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ARBORICULTURAL APPRAISAL

19 January 2016

75 Old Pittwater Road
Brookvale, NSW

Prepared for
Harrison Investments Pty Ltd

1. INTRODUCTION

1.1 **Instruction:** I am instructed by Harrison Investments Pty Ltd to inspect four trees at 75 Old Pittwater Road, Brookvale and to provide an arboricultural report addressing the health, structure and usefulness of trees within the landscape. The report will identify the works that need to be carried out in order to reduce associated risks within the property.

1.2 **Qualifications and experience:** I have performed training and I am licensed to perform Quantified Tree Risk Assessments (QTRA - Licence No. 1655) using the method developed by Quantified Tree Risk Assessment Ltd. The recommendations within this report are based primarily on the review of trees and my interpretation of the QTRA system. I have experience and qualifications in arboriculture, and include a summary in Appendix 1.

1.3 **Documents and information provided:** I was not provided with any documents.

1.4 **Scope of this report:** This report is only concerned with four trees, two located within the subject site and two adjacent to it, on private property. It takes no account of other trees, shrubs or groundcovers within the site unless stated otherwise. It includes a preliminary assessment based on the site visit.

2. SITE VISIT AND METHODOLOGY

2.1 **Site visit:** I carried out an accompanied site visit on 27 November 2015 and 18 January 2016. All my observations were from ground level and I estimated all dimensions unless otherwise indicated. Aerial inspections, root or soil analysis, exploratory root trenching and internal diagnostic testing was not undertaken as part of this assessment. I did not have access to trees on other private properties and have confined observations of them to what was visible from within the property. The weather at the time of inspection was clear and dry with good visibility.

2.2 **Brief site description:** 75 Old Pittwater Road is located in the residential suburb of Brookvale (refer figure 1). The site is on the eastern side of the road and surrounded by similar residential development. The property consists of a large factory and warehouses of Harrison Manufacturing Co Pty Limited. A variety of ornamental and indigenous trees are scattered throughout the site and around the site boundaries.

Figure 1: The location of the subject site (www.googlemaps.com).

2.3 **Identification and location of the trees:** I have illustrated the approximate locations of the trees on the Tree Location Plan included as Appendix 5. This plan is for illustrative purposes only and it should not be used for directly scaling measurements.

2.4 **Methodology – Visual Tree Assessment:** The subject trees were assessed using Visual Tree Assessment (VTA) techniques (Mattheck, 2004). VTA undertaken by tree professionals is a recognised systematic method of identifying tree characteristics and hazard potential. VTA is also an assessment method described by Claus Mattheck in the *Body Language of Trees – a handbook for failure analysis*.

2.5 **Methodology - Quantified Tree Risk Assessment (QTRA):** The Quantified Tree Risk Assessment (QTRA) system has led the way in the field of tree management with a risk assessment approach that is led by the usage and value of the targets having potential to be affected by trees. The target-led approach to tree management is a considerable shift from the generally accepted wisdom where the tree assessor focuses on identifying defects in trees and then seeks to avoid legal liability by removing or modifying the tree.

This defect-led approach results in the allocation of disproportionate resources to both tree surveys, inspections and to the remediation of defective trees where the risks are low if only they were actually assessed.

One of the greatest benefits of QTRA is that it enables an informed overview of the risks associated with a tree population to be carried out as a desktop exercise before the survey of trees. When the risk overview is complete, the assessment will usually record only the general attributes of groups or collections of trees.

Assessing and recording individual trees will be necessary only where they are likely to be significant in relation to the targets.

3. APPRAISAL

3.1 **General tree conditions:** After correlating the facts of the tree survey, it is evident that the four subject trees are of moderate to high significant value based on their individual merits. The tree varieties create shade, habitat and aesthetic value to the area. The vigour of the trees varies from poor to good, though the structure of the trees has been compromised by the borer, acute leaning or advanced decline.

3.2 **Tree 1 – *Angophora floribunda*:** This large tree is located near the front site entry and leans directly over Old Pittwater Road (refer figure 2). The tree has an acute lean of 58 degrees with a large branch failure wound on the tension side of its trunk (refer figure 3 and 4). There does not appear to be any heaving of the soil near the trunk base which suggests the tree has a stable root plate. However, given the lean and weight distribution of the tree and under typical conditions, tension wood (high side of trunk) is twice the strength than compression wood (lower side of trunk). Risk of tree failure is greatest when the tension wood is damaged, because wood fibers buckle much more easily than they tear (Mattheck 1994). Wounding and associated weaknesses inhibit the production of tension wood and therefore reduce trunk strength.

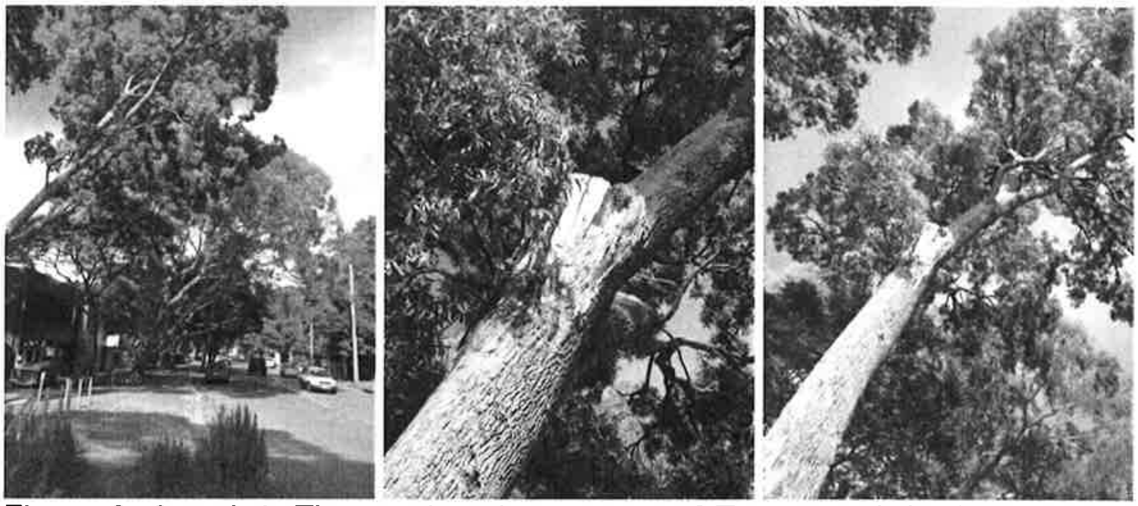

Figure 2, 3 and 4: The overhanging canopy of Tree 1 and the large branch failure wound on the tension side of the trunk.

