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LAMAN STREET FIGS, COOKS HILL NEWCASTLE

QUANTIFIED TREE RISK ASSESSMENT & REVIEW

JULY 2010

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17/02/10	Issued to client for comment	AS	AS
09/03/10	Final Report Issue	AS	AS
23/06/10	Reviewed Calculations with new inputs	AS	AS
01/07/10	Final Issue - Amended following client comments	AS	AS

Executive Summary

This report provides a revision of the QTRA assessment previously prepared in March 2010. The Newcastle City Council (NCC) originally commissioned Adrian Swain QTRA Licence Number 1472 with the following brief:

1. The review of the following four documents;

   a) An Arboricultural Statement titled Quantified Tree Risk Assessment, Fig trees in Laman Street, Cooks Hill – Newcastle, prepared by Dean Simonsen, Treelogic P/L, 02/09/09.

   b) A memo titled Civic Precinct – Laman Street Fig Trees – Quantified Tree Risk Assessment (QTRA), prepared by the Director Liveable City - Frank Cordingly, NCC, 08/12/10. (with included enclosures of; a) (above); and an additional email as sent by Dean Simonsen Treelogic P/L 26/11/09).

   c) A memo titled Civic Precinct – Laman Street Fig Trees – Risk Management Update, prepared by the Director Liveable City - Frank Cordingly, NCC, 17/12/10.

   d) The Laman Street, Cooks Hill Newcastle Traffic Control Plan prepared by NCC, 23/12/09.

   The revised brief now also requires the review of the following two documents:

   e) Documentation - Parked Vehicles After Hours - Laman Street Cooks Hill prepared by NCC, on the 29/04/10, 24/05/10, 27/05/10, 01/06/10, 02/06/10, & the 03/06/10.

   f) Photo - Laman St Barricade Removal - Laman Street Cooks Hill prepared by NCC, 4 June 2010.

2. Conduct a revised QTRA for the Laman Street Cultural Precinct trees having regard for the following:

   a) Risk management strategies as at 12/01/10.

   This revised report now also has regard for the following:

   b) The use of Laman Street for extended vehicle parking contrary to the posted 5 min parking restriction.

   c) Pedestrian and vehicle access to restricted areas during high risk weather events and when risk management strategies are implemented (including barricade removal during high risk weather events).

   d) Creating 30 minute parking and a loading zone in Laman Street.

The following recommendations are based on the review of supplied documentation, and our interpretation of the QTRA system.

I specifically recommend that the subject trees be retained until a suitable replacement strategy is approved and implemented. However this is conditional on amendment to the risk management plan to ensure targets are excluded from the target area at times of high risk ie. predicted mean wind speeds greater than 50km p/h.

Consideration should also be given to the following:

- The installation of temporary barriers during high risk times that exclude both pedestrians and vehicles from the target area, which are not able to be removed.

- Permanent road closure to ensure vehicles are excluded from the target area out of hours.

- Increase patrols from NCC compliance officers to ensure infringement notices are issued to those disobeying posted signs.

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1. Introduction

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   d) Creating 30 minute parking and a loading zone in Laman Street.

2. Methodology

2.1. Limitations

Care has been taken to obtain all information from reliable sources. All data has been verified as far as possible. However Adrian Swain - Consulting Arborist can neither guarantee nor be responsible for the accuracy of information provided by others. Unless stated otherwise:

- Information contained in this report covers only the tree/'s examined and reflects the health and structure of the tree at the time of inspection. The documented, observations, results, recommendations and conclusions given may vary after the site visit due to environmental conditions. Liability will not be accepted for damage to person or property as a result of natural processes, unforeseeable actions or occurrences.

- The inspection was limited to visual examination from the base of the subject tree without dissection, excavation, probing or coring; and

- There is no warranty or guarantee, expressed or implied, that problems or deficiencies of the subject tree may not arise in the future.

2.2. Site Inspection

A visual inspection of the tree/s' was performed from ground level on the 04/12/09, data collected includes:

- Genus, Species, Common Name;
- Height, Width, DBH (Diameter at Breast Height);
- Age and Health;
- Amenity or Ecological Value;
- Crown Form and Condition;
- Visible Defects or Evidence of Wounding.

2.3. Measurement

- Tree locations are supplied on the client supplied survey plan or triangulated using a measuring tape.
- Diameter at breast height (DBH) is measured using a diameter tape.
- Height is measured using a clinometer.
- Canopy width is measured using a measured stride paced out on site.

