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PEER REVIEW RELATING TO THE ARBORICULTURAL ASPECTS OF THE PROPOSED CONSTRUCTION OF THE UNITED KINGDOM HOLOCAUST MEMORIAL AND LEARNING CENTRE, AT VICTORIA TOWER GARDENS, MILLBANK, WESTMINSTER, LONDON, SW1 3JA.

CLIENT NAME:

Mr Donncha O'Shea
Gustafson, Porter and Bowman
1 Cobham Mews
Agar Grove
London
NW1 9SB

Ref: None specified

REFERENCE:

FH-Gustafson-Porter-Bowman-Holocaust-Memorial-and-Learning Centre-Westminster

PEOPLE PRESENT:

Dr Frank Hope
Mr Donncha O'Shea.

1.0 FORMAL DETAILS.

- 1.1 My name is Dr Frank Hope, and I am an independent Arboricultural Consultant based at Chestnut House, Northside, Thorney, Peterborough. The practice specialises in arboriculture, urban forestry, biological sciences and project management. I have advised many major clients during the past thirty years, for example, Sainsburys, Midland Bank, Alfred McAlpine, P&O, the BBC, Church of England, Ministry of Defence, Environment Agency, The Health and Safety Executive, Metropolitan Police, Local Authorities, Insurance Companies and Loss Adjusters.

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- 1.2 For five years (April 1998 to April 2003), I acted for the Office of the Deputy Prime Minister (ODPM) as an Inspecting Officer on Tree Preservation Order Appeals. This provided me with a detailed insight into this topic.
- 1.3 In addition to having a doctorate and master's degree in Biological Sciences (research on woody plants), I hold the National Diploma in Arboriculture (RFS) which is the foremost practical British qualification in trees and their management. I also hold numerous general horticultural qualifications, the most notable of which is the National Diploma of Horticulture (now the Master of Horticulture (RHS)).
- 1.4 I am a retired Fellow of the Arboricultural Association, and a retired Fellow of the Institute of Groundsmanship. I am a past member of the education committee of the Arboricultural Association, past vice Chairman of the East Anglian Branch, and am a past member of the governing council. I am also a past member of the governing body of the East of England Show.
- 1.5 During 1997 I was one of three people commissioned by the Arboricultural Association to develop a computerised model capable of assessing the future risk of subsidence damage to buildings when trees are growing close-by.
- 1.6 For further detail on my qualifications and experience see Appendix -A-.

2.0 AUTHORITY AND BRIEF.

2.1 The initial authority for this commission was provided by Mr Donncha O'Shea of Gustafson, Porter and Bowman, on behalf of the UK Holocaust Memorial Foundation, in the form of an email.

2.2 The objectives of this commission are to:

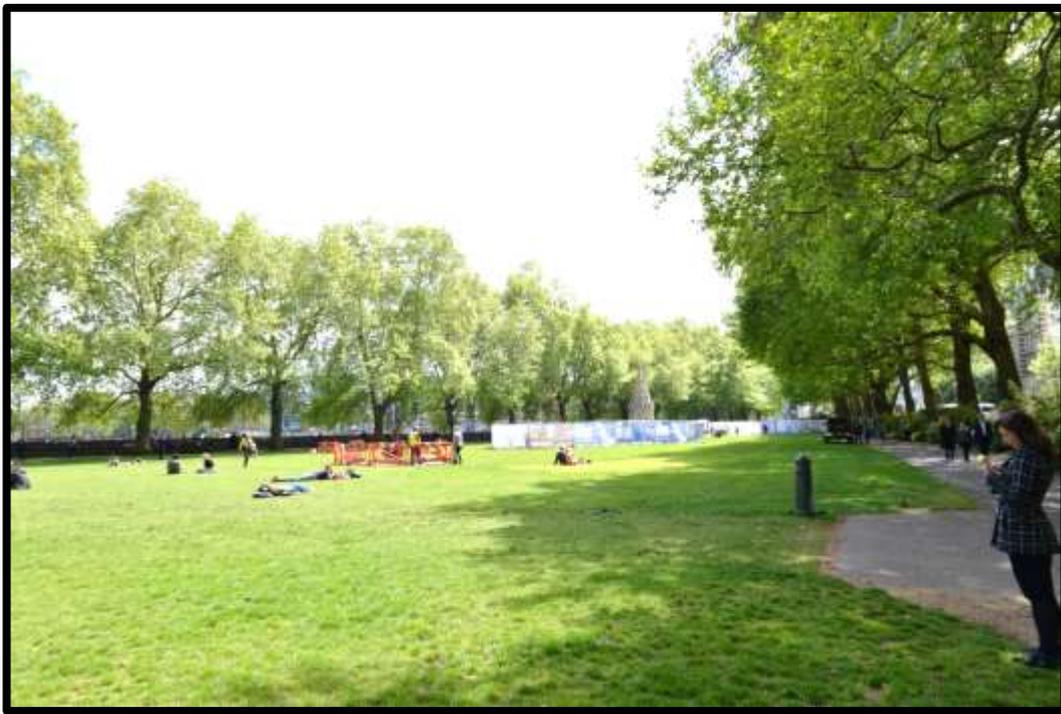
- visit Victoria Tower Gardens, and inspect the mature London Plane trees located around its perimeter;
- review the tree-related literature relevant to the proposed construction of the United Kingdom Holocaust Memorial and Learning Centre;
- carry out a peer review of the Arboricultural aspects of the proposed development.

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3.0 BRIEF INTRODUCTION TO THE TREE-RELATED ISSUES OF THE PROPOSED DEVELOPMENT.

- 3.1 Victoria Tower Gardens is a large, Grade II* listed public open space. It is an approximately triangular-shaped piece of land, located adjacent to the southern end of the Palace of Westminster, on Millbank, London. The site is generally level, and currently consists of ornamental lawns, and pedestrian paths, with a small ornate memorial (Buxton memorial), a playground area for children, a food kiosk, and a total of forty four mature London Plane trees. The Planes are mainly positioned along the eastern and western boundaries.

Picture taken on the 10th of May 2019 showing the trees along the two sides of Victoria Tower Gardens.



- 3.2 It is proposed to construct the UK Holocaust Memorial and Learning Centre within the central area of the open space, i.e. between the two rows of Plane trees.
- 3.3 All of the Planes appear generally healthy, and have a high visual amenity to the locality. They are located within the Westminster Abbey & Parliament Square Conservation Area, and are therefore legally protected by the Conservation Area legislation.

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- 3.4 No detail has currently been provided to indicate that any of the trees are legally protected by a Preservation Order, although they all appear to be worthy of Preservation Order protection, and should be retained on the site.
- 3.5 Concern has been voiced regarding the possibility that the Plane trees within Victoria Tower Gardens could be harmed, or even killed, if the Holocaust Memorial and Learning Centre is constructed within the open space.
- 3.6 The concept of the design and location of the development have been based throughout on the retention of all of the Planes, i.e. no tree removal will be required.
- 3.7 In order to address any potential perceived harm to the Plane trees, Gustafson, Porter and Bowman, commissioned Bartlett Consulting Limited, a highly regarded, international Arboricultural Consultancy, to conduct a tree survey of the Planes so as to identify any constraints they may pose to the proposed development, and to provide a technical report, with recommendations, to assist in the progression of the development scheme to planning.
- 3.8 Bartlett Consulting initially carried out their tree survey, based largely on British Standard 5837 (2012), on the 27th of February 2018.
- 3.9 To assist in the assessment of the proposed development, Gustafson, Porter and Bowman commissioned Sharon Hosegood Associates to carry out a Ground Penetrating Radar survey to identify the location and density of roots within the proposed area of development. This work was undertaken on the 27th of February 2018.
- 3.10 Sharon Hosegood Associates produced a detailed technical report on their investigations, and recommendations, dated the 23rd of March 2018 (Ref: SHA621), with subsequent follow-up reports dated the 1st of November 2018, and the 19th of April 2019.
- 3.11 Gustafson, Porter & Bowman Limited additionally commissioned Canopy Consultancy Limited to carry out a tree root survey of the Planes within the open space, so as to determine the extent of root activity from the Planes into Victoria Tower Gardens. The survey was undertaken between the 3rd and 14th of September 2018, and was carried out using a combination of air-spades, hand digging, and the use of a mini-digger.

Plan produced by Gustafson, Porter and Bowman showing the locations of the root surveys.



- 3.12 Bartlett Consulting produced their initial technical report on the 16th of November, 2018 (Ref: JH/180294/R/sh).
- 3.13 Following the site investigations and the production of the various technical reports, meetings were carried out by the design team to assess possible tree-related constraints on the proposed design of the buildings. The upshot of the discussions was to reposition the footprint of the proposed Holocaust Memorial and Learning Centre by moving it approximately 50.0 metres towards the north (towards the Palace of Westminster), and to include significant design modifications to reduce the possible perceived impact on the trees.
- 3.14 Following the initial design and layout of the proposed development Bartlett Consulting was commissioned to produce an updated and revised Arboricultural Impact Assessment report, to accompany a new planning application. Their brief was to:
- “discuss the constraints posed by the trees; the proposed development in relation to those trees, potential impacts of proposed development; and provide recommendations for tree management and protection where appropriate.”*
- 3.15 In order to assist Bartlett Consulting, Gustafson, Porter & Bowman Limited, commissioned Canopy Consultancy Ltd to carry out additional detailed rootzone investigations along the western boundary of Victoria Tower Gardens, i.e. at the public entrances and the interface with the pavement. This work was carried out in April 2019, and was conducted using a combination of air-spade technology and hand-digging.
- 3.16 Bartlett Consulting produced their updated report on the 26th of April, 2019.
- 3.17 At the time of my site visit on the 10th of May 2019 additional soil investigations were being carried out (See the picture on page 3 above).
- 3.18 I have been commissioned to review the available tree-related data, so as to check if the reports produced by Bartlett Consulting comply with good Arboricultural practice. I have also been commissioned to review and comment on the reports produced by Mr Jeremy Barrell, an Arboricultural consultant. All other none tree-related issues will be addressed by others.

4.0 THE UPDATED AND REVISED DEVELOPMENT SITE IMPACT ASSESSMENT, CARRIED OUT BY BARTLETT CONSULTING LIMITED.

- 4.1 The updated and revised Arboricultural Impact Appraisal produced by Bartlett Consulting was based on the following reference data:
- i. British Standard 5837 (2012) “Trees in Relation to Design, Demolition and Construction – Recommendations;
 - ii. the National Joint Utilities Group (2007) Publication Volume 4: Issue 2 “Guidelines for the Planning Installation and Maintenance of Utility Apparatus in Proximity to trees.”;
 - iii. The Town and Country Planning Act (Tree Preservation) (England) Regulations 2012;
 - iv. National House Building Council Standard Chapter 4.2 – “Building Near Trees);
 - v. various drawings and technical reports on tree root surveys.
- 4.2 A full list of all Bartlett Consulting’s references are to be found in item 1.3 of their updated and revised report (dated 26th April 2019).

