- Planning
- TPO
- Safety Inspection
- Subsidence
- Litigation
- Design

Forbes-Laird Arboricultural Consultancy

Principal Consultant:

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IN THE HIGH COURT OF JUSTICE,
QUEEN'S BENCH DIVISION

Claim No.
HQ10X1869 –

MULLINGER, BOWEN, FARLEY & FARTHING
AND
THE NATIONAL TRUST

EXPERT EVIDENCE (ARBORICULTURE) OF JULIAN FORBES-LAIRD

VOLUME 1 — REPORT TEXT

Prepared for the Claimants, on instructions from:

Ellisons Solicitors

FLAC Instruction ref:

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1	7	'Updated Field Guide for Visual Tree Assessment', Claus Mattheck, 1st edition 2007, p.2
2	7	'The Body Language of Trees', Claus Mattheck & Helge Breloer, TSO 1st edition 1994
3	11	'The Face of Failure in Nature and Engineering', Claus Mattheck, 1st edition 2004, .144
4	12	'Updated Field Guide...' op. cit. p.30
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6	14	'Updated Field Guide...' op. cit. p.21
7	15	Ibid. p.22
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9	17	'Stupsi Explains the Tree', Claus Mattheck, 3rd enlarged edition 1999, p.21
10	17	Ibid. p.22
11	22	'The Body language of Trees op. cit. p.12
12	22	Ibid. for example at p.36
13	33	'Principles of Tree Hazard Assessment & Management', David Lonsdale, TSO 1999, p.331
14	34	Ibid. p.347

PART A: BACKGROUND INFORMATION
(INTENDED TO BE FACTUAL EXCEPT WHERE STATED)

1 Introduction

1.1 Authorship

1.1.1 This report addresses arboricultural issues arising from a tree-related accident and is submitted as Expert Evidence. It has been prepared by me, Julian Forbes-Laird, a Director and Principal Consultant of Forbes-Laird Arboricultural Consultancy Ltd (FLAC).

Relevant Qualifications, Memberships and Accreditations

1.1.2 I am a Member and Registered Consultant of the Institute of Chartered Foresters, through examination as an arboriculturist at Masters level (equivalent), a Professional Member and Registered Consultant of the Arboricultural Association, a Member of the Expert Witness Institute, and a member of the Royal Forestry Society, holding its 'Professional Diploma in Arboriculture', a degree level (equivalent) qualification. Relevant Appointments

1.1.3 I am Senior Technical Editor for B58516 'Recommendations for Tree Safety Inspection', which is currently in draft form. I am a Technical Editor for BS5837 'Trees in Relation to Construction – Recommendations' and member of the British Standards Institution technical committee on trees, B/213. I am Special Advisor on Tree Risk to Network Rail Ltd. Full details of my qualifications and experience may be found at Appendix JFL1.

1.2 Instructions

1.2.1 I am instructed on this occasion by Ellisons solicitors on behalf of four families, being those of Mullinger, Farthing, Farley and Bowen, who have commenced an action in negligence against The National Trust (NT) arising from a tree-related accident at its property Felbrigg Hall, Norfolk, on 26th June 2007.

1.2.2 The scope of my instructions comprises a review of supplied documentation, a visit to the site, and the preparation of Expert Evidence (this report). Arising from these instructions, I have undertaken the following:

1. A visit to the site to study extant remains of the subject tree (section 4) in order to identify causation with regards to its structural failure;
2. In the context of a finding that the accident occurred due to a defect in the tree or branch, I provide an opinion as to whether a reasonable inspection should have discovered it, and whether this should have prompted a reasonable occupier to take remedial action that would have lead to the prevention of the accident; and
3. Preparation of an Expert Witness Report detailing the findings of my investigation (this report), compliant with Part 35 of the Civil Procedure Rules.

1.2.3 Additional material that may come to light might alter my conclusions in relation to section 5 'National Trust Tree Inspection Policy' or section 6 'Review of Felbrigg Estate tree risk management'. Section 4 'Observations made during site visit' is not reliant on any data other than that discovered by me (and my assistant, please see immediately below) on 3rd October 2007, and my own qualifications and experience.

1.2.4 I was assisted on the day of the site visit by my associate Patrick Stileman, a Chartered Arboriculturist. Mr Stileman accompanied me as part of his professional development. He collected physical tree data (height, stem diameter, crown spread etc.) and took down dictation from me of my observations. This defines the limits of the assistance provided to me by Mr Stileman and what follows in this report is in no other way whatsoever reliant on him or his opinions.

1.2.5 This report has been prepared on the assumption that it will be disclosed as expert evidence before the courts in a civil action in negligence. I am aware of the requirements of Part 35 of the Civil Procedure Rules, Practice Direction 35, the Protocol for the Instruction of Experts to give evidence in civil claims 2005, as amended, and the Practice Direction on pre-action conduct.

1.3 Documents supplied to me by instructing solicitors

1.3.1 I received the Inquest bundle on 21st July 2008, shortly after conclusion of the Inquest into the death of Daniel Mullinger, one of the children involved in the accident. Two documents were included within the Inquest bundle that I consider are particularly relevant to my investigation. These are:

1. National Trust tree inspection policy 1997; and
2. A map showing the orienteering route ('The Monster Trail') taken by children on the day of the accident.

1.3.2 I received a second bundle from instructing solicitors on 4th March 2011, supplemented by witness statements which I received on 10th March 2011. Supplied documents within the second bundle and witness statements referred to in my report are:

1. NT tree inspection policy 2007;
2. Map of the Felbrigg Estate marked up and titled 'Tree Health Zoning Felbrigg 2006 (Revised)';
3. Details of tree inspection training courses apparently attended by relevant staff members;
4. A letter from the Aylmerton Field Study Centre to the authorities at Felbrigg dated 3rd July 2006 giving details of (child) visitor numbers to the estate's woodlands; and
5. Witness statements submitted by Daplyn and Dowson.

I will refer to these in turn as necessary.

1.4 The accident

The accident occurred on 26th June 2007 shortly after 1550hrs, when four children on a field trip orienteering exercise were struck by a large branch falling from a mature common beech (*Fagus sylvatica* L). The children were among one of several groups taking part in the exercise and were accompanied by a teacher from their school. One of the four, Daniel Mullinger, was killed, another, Harry Bowen, received serious injuries, and two others, Katie Farthing and Max Farley, were less seriously hurt, though they still required hospital treatment and after-care.

2 Tree structure: morphology, defects and assessment

2.1 General

2.1.1 It is considered helpful to provide technical information on tree structure and the reasons for its collapse. It should be understood that the present matter arises due to the failure of the union between a branch and its parent stem: this is distinct from failure occurring along the length of the branch; the latter is not addressed in this report.

2.1.2 It should further be understood that standard practice for assessing tree structure within the UK is a method formalized in Germany known as 'Visual Tree Assessment' (VTA), The method's principle author, Prof. Dr Claus Mattheck of the Karlsrühe Research Centre (Forschungszentrum Karlsruhe GmbH) describes VTA in the following terms:

> *"Trees strive for uniform stress distribution over their surface. If this is disturbed by locally higher stresses, then the tree will lay down thicker annual rings at this place. Conversely, if it is locally underloaded, it will make less increment. The form of trees is thus a record of their loading history, a biography in wood….*
>
> *The method of Visual Tree Assessment (VTA)… is a method of tree diagnosis that is used world-wide and is legally accepted [in the German courts]. It interprets the body language of trees, linking internal defects to the tree's own repair-structures, confirming and measuring these defects, and finally assessing them with failure criteria and, from this, deducing measures for the 'therapy' of the tree. Accordingly, trees that are only apparently dangerous should be distinguished from trees that are really dangerous, thus avoiding unnecessary fellings and also accidents caused by tree failure*."[1]

2.1.3 The VTA method has been in widespread use in UK arboriculture since the mid-1990's. The illustrations in the remainder of section 3 are taken from various publications by Mattheck (per the corresponding references); whilst some of these publications are quite recent, the principles shown in the illustrations were first explained and illustrated in a 1994 textbook[2] published by the then Department of the Environment.

2.1.4 The VTA method and its theoretical basis, which is very comprehensible at craft level (as I believe the illustrations show), should be foremost in mind for anyone undertaking tree safety inspections: recognition of the defects illustrated in Figures 1-8, below, is an assumed standard of knowledge for tree inspectors and can be considered determinative of competence. Finally, I should explain that Figures 1-8 reflect the idiosyncratic approach of their author towards illustration which, cartoon characters notwithstanding, is considered to render the material quite accessible to students.