2.4. Quantified Tree Risk Assessment (QTRA)

The Quantified Tree Risk Assessment system quantifies three components of the tree failure risk:

1. Target;
2. Impact potential;
3. Probability of failure.

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

A risk of significant harm or death of 1/10,000 is considered by some authorities to be the limit of acceptable risk to the public at large. Using the 1/10,000 limit, a risk of death 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, the tree might confer benefits that could be set against the risk of harm. The 1/10,000 threshold is not intended to be applied absolutely rigidly but necessarily includes a degree of flexibility. For further information see **6. QTRA Australian Practice Notes** (page 16).

2.5. Desktop Review

The report is written following the review of the following documents:

- Assessment of Hill's Weeping Figs Ficus Macrocarpa var. hilli, In Civic Cultural Precinct, Laman Street Cooks Hill, Newcastle prepared by Denis Marsden, the Sugar Factory 07/08/09
- QTRA Arboricultural Statement prepared by Sean Simonsen, Tree Logic - 02/09/09
- Memo Civic Precinct – Laman Street Fig Trees – Quantified Tree Risk Assessment (QTRA) Prepared by Frank Cordingley NCC 08/12/09
- Memo Civic Precinct – Laman Street Fig Trees – Risk Management Update Prepared by Frank Cordingley NCC 17/12/09
- Laman Street Traffic Control Plan – prepared by NCC 23/12/09
- GPR Root Mapping Investigation Report – prepared by GBG Australia 19/02/10
- Documentation - Parked Vehicles After Hours - Laman Street Cooks Hill prepared by NCC, on the 29/04/10, 24/05/10, 27/05/10, 01/06/10, 02/06/10, & the 03/06/10.
- Photo - Laman St Barricade Removal - Laman Street Cooks Hill prepared by NCC, 4 June 2010.

3. Observations

3.1. Assessment of Hill's Weeping Figs *Ficus Macrocarpa var. hilli,* In Civic Cultural Precinct, Laman Street Cooks Hill, Newcastle prepared by Denis Marsden, the Sugar Factory 07/08/09

A recent (11/12/09) peer review of Report was prepared by Adrian Swain of this report. The report relates the casebook history of recent failures of Hills Figs in the Newcastle area.

The report assesses specifically the Laman St., Cooks Hill Figs and was prepared following recent failures of trees in that street. The report identifies similar defects within the remaining trees highlighting that these trees are classified as being of high risk of failure specifically under certain weather conditions.

This report identifies that the Hills Figs on Laman St, Cooks Hill Generally have restricted or linear root plates and are more likely to fail from root plate failure when exposed to prevailing winds greater than 100km/h.

3.2. QTRA Arboricultural Statement prepared by Sean Simonsen, Tree Logic - 02/09/09

The QTRA Statement was prepared following the preparation of the Sugar Factor report (above) to provide a quantified assessment of the risk of harm to people or property using the QTRA system for the subject trees. This report identified a risk of harm of 1:19.8.

3.3. Memo Civic Precinct – Laman Street Fig Trees – Quantified Tree Risk Assessment (QTRA) Prepared by Frank Cordingley NCC 08/12/09

This memo identifies that on the 26th November Dean Simonsen (Tree Logic) provided additional information which considered a risk abatement plan prepared by NCC and advice was provided that indicates a slightly reduced risk of harm of 1:78 stating in an email that "when winds reach over 80kmh (and you implement the barricades) there should technically be no people in the vicinity of trees .... However the probability of failure would remain the same." Hence the updated QTRA indicates a probability of significant harm of 1:78.

3.4. Memo Civic Precinct – Laman Street Fig Trees – Risk Management Update Prepared by Frank Cordingley NCC 17/12/09

This memo identifies the risk management strategy to be employed to manage the risk of tree failure as follows:

1. Risk of tree failure in moderate wind combined with rain:

Council has undertaken the following risk mitigation works:

- The closure of Laman Street to all east bound traffic;
- The elimination of parking on Laman Street except for some disabled parking outside the Library and Art Gallery (where the risk minimal, due to absence of trees) and two drop off sites with 15 minute parking;
- The removal of seating from the anticipated failure target areas in Civic Park;
- The installation of signs warning people not to shelter under the trees at any time and particularly during wind or rain;
- The installation of warning signs in the garden beds fronting Civic park warning people not to sit or stand there;
- The closure of the mezzanine level footpath in the garden bed between Laman Street and Civic park;
- Advise staff from the Library, Art Gallery and Place Management on the risks and how to minimise them;
- Advise staff who arrange events in Civic Park of the risks and required actions and have this incorporated into any licences;
- The modification and the supply of extra signs in the park and Laman Street to warn of risks.