5.0 BRITISH STANDARD 5837 (2012) - Trees in Relation to Design, Demolition and Construction – Recommendations.

- 5.1 The reports produced by Bartlett Consulting were based on the guidelines and recommendations of British Standard 5837 (2012), and specific site-related field data.
- 5.2 British Standard 5837 is the industry standard, and nationally accepted, document for providing guidance and recommendations in relation to the juxtaposition of trees and buildings. Although not a statutory document, the British Standard now forms the basis for almost all Arboricultural Impact Assessments relating to development sites. It was revised and updated in April 2012.
- 5.3 Westminster City Council typically recognises the use of British Standard 5837 in planning issues concerning trees, and has relied on it in their

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assessment of the proposed development at Victoria Tower Gardens.

- 5.4 There appears to be no disagreement between the various parties that British Standard 5837 is the relevant, and recognised, publication to use when considering developments near trees. However, there does appear to be significant disagreement as to the interpretation of the British Standard in this instance.

6.0 COMMENTS BY THE LOCAL PLANNING AUTHORITY SENIOR ARBORICULTURALIST.

- 6.1 Ms Barbara Milne, the senior Arboriculturalist for the Local Planning Authority, forwarded an email to Mr David Dorward (Development Planning) on the 19th of March 2019. In the email Ms Milne noted a number of tree-related concerns with the proposed development, and noted her recommended refusal of the planning application.

- 6.2 Ms Milne's recommended refusal of the proposed development was on the basis of the following:

“The likely loss or damage to valuable trees in Victoria Tower Gardens, and the inadequacy of the information submitted to explain and mitigate the likely impact of the proposal on the trees, and the inadequacy of the tree protection details.”

The allowed shapes of the RPAs:

- 6.3 Ms Milne asserts that:

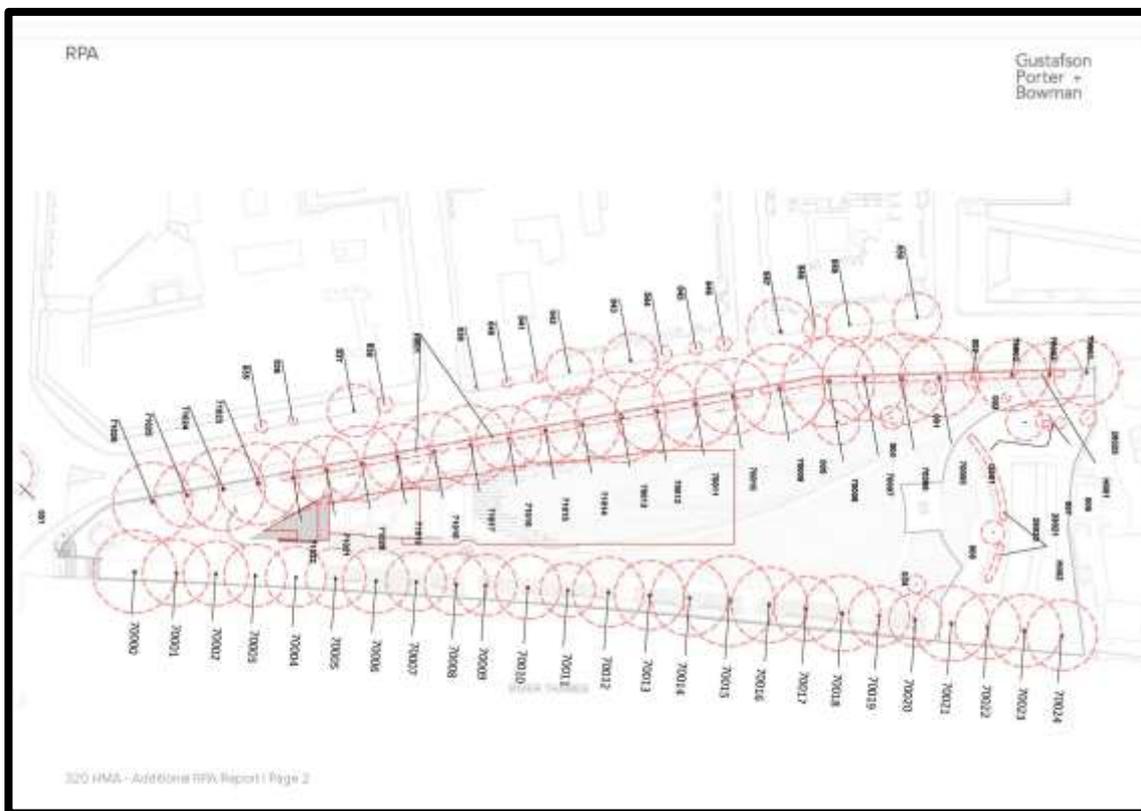
“... the root protection areas (RPAs) of the trees have not been plotted in accordance with the British Standard 5837:2012 Trees in relation to design, demolition and construction – Recommendations.”

- 6.4 Ms Milne has questioned the method of plotting the Root Protection Areas (RPAs) of the trees.

- 6.5 It is difficult to appreciate why Ms Milne has placed such emphasis on the use of RPAs, as they are simply notional, theoretical calculations. The results of actual site investigations provide far more accurate information to guide the planning process, and should, whenever possible, take precedence over theoretical RPAs.

- 6.6 During the production of their report Bartlett Consulting appear to have recognised the limitations of using circular RPAs, and their report acknowledged that some tree-related constraints were present on the site. They concluded that the use of circles, as asserted by Ms Milne, would not provide a representative image of the spatial root development of the trees, especially along the eastern side of the Gardens. In an attempt to address this issue, but to still comply with British Standard 5837, Bartlett Consulting utilised both circles and polygons.
- 6.7 Bartlett Consulting recognised in their report that if the RPAs of the Planes were plotted using circles only, the eastern side of the proposed building would be well away from the western side of the trees along the river side of the site (See the plan below). To compensate for this, they produced the RPAs of the eastern row of trees using polygons, which increased the theoretical spatial root development towards the west, i.e. towards the proposed building.

Plan provided by Gustafson, Porter and Bowman showing the Root Protection Areas of the trees plotted using circles.
Note that the circular representation places the expected root growth on the eastern side well away from the proposed building.



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Plan provided by Gustafson, Porter and Bowman, showing the British Standard Root Protection Areas of the Plane trees at Victoria Tower Gardens using circles and polygons.



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6.8 Item 4.6.2 of British Standard 5837 relates to the calculation of Root Protection Areas; it states:

*“... Where pre-existing site conditions or other factors indicate that rooting has occurred asymmetrically, a **polygon** of equivalent area should be produced. Modifications to the shape of the RPA should reflect a soundly based arboricultural assessment of likely root distribution.”* (Bolding added by Dr Hope).

6.9 There is no comment within British Standard 5837 which stipulates that it is unacceptable to have different shaped RPAs on the same site, and there is no comment that RPAs cannot overlap.

6.10 It appears critical to note that polygons need not be square or rectangular; they can be any shape so long as they take into account specific site-related features, and encompass the calculated area of the RPAs.

6.11 The only restriction on the calculation of RPAs is that the areas of individual trees should be capped at 707m², which gives a maximum safe distance of 15.0 metres between trees and construction.

6.12 Bartlett Consulting carried out their assessment using rectangles and squares (both polygons) for the trees along the eastern side of the site, and circles for the trees along the western side (See the plan on page 10 above). The Bartlett Consulting report indicates that these differing shapes of the RPAs were selected to specifically address the varying conditions of the site, and to provide a more realistic representation compared to the use of circles only.

6.13 Item 4.6.3 of British Standard 5837 continues:

“Any deviation in the RPA from the original circular plot should take account of the following factors whilst still providing adequate protection for the root system:

a) the morphology and disposition of the roots, when influenced by past or existing site conditions (e.g. the presence of roads, structures and underground apparatus;

b) topography and drainage;

- c) *the soil type and structure;*
- d) *the likely tolerance to root disturbance or damage based on factors such as species, age, condition and past management.”*
- 6.14 There are roads, footpaths, and structures within, and adjacent to, Victoria Tower Gardens. Relevant issues relating to these will be addressed within this Peer Review, and by others.
- 6.15 The site is generally level, and at the time of my site visit there were no visual signs to suggest that any significant drainage problems existed.
- 6.16 The detailed soil investigations carried out on the site did not identify any significant issues relating to the growth of the Plane trees, as can be confirmed by their long-term healthy growth.
- 6.17 London Plane is renowned for its tolerance to heavy pruning, which is confirmed by the process of Pollarding seen throughout London. The trees at Victoria Tower Gardens are mature, but are healthy and have long safe life expectancies. They have been significantly pruned in the past, and there is no Arboricultural reason why they should not be pruned in the future.
- 6.18 London Plane as a species is well-known to be capable of resisting heavy pruning of its roots, without reducing their safe life expectancy.
- 6.19 In my opinion, item 4.6 of British Standard 5837 - Root protection area (RPA), clearly identifies that the claim made by Ms Milne in regard to inappropriate plotting of the RPAs is incorrect. I consider the methodology selected by Bartlett Consulting i.e. to use a combination of circles and polygons, was compliant with British Standard 5837.

The likely root distribution

6.20 Ms Milne states the following in her email to Mr Dorwood:

“The likely root distribution means that the impact of the development on the trees will be greater than anticipated in the Arboricultural Impact Assessment dated December 2018.

Only a partial assessment of the development on the trees has been provided - many potential impacts are not considered or are not properly

considered.

As such the impact on the trees is underestimated and their loss or damage is likely.”

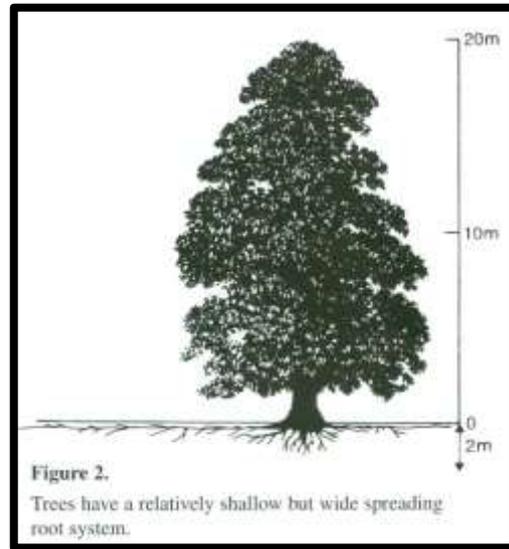
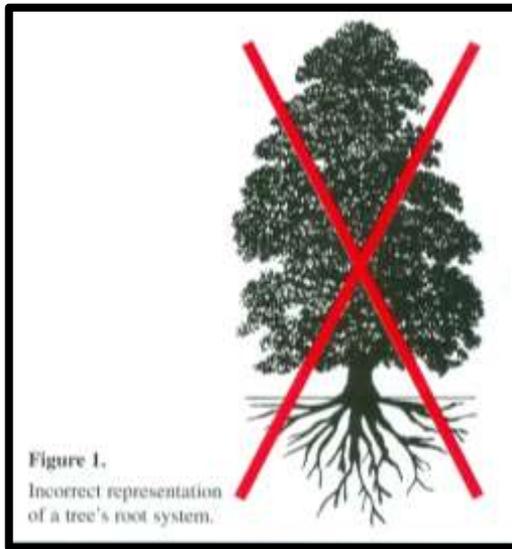
- 6.21 The use of circles only for plotting the RPAs of the trees would actually indicate that the trees along the eastern side of the Gardens would not be harmed in any way. I agree that it is only when polygons are used, as suggested by Bartlett Consulting, that a more realistic representation is achieved.
- 6.22 The basic tenet of theoretical Root Protection Area calculations is formulated in British Standard 5837. The calculated figures are generic and are used as a design aid only. As mentioned previously, they are notional and theoretical. Ms Milne appears to have used the calculations as the de-facto figures for the likely root distribution of the Planes at Victoria Tower Gardens, and she discounts the results of the site investigations as being inadequate, or possibly misleading.
- 6.23 The claim by Ms Milne that, based on the use of circular RPAs, the impact on the trees is likely to be greater than that anticipated in the submitted documentation seems to be based on what she perceives to be the incorrect plotting of the theoretical Root Protection Areas, not on the actual distribution of the tree roots.
- 6.24 In my opinion, the method of plotting the RPAs along the eastern side of the Gardens using polygons is not a valid reason to bring into question the safety of the Plane trees, or to justify refusal of the design proposal. I consider the critical point is that actual site investigations relating to root distribution have identified that the use of polygons was found to be far more accurate than circles alone.