Based on observations on site, it is evident that the occupancy rate beneath this tree is high to very high. The main target at risk was vehicle traffic with a Target rating of 2 (refer Appendix 2).

The tree has a moderate to high potential to fail at the wound site. Therefore, the Risk of harm for this tree was unacceptable due to the defective trunk, lean and high trafficked area beneath it. I see no realistic way of managing the tree or potential for improvement of the tree and therefore strongly recommend that it be removed and replaced with a similar indigenous tree species.

3.3 **Tree 2 – *Eucalyptus* sp.:** This large tree displays fair health however its structure has been compromised by borer activity. Three very large boughs have previously been removed from the trunk base and I believe this has resulted in borer infestation and the existing cambium death of the trunk base. The borer infestation has caused significant decline of the cambium leaving an estimated 10% of live cambium remaining on one of its main boughs (refer figure 5 and 6).

Insects that bore into wood not only cause defects in wood quality but their galleries also reduce wood strength (Shigo1989). Holes in the bark and stains or oozing liquid on limbs or trunks are common borer damage symptoms. Foliage often discolors and wilts, and limbs may break. Borers mostly attack stressed or damaged trees and vigorous, well-watered trees are rarely attacked.

Figure 5 and 6: Large boughs removed and cambium death of large remaining limbs.

It is unlikely that the tree will recover from the damage as extensive larval feeding at the inner bark-cambium-xylem interface can effectively girdle the tree. Trees at this stage of infestation are characterized by a thin canopy with wilted or dry leaves; the bark is cracked and packed with larval excrement. Infested trees are often killed in a matter of a few weeks. Resprouting may occur from the tree base and upper canopy.

Based on observations on site, it is evident that the occupancy rate beneath this tree is high. The main target at risk was persons occupying the area beneath the tree. A Target rating of 2 or occupancy of 2.4hr/day to 15 mins/day (refer Appendix 2).

The Risk of harm for this tree was unacceptable due to the trees condition and occupancy rate beneath. I see no realistic potential for the tree to improve and strongly recommend that it be removed and replaced with a similar indigenous tree species.

3.4 **Tree 3 – *Eucalyptus saligna*:** This tree is located within the adjoining property with 50% of its canopy overhanging 75 Old Pittwater Road. This tree is completely dead and brittle branches are beginning to fail from its canopy. Pedestrian traffic beneath its canopy was moderate and therefore the risk of harm was on the high side of tolerable, or 1 in 50,000. Branch failures are expected to increase as the wood dries further. I strongly recommend removal of this tree.

3.5 **Tree 4 – *Eucalyptus microcorys*:** This tree is located within the adjoining property with 50% of its canopy overhanging 75 Old Pittwater Road. The tree displays good health and structure with no visible defects. The trunk leans slightly to the north however I do not believe it is compromising the trees integrity. The risk was calculated on property (stationary vehicles) with the most likely damage being caused by dead falling twigs. The risk is tolerable at 1 in 300,000. General maintenance of the canopy will further reduce the risk and the amount of debris that falls.

3.6 **Overall site impacts:** The removal of the individual tree species within the site will be warranted with the beneficial planting of indigenous landscape plants/trees within available areas of the site following works.

Trees are just one of many competing requirements that have to be weighed up in high occupied areas. It is very unusual that the idea of keeping all trees is a realistic possibility and compromises are inevitable. No tree is above losing if there is a planning gain that is greater than the benefit of retaining it.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 **Summary of findings:** On the basis of the above information and discussions, I summarise my conclusions as follows:-

- Tree 1 displays good health however its structure has been compromised by a large wound on the tension wood. The tree overhangs Old Pittwater Road and is deemed as an unacceptable risk;
- Tree 2 has been compromised due to borer infestation and significant girdling of upper boughs. The affected limbs have a high probability to fail resulting in an unacceptable risk;
- Tree 3 is a tolerable risk, however it should be removed as it is completely dead; and
- Tree 4 is deemed as a tolerable risk however annual canopy maintenance is strongly recommended. Removal of deadwood and thinning of the overhanging canopy by 15% is recommended to reduce falling debris.

4.2 **Informing management decisions based on risk categories:** To ensure the best use of available resources, trees will fall into one of the four categories; Unacceptable, Unacceptable or Tolerable (refer Appendix 3). QTRA scoring is used to prioritise work by identifying the trees likely to cause the greatest harm. Those trees with a higher score will generally be dealt with first.

4.3 **Implementation of works:** All tree works should be carried out to comply with Code of Practice for The Amenity Tree Industry 1998.

5. OTHER CONSIDERATIONS

5.1 **Trees subject to statutory controls:** The following trees, 1, 2 and 4, are legally protected under Warringah Council's Tree Preservation Order, it will be necessary to consult the council before any pruning or removal works other than certain exemptions can be carried out. The works specified above are necessary for reasonable management and should be acceptable to the council. However, tree owners should appreciate that the council may take an alternative point of view and have the option to refuse consent.

5.2 **Trees outside the property:** Trees 3 and 4 are located in the adjacent properties effectively out of the control of the owners of 75 Old Pittwater Road, Brookvale. It will not be possible to easily carry out the recommended works without the full co-operation of the tree owners. The implications of non-cooperation require legal interpretation and are beyond the scope of this report.

6. BIBLIOGRAPHY

6.1 **List of references:**

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Mattheck, C.,Breloer, H (1994) The Body Language of Trees- A handbook for failure analysis . HMSO, London.

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Poynton, United Kingdom

Robinson, L (1994) Field Guide to the Native Plants of Sydney
Kangaroo Press, Kenthurst NSW

7. DISCLAIMER

7.1 Limitations on use of this report:

This report is to be utilized in its entirety only. Any written or verbal submission, report or presentation that includes statements taken from the findings, discussions, conclusions or recommendations made in this report, may only be used where the whole of the original report (or a copy) is referenced in, and directly attached to that submission, report or presentation.