2. In high wind:

Council has implemented a traffic control plan which allows for the closure of Laman Street to vehicles and pedestrians on the northern footway as per NCC Laman Street Traffic Control Plan (detailed below).

3.5. Ground Penetrating Radar Investigation – prepared by GBG Australia 19/02/10

The GPR Root Mapping Investigation Report attempts to ascertain the location of tree roots located within the Laman Street, Cooks Hill road reserve. Root investigations had previously been undertaken within the roadway, by excavating with an air knife under the supervision of Consulting Arborist Denis Marsden.

Unfortunately there is a distinct non – correlation with the data supplied when compared to the data collected during the previous root mapping investigations ie.

the GPR report indicates that there are roots where previously it had been demonstrated they were not.

There is however a general lack of roots indicated within the roadway, rather a predominance of roots are indicated to be located within the pedestrian or footpath areas.

3.6. Laman Street Traffic Control Plan – prepared by NCC 23/12/09

The Traffic Control Plan schematically describes the traffic control measures as proposed by NCC. The measures require the closure of Laman Street in strong winds and rain. The closure is triggered by SMS alert for mean wind speeds greater than 50kph and for storm/gale warnings.

The plan also details the permanent closure of eastbound Laman Street to vehicular traffic as well as the temporary signage/ barrier boards required to:

- Close westbound Laman Street to vehicular traffic.
- Close the northern footway to pedestrian traffic.
- Close the pedestrian access paths linking Civic Park to Laman Street.

3.7. Documentation - Parked Vehicles After Hours - Laman Street Cooks Hill prepared by NCC, on the 29/04/10, 24/05/10, 27/05/10, 01/06/10, 02/06/10, & the 03/06/10

This document records car parking observations made by Council staff monitoring the Laman Street site after hours. Observations include the number of vehicles parked, the positions in which the vehicles were parked, the date and time the observations were made and the direction the vehicles were facing.

Additionally the NCC Urban Trees Coordinator has advised that each time the road closure has occurred (refer to **3.6. Laman Street Traffic Control Plan – prepared by NCC 23/12/09** (page 9) pedestrians have been observed walking under and around installed barricades.

3.8. Photo - Laman St Barricade Removal - Laman Street Cooks Hill prepared by NCC, 4 June 2010

On June 4 to June 6 2010 the Laman Street risk management strategy - contingency plan was enacted and Laman Street was closed due to a strong wind warning (predicted mean wind speeds in excess of 50kph).

The Urban Trees Coordinator arrived on Saturday morning 5 June 2010 to find that the barricades had been moved and barrier tape for pedestrians pulled down and removed.

This photo also details that vandalism to risk management signage and structures was observed and that council officers received abuse from members of the public ignoring the road closure.

3.9. Loading and un loading vehicles in Laman Street.

It has been observed through anecdotal advice that currently delivery vehicles use Laman Street to make deliveries as there is no alternative access or rear loading dock to the Library or Art Gallery.

Delivery vehicles unload from Laman Street in the front of the Library for periods of 10 minutes at a time around 6 times a day.

Delivery vehicles unload from Laman Street in front of the Art Gallery monthly when an exhibition is delivered and again when it is removed. Unloading and Loading usually takes approximately 2 hours.

Effectively vehicles are parked whilst loading on Laman Street 2 days per month.

4. Discussion

4.1. QTRA Arboricultural Statement prepared by Sean Simonsen, Tree Logic - 02/09/09

This report identified a risk of harm of 1:19.8 which is considered significantly high when compared to a generally accepted 1:10000 risk of harm. On review I believe that this report provides a reasonable assessment of the quantified risk of harm associated with the subject trees.

4.2. Memo Civic Precinct – Laman Street Fig Trees – Quantified Tree Risk Assessment (QTRA) Prepared by Frank Cordingley NCC 08/12/09

The memo considered the NCC risk abatement plan and indicates a risk of harm of 1:78.

Justification is provided as “when winds reach over 80kmh (and you implement the barricades) there should technically be no people in the vicinity of trees .... However the probability of failure would remain the same." Hence the updated QTRA indicates a probability of significant harm of 1:78.

I disagree with this statement and recognise that it is taken anecdotally without documented methodology.