The development of tree root systems

- 6.25 There is a general misconception that tree roots grow to great depths within a soil, and often have large “Tap-Root” systems (See Figure 1 on page 14 below). However, in reality, the root systems of trees are typically shallow, and spread out for considerable distances (See Figure 2 below).
- 6.26 Tree roots typically grow parallel with the soil surface, rather than vertically, and on level sites the majority of their roots are within a depth

of between 600mm and 1.0 metre below ground level (See Appendix “B” of this peer review). However, it is possible for some roots to develop below these depths.

Scanned copies of Figures 1 & 2 of AAIS – APN12.



6.27 Roots can be up to 30cm or more in diameter at the base of the trunk of a tree, but they sub-divide and taper rapidly as they extend from the trunk. In the majority of cases the roots are only 2-3cm in diameter, or much less, at a distance of between 5.0 metres to 10.0 metres from the trunk.

6.28 The majority of feeding and moisture absorbing roots are produced close to the trunks of trees, not at great distances from them.

6.29 The standard recognised text in relation to tree root development is entitled “Tree Roots Systems”, written by Dr Martin Dobson for the Arboricultural Advisory and Information Service (AAIS) in 1995 (See Appendix “B” of peer review). The Summary section of the publication states the following:

*“The development and structure of tree root systems are described. They are wide spreading, extending radially in any direction for distances often in excess of the tree’s height. **Roots grow predominantly near the surface – over 90% of all roots, and virtually all the large structural supporting roots, are in the upper 600mm of soil.** Soil disturbance within the rooting area should be avoided, as this can significantly affect tree stability and moisture uptake.”* (Bolding added by Dr Hope).

6.30 Gustafson, Porter and Bowman commissioned Canopy Consulting to carry

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out detailed root investigations to a depth of between 600mm and 1000mm at a distance of approximately 6.0 metres from the trees. This would be expected to have identified over 90% of the tree roots within the area, as identified by Dr Dobson's research.

- 6.31 Gustafson, Porter and Bowman also commissioned Sharon Hosegood Associates to undertake Ground Penetrating Radar investigations approximately 6.0 metres from the trees, and to a depth of approximately 2.5 metres.
- 6.32 In my opinion, the small distance between the trees and the soil excavations was probably selected during the development of the initial design proposal. I consider that it would have been more prudent in relation to the current design to have carried out the excavations directly along the perimeter edges of the proposed new building.
- 6.33 The soil/root investigations indicated that few significant roots were present at 1000mm. Ms Milne has questioned the validity of the investigations, and is of the opinion that the majority of the feeding roots would be down to a depth of approximately 5.0 metres. She has provided no published research to confirm this thesis.
- 6.34 Having visited the site and viewed the site investigations, I consider that some root development will probably have taken place below 1000mm, which the investigations did not identify. In my opinion, in this instance, it would have been more appropriate to have carried out detailed investigations to a depth of between 1500mm and 2000mm, but recognise that tree root investigations are traditionally only to 1.0 metre.
- 6.35 Healthy trees produce a balance between their root systems and their branch/leaf structure. The balance of growth is known as the root:shoot ratio, and it ensures that the tree has enough roots to provide adequate moisture and nutrients to support the branches and leaves. If the root:shoot ratio of a healthy tree is altered to any extent, the tree will rapidly produce new growth to reinstate the balance.
- 6.36 The severing of some roots of the Planes would affect their Root:Shoot ratios to a minor extent. However, the trees are healthy, and can withstand heavy pruning. I consider that there is a high probability that the trees would rapidly re-balance the ratio producing new roots close to the pruning points, with no ill effects to the trees.

- 6.37 At the time of my site visit on the 10th of May 2019 additional site investigations were being carried out. These did not form part of the Bartlett Consulting investigations.
- 6.38 In my opinion, Bartlett Consulting carried out what they considered were industry recognised investigations to ascertain the depth of root development of the Planes. I accept Ms Milne’s assertion that the investigations were too shallow in this instance. However, I see no justification to have carried out investigations down to a depth of 5.0 metres, or more.

Can tree roots be severed without causing harm to trees?

- 6.39 The email from Ms Milne to Mr David Dorward (19th March 2019) makes no reference to the fact that it is possible to sever some tree roots without causing harm to trees. It appears to me from the text that she does not accept that it would be possible to sever any roots without hurting the trees.
- 6.40 It is generally accepted within the Arboricultural industry (See item 2 of the current British Standard 5837) that some roots can be severed without causing damage to trees, and that new root growth will be produced at, or close to, the pruning points. This is confirmed in The National Joint Utility Group publication entitled “NJUG Guidelines for the Planning, Installation and Maintenance of Utility Apparatus in Proximity to Trees – volume 4, Issue 2, 2007”, where it accepts that roots of up to 25mm diameter can be severed without specialist Arboricultural input, and that roots with greater than 25mm diameter may also be severed in certain circumstances following advice from a qualified Arboriculturalist. It is important to note that although roots of less than 25mm may be severed, special care must be taken where clumps of roots of this diameter are present.
- 6.41 I also consider it critical to note that the calculation of theoretical RPAs of trees using the BS:5837 methodology fully accepts that all roots of any type or size, i.e. smaller or greater than 25mm diameter, can be severed outside the RPAs without hurting trees, and that new, healthy regrowth will take place.
- 6.42 It is generally accepted within the Arboricultural industry that as the RPAs are theoretical only, and can therefore only be used as guidelines, it is possible, and reasonable, to have some flexibility in the encroachment of construction works in relation to trees. This accepted encroachment is

typically between 10% and 20%.

- 6.43 It appears that Ms Milne has not provided any evidence to support her assertion that severing any of the Plane roots would harm, or possibly kill, the trees.
- 6.44 The picture below provides an example where highly professional tree specialists acknowledge that significant root severance can take place without harming trees.

Picture showing exposed roots of a Sycamore (not in VTG). A senior Arboricultural Association Registered Consultant, and a senior Local Government Tree Officer considered that the tree would not be harmed if all the exposed roots were severed.



Tree rootzone compensation measures - Mitigation

- 6.45 In Ms Milne's email to Mr David Dorward (Development Planning) on the 19th of March 2019, in relation to refusal of the application she states:

“I support the refusal of planning permission for the proposal on the basis of likely loss or damage to valuable trees in Victoria Tower Gardens, and the inadequacy of the information submitted to explain and mitigate the likely impact of the proposal on the trees, and the inadequacy of the tree protection details.” (Bolding added by Dr Hope).

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6.46 Section 5.0 of the Bartlett Consulting report (V3) dated the 16th of November 2018, covers the detailed mitigation techniques that they envisage carrying out during, and after, the proposed development works. The Bartlett Consulting submission included the following mitigation works:

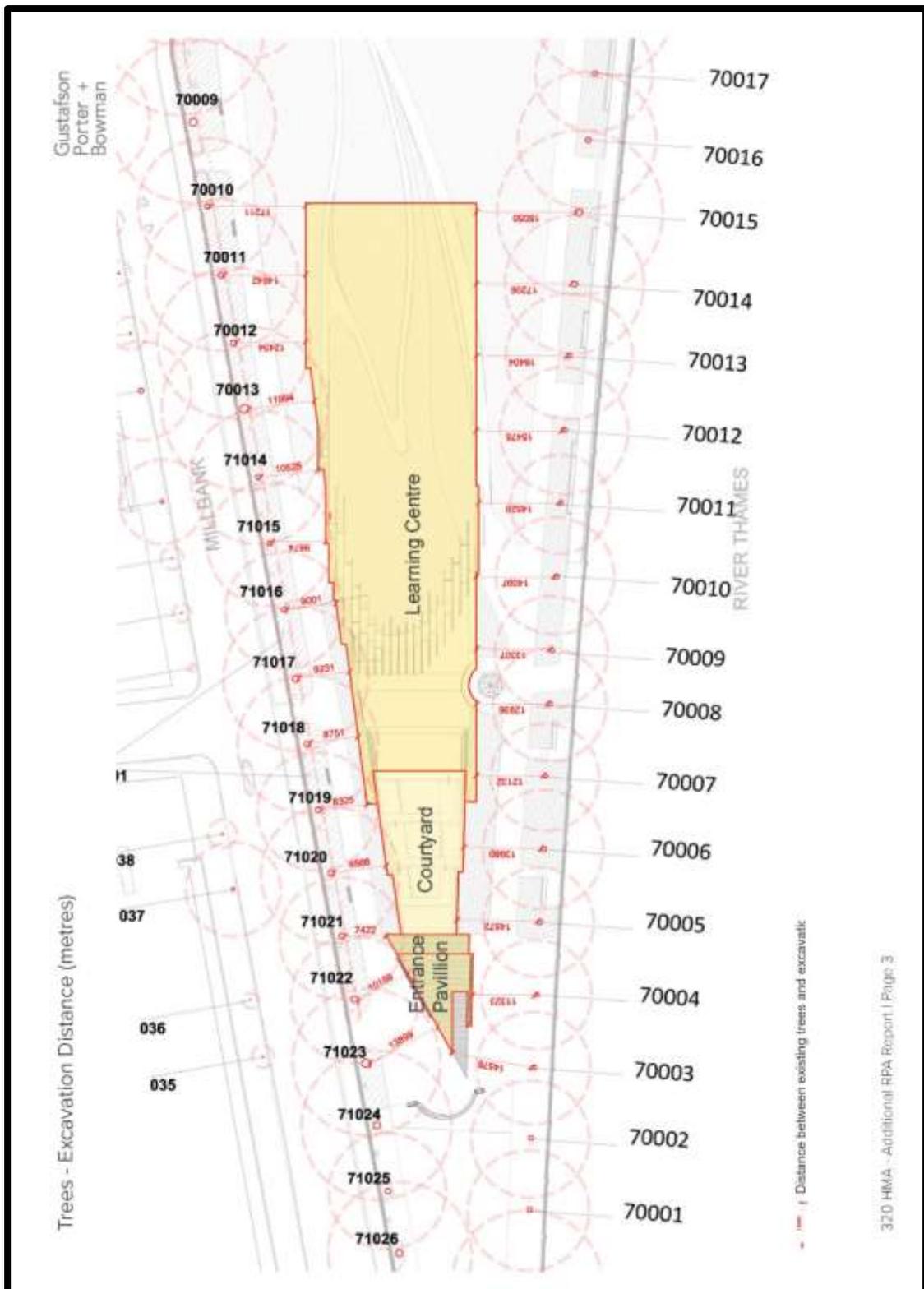
- i. root pruning using clean and sharp handsaws or secateurs;
- ii. immediately following root pruning the application of Potassium Phosphite on the cut surfaces;
- iii. the wrapping of exposed roots with pre-soaked Pulvium Zeba™ gel pack and hessian where roots are to be left uncovered for any length of time, or the re-covering of roots with soil immediately after the pruning operation;
- iv. application as a soil drench of Potassium Phosphite for all retained trees to stimulate tree vitality and root development, and improve the trees' resistance to diseases;
- v. spot treat for pruned roots;
- vi. applications of sucrose as a soil drench for all trees that have been root pruned;
- vii. soil nutrient analyses to be carried out to determine any nutrient deficiencies, unfavourable soil pH values, and adequacy of soil organic matter;
- viii. application in the form of a soil drench of slow-release tree fertiliser to maintain key levels of nutrients;
- ix. improvements to the footpath network, courtyard plaza, and landforms.