2.2 Adaptive growth in trees and its significance for visual tree assessment

2.2.1 In line with the Darwinian theory of 'survival of the fittest', where waste in nature ultimately counts against the wasteful, trees are evolutionarily programmed to make the most efficient use of their resources. For this reason, they grow up to be only as strong as is required for their precise microenvironmental circumstances, thereby saving the wasteful production of unnecessary material. However, trees are self-optimizing structures with a substantial ability to put on additional timber for localized reinforcement of structural vulnerability. This is a biomechanical response to load stresses, and is known as 'adaptive growth'.

2.2.2 For example, the longer a branch grows, the more its end-weight inevitably will bear upon its union with the stem (consider the kinetic potential of a lever of progressively increasing length); this is known as 'end-loading' or 'hyper-extension' of branches. Where trees are growing in competition with one another, such as where they occur in groups or as woodland, branches frequently over-extend in the search for light, an autonomic response known as 'phototropism'. This can also occur with individual trees where branches extend beyond their neighbours in the quest for better solar exposure. Where end-loading leads to an excess of mass over strength, the branch either breaks along its length or fails at the union, whichever is the weaker link in the load-bearing chain. However, in general, branch unions with the tree stem are over-engineered relative to branch timbers: all other things being equal, a branch subject to excessive loading will break somewhere along its length rather than tear out from the union. It is axiomatic, therefore, that failure at a union indicates an inherent weakness contrary to the typical case.

2.2.3 It is also axiomatic that a progressively extending branch requires an ever more secure union with the stem, and also timber along its length of increasing strength. The latter is enhanced in two ways: through the increased addition of lignin (one of the primary components of wood, which confers strength) and / or the addition of extra material. This additional material can further be differentiated into generalised 'secondary thickening', i.e. the branch as a whole becomes thicker, or localized adaptive growth. This form of structural augmentation also occurs at the union between branch and stem; I shall return to this particular situation shortly.

2.2.4 Regardless of where it occurs, the adaptive growth mechanism is an autonomic response and is believed to operate essentially in one of two ways, both starting with how trees grow. This occurs externally to their structure such that new annual rings are laid down outside older wood (the oldest wood in a cut tree stump is in the centre). Thus it follows that new wood is made in the outer region of stems and branches (the region known as the cambium), with growth occurring at a cellular level (the same as in humans).

2.2.5 The first type of adaptive growth response is driven by gravity: cells in the cambium are sensitive to this force (gravimetrically sensitive) such that alterations in their orientation to this force are 'detected' by the tree. Deflection of cambial cells relative to the gravity field outwith a 'normal' range, for example movement caused by swaying in the breeze, triggers the adaptive growth response: trees preferentially lay down new material at the critical point for optimum stabilisation of the detected excess deflection.

2.2.6 The second driver for adaptive growth formation is trees' biological imperative to lay down a complete annual ring, except where their genetic growth map allows a sub-division to occur, such as the formation of a branch. For example, where a split internal to the cambium occurs in the stem or a branch, trees seek to form a complete annual ring of wood around it. In cases where the split stabilises, annual rings are formed at normal or near normal rates in successive years until the split becomes no more than a historical event. Where the split propagates, however, the annual rings exaggerate in thickness, triggered by the tip stresses occurring at the ends of the lengthening split. Figures 3, 7 & 8 illustrate this.

2.2.7 The sensitivity, and effectiveness, of the adaptive growth response is affected by the vitality of the tree and the stiffness of the wood involved: wood with a high stiffness has a relatively high resistance to bending and so triggers a relatively late response to an increased structural distress (such as where a branch has cracked). The wood of beech trees (being the type of the subject tree, see below) is dense and lignin-rich, in consequence having a relatively high resistance to bending. Thus, with beech trees, the adaptive growth response is triggered relatively late on in the process of structural deterioration. This is a factor in the propensity of mature beech trees toward limb shedding: the adaptive growth response tends to be triggered rather far along the mass to strength ratio curve.

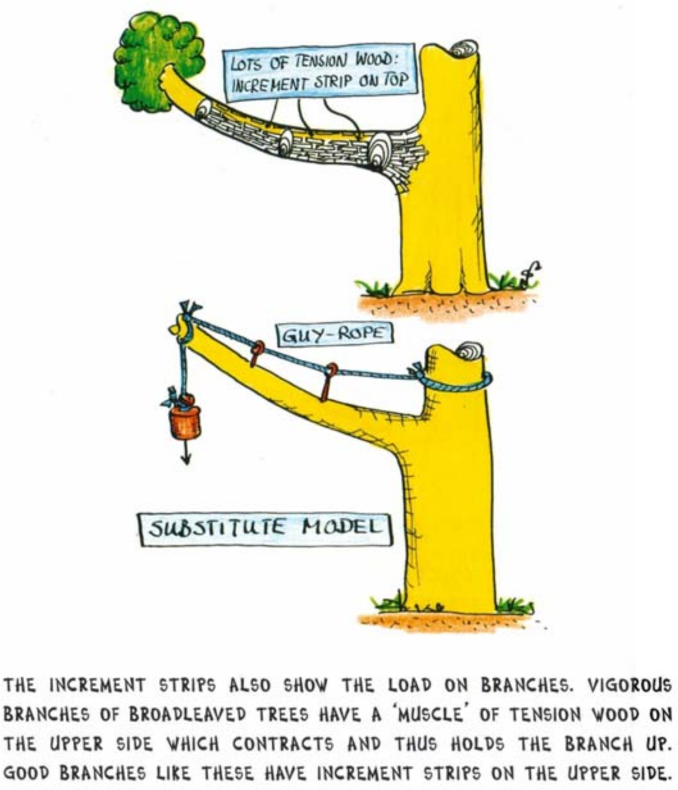
2.2.8 Trees of the subject's genus preferentially support themselves against wind and gravity in tension, rather than compression. Following this principle, where a branch extends excessively (e.g. bolting towards the light), additional material is preferentially laid down on its upper surface: over time, the branch develops an elliptical profile if viewed in section. Figure 1 illustrates this.

2.2.9 Secondary thickening (i.e. diametrical expansion) in branches typically occurs at circa 3-5mm radial increase per annum. Where additional, localized adaptive growth thickening occurs, this commonly ranges from 5mm, for gradual increases, to 10mm or more if extra wood is added as an 'emergency repair' (e.g. where a branch develops an internal crack).

2.2.10 In the case of progressively end-loading branches, in some cases they start to bend downwards (subside) under their own weight where the supporting function of the 'guy rope' of tension wood becomes inadequate (the Substitute Model in Figure 1 refers). If this occurs, the wood fibres on the branch underside, which are in compression, typically begin to buckle, with this often being observed near to the stem. This leads to the development of 'wrinkles' and disruption to the smooth flow of bark over the underlying timber (Figure 2 illustrates this process). These features can be apparent on visual inspection, demonstrating to the inspector that the affected branch may be approaching the limit of its natural safe working load. Recalling that new material is laid down externally, the trained observer can (and should) look for and identify significant localized accumulations during the course of tree safety inspection. Such accumulations are the symptoms of repair, which may not be successful.

2.2.11 The symptoms of repair will vary from extra wood of a more rounded profile in the case of gradual reinforcement, to wood of an acute profile, where an emergency repair is underway: an increasingly acute profile demonstrates that the repair is inadequate, such that collapse may be anticipated. Figure 3 illustrates the principle. It is for this reason that training in, and comprehension of, adaptive growth morphology is an essential and fundamental competence for tree safety inspectors (please see section 6.2).