4.3. Memo Civic Precinct – Laman Street Fig Trees – Risk Management Update Prepared by Frank Cordingley NCC 17/12/09

The memo identifies the implementation of risk management measures for Laman Street. I believe these measures are reasonable and appropriate given the circumstances and constraints associated with the site.

4.4. GPR Root Mapping Investigation– prepared by GBG Australia 19/02/10

It has been noted that the data collected by the Ground Penetrating Radar does not correlate with actual root distribution as found when previously excavated. In approximately 85% of instances where trenches had been excavated the data does not correlate.

The data does however indicate a predominance of roots within the pederstrian footpath areas. When combined with personal observations of the site, evidence provided of past root investigations and mapping undertaken with the use of an air knife excavation

4.5. Laman Street Traffic Control Plan – prepared by NCC 23/12/09

I believe these measures are reasonable and appropriate given the circumstances and constraints associated with the site.

4.6. Documentation - Parked Vehicles After Hours - Laman Street Cooks Hill prepared by NCC, on the 29/04/10, 24/05/10, 27/05/10, 01/06/10, 02/06/10, & the 03/06/10

This document demonstrates that vehicles have parked in no stopping zones contrary to posted "No Stopping" signage on no less than 6 occasions. It also demonstrates a general trend for vehicles to be parked facing the wrong way in a one way street. The site has been used for parking on many occasions by one or more cars for extended periods.

An option to rectify this identified risk management issue would require the provision of more frequent patrols by traffic officers to issue infringement notices to cars disobeying posted signs. Another option could be to close the street permanently for vehicular traffic. Both options have wider reaching issues which extend beyond this reports scope, however both would assist with risk management.

The resulting implication of the ignorance of posted parking and access restrictions is that targets are not being restricted from the target area. As such the risk management measures would be considered to be negated.

The QTRA calculation located at **4.9. QTRA Calculations - revised** (page 12) allows for the increased targets within the target zone during high risk weather events.

4.7. Photo - Laman St Barricade Removal - Laman Street Cooks Hill prepared by NCC, 4 June 2010

This document demonstrates that members of the public are ignoring the risk management measures in times of high risk. In some cases also the risk management measures are being sabotaged.

The resulting implications of the documented sabotage, vandalism and ignorance is that other members of the public may unknowingly enter the area during high risk periods. As such the risk management measures would be considered to be negated.

The QTRA calculation located at **4.9. QTRA Calculations - revised** (page 12) allows for the increased targets within the target zone during high risk weather events.

4.8. Creating 30 minute parking and a loading zone in Laman Street.

A request has been made regarding the possibility of changing the existing 5 minute parking located in Laman Street in front of the Art Gallery to 30 minute parking and creating a Loading Zone as close as possible to the main entrance to the Library.

Effectively these changes will allow and / or encourage targets to enter and linger within the target zone, contrary to the risk abatement strategy.

It has been demonstrated that Laman Street is required to be utilised for the loading and unloading of deliveries for both the Library and the Art Gallery due to a lack of alternative loading dock or entrance.

A hypothetical calculation of the QTRA for this scenario in Laman Street is included at **4.10. QTRA Calculations - with modified parking** (page13).

4.9. QTRA Calculations - revised

These revised calculations take into account the following:

- Members of the public can, have and will access the target area in times of high risk.
- Members of the public will park vehicles in the target area contrary to posted signs.
- Vehicles need to enter the target area to make deliveries on a regular basis.

4.9.1. Target Evaluation (TE)

Having reviewed evidence of how the general public has responded to the risk management measures as implemented, we know that:

- Vehicle and pedestrian traffic has been partially removed from the target area during times of high risk. The extent of removal is dependent on greater policing of exclusion measures and / or more robust immovable exclusion structures being installed as required and / or permanent exclusion structures being installed.
- Vehicle and pedestrian traffic is partially deterred or restricted at other times. The extent of deterrent or restriction is dependent on greater policing of deterrent or restriction measures and / or more robust immovable exclusion structures being installed as required and / or permanent exclusion structures being installed.
- Occupants are made aware of the hazard associated with entering the target area (during storms and high winds) periods of high risk.
- Pedestrian traffic and / or prolonged use ie. seating or parking has been discouraged and or restricted from the target area.

We must consider that pedestrian and vehicle targets are now known to be not fully excluded from the target area during times of high risk.

The Target Evaluation would be a high value > 10 pedestrians per hour or 1/20.