6.47 In my opinion, the claim by Ms Milne that Bartlett Consulting did not provide adequate tree mitigation proposals is incorrect. I consider that Bartlett consulting included significant mitigation and remedial measures to minimise any adverse influence to the trees. In my view what they proposed was good Arboricultural practice.

The distances between the Plane trees and the eastern side of the proposed development.

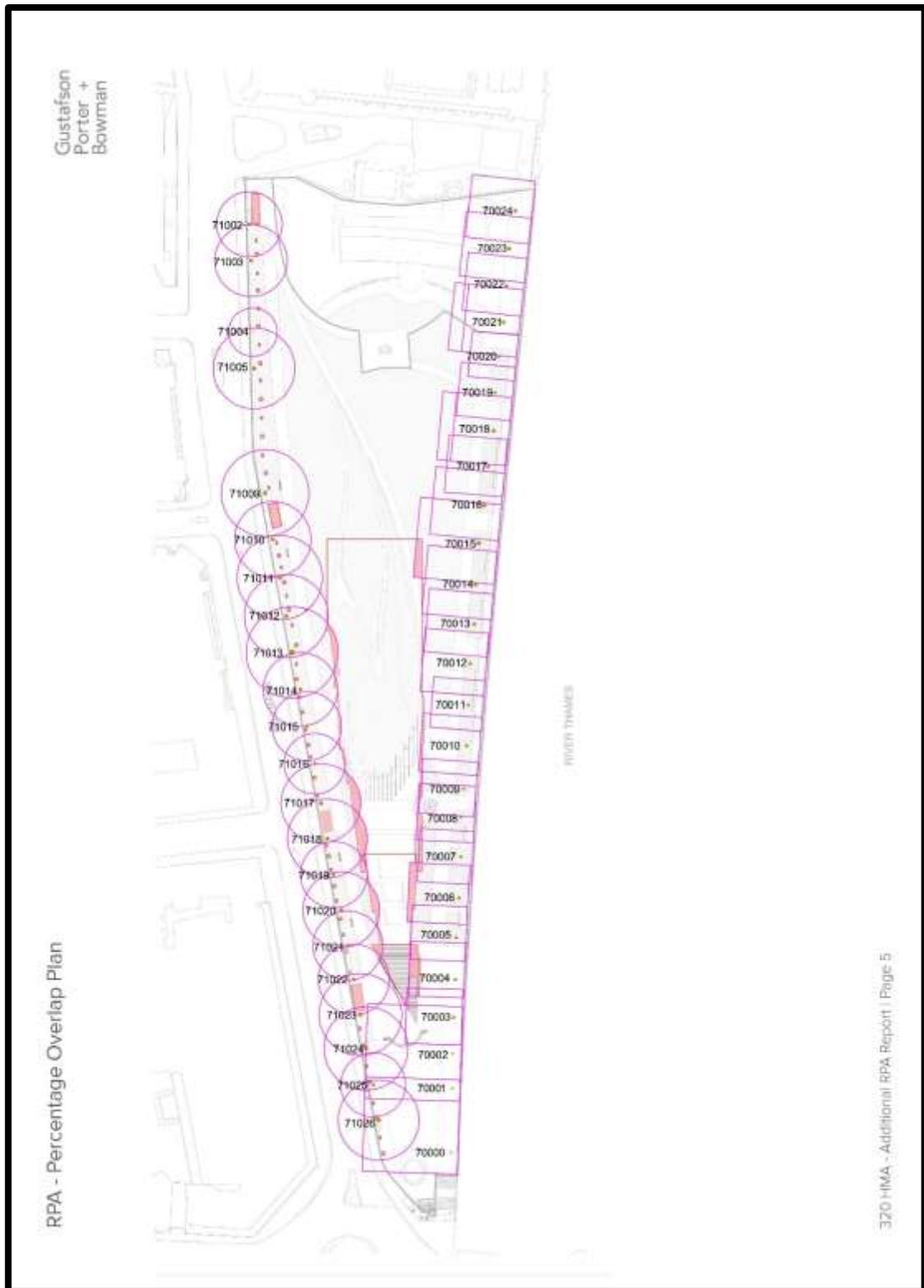
6.48 The plan on page 19 below, provided by Gustafson, Porter and Bowman, indicates the actual distances between the Plane trees and the edges of the proposed footprint of the construction. The plan on page 20 shows the area of encroachment (shaded areas) of the RPAs.

Plan provided by Gustafson Porter and Bowman showing the actual distances between the centre of the Planes and the edge of the proposed excavations.



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Plan provided by Gustafson, Porter and Bowman highlighting the theoretical areas of encroachment (shaded) of the proposed buildings into the RPAs



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Table provided by Gustafson, Porter and Bowman showing the distances between the edge of the construction and the trees along the eastern side of Victoria Tower Gardens.

TPO	Distance to excavation line (mm)
70015	18050
70014	17206
70013	16404
70012	15476
70011	14529
70010	14097
70009	13307
70008	12936
70007	12132
70006	13980
70005	14572
70004	11323
70003	14576

6.49 The table above, provided by Gustafson, Porter and Bowman, shows the distances between the trees and the eastern edge of the proposed building.

6.50 As mentioned throughout this review the use of RPAs should only be used as guidelines, i.e. to aid design. As such, it is reasonable to provide some flexibility into the encroachment of construction in relation to trees. The typically accepted flexibility is between 10% and 20% of the overall Root Protection Areas. I consider it would be arboriculturally unsound, and unrealistic, to claim that no encroachment would be acceptable.

6.51 Only two of the trees in the above table (70004 & 70006) have theoretical

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incursions above 10%. In my opinion, such incursions would not harm the trees in any way, as they would rapidly regenerate new root growth.

Table provided by Gustafson, Porter and Bowman showing the radii of the trees along the eastern side of Victoria Tower Gardens, with the RPAs (in square metres), and the RPA percentage infringements.

TPO	Root Protection Radius (m)	Root Protections (m ²)	RPA Infringement %
70015	14.88	695.59	4.10%
70012	11.64	425.65	0.39%
70010	10.80	366.44	2.91%
70009	10.14	323.02	1.04%
70008	10.50	346.36	6.04%
70007	9.84	304.19	4.44%
70006	10.98	378.75	11.55%
70005	10.02	315.42	4.57%
70004	10.14	323.02	11.70%
70003	10.32	334.59	1.91%
70002		966.65	0.25%
70001		966.65	0.41%

The interpretation of the theoretical British Standard 5837 Root Protection Areas of the Planes along the eastern side of the park

6.52 Ms Milne has made the following comment in relation to the probable spatial development of the roots of the Planes along the eastern side of Victoria Tower Gardens:

“It is more likely that the trees are rooting preferentially eastwards, into VTG, and less likely that the RPAs of the trees overlap on a north to south axis. As such, the trees are likely to be rooting into a larger proportion of the proposed excavation envelope than currently depicted, and into areas where other development and construction is proposed.

6.53 It seems that the assertion of preferential root growth towards the east, is

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incorrect, as the boundary wall along the Thames is to the east, with the main area of gardens to the west.

- 6.54 I know of no research to prove that the Planes along the eastern boundary would stimulate preferential root extension growth away from the boundary wall, i.e. towards the west of the trees. As the siting of the proposed development along the eastern side of the site appears contentious, it would be useful if any research information on this topic could be made available by the Local Planning Authority.
- 6.55 When trees grow, they typically send out their roots randomly to utilise the available soil moisture resource; the greatest percentage of moisture absorbing roots are closest to their trunks.
- 6.56 There is no evidence available to indicate that the roots of the Planes have ever fully exhausted the available moisture resource within the soil close to the trees. Had this happened the trees would have suffered, and would have exhibited reduced annual extension growth, and in severe cases they would have wilted. No record of such excessive soil drying has been provided. The trees appear healthy and are making acceptable annual extension growth.
- 6.57 No mechanism has been shown to prove that roots affected by the boundary wall have triggered additional root extension growth within Victoria Tower Gardens, i.e. specifically towards the west.
- 6.58 It would be useful for the Local Planning Authority to disclose any research information confirming that the moisture and oxygen reserves within the soil between the boundary wall and the proposed area of development, have ever been exhausted. My inspection of the trees and soil conditions highlighted no indication of any lack of extractable moisture or oxygen close to the trees.
- 6.59 I have seen no available evidence to suggest that there were so many roots present in the soil that they prevented other root development, i.e. akin to a pot-bound plant, and I know of no reason to prevent new root growth from naturally occurring between the trees. Roots often intermingle in the soil and it is commonplace for natural root grafting to occur.
- 6.60 The plan on page 10 above, provided by Gustafson, Porter and Bowman, indicates the theoretical RPAs of the trees. Note that the RPAs overlap each

other in a north to south direction whichever shape is used. This is a typical representation of RPAs and indicates that rooting between the trees is normal and expected.

- 6.61 I consider the comment by Ms Milne in relation to the likelihood of the RPAs not overlapping on a north to south axis is unsustainable. The RPAs are simply representations of the theoretical root spreads of the trees, and in my opinion, there is an extremely high probability that significant actual root development will have occurred between the trees within the rows.
- 6.62 In my opinion, the assessment carried out by Bartlett Consulting was sound, and the calculations of the polygon-shaped RPAs were appropriate under the circumstances, and based on good Arboricultural practice.
- 6.63 In my view there is adequate distance between the trees and the proposed development to allow the continued healthy growth of the trees.