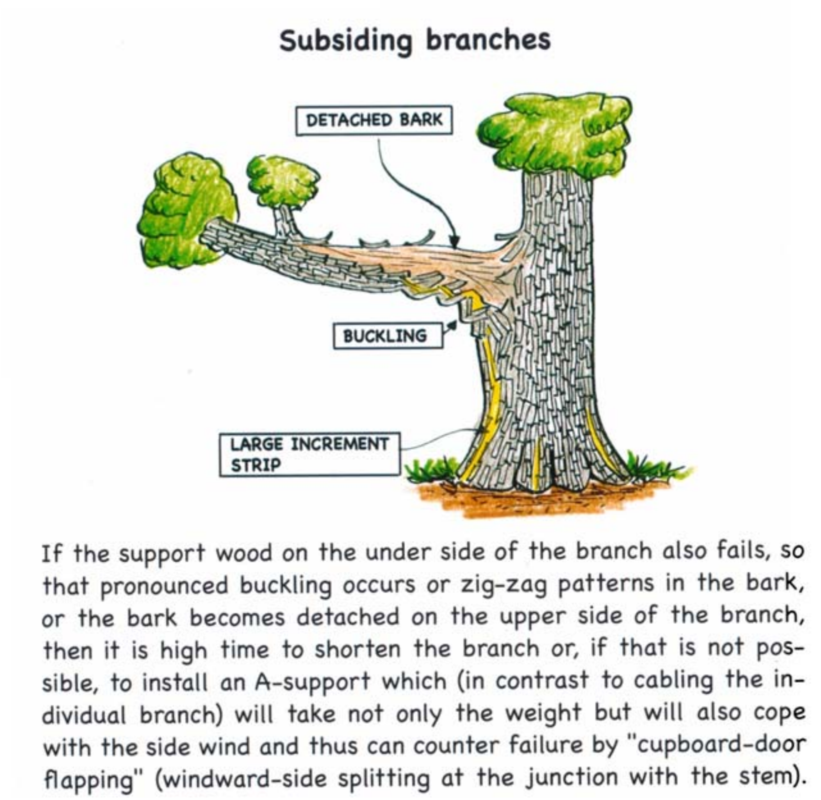
Figure 1 Development of tension wood adaptive growth on upper surface of extending branch[3]



2.3 Morphology of branch unions

2.3.1 The force of gravity dictates that any subdivision of a broadly upright structure, where a subdivided part attaches at an angle to the vertical, presents something of an engineering challenge. Where trees are concerned, branches emerge from the stem at a considerable variety of angles. Providing that their union with the parent stem conforms to certain biomechanical optima (see below) a well-formed and undamaged union is typically stronger (i.e. resists failure better) than the timber of the branch it supports (per 2.2.2, above).

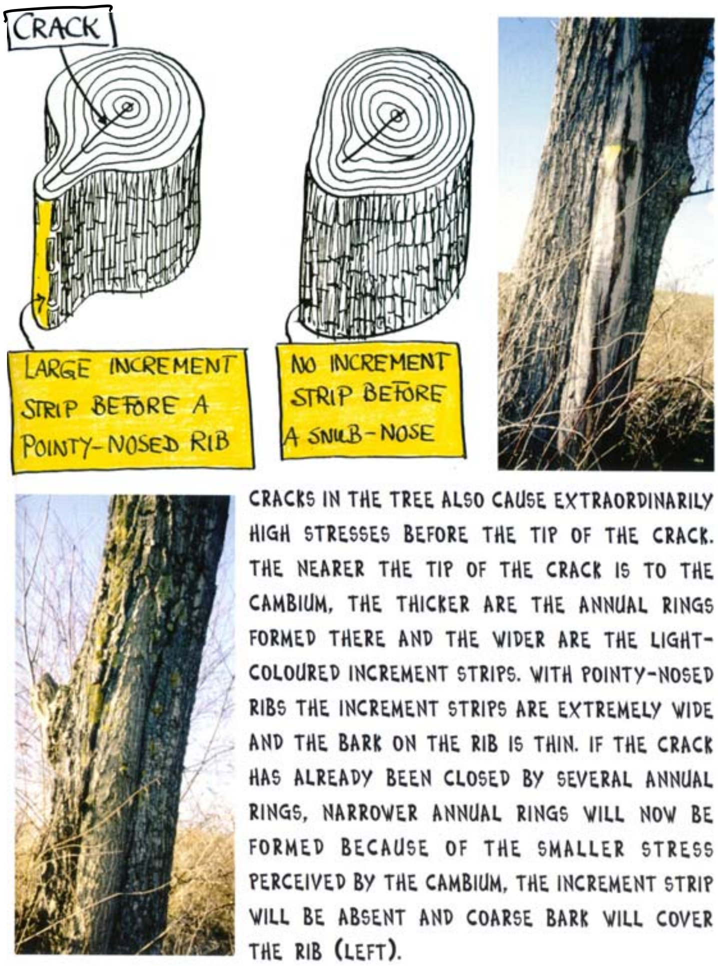
Figure 2 Fibre buckling in overloaded & subsiding branches[4]



2.3.2 An assessment of union morphology is actually quite a straightforward matter for the trained observer: strong unions have a U-shaped profile and the bark flows between stem and branch without significant interruption. Conversely, weak unions have a more V-shaped profile (known as 'acute forks' or 'compression forks'), and often the bark grows down into the crotch to form what is termed a 'bark inclusion', an area of bark-on-bark contact. Bark inclusion has a very destabilizing effect on the union, leading to its progressive separation and, commonly, eventual collapse. Figures 4, 5 and 6 refer.

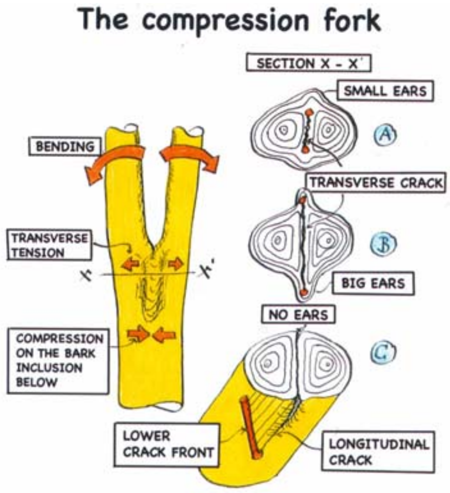
2.3.3 Due to the high potential for a major union failure to result in adverse effects on the structural integrity of the whole plant, for example where failure creates a severe wound leading to decay in the stem, it should be apparent that the morphology of branch unions is a fundamental element of a tree's structure. However, as with all living things, the form and habit of a tree is determined by the characteristics not just of species and environment, but also of its precise genetic inheritance, By this means, anomalous growth forms occur, including sub-optimal forms, with one example being a predisposition towards weak forking.

Figure 3 Rib formation differentiated according to propagating and resolved cracking[5]



2.3.4 Because weak forking can be a genetic trait, where present it frequently affects more than one branch: if left unmanaged, trees affected by weak forking often tend to undergo a series of branch failures. Some tree species (such as limes) are actually quite resistant to failure through weak forking; others, such as beech, are well-known to be susceptible to it, such that branch failure due to this defect is common, especially in mature specimens. This is one reason why an understanding of structural vulnerabilities of differing tree species is an important element of tree safety inspection. It follows, then, that where prior union failure is apparent on a tree, this should underline to an inspector the need for careful examination of other unions.

Figure 4 Explanation of compression forking[6]

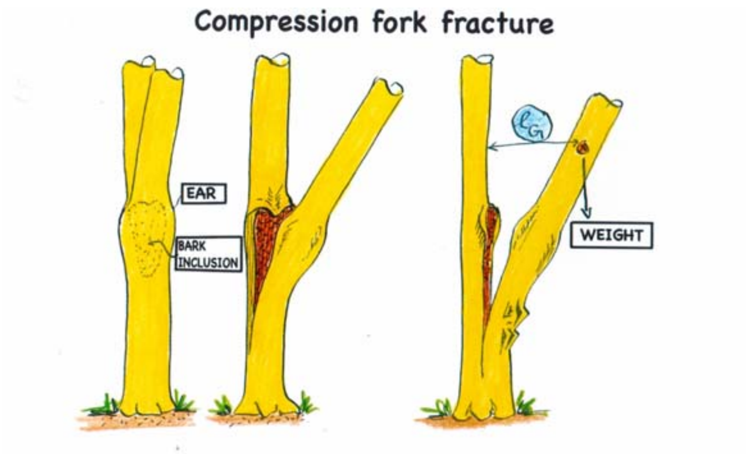


The compression fork usually occurs in dense forest stands as a result of phototropic growth upwards to the light. The stems mutually crush themselves and enclose bark, which acts mechanically like a crack. The crack becomes enclosed by all-embracing annual rings, which weld the stems together. The welding seams on both sides are also called "ears". The safest compression fork, which as a rule will rarely fail, is the one with small ears (A) with many all-embracing annual rings and little included bark. (B) is the fork basically threatened by tear-out, with big ears and only a few welded annual rings, and (C) shows a fork without any welded annual rings, which is therefore not a transverse crack but a dangerous longitudinal crack.

2.3.5 As with other types of structural weakness, such as end-loading of phototroplcally extending branches used as an example above, trees have the ability to reinforce / attempt repair of weak forks. However, the high frequency of weak fork failure in beech trees confirms that the repair of this type of vulnerability is often unsuccessful with this species (see 2.2.7 for an explanation); nevertheless an attempt at reinforcement / repair is typically in hand when failure occurs. The adaptive growth response, which indicates a weakness undergoing repair, is often at least as visible from the ground as the defect in the fork (for example, acuteness or bark inclusion) that comprises the structural aberration; indeed, adaptive growth 'flares' (the 'big ears' in Figure 4) adjacent to weak forks can be quite dramatic in appearance and they are a primary diagnostic indicator of structural distress at the union.