4.9.2. Impact Potential (IP)

When considering the impact potential of the subject trees we considered that the whole tree is likely to fail as root plate failure. However when considering the impact potential we also considered the surrounding environment (ie. adjacent tree canopies and buildings providing support to a potentially failing tree and cushioning impacts).

Whilst it could be considered that the part of the tree likely to cause harm to people or property could be 600mm it is fair to assume that it is more likely to be scaffold branches or branches in the outer canopy which will impact targets.

The Impact potential would be considered to be in the 250-450mm category or 1/2.

4.9.3. Probability of Failure (PoF)

The probability of failure in the next calendar year for the subject trees is moderate in my opinion. The basis for this statement is that the recent failures during instances of high wind and storms has removed those trees most prone to failure. Although some of the remaining trees are now exposed by the loss of adjoining tree canopy, these remaining trees are generally more protected from prevailing winds by the library and Art Gallery Buildings. The trees which have failed previously have tended to be those trees most exposed to prevailing winds.

The loss of failed trees has in effect removed some canopy support and created additional exposure to wind loading for the remaining adjacent trees. The remaining trees however are generally more sheltered from the prevailing southerly winds by the adjacent buildings than those which have previously failed.

Notwithstanding casebook history of failures of similar trees in the area, and the knowledge we have of the remaining root plates these trees have a reasonable probability of failure however it is in my opinion less than those previously failed.

The Probability of Failure would be considered to be Moderate or 1/10.

4.9.4. Risk of Harm (RoH)

1/20 (TE) x 1/2 (IP) x 1/10 (PoF) = 1/400 (ROH)

The calculated risk of harm is not within an acceptable limit of 1/10,000 (as prescribed by the British Health and Safety Executive).

4.10. QTRA Calculations - with modified parking

These revised calculations take into account the following:

- Parking for extended periods (ie. 30min) and a designated loading and unloading area will be created and therefore encouraging targets into the target area.
- Members of the public can, have and will access the target area in times of high risk.
- Members of the public will park vehicles in the target area contrary to posted signs.
- Vehicles need to enter the target area to make deliveries on a regular basis.

4.10.1. Target Evaluation (TE)

Having reviewed evidence of how the general public has responded to the risk management measures as implemented, we know that:

- Vehicle and pedestrian traffic has been partially removed from the target area during times of high risk. The extent of removal is dependent on greater policing of exclusion measures and / or more robust immovable exclusion structures being installed as required and / or permanent exclusion structures being installed.
- Vehicle and pedestrian traffic is not deterred or restricted at other times.
- Occupants are made aware of the hazard associated with entering the target area (during storms and high winds) periods of high risk.
- Pedestrian traffic and or prolonged use ie. seating has been discouraged and or restricted from the target area.

We must consider that pedestrian and vehicle targets are now known to be not fully excluded from the target area during times of high risk. Additionally targets are to be encouraged to dwell within the target area for extended periods by parking or loading or unloading vehicles at other times.

The Target Evaluation would be a very high value or 1/1.

When considering the impact potential of the subject trees we considered that the whole tree is likely to fail as root plate failure. However when considering the impact potential we also considered the surrounding environment (ie. adjacent tree canopies and buildings providing support to a potentially failing tree and cushioning impacts).

Whilst it could be considered that the part of the tree likely to cause harm to people or property could be 600mm it is fair to assume that it is more likely to be scaffold branches or branches in the outer canopy which will impact targets.

The Impact potential would be considered to be in the 250-450mm category or 1/2.

4.10.2. Probability of Failure (PoF)

The probability of failure in the next calendar year for the subject trees is moderate in my opinion. The basis for this assessment is that given the recent failures in high wind and storms has removed those trees most likely to fail. The remaining trees are less exposed to prevailing winds, due to the protection afforded by adjacent library and gallery buildings and also from the adjacent trees located on Laman Street and within Civic Park.

Although the removal of failed trees would expose the remaining adjacent trees to new stresses, these remaining trees however are sheltered from the prevailing southerly winds.

Notwithstanding casebook history of failures of similar trees in the area, and the knowledge we have of the remaining root plates these trees have a reasonable probability of failure however it is in my opinion less than those previously failed.

The Probability of Failure would be considered to be Moderate or 1/10.

4.10.3. Risk of Harm (RoH)

1/1 (TE) x 1/2 (IP) x 1/10 (PoF) = 1/20 (ROH)

The calculated risk of harm is not within an acceptable limit of 1/10,000 (as prescribed by the British Health and Safety Executive).