ASSUMPTIONS

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

Unless stated otherwise:

- *Information contained in this report covers only those trees that were examined and reflects the condition of those trees at time of inspection: and*
- *The inspection was limited to visual examination of the subject trees without dissection, excavation, probing or coring. There is no warranty or guarantee, expressed or implied, that problems or deficiencies of the subject trees may not arise in the future.*

Yours sincerely

Andrew Scales

Manager/ Consultant
Arboriculture Australia #2136
Dip. Horticulture / Arboriculture
Mobile: 0417 250 420

APPENDIX 1

Brief qualifications and experience of Andrew Scales

1. **Qualifications:**

Associate Diploma Horticulture	Northern Sydney Institute of TAFE	1995-1998
Certificate in Tree Surgery	Northern Sydney Institute of TAFE	1998
Associate Diploma Arboriculture	Northern Sydney Institute of TAFE	1999-2006

2. **Practical experience:** Being involved in the arboricultural/horticultural industry for in excess of 10 years, I have developed skills and expertise recognized in the industry. Involvement in the construction industry and tertiary studies has provided me with a good knowledge of tree requirements within construction sites.

   As director of Naturally Trees, in this year alone I have undertaken hundreds of arboricultural consultancy projects and have been engaged by a range of clients to undertake tree assessments. I have gained a wide range of practical tree knowledge through tree removal and pruning works.

3. **Continuing professional development:**

Visual Tree Assessment (Prof. Dr. Claus Mattheck)	Northern Sydney Institute of TAFE 2001
Wood Decay in Trees (F.W.M.R.Schwarze)	Northern Sydney Institute of TAFE 2004
Visual Tree Assessment (Prof. Dr. Claus Mattheck)	Carlton Hotel, Parramatta NSW 2004
Tree A-Z / Report Writing (Jeremy Barrell)	Northern Sydney Institute of TAFE 2006
Up by Roots – Healthy Soils and Trees in the Built Environment (James Urban)	The Sebel Parramatta NSW 2008
Tree Injection for Insect Control (Statement of Attainment)	Northern Sydney Institute of TAFE 2008
Quantified Tree Risk Assessment (QTRA) Registered Licensee #1655	South Western Sydney Institute TAFE 2011
Practitioners Guide to Visual Tree Assessment	South Western Sydney Institute TAFE 2011
Quantified Tree Risk Assessment (QTRA) Registered Licensee #1655	Richmond College NSW TAFE 2014

4. **Current professional memberships:**
   Arboriculture Australia – (Registered Consulting Arborist #2136)

APPENDIX 2

Tree schedule and QTRA assesment

No.	Species	Height	Spread	DBH	Age Range	Vitality	Defects	Most Signi	Target	Target Range	Size Range	Prob Failu	Risk Index	Recommendations
1	*Angophora floribunda*	28	22	800	M	Good	Acute lean over road, Wound on tension side of trunk	Whole tree	Vehicles	2	1	3	4	Remove tree
2	*Eucalyptus tereticornis*	34	27	1100	M	Good	Borer, Cambium loss, 3x large boughs removed	First order branch	Occupancy	2	2	3	10	Remove tree
3	*Eucalyptus saligna*	16	8	380	M	Dead	Dead tree	First order branch	Pedestrians	2	3	3	50	Remove tree
4	*Eucalyptus microcorys*	23	23	600	M	Good	Slight lean to north	Deadwood	Property	4	Property	3	300	Thin canopy and remove deadwood

Explanatory Notes

NO.: TREE REFERENCE

SPECIES: THE SPECIES IDENTIFICATION IS BASED ON VISUAL OBSERVATIONS AND THE BOTANICAL NAME. IN SOME INSTANCES, IT MAY BE DIFFICULT TO QUICKLY AND ACCURATELY IDENTIFY A PARTICULAR TREE WITHOUT FURTHER DETAILED INVESTIGATIONS. WHERE THERE IS SOME DOUBT OF THE PRECISE SPECIES OF TREE, IT IS INDICATED WITH A '?' AFTER THE NAME IN ORDER TO AVOID DELAY IN THE PRODUCTION OF THE REPORT. THE BOTANICAL NAME IS FOLLOWED BY THE ABBREVIATION SP IF ONLY THE GENUS IS KNOWN. THE SPECIES LISTED FOR GROUPS AND HEDGES REPRESENT THE MAIN COMPONENT AND THERE MAY BE OTHER MINOR SPECIES NOT LISTED.

AGE RANGE: Y = YOUNG, SM = SEMI MATURE, EM = EARLY MATURE, M = MATURE, PM = POST MATURE

HEIGHT: OTHER THAN WHERE THE HEIGHT OF A TREE IS CRITICAL TO THE OUTCOME OF THE RISK ASSESSMENT, APPROXIMATELY 1 IN 10 TREES ARE MEASURED AND THE REMAINDER ESTIMATED AGAINST THE MEASURED TREES

SPREAD: MEASURED OR ESTIMATED DIAMETER OF CROWN AT THE WIDEST POINT

DBH: STEM DIAMETER - MEASURED AT A HEIGHT OF APPROXIMATELY 1.3 METRES

VITALITY: A MEASURE OF PHYSIOLOGICAL CONDITION. D = DEAD, MD = MORIBUND, P = POOR, M = MODERATE, G = GOOD

SIZE RANGE: SIZE CATEGORY OF MOST SIGNIFICANT PART CONSIDERED LIKELY TO FAIL. RANGES 1-5. 1 = LARGE, 5 = SMALL

PROB OF FAILURE RANGE: PROBABILITY OF FAILURE WITHIN 12 MONTHS. RANGES 1-5. 1 = HIGH, 5 = LOW

TARGET RANGE: HIGHEST VALUE TARGET THAT THE MOST SIGNIFICANT PART LIKELY TO FAIL COULD STRIKE. RANGES 1-6. 1 = HIGH, 6 = LOW VALUE/OCCUPANCY

WEATHER FACTOR: ALLOWANCE FOR REDUCED ACCESS DURING HIGH WINDS WHEN IN SOME SITUATIONS TREE FAILURE IS MOST LIKELY, OR SITUATIONS WHERE THE PROBABILITY OF TREE FAILURE IS INCREASED BY HOT DRY WEATHER, WHICH AT THE SAME TIME INCREASES PEDESTRIAN ACCESS. TO BE APPLIED BY MULTIPLYING THE RISK INDEX BY THE WEATHER FACTOR

REDUCED MASS % WHERE THE MASS OF A TREE OR BRANCH IS REDUCED BY DEGRADATION THE RISK INDEX IS MULTIPLED TO REFLECT THE PERCENTAGE OF MASS REDUCTION