2.3.6 Because the morphology of visible adaptive growth signals to the trained observer both the presence of the weakness and its severity (Figures 7 & 8 refer), this should inform both the risk assessment and the management decision. The main point to note is that weak forking is a predictable failure-predisposing factor in mature beech trees, and is, or should be, specifically looked for during tree safety inspections. It should be obvious that the attachments of large branches with the stem of such trees should attract particular scrutiny. Due to increased end-loading on larger branches, the largest branches warrant a closer look for defects than those of more common size. This is particularly the case with older trees of other species known to be structurally problematic in maturity with regards to limb shedding, such as beech trees.

Figure 5 Typical failure mode of compression fork[7]

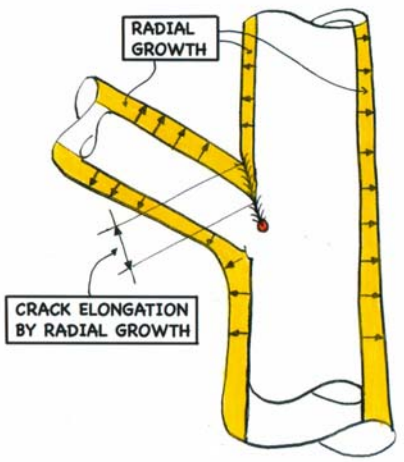


In normal compression fork fracture, the welded annual rings in the fork ears loaded by transverse tension will rupture first. The transverse crack ruptures from the inside outwards, and the lower crack tip, which has long been loaded in lateral compression, experiences tension and runs downwards. The semi-circular profile of the lower stem splitting off is weak in bending and inclines outwards because of the peripheral crown weight, the crack extends further and, at a critical crack length, transverse fracture of the stem occurs. The typical fork failure thus consists of the change from transverse crack to longitudinal crack:

1: Cracking through the ears.
2: Longitudinal splitting, as an elongation of the included bark.
3: Transverse fracture of one of the split-off halves of the stem.

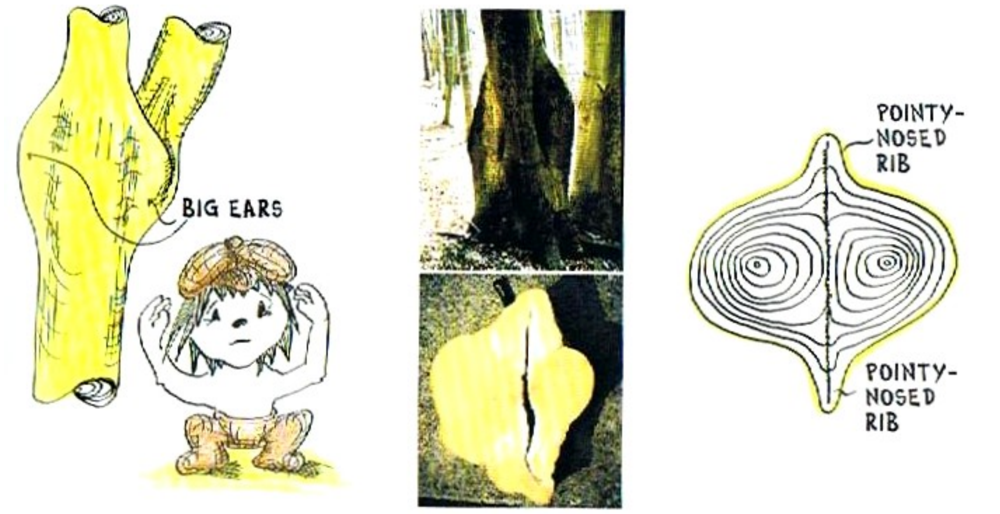
Figure 6 Explanation of weak fork failure[8]

Branch breakage as a consequence of bark inclusion



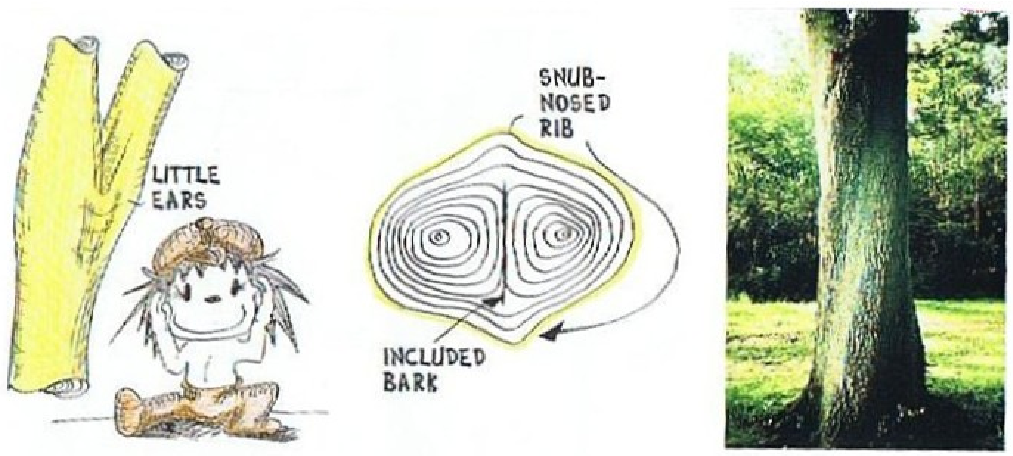
Steep branch attachments can also cause bark inclusions (crack!). Branches which are no longer forming welded annual rings with the stem wood along the bark inclusion are particularly vulnerable to tear-out. Here the ingrown crack becomes longer and longer with the radial growth of the branch, and thus more and more dangerous; moreover, the branch becoming increasingly thick will also become increasingly heavy. When the critical crack length is reached, the branch tears out, and this can even happen in calm weather. Reason: the radial growth of branch and stem is sufficient to cause bark inclusion by self-crushing, but is too small to produce the welding of branch-wood and stem-wood.

Figure 7 Illustration of adaptive growth as a failed repair of a weak fork[9]



IF SUCH AN ACUTE FORK HAS A LOT OF BARK BETWEEN THE TWO STEMS, AND ONLY A FEW ANNUAL RINGS BINDING THE TWO STEMS TOGETHER, THE FORK CAN EASILY BREAK APART. THE BARK BETWEEN THE STEMS ACTS LIKE A CRACK, AND THEREFORE A POINTY-NOSED RIB IS FORMED ON EACH SIDE. FROM THE SIDE THE TREE FORK THEN LOOKS AS IF IT HAS BIG EARS.

Figure 8 Successful adaptive growth repair of weak fork[10]
(Note clear morphological difference to Fig.7)



HERE THERE IS ONLY A LITTLE BARK ENCLOSED BETWEEN THE STEMS, AND THERE ARE MANY ANNUAL RINGS BINDING THE TWO STEMS OF THE FORK TOGETHER. THEREFORE THE RIBS IN FRONT OF THE ENDS OF THE INCLUDED BARK, WHICH IS ACTING LIKE A CRACK, ARE SNUB-NOSED. THE TREE FORK HAS ONLY LITTLE EARS AND IS MUCH LESS DANGEROUS THAN A FORK WITH BIG EARS. THE BEST TREE FORKS DO NOT HAVE ANY INCLUDED BARK BETWEEN THE STEMS AND THEREFORE DO NOT FORM ANY EARS.

2.4 Tree risk assessment and control

2.4.1 For locations where people or property are potentially exposed to hazards from trees, an effective system of tree risk management should include safety inspection. This should be undertaken at a suitable interval and with sufficient competence for the trees' context, and in light of their nature and condition. This is especially important where access is frequent and / or involves children, who have a lower awareness of danger than adults, or other people at higher risk, such as the elderly or infirm.

2.4.2 Professional competence in tree safety inspection is most suitably acquired through training in the recognition, significance, and remediation of tree defects. Where a phased system of inspections and / or remedial action is in operation, and / or where the trees stand within areas of differing 'target value', it is helpful if the training includes the principles and, better still, the practice of tree risk assessment.