5. Recommendations

The following recommendations are based on the review of supplied documentation, and our interpretation of the QTRA system.

I specifically recommend that the subject trees be retained until a suitable replacement strategy is approved and implemented. However this is conditional on amendment to the risk management plan to ensure targets are excluded from the target area at times of high risk ie. predicted mean wind speeds greater than 50km p/h.

Consideration should also be given to the following:

- The installation of temporary barriers during high risk times that exclude both pedestrians and vehicles from the target area, which are not able to be removed.

- Permanent road closure to ensure vehicles are excluded from the target area out of hours.

- Increase patrols from NCC compliance officers to ensure infringement notices are issued to those disobeying posted signs.

6. QTRA Australian Practice Notes

Quantified Tree Risk Assessment Practice Note

1. INTRODUCTION

For a tree-failure hazard to exist, two criteria must be fulfilled. There must be potential for failure of the tree, and potential for injury or damage to result. The tree owner or manager needs to consider the likelihood of a combination of tree failure, people and property resulting in harm, and the likely severity of the harm.

The system enables tree assessors to allocate numerical estimates of risk, which can be compared with a generally accepted level of risk.

2. DEFINITION OF TERMS

Risk of Significant Harm

The risk of significant harm from tree failure is an estimate of the likelihood that within the coming year something of significant value will be lost or substantially harmed by tree failure.

Acceptable Risk

We are constantly exposed to and accept risks of varying degrees. For example, if we desire the convenience of electric lighting, we must accept that, having implemented control measures such as insulation, there remains a low risk of electrocution; this is an everyday risk taken and accepted by millions of people.

Having considered The British Medical Association Guide "Living With Risk" (1987) and with particular reference to the conclusion "*few people would commit their own resources to reduce an annual risk of death that was already as low as 1/10,000*", Helliwell (1990) suggests that 1/10,000 might be a suitable figure to start with as the limit of acceptable risk from tree failure. Furthermore, "*For members of the public who have a risk imposed on them 'in the wider interest' HSE (Health and Safety Executive) would set this limit at 1/10,000 per annum*" (Health and Safety Executive 1996). A tree owner or manager may adopt the 1/10,000 limit of acceptable risk or choose to operate to a higher or lower level.

Cost and Benefit

Trees confer many benefits, being essential to our well being and generally enhancing our built and natural environments. It can therefore be assumed that removal of all tree hazards would lead to certain impoverishment in the quality of human life. It is essential to maintain a balance between the benefits and costs of risk reduction, not only financial cost but also loss of amenity and other tree related benefits.

Value of Statistical Life

'Value of statistical life' is a term used in risk assessment to express the monetary value of an individual life, which is used to apportion resources to risk reduction. In the UK, this value is currently in the region of £750,000 - £1,000,000, (Health and Safety Executive 1995) and is used in Quantified Tree Risk Assessment to correlate the value of damage to property with the value of human life e.g. risk of death 1/2 is equivalent to a loss of property with a value of £500,000.

3. OWNERSHIP OF RISK

Where a risk is being considered in relation to the public at large, the risk of significant harm is a measure of how likely it is that a death or significant harm will result from failure of the tree. This risk usually affects many, largely anonymous, individuals. In these situations the tree owner/manager must make an informed decision and some level of risk will be imposed upon the wider public in the wider interest, unless the tree is removed.

Where the risk of harm relates to a specific individual or a select group of people, those at risk can be identified. Where the individuals otherwise have no control over their exposure to the risk (as with a tree leaning towards a dwelling on neighbouring land) it might, in some situations, be reasonable to allow the exposed person/s to input their views to the risk management process.

4. QUANTIFIED TREE RISK ASSESSMENT

The system quantifies three components of the tree failure risk - 1) target 2) impact potential and 3) probability of failure. The product of these component probabilities is referred to as the 'Risk of Significant Harm'.

A risk of death 1/10,000 is considered by some authorities to be the limit of acceptable risk to the public at large where it is imposed in the wider interest (Health and Safety Executive 1996). Using the 1/10,000 limit, a risk of death 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, the tree might confer benefits that could be set against the risk of harm. The 1/10,000 threshold is not intended to be applied absolutely rigidly but necessarily includes a degree of flexibility.

Target Evaluation

A target is anything of value that could be harmed in the event of tree failure. Frequent assessment of trees and of associated risks may be essential in areas of high public access or where trees are within striking range of people or valuable property. Conversely, in locations without property and having very low public access, the survey and assessment of tree hazards may be unnecessary. Therefore, the nature of the target beneath or adjacent to a tree should dictate the level of risk assessment that is required.