The distances between the Plane trees and the western side of the proposed development

- 6.64 The plan on page 19 above, provided by Gustafson, Porter and Bowman, indicates the actual distances between the Plane trees along the western side of Victoria Tower Gardens, and the edges of the proposed footprint of the construction. The plan on page 20 shows the area of encroachment (shaded areas) of the circular RPAs.
- 6.65 The table printed on page 25 below, provided by Gustafson, Porter and Bowman, shows the distances between the trees and the western edge of the proposed building.

Table provided by Gustafson, Porter and Bowman showing the distances between the edge of the construction and the trees along the western side of Victoria Tower Gardens.

TPO	Root Protection Radius (m)	Root Protections (m ²)	RPA Infringement %	Distance to excavation line (mm)
71026	13.20	547.39	0.68%	
71025	10.56	350.33	0.63%	
71024	13.68	587.93	1.03%	
71023	13.44	567.48	4.74%	13899
71022	11.64	425.65	7.69%	10159
71021	11.40	408.28	4.11%	7422
71020	12.48	489.30	4.70%	9588
71019	10.92	374.62	3.41%	8325
71018	12.96	527.67	13.04%	8751
71017	13.08	537.48	11.29%	9231
71016	10.08	319.21	1.52%	9001
71015	11.34	403.99	2.04%	9674
71014	12.12	461.48	1.29%	10525
71013	15.00	706.86	3.46%	11994
71012	13.68	587.93	0.90%	12454
71011	13.92	608.74	0.74%	14642
71010	12.48	489.30	5.30%	17211
71009	14.28	640.63	4.05%	
71006	13.32	557.39	0.54%	
71004	2.82	24.98	6.91%	
71003	11.82	438.92	0.68%	
71002	10.68	358.34	6.90%	

The interpretation of the British Standard 5837 Root Protection Areas of the Planes along the western side of the gardens

6.66 Ms Milne makes the following comment in relation to the development of roots on the western side of Victoria Tower Gardens:

“The RPAs of the trees adjacent to Millbank are shown extending into the carriageway of Millbank. The AIA Dec 18 justifies this on the basis that this was deemed reasonable before the appointment of the current arboricultural consultant, and although the carriageway is inhospitable for feeding roots of the trees, it is ‘entirely possible’ root growth for stability and anchorage is occurring.

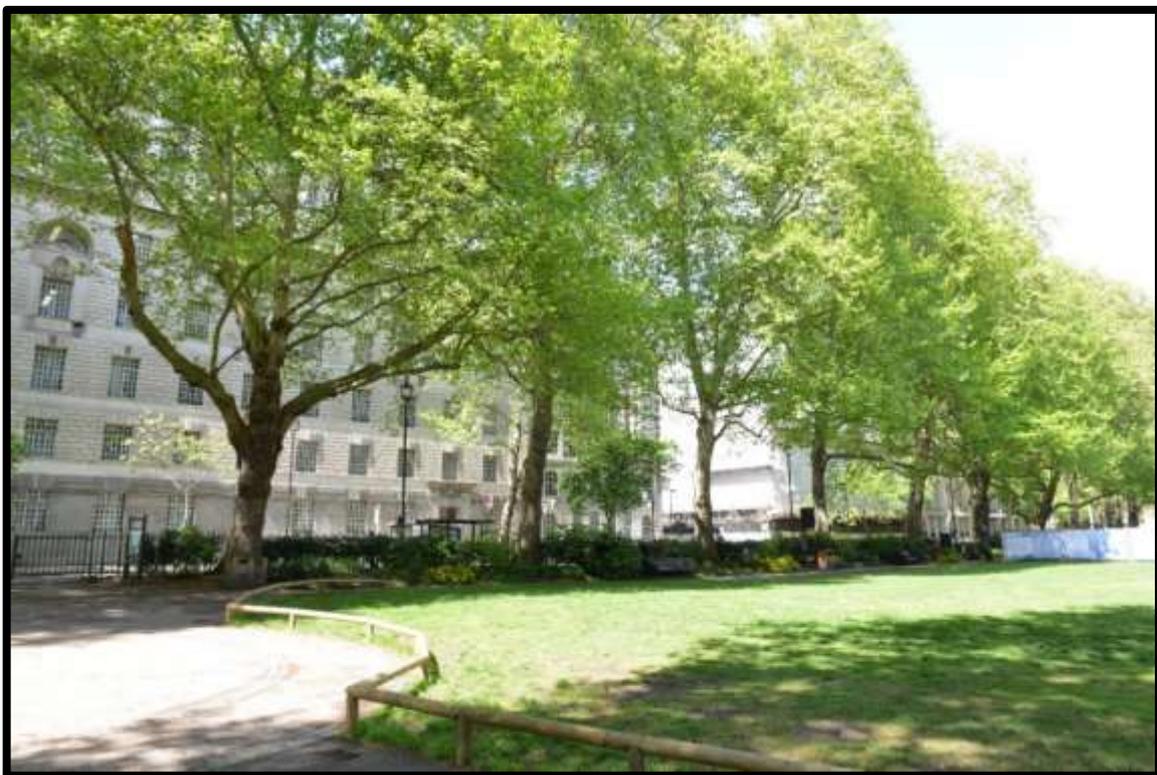
Gustafson, Porter and Bowman – Holocaust Memorial and Learning Centre, Victoria Tower Gardens, Westminster, London.

Whilst it is possible that there are structural roots below the carriageway of Millbank, it is improbable, and is not supported by any root investigation. Given that tree roots are opportunistic, and will grow preferentially into areas where moisture, nutrient and aeration are more favourable, a sound arboricultural judgement is that it is more likely that the trees are rooting preferentially westwards into VTG, and it is less likely that they are rooting to any extent below the carriageway of Millbank. (Bolding added by Dr Hope).

With regard to the rooting of these trees below the pavement on Millbank, the AIA Dec 18 says, 'a proportion of each tree root plate will be found under the pavement'. This may or may not be the case, and is not supported by any root investigation, but with reference to the Planning Utilities Statement December 2018, it appears there are constraints to rooting below the pavement."

- 6.67 The above extract from Ms Milne confirms that it is possible, although she considers unlikely, for roots to be beneath the carriageway of Millbank, which is consistent with the Bartlett Consulting assessment.

Picture taken on the 10th of May 2019 showing the Planes along the western boundary of Victoria Tower Gardens.



Gustafson, Porter and Bowman – Holocaust Memorial and Learning Centre, Victoria Tower Gardens, Westminster, London.

Picture taken on the 10th of May 2019 showing a close-up of the Planes along the western edge of the Gardens.



Picture taken on the 10th of May 2019 showing the proximity of the Plane trees to the public pavement and Millbank.



6.68 The plan on page 10 of this review indicates the British Standard 5837 RPAs along the western side of the gardens. The trees are positioned in a narrow border adjacent to the boundary fencing, along Millbank.

Will there be any roots beneath the public pavement and carriageway of Millbank?

6.69 Ms Milne has asserted that no supporting evidence has been provided to justify the claim that tree roots will be beneath the footpath and carriageway along Millbank, to the west of Victoria Tower Gardens. However, I consider that it is simply impracticable and unjustified, to excavate all along the pavement and carriageway. In my opinion, it is equally difficult to carry out a 5.0 metre deep excavation along the pavement/carriageway without harming the roots of the trees.

6.70 I note that Ms Milne appears to have the northing of her comment incorrect, as the proposed building is to the east of the Planes, and the footpath and carriageway are to the west.

6.71 Ms Milne States:

“... a sound arboricultural judgement is that it is more likely that the trees are rooting preferentially westwards into VTG...”

6.72 Ms Milne has made no comment on the fact that the reason why roots do not encroach into apparent inhospitable areas is because of the bulk density of the substrate, i.e. high bulk densities restrict root development. To my knowledge there are no current data on the bulk density of the soil to justify her “sound arboricultural judgement”, and the site investigations do not identify any high bulk densities. Ms Milne makes no assessment as to the potential instability of the trees if no roots are present on the pavement/road side only.

6.73 In my experience it is commonplace for trees to produce roots beneath paths and carriageways, and there are many hundreds, if not thousands, of large Plane trees growing throughout London in similar situations.

6.74 The picture on page 29 below, taken at the time of my site visit on the 10th of May 2019, shows a large Plane tree located within the pavement on the opposite side of Millbank to Victoria Tower Gardens.

Picture showing a large Plane growing within the pavement along Millbank, opposite Victoria Tower Gardens.



Picture taken on the 10th of May 2019 showing the base of the Plane on the pavement adjacent to the carriageway.



Picture taken on the 10th of May 2019 showing a close-up of the base of the Plane tree with large structural, buttress roots growing beneath the Kerb and carriageway.



- 6.75 The Plane tree is growing within the pavement, close to a multi-storey building; the foundations of which will be extensive, and the likelihood of any roots from the tree encroaching beneath them must be remote.
- 6.76 The above picture clearly identifies that large structural roots are growing on the carriageway side of the Plane tree; and I consider that there is a high probability that roots will have developed beneath the carriageway.
- 6.77 If, as asserted by Ms. Milne, no roots are growing beneath the carriageway, then all of the roots of the Plane must have grown beneath the public pavement; there simply would be nowhere else to grow. This means that if no root growth had been produced by the Plane beneath the carriageway of Millbank, there must be adequate room for it to grow beneath the pavement only. This indicates that the use of RPAs can be unreliable in certain circumstances.
- 6.78 I consider it is critical to note that the distance between the tree and the building is less than the distance between the trees and the proposed building in Victoria Tower Gardens. This suggests to me that there is

adequate area of growth between the trees and the western side of the proposed buildings.

- 6.79 The picture below shows a large London Plane located against a carriageway. Large, structural roots have developed beneath the carriageway, which brings into question the validity of the claim that roots will not be beneath the pavement and carriageway along Millbank.

A picture showing a large Plane located adjacent to a main road. Large structural roots have moved the kerb, and have developed beneath the carriageway.



7.0 ROOT INVESTIGATIONS.

- 7.1 Section 3.3 of the Bartlett Consultancy report dated the 26th of April 2019, confirms that there were four individual reports relating to the identified tree root systems of the Planes.
- 7.2 Canopy Consulting carried out detailed root investigations to a depth of between 600mm and 1000mm within the border at the base of the trees and at a distance of approximately 6.0 metres from the trees. This would be expected to have identified over 90% of the tree roots within the area. The depth would be typical of that identified by Dr Dobson's research.