2.4.3 There is broad agreement within the arboricultural profession on these principles, with three underlying considerations being widely accepted by arboriculturists as defining the level of risk posed by a tree:

1. Whether the tree is in such a condition that failure either of the whole tree or of a part of it may be anticipated;
2. Assuming that failure can be anticipated, whether the tree is located so that personal injury or property damage is a foreseeable result of the failure actually occurring; and
3. The likely consequences of failure, in light of identified defects (parts likely to fail), and the presence of persons or property within striking distance (termed 'targets'}.

2.4.4 Concerning measures to control tree risk, there are, broadly, three options available:

1. Reduce the target value, for example by diverting a footpath away from the tree;
2. Reduce the likelihood of failure, for example by shortening a weak branch; and
3. End the risk by felling the tree (an option of last resort that is frequently unnecessary).

2.4.5 It should be noted that merely increasing frequency of inspection does not necessarily control the risk posed by a dangerous tree: potentially, the risk is merely observed while it increases. A cycle of successive inspections is often known as 'monitoring' where what is being monitored is change in the condition of the tree or its parts. The change can be physiological (i.e. related to tree health) or structural, or both. However, in the same way that one does not notice the growth of children one sees every day, having a tree under too frequent observation can actually reduce the awareness of change, unless something dramatic occurs. This is one reason why tree safety inspection need not be undertaken at greater frequency than every six months (except, in certain cases, for example following severe weather events that might have resulted in partial structural failure).

2.4.6 The main reason for placing a tree under monitoring is to delay management intervention (for example, to enable a phased expenditure of resources) until the point at which a more immediate need for action (see 2.4.4) is reached. Accordingly, in order for monitoring to be effective as a measure of risk control, rather than being simply a process of risk observation, the discovery of change should, at some point during a hazardous tree's deterioration, trigger a response to address the risk in a more active way.

PART B: OBSERVATIONS
(MATTERS OF OPINION)

3 Danger and safety In trees

3.1 The working draft of the Introduction to BS8516 'Recommendations for Tree Safety Inspection' (which is not an operative British Standard and is referenced out of courtesy to the British Standards Institution) commences thus:

> "The laws and forces of nature dictate a natural failure rate even among trees that are healthy and structurally sound. By their very nature, therefore, trees cannot be considered entirely hazard free, though it is stressed that the risk posed is generally present at very low and acceptable levels. For this reason it is important that trees are not managed in a risk-averse way."

3.2 I consider this to be a good summary of the caution that should pertain to any consideration of tree risk: generally, trees are not hazard free and so it is a mistake to expect them to be so. Thus, whilst there is no such thing as a 'safe tree', the vast majority are what I would describe as 'reasonably un-dangerous'. However, where a tree has a recognizable defect, the level of risk can, depending on the factors outlined at 2.4.3, move from the acceptable to the unacceptable. Danger and safety in trees can, therefore, be viewed as points on a continuum.

3.3 In my opinion, a dangerous tree is one that has lost its natural margin of safety against the load stresses imposed upon it or its major parts, and is located so as to threaten people or property. Typically, such trees have suffered primary failure (including the onset of irreversible, serious weakness) at a critical point in the load-bearing chain of their major parts, for example biomechanical inability to stabilize weak structures through adaptive growth. For such trees, the moment of progression from primary failure to secondary failure (collapse) resists reliable prediction: accordingly, a dangerous tree is one that could collapse at any time.

4 Observations made during site visit undertaken on 03.10.07

4.I General

As noted already, I was accompanied on my site visit by my associate, Patrick Stileman, who assisted me throughout. In addition, representatives of the National Trust (NT) and Zurich Municipal Insurance were also present. A selection of photographs taken during the site visit is appended at JFL4; the photographs are numbered P1, P2 etc, and are referenced correspondingly in the text below in square brackets.

4.2 Site & tree description - summary

The tree in its context

4.2.1 The subject tree is a large mature beech tree, one of approximately eight such trees located in this area of the Great Wood. Unlike the other (circa) seven beech trees, which stand back somewhat from the main path, the subject tree stands at a junction of three paths (major, secondary and informal). The major and secondary paths are marked on estate maps and on the Ordnance Survey map base: please see the map printed from the MAGIC database (Multi-Agency Geographic Information for the Countryside, www.magic.gov.uk at JFL5, which I have marked up to show the approximate location of the tree. These paths come together to form a natural glade, the only one of its kind in this part of the woodland. Please see the site sketch plan that I have prepared at JFL6.

4.2.2 Eight metres to the east of the subject tree is a sweet chestnut tree, from the base of which has sprouted a number of substantial shoots (basal epicormic growth). These form a thicket which appears to have attracted the attention of children visiting the woodland. A den has been made, with sticks piled around and onto the shoots. The NT employee commented to me that this had been going on for a number of years, The locality of the subject tree is distinct from the surrounding woodland, and it seemed to me to form a natural focal point for visitors to this part of the woodland, and, it would appear, especially children.

Condition of the subject tree

4.2.3 The subject tree has clearly suffered a prior major structural failure which occurred, by my estimate, approximately 20-25 years ago. This first (earliest) failure comprised the failure of a compression fork with bark inclusion. The failed member was very large and bore, by my estimate, at least one third of the then contemporary crown, and probably more than this. As such, the fork failure resulted in a very large structural wound on the stem of the tree [P1].

4.2.4 Large structural wounds such as this are prone to decay and also they disrupt the normal load distribution (what Mattheck refers to as 'the axiom of uniform stress'[11]) down / within the stem as the tree is tested by the wind. This results in what is termed a 'notch stress', i.e. a concentration of load at a particular point. In the case of large structural stem wounds located higher than ca. 1.5m above ground level and below the main crown architecture, the notch stress occurs precisely where the damaged stem is least able to cope with it. This frequently combines with the effects of decay at the wound site to result in stem breakage 20-40 years after the original failure that caused the wound. For this reason, large structural stem wounds are typically a key focus of attention during tree safety inspection. In my opinion, large-sized mature trees with this type of defect should be subject to close inspection by a competent person if there is public access nearby.

4.2.5 A second, smaller branch [P2] fell from the tree around two or three years before the fatal accident (therefore in 2004-2005); this failure also occurred at the branch union with the stem, though whether this was a direct result of weak fork formation was unclear. The second branch fell across the secondary path to the north, and was cleared into adjacent undergrowth [P3 & P4]. Although this second branch was also possibly weakly attached, it is unlikely that this would have been determinable from ground level inspection prior to failure, due to its location high in the crown and obscuration by intervening branches and foliage (when in leaf).

4.2.6 The third branch which fell from the tree caused the accident of 26th June 2007. This branch also had a weak attachment, arising as it did as a compression fork which had split [P8]. The compression fork would have been readily visible from ground level and its significance would have been apparent on competent inspection.

The attachment had cracked in the centre of the fork [P9] several years prior to failure, probably during the growing season of 2003 or 2004 (based on the morphology and extent of woundwood formation, the extent of internal staining, and the presence of composting within the internal area of the union). Whilst the crack would not have been visible from ground level, the pronounced adaptive growth flares to either side of the fork, i.e. the symptoms of repair, most certainly would have been.

4.2.7 As has already been explained, these features are a clear indication of structural distress: for this reason proper inspection would have identified the branch to have been at high risk of failure. Recalling my exposition of dangerous trees at 3.3, primary failure had already occurred with progression towards secondary failure both inevitable and to be expected at any time. The morphology of the union as a compression fork would have been apparent for many years (probably twenty or more) prior to the onset of actual structural distress, with this latter being the trigger for the adaptive growth response (per section 2.2). The size of the adaptive growth flares, clear symptoms that the fatal branch was weakly attached, could only have been attained over a number of years.

4.3 Detailed description of the subject tree

4.3.1 The subject tree is a mature beech (*Fagus sylvatica* L). A direct measure of tree vitality is annual twig extension growth. As viewed on the fatal branch (B3) this is even throughout, averaging between 10 and 15cm per year, which is satisfactory for a mature beech tree in a woodland context in this locality. The condition of B3 at the time of my site visit showed that the tree was in full leaf with a moderate crop of mast at the time of the accident. I recorded no indications of pests, diseases or disorders of arboricultural significance.

4.3.2 The base of the tree and its primary root buttresses returned no indications of decay on sounding with a mallet (a preliminary but effective method of decay investigation). The tree leans south by approximately 10 degrees, though this has no apparent significance for its stability. The tree has shed several branches, which are discussed below in chronological order of failure, oldest failure first. The propensity of the subject tree to union failure due to weak fork formation is probably a genetically determined trait.