Vehicle and pedestrian targets and the value of damage to property are combined in Table 1. In the case of vehicles, probability of occupation may relate either to the tree part striking the vehicle or the vehicle striking the fallen tree part. 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. 'Stopping distances' and an average vehicle length are used in the calculation of vehicle occupation of highways. The probability of a vehicle occupying any point in the road is the ratio of the time a point in the road is occupied by vehicles - including safe stopping distance - to the time in a day.

The probability of pedestrians occupying a target is calculated on the basis that an individual will spend, on average, five seconds occupying the average target area, unless a longer occupation is likely as with a habitable structure, outdoor café or park bench. For example, ten pedestrians per day each occupying the target for five seconds is a daily occupation of fifty seconds, by which the total seconds in a day are divided to give a probability of target occupation (50/86,400 = 1/1,728).

When evaluating target property, it is necessary to consider the approximate cost of repairs or replacement that might be required if the tree or branch under consideration should fail. The values in Table 1 represent the likely cost of repair or replacement. Quantified Tree Risk Assessment Ltd. provides Licensed Users of the system with annual monetary conversion rates that enable application of the system internationally.

The ranges of monetary value for property used in Table 1 are derived from a value of "hypothetical life" of £1,000,000. For example, Target Range 2 represents a probability of pedestrian occupation up to 1/20; £1,000,000 ÷ 20 = £50,000. Thus, property likely to incur a repair cost of £50,000, which is one-twentieth the value of a hypothetical life, is apportioned a ratio of 1/20.

Targets will ordinarily be recorded in the survey as a range (1-6 Table 1), but may be more accurately calculated and recorded as a ratio where circumstances dictate.

Often the nature of the defect is such that probability of failure is greater during windy weather, whilst the probability of the site being occupied during such weather conditions is considerably reduced, e.g. woodland, park or private garden, thus reducing the risk of harm from tree failure. Conversely risks may be increased by weather such as in case of the phenomenon known as 'Summer Branch Drop', which is the shedding of branches in some tree species during hot dry weather when in some settings the likelihood of people being beneath the tree might be increased. In both of these situations we might apply a 'Weather Factor' to our calculation, which is a fraction that represents the combined effects of weather on site usage and on tree failure in reducing or increasing the 'Risk of Significant Harm'

e.g. a 'Weather Factor' of 1/2 has the effect of reducing the 'Risk of Significant Harm' by half.

Target Range	Property (repair or replacement costs)*	Pedestrian Frequency	Vehicular Frequency examples	Probability Ratio (of occupation or fraction of value of $1,796,000)
1	Very high value >$89,800 - $1,796,000	>36 per hour - constant	26,102 vehicles @ 110kph (68mph) 32,359 vehicles @ 80kph (50mph) 46,702 vehicles @ 50kph (32mph)	1/1
2	High value >$24,943- $89,800	>10 per hour - 36 per hour	1,305 vehicles @ 110kph (68mph) 1,617 vehicles @ 80kph (50mph) 2,335 vehicles @ 50kph (32mph)	1/20
3	Moderate - high value $2,493 - $24,943	>1 per hour - 10 per hour	363 vehicles @ 110kph (68mph) 449 vehicles @ 80kph (50mph) 649 vehicles @ 50kph (32mph)	1/72
4	Moderate value >$103.93 - $2,493	>1 per day - 1 per hour	36 vehicles @ 110kph (68mph) 45 vehicles @ 80kph (50mph) 65 vehicles @ 50kph (32mph)	1/720
5	Low value >$15.45 - $103.93	> 1 per week - 1 per day	1.5 vehicles @ 110kph (68mph) 1.87 vehicles @ 80kph (50mph) 2.7 vehicles @ 50kph (32mph)	1/17,280
6	Very low value ≤ $15.45	≤ 1 per week	None	1/120,960

Table 1. 'Target' ranges for property, pedestrians and vehicles.

Vehicular, pedestrian and property targets are categorised by their frequency of use or their monetary value. For example, the probability of a vehicle or pedestrian occupying a target area in 'Target' range 4 is between the lower and upper limits of >1/17,280 and 1/720. Using the value of a 'Hypothetical Life' of $1,796,000 (£1,000,000) the structure value within the 'Target' range 4 is >$103.93-$2,493.