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- 7.3 Sharon Hosegood Associates undertook Ground Penetrating Radar investigations approximately 6.0 metres from the trees, and to a depth of approximately 1000mm. Once again, this would be expected to have identified over 90% of the tree roots, and the depth would comply with Dr Dobson's research.
- 7.4 The distance of 6.0 metres from the trees is important, as the closest tree to the proposed development on the eastern side of the site is 11.3 metres (tree 7004), with the furthest being 18.0 metres away (tree 70015). The closest tree to the western side of the construction is 7.4 metres (tree 71021), and the furthest away is 17.2 metres (tree 71010).
- 7.5 As mentioned previously in this review, I consider that it would have been more appropriate to have carried out the soil investigations around the perimeter of the proposed development down to a depth of between 1500mm and 2000mm, as this would have identified any actual roots that would be affected by the building construction. In my view, the likelihood of any large, significant, roots being present is extremely low, and I consider that the root severance at between 7.4 metres to 18.0 metres away from the trees would not harm them in any way.
- 7.6 Ms Milne declined to accept the results of the Air-Spade and Ground Penetrating Radar Investigations – she states:
- “Taking into account the constraints on tree root distribution set out above, the roots found in the trenches and the known deep rooting habit of London planes to 5 or more metres in depth, it is a reasonable arboricultural judgement that significant roots of the trees will be severed in order to accommodate the excavation and it is likely that trees will be lost or harmed as a result.”*
- 7.7 No evidence has been identified in Ms Milne's objection to confirm that Plane roots grow down to depths of over 5.0 metres outside their root plates, and no mention has been made that the likelihood of roots being down to 5.0 metres at the edges of the proposed excavations is extremely unlikely.
- 7.8 There is a lack of awareness on how a trench below 5.0 metres depth within the site, and along the pavement/carrage-way of Millbank, would sever the majority of roots present. No account appears to have been taken of the soil type, and the issue of shoring-up the sides of such trenches, and the related

safety aspects involved, have not been addressed.

Western Interface of Proposed Development and Tree RPA				
Tree Ref	Root Ref	Diameter & Depth	Aspect of Memorial	Implications
T71022	R25	50 mm - 900 mm	- Entrance Pavilion	- Retained - Shallow building foundations above root - No pruning or direct damage
T71021	R24 – R22	40 mm – 30 mm - 900 mm – 1.0 metre	- Entrance Pavilion	- Retained - Shallow building foundations above roots - No pruning or direct damage
T71020	R21 – R19	60 mm – 20 mm - 800 mm – 900 mm	- Pavilion Courtyard	- Retained - Retaining wall to terminate above roots - Level changes to incorporate roots - No pruning or direct damage - Root R19 dead at time of investigation
T71019	R18 - R16	15 mm – 40 mm - 800 mm – 1.0 metre	- Pavilion Courtyard	- Retained - Retaining wall to terminate above roots - Level changes to incorporate roots - No pruning or direct damage
T71018	R15 – R14	100 mm (R15) 50 mm (R14) - 900 mm – 1.0 metre	- Pavilion Courtyard - Basement Box	- Pruning required to facilitate development
T71017	R13 – R12	20 mm – 60 mm - 400 mm – 900 mm	- Basement Box	- Pruning required to facilitate development
T71016 to T71014	R11 – R04	10 mm – 60 mm 500 mm – 700 mm	- Basement Box	- Pruning required to facilitate development - Root 10 was severed and pruned during works
T71013 to T71012	R03 – R01	15 mm – 20 mm - 500 mm – 900 mm	- Landforms	- Retained - No pruning or direct damage

Eastern Interface of Proposed Development and Tree RPA				
Tree Ref	Root Ref	Diameter & Depth	Aspect of Memorial	Implications
T70006	R26 – R27	50 mm (R26) - 400 mm (R26)	- Pavilion Courtyard	- Retained - Shallow building foundations above root - No pruning or direct damage - R25 pruned during investigations
T70007	R28	30 mm - 1.0 metre	- Pavilion Courtyard	- Retained - Shallow building foundations above roots - No pruning or direct damage
T70008	R29 – R30	35 mm – 40 mm - 700 mm	- Pavilion Courtyard - Basement Box	- Pruning required to facilitate development
T70009	R31 – R32	30 mm – 35 mm - 900 mm	- Basement Box	- Pruning required to facilitate development
T70010	R33 – R36	20 mm – 50 mm - 230 mm – 900 mm	- Basement Box	- Pruning required to facilitate development
T70011	R37 – R40	15 mm – 50 mm - 500 mm – 900 mm	- Memorial Fins	- Retained – R37, 50 mm diameter - Bespoke foundations for memorial fins - Roots R38 – R40 pruned during investigations
T70014 to T70015	R41 – R43	20 mm – 45 mm - 400 mm – 900 mm	- Basement Box	- Pruning required to facilitate development

7.9 The tables above, extracted from the Bartlett Consultancy Report, provide data on the known roots found during the investigations.

7.10 In my view all of the roots identified for pruning by Bartlett Consultancy would not harm the trees.

Recent soil investigations

7.11 At the time of my site visit on the 10th of May 2019, Ground Engineering Limited of Newark Road, Peterborough, were on site excavating a total of six trial pits as part of an archaeological investigation.

7.12 Three of the trial pits (TP01, TP02 & TP03) were located within the grassed area to the south of the footpath running west to east from Millbank to the Buxton Memorial. Two trial pits (TP04 & TP05) were located in the northern section of the grassed area, and TP06 was located against the eastern boundary wall, to the southeast of the Buxton memorial (See the plan on page 35 below).

7.13 Although the Ground Engineering works were not designed as part of the tree root survey investigations, they do provide useful information relating to root sizes and depths below ground level.

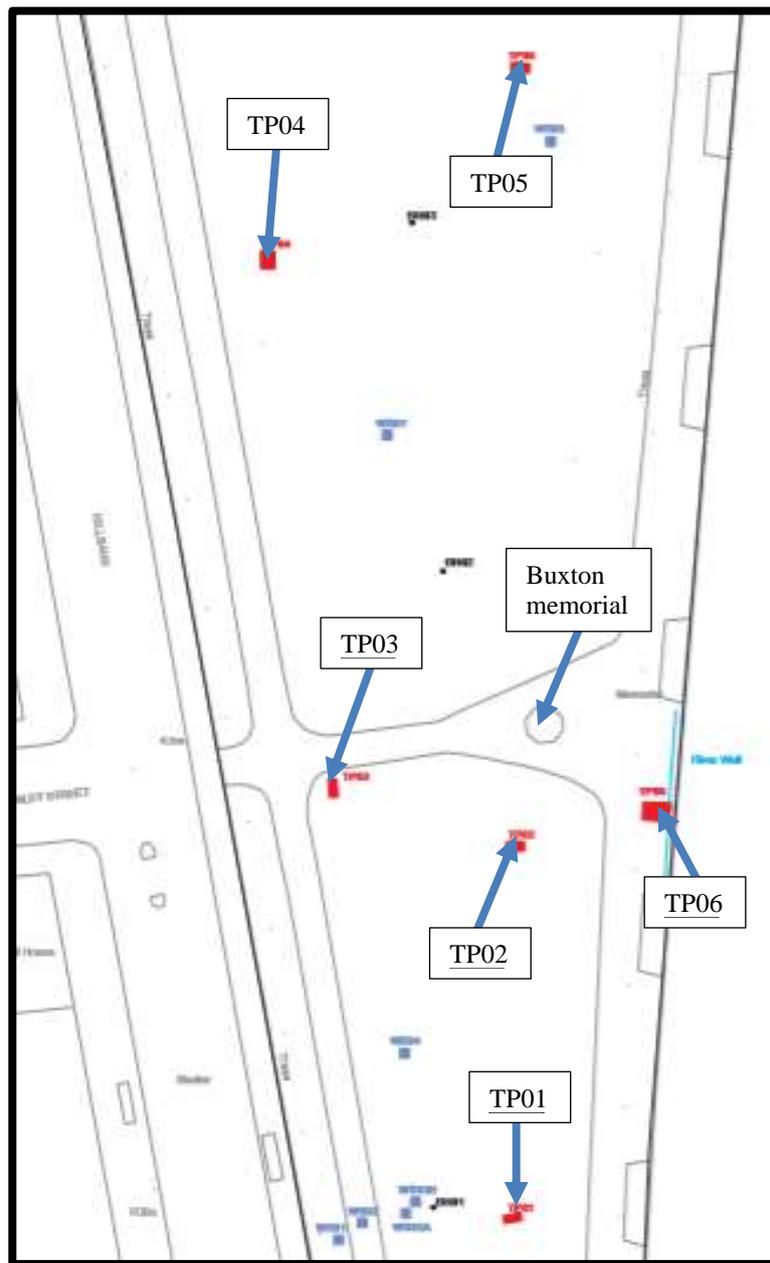
7.14 Trial pit 01 was located at the southern end of the Gardens, to the northwest of the Spicer Memorial, and well away from the proposed siting of the Holocaust Memorial and Learning Centre. The trial pit data are consistent with the research carried out by Dr Martin Dobson, in that other than one root going down to 2.0 metres, all the others were within the top 1.0 metre of the soil surface.

7.15 Trial pit 02 was located to the south of the area of proposed development. No root presence was noted throughout the excavation.

7.16 Trial pit 03 was located on the western side of the site, adjacent to the path leading from off Milbank to the Buxton monument. Only one root down to a depth of 2.1 metres was found within the trial pit. As mentioned above this is consistent with Dr Dobson's research. Severing one root of 30mm to 40mm diameter would not harm any of the trees within that location. The investigation fails to validate the claim that roots of the Planes would be down to 5.0 metres, or deeper, within the area.

7.17 Trial pit 04 was located on the western side of the grassed area close to the area of proposed development. Only two roots with diameters of 50mm-90mm were found at a depth of 1.1 metre. The photographic evidence for the trial pit suggests that the roots were originally one root, that has bifurcated, which confirms the diminishing diameter of roots the farther away from the tree they are. Severing these two roots would not harm the trees in any way.

Plan showing the locations of the trial pits, based on the MOLA report produced in May 2019.



- 7.18 Trial pit 05 was located on the eastern side of the grassed area, close to the area of proposed development. Only one root with a diameter of 70mm-90mm was found within the excavation, i.e. at a depth of 1.1 metre below ground level. The depth of the root is broadly consistent with Dr Dobson's research. The severance of this solitary root would not harm the Planes in any way.
- 7.19 Trial pit 06 was located up against the eastern boundary wall, to the southeast of the area of proposed development. No roots were found within the trial pit.
- 7.20 In my opinion, the most recent site investigations do not validate Ms Milne's claim that the roots of the Plane trees would be down to five metres depth, or more, and they do not confirm to me that the trees would be harmed, or killed, if the proposed development were to go ahead. In my view the investigation results are in line with the research findings of Dr Dobson, and are consistent with the views of Bartlett Consulting.