Branch B1

4.3.3 Historic failure of co-dominant leader formerly arising at a compression fork ca. 6.5 m above ground level (AGL) on the north side of the stem. The morphology of the breakout wound [P1] reveals that the attachment to the stem had severe bark inclusion at the time of failure, which is assessed to have occurred in the region of 20 - 25 years ago. The weak fork would have been readily apparent from ground-level inspection by a competent person prior to failure. It is currently apparent from ground level that substantial stem decay is associated with the large structural wound that has resulted from the loss of B1. The width of the wound is approximately 800mm.

Branch B2

4.3.4 The remaining fallen timber from this branch is located in undergrowth [P3, P4] 16m from the tree to the north. The position of the breakout wound [P2] is located on the north side of the tree at a height of 16.9m above ground level, on the junction of the stem with a secondary lateral branch. B2 has a diameter of 213mm at ca. 1.5m from the point of failure. The limb was located on the tree such that on falling it would have lain across the adjacent secondary path. Assuming that this branch was cleared shortly after the failure, so as to remove the obstacle from the secondary path, the failure event took place 2-3 years prior to the accident. I base this figure on the amount of vegetation which has grown over the branch [P3] and on the condition of the timber [P4].

Branch B3 (the fatal branch)

4.3.5 The B3 breakout wound [P5, P8] is located on the south-east side of the tree stem at a height of ca. 9m above ground level. B3 has a pronounced adaptive growth flare on the southwest side of the union (NB compass directions are referenced as when attached). This feature had / has a width of approximately 140mm. A smaller but still pronounced adaptive growth flare is present on the southeast side of the union. Both these would have been readily visible from ground level, and should, on competent inspection, have given cause for serious concern, in turn prompting a management response. Typically, this latter would normally involve reducing the length of the branch concerned. The size of the two adaptive growth flares confirms that they had been developing for several years: in my opinion certainly five and probably ten.

4.3.6 By my assessment, B3 would have grown out from the tree at approximately 45 degrees [P14]. A measurement made of B3 as it lies on the ground shows that it was 21.7m in length, from breakout wound to tip. B3 would therefore have terminated just over 10.5m from the stem, against a current crown spread of just over 7.6m in the relevant direction: prior to its failure, B3 would, therefore, have borne a significant portion of the crown, extending this substantially beyond the remainder of the south to east aspect of the tree. The diameter of B3 measured at 100mm distal to the breakout wound is 500mm. Based on these dimensions, it is fair to say that B3 was a truly massive limb, and in fact it was the largest on the tree prior to its detachment.

4.3.7 Woundwood is a type of scar tissue formed as a tree tries to cover internal wood with new bark, following exposure of underlying timber to the air through rupture or loss of bark. Woundwood is present on the upper margin of the former point of B3's attachment to the stem [P9], and is located to comprise, in this case, a region of bark inclusion. The morphology and extent of this feature suggests it has been present for certainly in excess of two, and probably in excess of three full growing seasons. Adjacent to this, the central area of the attachment zone shows a complex of knots and rolls [P13] which has developed within the fibres of the wood. This indicates structural distress, with the autonomic structural adaptation / enhancement mechanism of the tree working hard in an effort to retain the limb as it grew.

4.3.8 The internal face of the union shows darkening of the wood [P9], apparently caused by oxidisation and water ingress. This is more apparent from the crime scene photographs (see, especially, PCS4 within Appendix JFL7), where the freshness of the broken timber readily permits identification of the oxidized / stained region within the union. This demonstrates that a fissure had been open into the interior wood for several years, which I find consistent with the likely duration of woundwood formation. The fissure represents a primary failure, and its occurrence at a critical point such as this is typically catastrophic for the security of massive limbs.

4.3.9 At a distance into the interior of the union of ca. 200mm, composted matter from decaying organic detritus is evident in small quantity. The internal timber shows evidence of saprophytic but not pathogenic decay.

The extent of the decay in the internal timbers is slight [P9], with minimal breakdown of the wood and consequent modest significance for structural integrity in relation to reduced wood quality in the affected region. However, the presence of composting is strongly suggestive evidence that the crack had been open for several years.

4.3.10 The southeast portion of the attachment zone is flared, and exhibits longitudinal tearing along the grain of the wood fibres [P12]. In contrast, the wood fibres to the southwest appear to have broken (sheared) across the grain. In other words, the secondary failure (i.e. the shedding of the limb) initiated to the southwest as a shear before being completed to the southeast as a tear.

4.4 B3 Failure analysis

4.4.1 Given the general absence of decay exhibited by the deeper internal timbers of the fallen section, I do not consider that B3 failed primarily as a result of stem decay associated with the B1 breakout wound through the mechanism known as decay coalescence (the joining-up within the tree of internal decay). However, this as a possibility and in this regard the mid-brown colouration of the central wood visible in the police photographs (especially PCS4 at JFL7) is at least suggestive. Instead, I believe that the morphology of the union and its primary failure was responsible, as outlined below. However, the precise reason for the failure has little impact on my conclusions for reasons that I will return to in due course.

4.4.2 Although B3 grew out from the stem at an angle that trees commonly tolerate, the continually extending limb was massive: clearly, it bore a considerable end-weight of foliage, as noted already (4.3.6) extending this substantially beyond the remainder of the south to east aspect of the tree. A general absence of defects along (especially) the upper surface of the limb prevented the development of a critical weakness (notch-stress) in the load-bearing chain of tension-wood fibres (please refer to the Substitute Model at Figure 1): the weakest link in the chain was, therefore, the inherently defective union.

4.4.3 Probably during the summer of 2003 or 2004, primary failure occurred such that a crack opened in the centre of the fork, transferring very high stresses to the adjacent wood, which was already severely tested by the weight of the branch. The stresses would have included tip stresses at the ends of the split.

The morphology of the adaptive growth flares confirms that the tree had by then already laid down significant adaptive growth around the union with B3 (described at 4.3.5): the high stiffness of beech wood (explained further at 2.2.7) had been overcome by the sheer size of the branch.

4.4.4 The formation of the crack would have accelerated the adaptive growth response, with the tree increasing the rate of localized reinforcement: rapidly formed new wood is present indicating that ongoing emergency repair was in hand at the time of failure. However, given the inherent weakness in the union, which was exacerbated by its rupture, the continued extension of the branch added mass more rapidly than the tree could add strength. The combination of a massive, continually extending, end-loaded branch with a weak and subsequently cracked fork made eventual secondary failure inevitable without human intervention.

4.4.5 Finally, I wish to point out that as part of my investigation I explored the extent to which weather conditions might have been a causal factor in the failure of B3. I found no evidence that this was the case.

5 National Trust Tree Inspection Policy

5.1 General

5.1.1 In 2007, The National Trust produced a document titled 'Health and Safety Instruction No. 11 and explanatory guidance: Tree Safety Management' (HAS11, copy appended at JFL3). This document sets out the tree inspection protocol that the NT requires is implemented at its properties.

5.1.2 The document HAS11 is a 'development' of a text published in 1997 (appended at JFL2), and its issue date of 21st May 2007 means that it was prepared after the South Manchester Coroner's narrative verdict of 19th July 2006 on the death of Timothy Sutton, killed by a falling tree at the NT property Dunham Massey.

5.1.3 However, it appears that it was the 1997 inspection manual that was in use at the time of the accident, as the 2007 version had not, by then, been rolled out across the NT landholding. In that this is the performance standard that the NT had set itself, clearly its supersession by the 2007 version is of limited Interest to my enquiry, except in one specific area to which I shall return.

5.2 Requirements of the National Trust tree inspection policy 1997

5.2.1 In 1997 the National Trust published its policy 'The Inspection of Trees' (appended at JFL2). In summary, this document highlights the need for tree inspection where trees stand in or near public places or buildings, with this inspection accompanied by a risk assessment where necessary (i.e. where a hazard is identified). Hazard is defined in the document as 'the potential to cause harm'; risk is defined as 'the level of likelihood that a hazardous tree will cause actual damage'. The document states that 'risk is related to the location of the tree'.

5.2.2 The text stipulates that ensuring tree inspection occurs is the responsibility of the designated property manager, and that it should only be undertaken by suitably competent people, defined at section 8 of the document (and discussed below).

The components of a tree inspection programme are identified as being ‘an assessment of risk, an assessment of hazard, a prescription for remedial action’, stating that these three steps need not be undertaken by the same person.

5.2.3 Section 4 of the document deals with assessing the level of risk, which commences with target zoning the property according to usage (presence of people / structures). Three levels of zoning are identified to derive high, medium and low risk areas. Under criteria given in the text, major footpaths are ‘high risk’ whereas footpaths with ‘regular but not intensive public use’ are ‘medium risk’. It is stressed that the zoning should be ‘kept under review’ and that ‘plans to hold an event involving many people in a medium risk zone will change its status to high risk for the duration of the event’. Further, permanent changes to usage patterns can drive the need permanently to change zoning status.