RISK INDEX: RISK OF SIGNIFICANT HARM ÷ 1,000 = RISK INDEX (E.G. RISK INDEX 20 = RISK OF SIGNIFICANT HARM 1 IN 20,000) AN ADDITIONAL FIGURE IN BRACKETS MAY BE SUFFIXED EITHER T OR F REPRESENTING 'F' THE RATE OF FAILURES OVER THE YEAR, AND 'T' THE RATE OF MULTIPLE OCCUPATION OVER THE YEAR, E.G. 1(10T)/10,000 REPRESENTS A RISK OF HARM 1/10,000 TO 10 OCCUPANTS OR AN EQUIVALENT MONETARY VALUE
SUFFIXES: (M) = FOR GENERAL ARBORICULTURAL OR SILVICULTURAL MANAGEMENT; (S) = TO REMOVE OR REDUCE THE RISK OF DIRECT DAMAGE TO A FIXED STRUCTURE BY MEANS OF CIRCUMFERENTIAL GROWTH

REVIEW: PERIOD (YEARS) TO NEXT INSPECTION

APPENDIX 3

Quantified Tree Risk Assessment (QTRA)

The QTRA system quantifies three primary components of the tree failure risk:

1) **Target** - in tree risk management, the target is that which may be harmed by a falling tree or branch;
2) **Size** - of tree or tree part most likely to fail; and
3) **Probability of failure** - of the tree or branch within 12 months.

The product of these component probabilities is referred to as the 'Risk of Significant Harm';

Target Value X Size X Probability of Failure = **Risk of Harm**

A risk of significant harm of 1/10,000 (or 1 in 10,000) is considered by QTRA and a number of sources to be the limit of acceptable risk to the public at large. Using the 1/10,000 limit, a risk of harm exceeding 1/10,000 requires remedial action to reduce the risk (unless the risk is limited to a selective individual or group - such as a tree owner, who may choose to accept a greater or lesser risk).

Additionally, a tree might confer benefits that could be set against the risk of harm e.g. one with very high amenity. The 1/10,000 threshold is not intended to be applied absolutely rigidly but necessarily includes a degree of flexibility. For further information Quantified Tree Risk Assessment Practice Note, a copy of which is included at Appendix 5. Tree owners also need to be able to demonstrate that the risks posed by their trees are 'As Low As Reasonably Practicable' (ALARP), taking into account the benefit provided by the individual tree. This may result in work to some trees of a risk lower than the above threshold.

Where trees are identified to pose a risk of harm greater than 1 in 10,000 to users or structures, the tree owner should seek to ensure that the risk is reduced to an acceptable level and will, where such trees are identified to be 'Dangerous', take action using its powers under the local governing body.

Risk Thresholds	Description	Action
	Unacceptable Risks will not ordinarily be tolerated	• Control the risk
1/1 000		
	Unacceptable (where imposed on others) Risks will not ordinarily be tolerated	• Control the risk • Review the risk
	Tolerable (by agreement) Risks may be tolerated if • those exposed to the risk accept it, or • the tree has exceptional value	• Control the risk unless there is broad stakeholder agreement to tolerate it, or the tree has exceptional value • Review the risk
1/10 000		
	Tolerable (where imposed on others) Risks are tolerable if ALARP	• Assess costs and benefits of risk control • Control the risk only where a significant benefit might be achieved at a reasonable cost • Review the risk
1/1 000 000		
	Broadly Acceptable Risk is already ALARP	• No action required currently • Review the risk

Table 1: The risk categories and the risk of harm threshold. A risk higher than 1 in 10,000 is generally unacceptable.

APPENDIX 4

Glossary of arboricultural terms

Acceptable risk level- a level of risk after mitigation has taken place that is accepted as 'generally safe'.
Apical dominance- a condition in which the apical bud inhibits the growth and development of lateral buds on the same stem.
Australian Standards – 'Pruning of Amenity Trees' – a guide to explain the Australian Standards of how trees are to be pruned correctly
Branch bark ridge- a ridged area located at the union of a branch to a trunk or stem.
Co-dominant stems/trunk- are forked branches or trunks of nearly the same size in diameter and lacking a normal branch union.
Compacted soils- Soils in which the air-space (oxygen space) has been reduced or eliminated, reducing water infiltration and percolation, reducing root presence and inhibiting new root development.
Crotch- another name for a branch union
Crown Raising- The removal of the lowest branches of a tree canopy to allow clearance and increase height between the ground and the tree's lowest branches
Dead wooding- The removal of dead branches from a tree's canopy, usually of a specified size (in diameter)
Defoliation- the losing of plants foliage
Epicormic- Fast growing, weakly attached shoots/branches that grow as a response to stress factors upon a tree
Grade change- the raising or lowering of a soil profile from its original grade.
Heartwood- inner non functioning tissues that provide structural support to trunk
Included bark- bark that becomes embedded in a crotch between branch and trunk or between co-dominant stems and causes a weak structure.
Infiltration- the movement of water through the surface soil.
Leader- The primary terminal shoot or trunk of a tree.
Lopped/ Topped- Incorrect pruning method of removing branches to stubs, resulting poor form and weak branch unions.
Longicorn Beetle- wood boring insects
Mitigation- The process of reducing damages of risk.
Primary Roots- Roots of a tree that provide structural support and anchorage to a tree, also aiding in storage of essential starches and sugars used in tree growth
Removal- cutting down of a tree
Risk Potential- the probability of something adverse happening
Root Crown- The area where the trunk turns into the roots, usually at soil level, the trunk tapers out at the base
Secondary Feeder Roots- Fine fibrous Water and nutrient absorbing roots located in the outer root system
Scaffold branches- The Permanent or structural branches of a tree.
Senescent- a decline in growth and vigor due to age or stress factors
Soil Profile- The 'make up' of the soil; the soil type, texture and structure as a whole
Stress factors- Factors influencing the vigor and amenity of the tree, such as environmental factors, construction damage, mechanical damage and vandalism.
Tree Crown- The upper canopy of a tree, including upper trunk, scaffold branches, secondary branches, stems and leaves
Wind loading- Forces placed upon tree canopy, branches, trunk and roots of a tree under windy conditions.
Wind Throw- The moving of the tree canopy under wind loading.

APPENDIX 5

Tree location plan

-refer attached Tree Location Plan, Dwg No. TLP01,
by Naturally Trees dated 19 January 2016

APPENDIX 6
Quantified Tree Risk Assessment
Practice Note

"When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind"

William Thomson, Lord Kelvin. Popular Lectures and Addresses [1891-1894]

1. INTRODUCTION

Every day we encounter risks in all of our activities, and the way we manage those risks is to make choices. We weigh up the costs and benefits of the risk to determine whether it is acceptable, unacceptable, or tolerable. For example, if you want to travel by car you must accept that even with all the extensive risk control measures, such as seat-belts, speed limits, airbags, and crash barriers, there is still a significant risk of death. This is an everyday risk that is taken for granted and tolerated by millions of people in return for the benefits of convenient travel. Managing trees should take a similarly balanced approach.