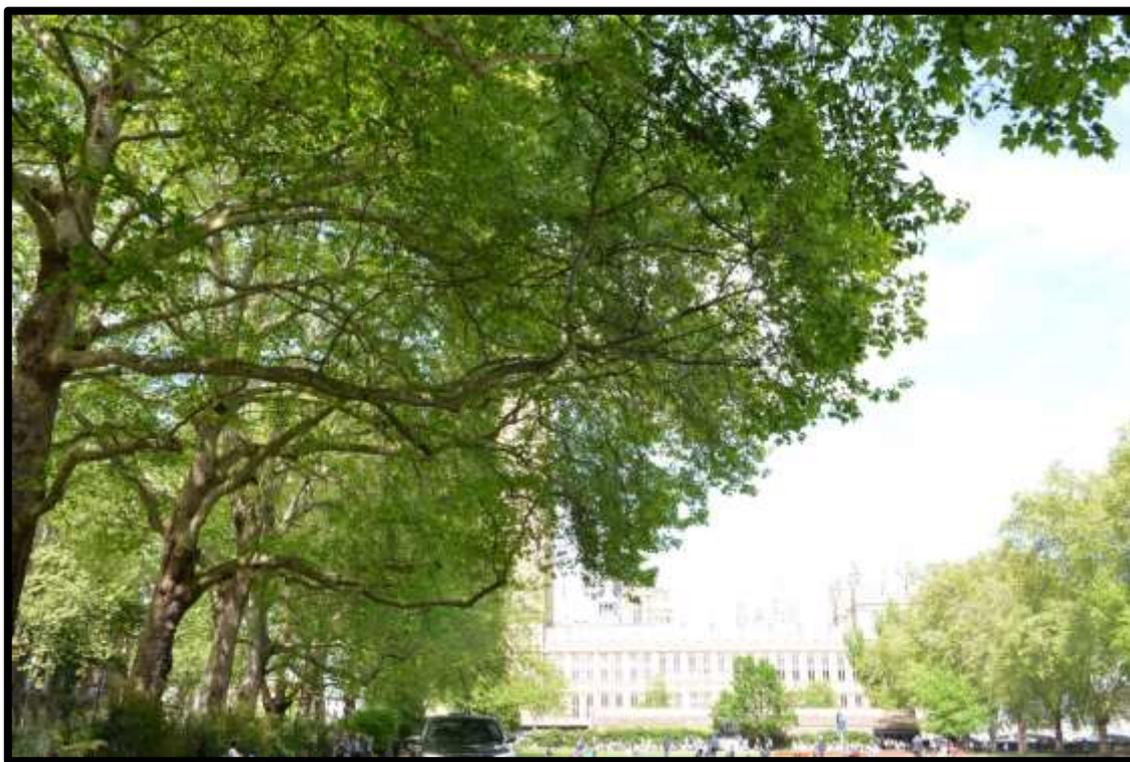
8.0 TREE CANOPIES.

- 8.1 Ms Milne states the following in relation to the pruning of the Plane tree canopies:

"The AIA Dec 18 identifies 9 trees to be pruned by lifting the canopies to provide clearance either for vehicular access or the proposed memorial fins. Whilst the proposals for pruning are not considered contentious, the need for additional tree pruning for operational, site logistics and construction management reasons, or in order to account for dieback or dysfunction in the tree canopies as a result of the cumulative impacts of the proposal, are likely to be greater than identified."

- 8.2 Having inspected the trees and identified the previous pruning positions, I am of the opinion that the pruning requirements identified by Bartlett Consulting to allow the proposed development to go ahead are appropriate, and follow good Arboricultural practice. The pruning will not harm the trees in any significant way, and the trees will quickly re-generate healthy new growth.
- 8.3 In my opinion, the requirement for pruning in this instance should not be used as a reason for refusal of the proposed development.

Picture taken on the 10th of May 2019 showing the previous pruning of the Planes.



9.0 TREE PROTECTION MEASURES.

9.1 Ms Milne states the following in relation to tree protection:

*“Given the complex nature of the proposed development, the intensity and nature of the proposed construction activity and the limited nature of the impact assessment, **insufficient detail has been provided to demonstrate that the trees could be protected adequately for the duration of construction.**”* (Bolding added by Dr Hope).

9.2 In my opinion, it would be possible to provide adequate protection of the trees during the proposed development. The protection could comply with the guidelines of British Standard 5837. In this instance I consider the proposal by Bartlett Consulting to be appropriate, although if Ms Milne were to suggest added protection, it could be incorporated in the scheme.

9.3 I consider that the issue relating to tree protection could be covered by a planning condition, and should not be used as a reason for refusal of the development.

10.0 THE CLAIMED POTENTIAL DAMAGE TO THE TREES BY THE CUMULATIVE EFFECT OF SITE, AND MANAGEMENT RELATED FACTORS.

10.1 Ms. Milne has asserted that if the proposed development goes ahead, it is likely that the Planes will be lost, or damaged, because of cumulative affects on the trees.

Tree pruning:

10.2 Ms Milne has accepted that pruning would not harm the trees, and it is generally accepted within the arboricultural industry that Planes can withstand severe pruning. The trees within Victoria Tower Gardens have been pruned on a number of occasions in the past, and they have produced healthy regrowth, with no signs of significant decay, or deterioration. They are making average, healthy, annual extension growth. There is no arboricultural evidence to indicate that pruning the trees back to their previous pruning points would harm them.

13.3 Only minor pruning will be required to the trees to allow the proposed development to go ahead. The pruning of the trees will assist the balance of the root:shoot ratio following construction, which will be an important factor in negating any possible stress levels in the trees. The importance of the balance of the root:shoot ratio is an accepted fact within the arboricultural industry, which Ms Milnes appears not to have considered.

10.4 In my opinion, the minor pruning requirement will be advantageous, and will not form part of any cumulative damage to the trees. The pruning will actually ensure the healthy balance between above and belowground parts of the trees.

10.5 In my view the mitigation proposals recommended by Bartlett Consultancy will minimise any possible accumulation factors following the development.

Drainage/compaction:

10.6 All of the Planes appear healthy, and there are no signs to indicate that there are any problems with drainage on the site. The soil is naturally free-draining. The grassed area where the development is to be located is effectively open ground. The drainage of the area occurs in a normal

vertical plane. No perched water tables have been seen in any of the site investigations, and no signs are present to suggest that any reduction of lateral movement of water will occur once the construction is complete. There are no signs to indicate that the soil between the development and the trees will be subject to any additional drying.

10.7 It is critical to note that there are no indications of any compaction of the soil between the trees and the proposed excavations. Compaction of the soil manifests itself in high bulk densities, and no such evidence has been shown to justify this phenomenon. Had there been drainage problems, or compaction, I would have expected to see significant adverse growth of the trees and grass, such thinning and yellowing of the foliage/sward within the Gardens, but no such signs are apparent.

10.8 It may be that the comment made by Ms Milne concerns the possibility of affecting the surface drainage, or compaction of the upper soil horizons between the trees and the edge of the construction, and that this is a theoretical consideration. However, it is standard arboricultural practice, identified in British Standard 5837, that soils within the RPAs of trees should be adequately physically protected with ground protection measures so as to prevent damage by compaction, or any breakdown of the soil structure.

10.9 In my opinion, the claim that trees would be adversely affected by the cumulative affects of drainage/compaction is unproven and unjustified. Any potential problems could be addressed by adequate ground protection, as recommended in British Standard 5837.

Ground level changes:

10.10 As mentioned previously in this review, the site is generally level, and free draining. The proposed construction will lead to a minor rise in soil level in a small area of the Gardens, and a reduced level where the building is located below ground. The vast majority of the remaining site will be retained at its present level.

10.11 The minor increased height level will not affect the roots of the trees, as they will be outside the RPAs. It is recommended that any additional soil placed on the current ground level should be free-draining so as to allow adequate moisture and air to percolate, thus preventing any adverse impact on the trees. Appropriate soil textural analyses could be identified prior to

the construction commencing so as to ensure that the trees are not harmed.

- 10.12 There will clearly be a change in level in the area of development as some excavation will be required. However, this will not affect the trees on this site in any way, and is typical of all development sites where excavations take place. There is nothing special in this regard at Victoria Tower Gardens. The piled foundations of the construction will not be in the RPAs to any extent, and will not prevent the ingress of moisture between the trees and the edge of the building. There are no signs to indicate that the piles will reduce, or increase, the natural downwards movement of moisture. The soil conditions will remain unchanged.
- 10.13 In my opinion, no additional buried structures, or additional foundations elsewhere within the Gardens, will adversely affect the safe life expectancy of the Planes. The rapid regrowth of the roots of the trees would negate any possible insignificant influence.
- 10.14 The claimed inadequacy of information to explain the mitigation of the proposal, and the claimed inadequacy of any tree protection details do not physically combine with some minor root severance, or other factors, to cause the likely death, or damage, to the trees. The mitigation and physical protection measures are actually designed to ensure that the trees are not harmed, and cannot therefore be looked upon as cumulative factors adversely affecting the trees.
- 10.15 In my opinion, the claim made by Ms Milne that the trees could be harmed, or even lost, because of cumulative factors is unproven and unjustified. The cumulative factors identified by Ms Milne will not increase the risk of damage to the trees, and should not be cited in an attempt to affect the viability of the proposal.

11.0 COMMENTS BY MR JEREMY BARRELL.

- 11.1 Mr Jeremy Barrell, an Arboricultural Consultant, produced a report on the tree-related aspects of the proposed development at Victoria Tower Gardens, dated the 4th of February 2019. He has since produced a small supplementary report dated the 18th of May 2019.
- 11.2 It should be noted that some of what Mr Barrell states within his reports, especially in relation to his comments on the Bartlett Consultancy

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Victoria Tower Gardens, Westminster, London.*

submissions, are his personal opinion only, and in some instances are not based on readily available peer-reviewed facts. In my opinion, the technical aspects of Mr Barrell's assertions must be examined closely, as they do not all appear to be substantiated by reliable data.

- 11.3 Mr Barrell goes to considerable lengths to criticise the site investigation data, and analyses carried out by both peer professionals, and well recognised commercial entities. In my view, for Mr Barrell's claims to be valid he should provide reliable verifiable data to justify his claims.

Value of the trees

- 11.4 On page 1 of Mr Barrell's initial report he makes the following conclusions:

- “1, *The trees are Grade II* assets, i.e. trees of “more than special interest”, comparable on a scale of importance to Grade II* listed buildings.*
2. *They have a monetary value that is in the range of million of pounds.*
3. *No evidence has been provided to show that the heritage importance and monetary value has been considered in the planning assessment, which sets it at odds with emerging national government aspirations and policy.*
4. *There are significant shortcomings in the submitted supporting tree investigations and analysis, which reduces the reliance and weight that can be placed on them.”*

- 11.5 Mr Barrell continues:

“The inadequate nature of the planning submission is significant and does not reliably demonstrate that the proposal can be implemented without adverse impacts on the health, life expectancy and visual amenity of trees of national importance. This is contrary to the national government guidance and policy, and Westminster City Council (WCC) planning policies at the local level.”

- 11.6 In item 3.0 of Mr Barrell's initial report he addresses the status and value of the trees. He goes to considerable lengths to identify the following:

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Victoria Tower Gardens, Westminster, London.*

“the heritage importance of the trees;
their structural replacement value,
their annual value of the delivery of benefits.”

11.7 I consider that the comments made by Mr Barrell on the value of the trees, both visual and monetary, do not meaningfully add to the debate relating to the influence of the proposed development within Victoria Tower Gardens. His comments simply reinforce what everybody already appreciates and accepts.