5.2.4 Section 5 sets out the process of hazard identification, stating that ‘in practice, only visible defects are likely to be identified’. The document advises that ‘knowledge of the propensity of some species to break up or decay more rapidly than others is necessary’, and also that ‘most property based staff who routinely work with trees would be competent to undertake this inspection after receiving basic introductory training’. A programme of inspection frequency is given with high risk zones requiring annual inspection. The phrase ‘retained trees’ is used to describe trees being kept despite ‘showing significant defects’, with the stipulation that such trees are inspected ‘at least six monthly and after storms’. Trees in medium risk areas should be inspected ‘at least every two years’,

5.2.5 Section 6 advises that ‘trees that appear to be sound during formal inspections require no documented record of their condition’ with ‘any omission from the record therefore implying that the tree has been judged to represent a negligible hazard’. It continues, ‘trees that are hazardous or potentially hazardous must be documented’. (These provisions are fully in line with current normative practice, which is known as ‘negative recording’.)

5.2.6 In relation to remedial action, this ‘must be prescribed by a competent person’ (section 7) and ‘must be implemented without unreasonable delay’.

Section 8 deals with competence of inspectors, with a requirement given that anyone 'undertaking the initial assessment of hazard should have some experience of tree work and must have received a minimum of one day's training in the recognition of tree defects.'

Commentary

5.2.7 The most striking aspect of this guidance is the assertion that 'risk is related to the location of the tree', with this followed through in the thought-process such that an assessment of the risk in light of tree condition as discovered by inspection is not recommended. This is a singular and serious omission: by ignoring the essential input factor of tree condition, the tree inspection process set out in the 1997 document is fundamentally flawed.

5.3 Requirements of the National Trust tree Inspection policy 2007

5.3.1 As has been noted already, the 2007 edition of the NT's tree inspection policy, titled 'Health and Safety Instruction No. 11 - Tree Safety Management' was prepared following the events at Dunham Massey. Although the 2007 version bears a number of similarities to the 1997 edition, there is a critical way in which it differs: instead of a three-step tree risk assessment process, comprising zone, inspect, and remediate if required, the 2007 requirement is for a four-step process: zone, inspect, assess risk (identified as a consideration of the likelihood of failure and its consequences), and remediate if required. As noted above, the serious deficiency of the 1997 system was the assumption that target zoning (i.e. tree location) equated to tree risk assessment. This is not the case: clearly, the condition of the tree must also be factored in, which the 2007 edition accepts.

5.3.2 The process set out in the 2007 document is, therefore, correct: first a site should be zoned in order to classify target occupancy, then the trees should be inspected, then the findings of the inspection (e.g. observed structural defects) should be cross-referenced with target occupancy in order to derive risk. It is this essential last step that drives future management, whether this is target modification, tree work or reinspection; without it, the thought process of risk assessment is prematurely truncated such that the risk is, in fact, never actually assessed.

5.3.3 The assessment of the risk posed by individual trees is differentiated in the 2007 document into the following processes and factors:

1. 'The magnitude of the hazard' which 'can be estimated from the size of the part of the tree most likely to fall, and the distance it will fall';
2. 'The probability of tree failure' which 'is a matter of informed judgement'; and
3. 'The consequences of tree failure' which derives from likely target occupancy, including, most importantly, 'the type of use - for example, if people stay longer in an area because of the facilities provided, the probability of impact if failure occurs will be greater'.

This guidance is broadly in tune with contemporary thinking on the subject of tree risk assessment. It should lead, if properly implemented, to a balanced and supportive process of hazard tree management.

5.3.4 With regards to target zoning, the criteria for High Risk zones set out in the 2007 document include, under 'level of use': 'some likelihood of staff/volunteers/visitors gathering or staying in the area'. The target 'description' encompasses, *inter alia* 'footpaths with a high level of use' and 'routes with high visitor numbers in parks and woods'. The criteria for Medium Risk zones include, under 'level of use': 'visitors tend to disperse rather than gather'. The target description encompasses, again *inter alia* 'footpaths with moderate levels of visitor use'. This all seems sensible to me. Finally, it should be noted that the 2007 guidance differentiates usage zones into five classes: this is preferable to the three-zone system of the 1997 version, which I would categorize as over-simplistic.

6 Review of Felbrigg Estate tree risk management

6.1 General

6.1.1 As part of the documentation supplied to me I have been given over 350 pages of tree inspection data and tree work planning records. This takes three main forms:

1. Field notes in a waterproof notebook (ca. 84 pages);
2. Work plan for monitoring/ tree surgery; and
3. Tree survey data sheets.

Some of the data sheets appear to be written-up versions of the waterproof notebook record. The tree work plan appears to derive from the waterproof notebook and / or the survey data sheets. A few photographs are also included which appear to have been taken, selected, or retained more or less at random, The bundle is rounded off with inclusion of various related documentation which I found to be of no material relevance to my enquiry.

6.1.2 It is a necessary part of my enquiry to examine whether the processes set out in the 1997 inspection manual were, in fact, put in hand in relation to the subject tree and to what extent identified risks were being properly controlled. In this latter regard, it should be noted that the trees which have been recorded are those judged to be 'hazardous or potentially hazardous': in other words, the trees in the record are those that a) are located so as to threaten life or property and b) were found on inspection to have significant defects.

6.1.3 It is clear from the records that the senior tree Inspector at Felbrigg was a Mr Richard Daplyn. Mr Daplyn is a graduate of a four-day tree inspection training course run by the National Trust in 2000, and he attended a one-day NT tree inspection training course as a 'refresher' in 2004 (per his Witness Statement). Mr Daplyn further advises that:

> "*I do not recall these being a pass or fail course and I cannot recall if I had a certificate from the courses but they will be logged with the Trust as being completed, under the guide we follow, when we have completed the course it's done, it's complete, but under a new policy which is being rolled out for the autumn, we hope to complete a refresher on a regular basis*."

6.1.4 Presumably the 'guide we follow` is the 1997 inspection manual and the 'new policy' is the 2007 edition. This appears to confirm that Mr Daplyn did not consider that the 2007 requirements were by then in force, or at least they had not yet been adopted at Felbrigg at the time of the accident.

6.2 National Trust tree inspection training

6.2.1 I have been supplied with a copy of the syllabus for the National Trust's one-day tree inspection training course (appended at JFL9) as attended by Mr Daplyn in 2004. Within the one-day syllabus is a list of defects and areas of knowledge that are required for basic tree inspection at National Trust properties. Under the heading 'Biomechanics and Signs for Inspection' are listed (*inter alia*):

- Forks and other unions with included bark
- Weak and strong unions
- Adaptive growth - response to damage and decay

6.2.2 All of the above are clearly germane to the circumstances of the accident. The following slide refers to 'Properties of Different Species' and refers the trainee to 'lists from "Lonsdale"', by which is meant this author's book 'Principles of Tree Hazard Assessment and Management[12]'. The 'lists' in question (by which I assume is meant that book's Appendix 2 'Observation on selected tree genera and species'), include a 'score' against various tree genera that identifies: their 'propensity to form weak forks', their 'propensity for fork failure' and their 'propensity to fail due to decay'. I have appended a copy of the scoring table[13] for broadleaved tree species (including beech, or *Fagus*) at JFL10. From this, it is apparent that *Fagus* scores:

1. 3.59 for weak forking, against a range for 32 other species of 1.32 - 3.71 with only one genus scoring higher;
2. 3.54 for fork failure, against a range for 32 other species of 1.32 - 3.92 with only three genera scoring higher; and
3. 3.59 for decay related failure, against a range for 32 other species of 1.32 - 3.71 with only one genus scoring higher.

6.2.3 From this data, which reflects my own experience of beech trees, it is clear that those attending the National Trust one-day course had their attention drawn to two specific problems commonly associated with beech trees, which directly bear on the subject tree: decay (at the site of the first major failure) and weak forking leading to limb shedding (for example, the fatal branch). Lonsdale places further emphasis on limb shedding in beech trees in the specific entry[14] for *Fagus*; under 'mechanical properties' he states:

> *'Individual trees show genetic variation in the propensity to form forks with included bark. Failure at such forks and at acute branch attachments becomes common in old specimens. Widely spreading branches in such trees are rather prone to the phenomenon of summer branch drop*."