A risk from falling trees exists only if there is both potential for tree failure and potential for harm to result. The job of the risk assessor is to consider the likelihood and consequences of tree failure. The outcome of this assessment can then inform consideration of the risk by the tree manager, who may also be the owner.

Using a comprehensive range of values[1], Quantified Tree Risk Assessment (QTRA) enables the tree assessor to identify and analyse the risk from tree failure in three key stages. 1) to consider land-use in terms of vulnerability to impact and likelihood of occupation, 2) to consider the consequences of an impact, taking account of the size of the tree or branch concerned, and 3) to estimate the probability that the tree or branch will fail onto the land-use in question. Estimating the values of these components, the assessor can use the QTRA manual calculator or software application to calculate an annual Risk of Harm from a particular tree. To inform management decisions, the risks from different hazards can then be both ranked and compared, and considered against broadly acceptable and tolerable levels of risk.

A Proportionate Approach to Risks from Trees

The risks from falling trees are usually very low and high risks will usually be encountered only in areas with either high levels of human occupation or with valuable property. Where levels of human occupation and value of property are sufficiently low, the assessment of trees for structural weakness will not usually be necessary. Even when land-use indicates that the assessment of trees is appropriate, it is seldom proportionate to assess and evaluate the risk for each individual tree in a population. Often, all that is required is a brief consideration of the trees to identify gross signs of structural weakness or declining health. Doing all that is reasonably practicable does not mean that all trees have to be individually examined on a regular basis (HSE 2013).

The QTRA method enables a range of approaches from the broad assessment of large collections of trees to, where necessary, the detailed assessment of an individual tree.

Risk of Harm

The QTRA output is termed the Risk of Harm and is a combined measure of the likelihood and consequences of tree failure, considered against the baseline of a lost human life within the coming year.

ALARP (As Low As Reasonably Practicable)

Determining that risks have been reduced to As Low As Reasonably Practicable (HSE 2001) involves an evaluation of both the risk and the sacrifice or cost involved in reducing that risk. If it can be demonstrated that there is gross disproportion between them, the risk being insignificant in relation to the sacrifice or cost, then to reduce the risk further is not 'reasonably practicable'.

Costs and Benefits of Risk Control

Trees confer many benefits to people and the wider environment. When managing any risk, it is essential to maintain a balance between the costs and benefits of risk reduction, which should be considered in the determination of ALARP. It is not only the financial cost of controlling the risk that should be considered, but also the loss of tree-related benefits, and the risk to workers and the public from the risk control measure itself.

[1] See Tables 1, 2 & 3.

When considering risks from falling trees, the cost of risk control will usually be too high when it is clearly 'disproportionate' to the reduction in risk. In the context of QTRA, the issue of 'gross disproportion'[2], where decisions are heavily biased in favour of safety, is only likely to be considered where there are risks of 1/10 000 or greater.

Acceptable and Tolerable Risks

The Tolerability of Risk framework (ToR) (HSE 2001) is a widely accepted approach to reaching decisions on whether risks are broadly acceptable, unacceptable, or tolerable. Graphically represented in Figure 1, ToR can be summarised as having a Broadly Acceptable Region where the upper limit is an annual risk of death 1/1 000 000, an Unacceptable Region for which the lower limit is 1/1 000, and between these a Tolerable Region within which the tolerability of a risk will be dependent upon the costs and benefits of risk reduction. In the Tolerable Region, we must ask whether the benefits of risk control are sufficient to justify their cost.

In respect of trees, some risks cross the Broadly Acceptable 1/1 000 000 boundary, but remain tolerable. This is because any further reduction would involve a disproportionate cost in terms of the lost environmental, visual, and other benefits, in addition to the financial cost of controlling the risk.

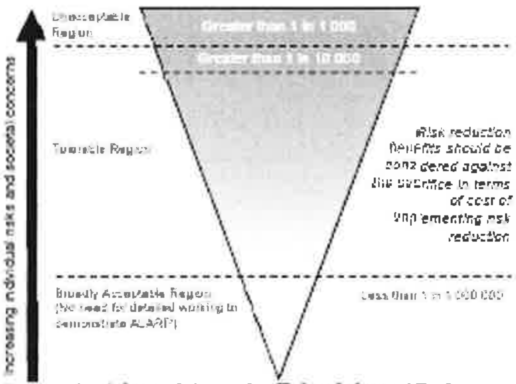

Figure 1. Adapted from the Tolerability of Risk framework (HSE 2001).

Value of Statistical Life

The Value of Statistical Life (VOSL), is a widely applied risk management device, which uses the value of a hypothetical life to guide the proportionate allocation of resources to risk reduction. In the UK, this value is currently in the region of £1 500 000 ($2 850 000), and this is the value adopted in the QTRA method.

In QTRA, placing a statistical value on a human life has two particular uses. Firstly, QTRA uses VOSL to enable damage to property to be compared with the loss of life, allowing the comparison of risks to people and property. Secondly, the proportionate allocation of financial resources to risk reduction can be informed by VOSL. *"A value of statistical life of £1 000 000 is just another way of saying that a reduction in risk of death of 1/100 000 per year has a value of £10 per year"* (HSE 1996).

Internationally, there is variation in VOSL, but to provide consistency in QTRA outputs, it is suggested that VOSL of £1 500 000 ($2 850 000) should be applied internationally. This is ultimately a decision for the tree manager.

2. OWNERSHIP OF RISK

Where many people are exposed to a risk, it is shared between them. Where only one person is exposed, that individual is the recipient of all of the risk and if they have control over it, they are also the owner of the risk. An individual may choose to accept or reject any particular risk to themselves, when that risk is under their control. When risks that are imposed upon others become elevated, societal concern will usually require risk controls, which ultimately are imposed by the courts or government regulators.

Although QTRA outputs might occasionally relate to an individual recipient, this is seldom the case. More often, calculation of the Risk of Harm is based on a cumulative occupation – i.e. the number of people per hour or vehicles per day, without attempting to identify the individuals who share the risk.

Where the risk of harm relates to a specific individual or a known group of people, the risk manager might consider the views of those who are exposed to the risk when making management decisions. Where a risk is imposed on the wider community, the principles set out in the ToR framework can be used as a reasonable approach to determine whether the risk is ALARP.

