form an *adventitious root mass* in monocotyledonous angiosperms (palms). Such roots may be crossed and grafted and are usually contained within the area of *crown projection* or extend just beyond the *dropline*.

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Assumptions and Limiting Conditions

Any legal description provided to the consultant is assumed to be correct. Any titles and ownership to any property are assumed to be good and marketable. No responsibility is assumed for matters legal in character. Any and all property is appraised as though free and clear, under responsible ownership and competent management.

It is assumed that any property is not in violation of any applicable codes, statutes, or any other Local, State or Federal Government regulations.

Care has been taken to obtain all information from reliable sources. All data has been verified insofar as possible; however, the consultant can neither guarantee nor be responsible for the accuracy of information supplied by others.

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An important statement is made at this point that all standing trees are inherently dangerous and require ongoing maintenance for their life span. Regular checks by qualified Arborists should be carried out on all trees to reduce risks.

Graham Brooks Arboricultural Tree Services Pty Ltd take no responsibility for actions taken and their consequences, contrary to those expert and professional instructions given as recommendations pertaining to safety by way of exercising our responsibility to our client and the public as our duty of care commitment, to mitigate or prevent hazards from arising, from a failure moment in full or part, from a structurally deficient or unsound tree or a tree likely to be rendered thus by its retention and subsequent deterioration from modification/s to its growing environment either existing or proposed, either above or below ground, contrary to our advice.

Graham Brooks. Senior Principal Arborist

Appendix 5

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