One point to note here is that although 'summer branch drop' is a failure driven at the time by a confluence of specific climatic factors and their effects on the tree, it is essentially a mechanical failure due to end-loading, with failure typically initiating at a notch-stress within the tensionwood fibres along the upper surface of the branch (please refer to the Substitute Model on Figure 1).

6.2.4 The training material goes into detail on the process of 'Visual Tree Assessment` (VTA) referred to already, provides training on remedial action, including the three options that I list at 2.4.4, and sets out what is required for 'monitoring'. It is made clear that this latter means 'monitoring for change' and that this 'implies an individual tree record'.

6.2.5 I have been supplied with a copy of the programme for the National Trust's four-day tree inspection training course. As I would expect, the material covered under the four-day course appears to be substantially more extensive than that covered under the one-day course, though it appears that the former encompasses the one-day course material.

6.2.6 I have also been supplied with a Witness Statement made by Mr David Dowson. Mr Dowson is the leading independent provider of arboricultural education in the UK, including in the field of tree safety inspection in which he specializes. As his statement makes clear, weak fork formation and related indicators of this are an essential element of the courses he has designed and runs, for trainees at both basic (one-day course) and intermediate (four-day course) level.

Two conclusions may be drawn from this:

1. The National Trust course conforms to the generality of the industry standard; and
2. A considerable emphasis is placed in tree inspection training material on the identification and significance of weak forks, including adaptive growth and how to read its significance as a symptom of structural distress.

6.3 Usage zone assigned to the locality of the subject tree

6.3.1 In line with the requirement of the 1997 tree inspection manual, the estate has been divided into three 'usage zones'. It is apparent from the zone map appended at JFL8 that the subject tree was located in Zone 7, in an area classed as 'medium risk'. High risk zones include areas adjacent to roads, paths within the woodland assessed as being more frequently used, and various locations in the vicinity of the Hall itself, including the car parks.

6.3.2 In my opinion, the zoning of the Felbrigg estate is too broad brush, an approach encouraged by the low subtlety of the 1997 system that was in place. This is a systemic failing, which I consider led directly to the application of an artificially low target rating for the locality of the subject tree: it was lumped in with medium risk woodland paths generally, with the specific circumstances of the confluence of paths, the glade and the den (what I would term 'exacerbation factors') being inappropriately overlooked. In addition to what I characterize as a systemic failing, it is also the case that those responsible for tree safety inspection at Felbrigg had at their disposal local knowledge and, one assumes, common sense: they should have been aware of the exacerbation factors I identify. In my opinion, this should have informed the assessment of the local usage zone.

6.3.3 My reasoning for taking this view is that as the footpaths adjacent to where the subject tree stands are individually classed as medium risk, it follows that their confluence is a higher risk location. Furthermore, the presence of the glade is likely to encourage groups visiting the woodland to congregate (cf. places where people tend to 'gather' as a driver for high risk zoning in the 2007 document, quoted at 5.3.4, above).

6.3.4 One of the woodland's key user groups, the Aylmerton Field Study Centre (AFSC, explicitly routes thousands of children along the relevant paths annually during the Monster Trail orienteering exercise (per the letter from the AFSC referred to at 1.3.2.4).

This arrangement is well-known to, and indeed agreed with the Felbrigg authorities. It is somewhat in the nature of orienteering exercises that one stops to look at a map when reaching a junction between paths, and so it is to be expected that children on the Monster Trail exercise would have been inclined to linger at the accident site as they deliberated which path to take. Finally, the ongoing den-making in hand confirms this to be a distinct and popular spot, especially with children.

6.4 Whether the subject tree should have been noted in the hazard tree record

6.4.1 A striking fact to have emerged from my investigation is that the subject tree does not appear within the hazard tree record. This arises from Mr Daplyn's assessment of it as non-hazardous, and the system of negative recording in use at Felbrigg (whereby only hazardous trees are noted). (For the avoidance of doubt, I am not seeking to criticise negative recording, which generally works well when applied competently.)

6.4.2 As has been canvassed already, the pronounced adaptive growth flares at the attachment of the fatal branch were readily visible to ground-level inspection, they were well within the compass of the National Trust training material, and they were clear telltales that the fatal branch was undergoing progression towards failure. A competent routine inspection, therefore, should have identified the weakness and associated high failure risk, leading to the inclusion of the tree in the hazard record, and the remediation of the danger.

6.4.3 In addition, the known propensity of beech trees to suffer decay-related failure goes directly to the significance of the large, decaying structural stem wound: this, in itself, should have prompted classification of the tree as hazardous. This wound clearly merited close inspection, which could not properly be done from ground level. Accordingly, I would have expected a climbing inspection to have been undertaken, in order to assess the extent of the cavity and its significance for safety. Because major unions would normally be examined, as a matter of course, during a climbing inspection, I would expect this to have identified the crack in the fork of the fatal branch (the nearest branch to the stem wound), if viewed after its formation. Even setting aside the weak fork and the adaptive growth flares, I am surprised that the large breakout wound from the loss of the first branch (at a weak fork) was not classified by Mr Daplyn as a 'significant defect'. This makes me wonder just how severe a defect needed to be before it *was* thought by him to be 'significant'.

7 Conclusions

7.1 I consider that at the time of the accident, an unsafe system of tree inspection was in place: the NT's 1997 tree inspection manual wrongly states that the context of the tree determines risk. Whilst this factor determines the likely exposure of people to hazard, the nature of the hazard is a critical element in identifying the level of risk and thereby enabling its control. The 2007 inspection manual is significantly better than the 1997 version, and, notably, corrects its erroneous methodology for tree risk assessment.

7.2 The target value of many of the woodland paths was accurately described as medium risk, with other paths in the woodland being classed as high risk. In my opinion, the nature of the subject tree's immediate context was such that it, too, should have been treated as high risk within the context of the 1997 three-zone system: within striking distance are a confluence of paths, an attractive gathering place and a site where children were routinely sent with the agreement of the estate, and where children were known to linger and play.

7.3 Relevant staff at Felbrigg had undergone suitable training in tree safety inspection. This included a specific emphasis on the hazards associated with mature beech trees, which precisely covered the defects exhibited by the subject tree prior to the accident.

7.4 In the case of the fatal branch, branch B3, the pronounced adaptive growth flares would have been readily apparent from ground level visual inspection, even without binoculars. The significance of these features and their implications for the safety of the branch should have been obvious to a competent person, especially given the tree's apparent history and the species' well-known propensity toward branch shedding in maturity. The use of the highly accessible VTA method should have led to an understanding of the significance of the adaptive growth flares. In turn, this should have led to remedial action, with a routine and inexpensive remedy to the risk of collapse being a reduction in the length of the fatal branch. This would have stabilized it.

7.5 A proper observation of the weak attachment between the largest branch on the tree and its stem should have resulted in the inclusion of the tree within the hazard tree record. According to the requirements of the 1997 tree inspection system, records of its inspection should have been made and retained. They were not.

7.6 The crack in the fork would only have been confirmed during aerial access into the tree, such as for a climbing inspection or for tree surgery. However, the age, species and prior history of the tree, and the size and morphology of adaptive growth associated with the union of the branch concerned, render the discovery of the crack an unnecessary component of the decision-making process. That said, a logical conclusion from observation of the adaptive growth would probably have been that the fork had cracked, as this is a classic driver for the growth morphology in question.

7.7 In addition, the subject tree showed evidence of prior branch failure at a weak union, resulting in the obvious significant defect in the stem. Defects of this type are known to predispose trees to stem breakage and can undermine the security of attachment of adjacent branches (through decay coalescence). Beech trees are known to be particularly susceptible to decay-related failure, to weak fork formation and limb shedding. Even without the congenital weak forking being observed, which it should have been, the subject tree should have been classed as hazardous.

Statement of Compliance with the Duties of an Expert Witness

I understand that my duty as an expert witness in this matter is to any court before which my evidence may come, including such successors in jurisdiction as may arise. I have complied with this duty and will continue to comply with it. I have set out, in this report, all matters relevant to the issues on which my expert opinion is given. This includes details of any matters that might run counter to my overall conclusions, and/or to the interests of my instructing client. As such, this report is written in compliance with Part 35 Civil Procedure Rules governing expert witnesses and I have addressed it to the court.

Statement of Truthfulness

The contents of this report comprise my honest opinion on the matters addressed herein, and are a true and accurate reflection of my conclusions. I confirm that I have made clear which facts and matters referred to in this report are within my own knowledge and which are not. Those that are within my own knowledge I confirm to be true. The opinions I have expressed represent my true and complete professional opinions on matters to which they refer.

JULIAN FORBES-LAIRD