3. THE QTRA METHOD - VERSION 5

The input values for the three components of the QTRA calculation are set out in broad ranges[3] of Target, Size, and Probability of Failure. The assessor

[2] Discussed further on page 5.

[3] See Tables 1, 2 & 3.

estimates values for these three components and inputs them on either the manual calculator or software application to calculate the Risk of Harm.

Assessing Land-use (Targets)

The nature of the land-use beneath or adjacent to a tree will usually inform the level and extent of risk assessment to be carried out. In the assessment of Targets, six ranges of value are available. Table 2 sets out these ranges for vehicular frequency, human occupation and the monetary value of damage to property.

Human Occupation

The probability of pedestrian occupation at a particular location is calculated on the basis that an average pedestrian will spend five seconds walking beneath an average tree. For example, ten pedestrians per day, each occupying the Target for five seconds, is a daily occupation of fifty seconds. The total seconds in a day are divided to give a probability of Target occupation (50/86 400 = 1/1 728). Where a longer occupation is likely, as with a habitable building, outdoor café, or park bench, the period of occupation can be measured, or estimated as a proportion of a given unit of time, e.g. six hours per day (1/4). The Target is recorded as a range (Table 2).

Weather Affected Targets

Often the nature of a structural weakness in a tree is such that the probability of failure is greatest during windy weather, while the probability of the site being occupied by people during such weather is often low. This applies particularly to outdoor recreational areas. When estimating human Targets, the risk assessor must answer the question 'in the weather conditions that I expect the likelihood of failure of the tree to be initiated, what is my estimate of human occupation?' Taking this approach, rather than using the average occupation, ensures that the assessor considers the relationship between weather, people, and trees, along with the nature of the average person with their ability to recognise and avoid unnecessary risks.

Vehicles on the Highway

In the case of vehicles, likelihood of occupation may relate to either the falling tree or branch striking the vehicle or the vehicle striking the fallen tree. Both types of impact are influenced by vehicle speed; the faster the vehicle travels the less likely it is to be struck by the falling tree, but the more likely it is to strike a fallen tree. The probability of a vehicle occupying any particular point in the road is the ratio of the time it is occupied - including a safe stopping distance - to the total time. The average vehicle on a UK road is occupied by 1.6 people (DfT 2010). To account for the substantial protection that the average vehicle provides against most tree impacts and in particular, frontal collisions, QTRA values the substantially protected 1.6 occupants in addition to the value of the vehicle as equivalent to one exposed human life.

Property

Property can be anything that could be damaged by a falling tree, from a dwelling, to livestock, parked car, or fence. When evaluating the exposure of property to tree failure, the QTRA assessment considers the cost of repair or replacement that might result from failure of the tree. Ranges of value are presented in Table 2 and the assessor's estimate need only be sufficient to determine which of the six ranges the cost to select.

In Table 2, the ranges of property value are based on a VOSL of $2 850 000, e.g. where a building with a replacement cost of $28 500 would be valued at 0.01 (1/100) of a life (Target Range 2).

When assessing risks in relation to buildings, the Target to be considered might be the building, the occupants, or both. Occupants of a building could be protected from harm by the structure or substantially exposed to the impact from a falling tree if the structure is not sufficiently robust, and this will determine how the assessor categorises the Target.

Multiple Targets

A Target might be constantly occupied by more than one person and QTRA can account for this. For example, if it is projected that the average occupation will be constant by 10 people, the Risk of Harm is calculated in relation to one person constantly occupying the Target before going on to identify that the average occupation is 10 people. This is expressed as Target 1(10T)/1, where 10T represents the Multiple Targets. In respect of property, a Risk of Harm 1(10T)/1 would be equivalent to a risk of losing $28 500 000 as opposed to $2 850 000.

Tree or Branch Size

A small dead branch of less than 25mm diameter is not likely to cause significant harm even in the case of direct contact with a Target, while a falling branch with a diameter greater than 450mm is likely to cause some harm in the event of contact with all but the most robust Target. The QTRA method categorises

Size by the diameter of tree stems and branches (measured beyond any basal taper). An equation derived from weight measurements of trees of different stem diameters is used to produce a data set of comparative weights of trees and branches ranging from 25mm to 600mm diameter, from which Table 1 is compiled. The size of dead branches might be discounted where they have undergone a significant reduction in weight because of degradation and shedding of subordinate branches. This discounting, referred to as 'Reduced Mass', reflects an estimated reduction in the mass of a dead branch.

Table 1. Size

Size Range	Size of tree or branch	Range of Probability
1	> 450mm (>18") dia.	1/1 - >1/2
2	260mm (10¼") dia. - 450mm (18") dia.	1/2 - >1/8.6
3	110mm (4¼") dia. - 250mm (10") dia.	1/8.6 - >1/82
4	25mm (1") dia. - 100mm (4") dia.	1/82 - 1/2 500

* Range 1 is based on a diameter of 600mm.

Table 2. Targets

Target Range	Property (repair or replacement cost)	Human (not in vehicles)		Vehicle Traffic (number per day)	Ranges of Value (probability of occupation or fraction of $2 850 000)
1	$2 850 000 – >$285 000 (£1 500 000 – >£150 000)	**Occupation:** **Pedestrians & cyclists:**	Constant – 2.5 hours/day 720/hour – 73/hour	26 000 – 2 700 @ 110kph (68mph) 32 000 – 3 300 @ 80kph (50mph) 47 000 – 4 800 @ 50kph (32mph)	1/1 – >1/10
2	$285 000 – >$28 500	**Occupation:** **Pedestrians & cyclists:**	2.4 hours/day – 15 min/day 72/hour – 8/hour	2 600 – 270 @ 110kph (68mph) 3 200 – 330 @ 80kph (50mph) 4 700 – 480 @ 50kph (32mph)	1/10 – >1/100
3	$28 500 – >$2 850	**Occupation:** **Pedestrians & cyclists:**	14 min/day – 2 min/day 7/hour – 2/hour	260 – 27 @ 110kph (68mph) 320 – 33 @ 80kph (50mph) 470 – 48 @ 50kph (32mph)	1/100 – >1/1 000
4	$2 850 – >$285	**Occupation:** **Pedestrians & cyclists:**	1 min/day – 2 min/week 1/hour – 3/day	26 – 4 @ 110kph (68mph) 32 – 4 @ 80kph (50mph) 47 – 6 @ 50kph (32mph)	1/1 000 – >1/10 000
5	$285 – >$29	**Occupation:** **Pedestrians & cyclists:**	1 min/week – 1 min/month 2/day – 2/week	3 – 1 @ 110kph (68mph) 3 – 1 @ 80kph (50mph) 5 – 1 @ 50kph (32mph)	1/10 000 – >1/100 000
6	$29 – $2	**Occupation:** **Pedestrians & cyclists:**	<1 min/month – 0.5 min/year 1/week – 6/year	None	1/100 000 – 1/1 000 000

Vehicle, pedestrian and property Targets are categorised by their frequency of use or their monetary value. The probability of a vehicle or pedestrian occupying a Target area in Target Range 4 is between the upper and lower limits of 1/1 000 and >1/10 000 (column 5). Using the VOSL $2 850 000, the property repair or replacement value for Target Range 4 is $2 850- >$285.