Vehicular frequency examples for 'Target' range 1 are calculated on the basis of the stopping distance for a given road speed providing a duration of occupation for the average vehicle on that road. The total time in a day is divided by the duration of occupation with the quotient being the number of vehicles per day required to produce constant occupation. All other 'Target' ranges are calculated as a proportion of the 'Target' range 1 value e.g. 'Target' range 2 (probability ratio 1/20) 26,102/20 = 1305.1.

* Property values represent the likely cost of repair or replacement.

Impact Potential

A small dead branch of less than 10mm diameter is unlikely to cause significant harm even in the case of direct contact with a target, whilst on average a falling branch with a diameter greater than 150mm is likely to cause harm in the event of contact with all but the most robust target. The increased potential for injury in relation to the size of tree or branch is proportional to a degree, yet the tree or branch will reach a size where the increased severity of injury is no longer proportional to the increase in size. Similarly, most property likely to be affected by tree failure can incur only a limited level of damage before further damage is likely to be inconsequential, i.e. when it is beyond economic repair.

The system categorises 'Impact Potential' by the diameter of tree stems and branches. A biomass equation derived from weight measurements of trees of different stem diameters is used to produce a data set (Table 2) of comparative weight estimates of trees and branches ranging from 10 to 600mm diameter. An upper limit of 600mm has been selected to represent a 1/1 'Impact Potential' on the premise that impact from a tree with a stem diameter of 600mm has a 1/1 probability of causing maximum possible damage to most frequently encountered targets. From this point, the Impact Potential reduces to 1/23,500 for a 10mm branch or tree. For initial assessments the probabilities are grouped into ranges 1-5 (Table 3). '

Dbh (mm)	Dry weight (kg) $y=ax^b$	Fraction of dry weight as a ratio
10	0.11263	1/23,505.722
25	1.0713	1/2,471.6699
50	5.8876	1/449.74
100	32.357	1/81.834
150	87.67	1/30.203
200	177.82	1/14.891
250	307.77	1/8.604
300	481.81	1/5.496
350	703.8	1/3.762
400	977.26	1/2.71
450	1305.5	1/2.03
500	1691.4	1/1.566
550	2138	1/1.24
600	2647	1/1

Table 2. Biomass weight estimates.
Source. Tritton & Hornbeck (1982)
x=dbh (mm); y=dry weight estimate; a=allometric coefficient 0.1126294414;
b= allometric coefficient 2.458309949
Dbh (US - diameter measured at breast height – 1.37 metres)

Impact potential range	Size of part likely to impact target	Impact Potential
1	> 450mm (18") dia.	1/1
2	> 250mm (10") dia.- 450mm (18") dia.	1/2
3	>100mm (4") dia.- 250mm (10") dia.	1/8.6
4	> 25mm (1") dia.- 100mm (4") dia.	1/82
5	10mm ($^2/_5$") dia.- 25mm (1") dia.	1/2500

Table 3. Impact Potential.
* Range 1 is based on a diameter of 600mm.

Probability of Failure

The Probability of Failure component of the system provides five ranges. Each range represents a range of probability of failure occurring within a year, expressed as a ratio calculated from the upper value of that range. Probability of failure will ordinarily be recorded in the tree survey schedules as a range (1-5 Table 4), but may be more accurately evaluated and recorded as a ratio where circumstances dictate.

Probability of failure range	Probability of failure percentage	Probability ratio
1	>10% - 100%	1/1
2	> 1% - 10%	1/10
3	> 0.1% - 1%	1/100
4	>0.01% - 0.1%	1/1,000
5	≤ 0.01%	1/10,000

Table 4. Probability of Failure.
The probability that the tree or selected tree-part will fail within a year.

Example

A 25.0 metre high, mature oak tree (*Quercus robur*), stem diameter 900mm (36"), in a low use area of woodland with no regular access within 30.0 metres but members of the public occasionally enter the target area. There is extensive heartwood decay and axial splitting in the main stem and the tree is highly unstable. The most significant part likely to strike the target area is the stem or part of the crown with the weight of the whole tree behind it.

	Target		Impact Potential		Probability of Failure		Risk of Harm
Range	6		1		1		
Probability	1/120,960	x	1/1	x	1/1	=	1/120,960

The absence of structures and the very low level of public access indicate that detailed assessment of the tree is not essential. If it could be established that a 'Weather Factor' of 1/4 was appropriate, the overall probability of harm would be reduced to 1/483,840.

Intellectual Property

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