Probability of Failure

In the QTRA assessment, the probability of tree or branch failure within the coming year is estimated and recorded as a range of value (Ranges 1 - 7, Table 3).

Selecting a Probability of Failure (PoF) Range requires the assessor to compare their assessment of the tree or branch against a benchmark of either a non-compromised tree at Probability of Failure Range 7, or a tree or branch that we expect to fail within the year, which can be described as having a 1/1 probability of failure.

During QTRA training, Registered Users go through a number of field exercises in order to calibrate their estimates of Probability of Failure.

Table 3. Probability of Failure

Probability of Failure Range	Probability
1	1/1 - >1/10
2	1/10 - >1/100
3	1/100 - >1/1 000
4	1/1 000 - >1/10 000
5	1/10 000 - >1/100 000
6	1/100 000 - >1/1 000 000
7	1/1 000 000 - 1/10 000 000

The probability that the tree or branch will fail within the coming year.

The QTRA Calculation

The assessor selects a Range of values for each of the three input components of Target, Size and Probability of Failure. The Ranges are entered on either the manual calculator or software application to calculate a Risk of Harm.

The Risk of Harm is expressed as a probability and is rounded, to one significant figure. Any Risk of Harm that is lower than 1/1 000 000 is represented as <1/1 000 000. As a visual aid, the Risk of Harm is colour coded using the traffic light system illustrated in Table 4 (page 7).

> **Risk of Harm - Monte Carlo Simulations**
>
> The Risk of Harm for all combinations of Target, Size and Probability of Failure Ranges has been calculated using Monte Carlo simulations[4]. The QTRA Risk of Harm is the mean value from each set of Monte Carlo results.
>
> In QTRA Version 5, the Risk of Harm should not be calculated without the manual calculator or software application.

Assessing Groups and Populations of Trees

When assessing populations or groups of trees, the highest risk in the group is quantified and if that risk is tolerable, it follows that risks from the remaining trees will also be tolerable, and further calculations are unnecessary. Where the risk is intolerable, the next highest risk will be quantified, and so on until a tolerable risk is established. This process requires prior knowledge of the tree manager's risk tolerance.

Accuracy of Outputs

The purpose of QTRA is not necessarily to provide high degrees of accuracy, but to provide for the quantification of risks from falling trees in a way that risks are categorised within broad ranges (Table 4).

4. INFORMING MANAGEMENT DECISIONS

Balancing Costs and Benefits of Risk Control

When controlling risks from falling trees, the benefit of reduced risk is obvious, but the costs of risk control are all too often neglected. For every risk reduced there will be costs, and the most obvious of these is the financial cost of implementing the control measure. Frequently overlooked is the transfer of risks to workers and the public who might be directly affected by the removal or pruning of trees. Perhaps more importantly, most trees confer benefits, the loss of which should be considered as a cost when balancing the costs and benefits of risk control.

When balancing risk management decisions using QTRA, consideration of the benefits from trees will usually be of a very general nature and not require detailed consideration. The tree manager can consider, in simple terms, whether the overall cost of risk control is a proportionate one. Where risks are approaching 1/10 000, this may be a straightforward balancing of cost and benefits. Where risks are 1/10 000 or greater, it will usually be appropriate to implement risk controls unless the costs are grossly disproportionate to the benefits rather than simply disproportionate. In other words, the balance being weighted more on the side of risk control with higher associated costs.

Considering the Value of Trees

It is necessary to consider the benefits provided by trees, but they cannot easily be monetised and it is often difficult to place a value on those attributes such as habitat, shading and visual amenity that might be lost to risk control.

A simple approach to considering the value of a tree asset is suggested here, using the concept of 'average benefits'. When considered against other similar trees, a tree providing 'average benefits' will usually present a range of benefits that are typical for the species, age and situation. Viewed in this way, a tree providing 'average benefits' might appear to be low when compared with particularly important trees – such as in Figure 2, but should nonetheless be sufficient to offset a Risk of Harm of less than 1/10 000. Without having to consider the benefits of risk controls, we might reasonably assume that below 1/10 000, the risk from a tree that provides 'average benefits' is ALARP.

In contrast, if it can be said that the tree provides lower than average benefits because, for example, it is declining and in poor physiological condition, it may be necessary to consider two further elements. Firstly, is the Risk of Harm in the upper part of the Tolerable Region, and secondly, is the Risk of Harm likely to increase before the next review because of an increased Probability of Failure. If both these conditions apply then it might be appropriate to consider the balance of costs and benefits of risk reduction in order to determine whether the risk is ALARP. This balance requires the tree manager to take a view of both the reduction in risk and the costs of that reduction.

[4] For further information on the Monte Carlo simulation method, refer to http://en.wikipedia.org/wiki/Monte_Carlo_method

Fig. 2

Lower Than Average Benefits from Trees
Usually, the benefits provided by a tree will only be significantly reduced below the 'average benefits' that are typical for the species, age and situation, if the life of the benefits is likely to be shortened, perhaps because the tree is declining or dead. That is not to say that a disbenefit, such as undesirable shading, lifting of a footpath, or restricting the growth of other trees, should not also be considered in the balance of costs and benefits.

The horse chestnut tree in Figure 3 has recently died, and over the next few years, may provide valuable habitats. However, for this tree species and the relatively fast rate at which its wood decays, the lifetime of these benefits is likely to be limited to only a few years. This tree has an already reduced value that will continue to reduce rapidly over the coming five to ten years at the same time as the Risk of Harm is expected to increase. There will be changes in the benefits provided by the tree as it degrades. Visual qualities are likely to reduce while the decaying wood provides habitats for a range of species, for a short while at least. There are no hard and fast measures of these benefits and it is for the tree manager to decide what is locally important and how it might be balanced with the risks.

Where a risk is within the Tolerable Region and the tree confers lower than average benefits, it might be appropriate to consider implementing risk control while taking account of the financial cost. Here, VOSL can be used to inform a decision on whether the cost of risk control is proportionate. Example 3 below puts this evaluation into a tree management context.

There will be occasions when a tree is of such minimal value and the monetary cost of risk reduction so low that it might be reasonable to further reduce an already relatively low risk. Conversely, a tree might be of such considerable value that an annual risk of death greater than 1/10 000 would be deemed tolerable.

Occasionally, decisions will be made to retain elevated risks because the benefits from the tree are particularly high or important to stakeholders, and in these situations, it might be appropriate to assess and document the benefits in some detail. If detailed assessment of benefits is required, there are several methodologies and sources of information (Forest Research 2010).

Fig. 3

Delegating Risk Management Decisions
Understanding of the costs with which risk reduction is balanced can be informed by the risk assessor's knowledge, experience and on-site observations, but the risk management decisions should be made by the tree manager. That is not to say that the tree manager should review and agree every risk control measure, but when delegating decisions to surveyors and other staff or advisors, tree managers should set out in a policy, statement or contract, the principles and perhaps thresholds to which trees and their associated risks will ordinarily be managed.

Based on the tree manager accepting the principles set out in the QTRA Practice Note and or any other specific instructions, the risk assessor can take account of the cost/benefit balance and for most situations will be able to determine whether the risk is ALARP when providing management recommendations.

Table 4. QTRA Advisory Risk Thresholds

Thresholds	Description	Action
	Unacceptable Risks will not ordinarily be tolerated	• Control the risk
1/1 000		
	Unacceptable (where imposed on others) Risks will not ordinarily be tolerated	• Control the risk • Review the risk
	Tolerable (by agreement) Risks may be tolerated if those exposed to the risk accept it, or the tree has exceptional value	• Control the risk unless there is broad stakeholder agreement to tolerate it, or the tree has exceptional value • Review the risk
1/10 000		
	Tolerable (where imposed on others) Risks are tolerable if ALARP	• Assess costs and benefits of risk control • Control the risk only where a significant benefit might be achieved at reasonable cost • Review the risk
1/1 000 000		
	Broadly Acceptable Risk is already ALARP	• No action currently required • Review the risk

QTRA Informative Risk Thresholds

The QTRA advisory thresholds in Table 4 are proposed as a reasonable approach to balancing safety from falling trees with the costs of risk reduction. This approach takes account of the widely applied principles of ALARP and ToR, but does not dictate how these principles should be applied. While the thresholds can be the foundation of a robust policy for tree risk management, tree managers should make decisions based on their own situation, values and resources. Importantly, to enable tree assessors to provide appropriate management guidance, it is helpful for them to have some understanding of the tree owner's management preferences prior to assessing the trees.

A Risk of Harm that is less than 1/1 000 000 is Broadly Acceptable and is already ALARP. A Risk of Harm 1/1 000 or greater is unacceptable and will not ordinarily be tolerated. Between these two values, the Risk of Harm is in the Tolerable Region of ToR and will be tolerable if it is ALARP. In the Tolerable Region, management decisions are informed by consideration of the costs and benefits of risk control, including the nature and extent of those benefits provided by trees, which would be lost to risk control measures.

For the purpose of managing risks from falling trees, the Tolerable Region can be further broken down into two sections. From 1/1 000 000 to less than 1/10 000, the Risk of Harm will usually be tolerable providing that the tree confers 'average benefits' as discussed above. As the Risk of Harm approaches 1/10 000 it will be necessary for the tree manager to consider in more detail the benefits provided by the tree and the overall cost of mitigating the risk.

A Risk of Harm in the Tolerable Region but 1/10 000 or greater will not usually be tolerable where it is imposed on others, such as the public, and if retained, will require a more detailed consideration of ALARP. In exceptional circumstances a tree owner might choose to retain a Risk of Harm that is 1/10 000 or greater. Such a decision might be based on the agreement of those who are exposed to the risk, or perhaps that the tree is of great importance. In these circumstances, the prudent tree manager will consult with the appropriate stakeholders whenever possible.

5. EXAMPLE QTRA CALCULATIONS AND RISK MANAGEMENT DECISIONS

Below are three examples of QTRA calculations and application of the QTRA Advisory Thresholds.

Example 1.

	Target		Size		Probability of Failure		Risk of Harm
Range	6	x	1	x	3	=	<1/1 000 000

Example 1 is the assessment of a large (Size 1), unstable tree with a probability of failure of between 1/100 and >1/1 000 (PoF 3). The Target is a footpath with less than one pedestrian passing the tree each week (Target 6). The Risk of Harm is calculated as less than 1/1 000 000 (green). This is an example of where the Target is so low consideration of the structural condition of even a large tree would not usually be necessary.

Example 2.

	Target		Size		Probability of Failure		Risk of Harm
Range	1	x	4	x	3	=	1(2T)/50 000

In Example 2, a recently dead branch (Size 4) overhangs a busy urban high street that is on average occupied constantly by two people, and here Multiple Target occupation is considered.

Having an average occupancy of two people, the Risk of Harm 1(2T)/50 000 (yellow) represents a twofold increase in the magnitude of the consequence and is therefore equivalent to a Risk of Harm 1/20 000 (yellow). This risk does not exceed 1/10 000, but being a dead branch at the upper end of the Tolerable Region it is appropriate to consider the balance of costs and benefits of risk control. Dead branches can be expected to degrade over time with the probability of failure increasing as a result. Because it is dead, some of the usual benefits from the branch have been lost and it will be appropriate to consider whether the financial cost of risk control would be proportionate.

Example 3.

	Target		Size		Probability of Failure		Risk of Harm
Range	3	x	3	x	3	=	1/500 000

In Example 3, a 200mm diameter defective branch overhangs a country road along which travel between 470 and 48 vehicles each day at an average speed of 50kph (32mph) (Target Range 3). The branch is split and is assessed as having a probability of failure for the coming year of between 1/100 and 1/1 000 (PoF Range 3). The Risk of Harm is calculated as 1/500 000 (yellow) and it needs to be considered whether the risk is ALARP. The cost of removing the branch and reducing the risk to Broadly Acceptable (1/1 000 000) is estimated at $665. To establish whether this is a proportionate cost of risk control, the following equation is applied. $2 850 000 (VOSL) × 1/500 000 = $5.7 indicating that the projected cost of $665 would be disproportionate to the benefit. Taking account of the financial cost, risk transfer to arborists and passers-by, the cost could be described as being grossly disproportionate, even if accrued benefits over say ten years were taken into account.

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