11.8 In my opinion, there is no doubt that the trees growing in Victoria Tower Gardens provide an extremely high visual amenity to the locality, and that they should be retained in situ. I have seen no evidence put forward by anyone to suggest that the trees are anything but important, or that they should be removed or harmed.

11.9 Item 4.0 of Mr Barrell’s report relates to his concerns arising from the planning submission on trees. He appears to be particularly critical of the technical report produced by Bartlett Consulting. In item 4.1 of his initial report Mr Barrell produces an overview; he states:

“In overview, the BC Report has failed to identify the importance of the three-dimensional excavation envelope, what its full extent will be, how many roots will be cut during its creation, and what impact those losses will have on the trees. Instead, we have incomplete and inadequate investigations, forcing analysis based on leaps of faith to cover gaps in the data, leading to unreliable and unsubstantiated conclusions.”

11.10 It appears to me that Bartlett Consulting, an internationally recognised company specialising in Arboriculture, will almost certainly disagree with the comments of Mr Barrell.

Potential deep rooting in Plane trees

11.11 In item 4.3 of Mr Barrell’s initial report he makes comment on the potential of Plane trees to develop deep rooting systems of between 4.0 and 6.0 metres, and sometimes deeper. Mr Barrell cites his experience in the subsidence and planning sectors in London. I must say that his experience is divergent to mine in relation to Plane tree root development.

11.12 In justification of his claim, Mr Barrell cites his experience of root

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development of a Plane outside the Connaught Hotel in Mayfair, London. However, in my opinion, his evidence does not justify the claim that the roots of the Planes at Victoria Tower Gardens will have similar root systems anywhere near the position of the new buildings.

11.13 In an attempt to justify his claims Mr Barrell includes a picture (Figure 2) in his report showing an excavation at the Connaught Hotel (See the picture below). He states that roots with diameters greater than 30.0 centimetres at a depth of up to 5.0 metres were present, as identified by yellow arrows. In my view the picture is misleading and worthy of analysis as it does not provide accurate detail in relation to the depth or location of the roots.

Scanned copy of Figure 2 of Mr Barrell's report.



11.14 No information has been provided by Mr Barrell to confirm the distance of the roots from the base of the trunk of the tree, although Figure 2 suggests that the roots are adjacent to the basal trunk, not several metres away. The horizontal beam at the bottom of the picture appears to be up against the trunk of the tree. This is critical, as it is generally accepted within the

Arboricultural industry, and by research, that large diameter roots are produced close to the trunks of trees, and that they rapidly reduce in size the further they are from the trunk. Mr Barrell does not discuss this, or its implications, in his report.

11.15 I have seen no research evidence to prove that Plane tree roots over 30.0 centimetres in diameter and to depths of 4.0 metres to 6.0 metres, or deeper, can develop at distances of between 7.5 metres and 17.0 metres from trees, i.e. where the development of the buildings at Victoria Tower Gardens is in relation to the Planes. Mr Barrell has not provided any research, or peer-reviewed data to confirm his assertion.

11.16 Figure 2 of Mr Barrell's report was taken from an elevated position. It purports to claim that the large 30.0 centimetre diameter roots are up to 5.0 metres (16½ft) below ground level, i.e. the base of the trunk of the tree where the roots emanate is over 5.0 metres above the level of the soil in the picture, and over 6.0 metres above the exposed roots. In my opinion, Figure 2 does not justify this claim in any way.

11.17 Figure 2 shows that the excavation is supported (shuttered) by vertical wooden planks butting up against each other, with two levels of wooden, horizontal supporting cross-members. In the top left-hand corner of the picture there are three vertical planks the tops off which are in the region of only 1.0 metre above soil level. The visible soil around the outside of the top of the pit appears to be at the same depth as the top of the excavation.

11.18 Figure 2 shows that the operative is bent over slightly, and he is standing below the level of the roots in the pit; i.e. it is clear that the roots are at, or slightly above, his knees. His feet are simply not 4.0 metres to 5.0 metres below the level of the surrounding ground.

11.19 For the exposed roots to be at the depth Mr Barrell claims, the base of the trunk of the tree would have to be between 4.0 metres and 5.0 metres above the roots, which is clearly not the case.

11.20 Having viewed Figure 2 my assessment is that the large, 30cm+ diameter roots emanated directly from the base of the trunk of the tree, and were within 1.0 metre of ground level at their lowest point; not 4.0 to 5.0 metres as claimed by Mr Barrell. The depth of the roots appear fully consistent with the research carried out by Dr Dobson. Mr Barrell has provided no

evidence to confirm how far the large roots extended.

- 11.21 In my opinion, the photographic evidence provided by Mr Barrell does not prove that large roots of over 300mm to 400mm diameter, and at a depth of between 4.0 and 5.0 metres, would be anywhere near the position where the buildings are to be constructed at Victoria Tower Gardens. **In my opinion, the probability that such roots will be present adjacent to the proposed excavations is remote.**

Roots beneath the pavement and carriageway along Millbank

- 11.22 Mr Barrell has discounted the likelihood/probability of significant roots from the Planes being capable of extending beneath the public footpath and carriageway along Millbank. He is of the opinion that the conditions would be unsuitable for such growth. However, in item 4 of his initial report Mr Barrell states the following in relation to the tree at the Connaught Hotel:

*“... during that project, very few roots were discovered in the top 1m or so of the soil profile **because it was mainly concrete and other hard infrastructure.**”* (Bolding added by Dr Hope).

- 11.23 In my view the above comment made by Mr Barrell clearly identifies that roots of the Plane trees along the western edge of Victoria Tower Gardens would be quite capable of growing beneath the pavement and carriageway, just as the roots did at the Connaught Hotel. Mr Barrell makes no comment in relation to the Planes growing on the opposite side of Millbank.

The presence of an historic culverted stream/sewer running beneath the southern end of Victoria Tower Gardens

- 11.24 In item 4.3 of his initial report Mr Barrell makes comment about the presence of an historic culverted stream/sewer running beneath the southern end of Victoria Tower Gardens (See the picture on page 2 of Mr Barrell’s supplementary report dated the 18th of June 2019). Mr Barrell states:

“... if there are any flaws in the culvert/sewer, the tidal fluctuation could easily be driving regular daily fresh air and water inputs upwards into the soil profile below 1.0 metre from the upper surface. If that is the case then this could account for the lack of any roots close to the surface.”

11.25 In my opinion, the above assertion of Mr Barrell is unsustainable. Any tidal fluctuation would take place twice a day, and the water would be salty, not fresh. Plane trees would simply not be capable of producing roots within saline conditions, and the death would be at, or below, the level of the culvert/sewer. The trees have been growing close to the culvert/sewer for many decades, and are quite healthy; which indicates that the culvert/sewer is not an issue with the growth of the trees. It is also critical to note that the location of the proposed development is a considerable distance away from the culvert/sewer which is along the southern boundary of Victoria Tower Gardens, and that it will not affect the trees within the area of development in any way.

11.26 In my opinion, the introduction of the unproven influence of the culvert/sewer on the trees appears to be an attempt at bringing unjustified doubt into the situation. I can fully appreciate why no detailed investigations relating to this issue have been carried out, and that no mention of it was made in the Bartlett Consulting reports.

11.27 In item 4.4(1) of his initial report, Mr Barrell questions the reliability of the Ground Penetrating Radar investigations at Victoria Tower Gardens. He states:

“... Indeed, concerns over its reliability in practice have resulted in some local planning authorities not normally accepting such investigations as evidence of the extent of below-ground rooting in a development context, e.g. the London Borough of Kensington & Chelsea...”

11.28 The picture on page 17 of this review report was taken showing the roots of a legally protected Sycamore tree with a British Standard 5837 category rating of “A/B”, within the London Borough of Kensington and Chelsea. A long-established, and highly regarded Arboricultural Association registered consultant initially commissioned a Ground Penetrating Radar investigation, and the Local Planning Authority declined to accept the findings. Instead, an Air-Spade investigation was carried out, and although considerable numbers of roots were found, as can be seen in the picture, both the Local Planning Authority Tree Officer, and the Arboricultural consultant, assessed the findings and concluded that the severance of all the exposed roots would not harm the tree. This was clearly a matter of interpretation by highly qualified Arboriculturalists, which appears to me to be totally at odds with Mr Barrell’s claim that severing roots within the proposed development area at Victoria Tower Gardens would harm or kill

the trees.

- 11.29 I will defer to others as to if Mr Lee is qualified and experienced enough to carry out his professional work in relation to the interpretation of Ground Radar investigations. However, I note that Mr Barrell does not provide any evidence to sustain his assertion, and does not provide evidence of his own detailed knowledge of interpretation of such results.
- 11.30 In item 4.5(1) of his initial report Mr Barrell criticises the depth of the investigations carried out by Canopy Consultancy, as the works were only carried out to 1.0 metre depth, and Mr Barrell considers that there was potential for rooting below this depth (5.0 metres or greater).
- 11.31 It appears to me that Mr Barrell has failed to recognise, or accept, that Air-Spade testing is typically only carried out to between 600mm and 1.0 metre below ground level unless there is a specific site-related reason why such investigations should be deeper.
- 11.32 In my experience of commissioning, and inspecting Air-Spade investigations, the majority have been down to 1.0 metre, as this is recognised as being the range of maximum root development.
- 11.33 I note that Mr Barrell has carried out Air-Spade tests on other sites in the past down to only 1.0 metre, for example on Avenue Road, London, where large mature London Planes were present.
- 11.34 Mr Barrell cites the Borough of Kensington and Chelsea in item 4.4(1) of his initial report. As he cited that specific Borough, I note that in my experience, on numerous occasions, and with various Arboricultural Officers, they have actually stopped Air-Spade investigations if insignificant numbers and sizes of roots have been found within 1.0 metre of the soil surface. An example of this was in relation to a Plane tree on Horton Street where the Senior Arboriculturalist stopped investigations at a depth of approximately only 600mm.

Reliance on dated technical references

- 11.35 In item 4.6(4) of his Initial report Mr Barrell makes comment on the reliance of dated technical references. He states the following in relation to the production of the site related reports:

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“It is often the case that inexperienced writers attempting to hide weaknesses in their experience quote references and then fail to provide those references as an Appendix. Failure to reproduce references, especially old ones that are out of print, prevents the readers from verifying the reliability of the information and whether it can be reasonably applied in the way that it is being advocated.” (Bolding added by Dr Hope).

11.36 Mr Barrell’s main criticism appears to have been aimed at Bartlett Consultancy. I have seen no evidence to support the claim by Mr Barrell that the writers of the Bartlett Consultancy reports were inexperienced, or that they attempted to hide any weaknesses in their reports.

11.37 In item 4.6(4) of Mr Barrell’s initial report he states:

“... Indeed such an approach contributes to the veneer of credibility that the BC Report attempts to cumulatively build, creating a potentially misleading analysis and conclusions.”

11.38 I find it inconceivable that Mr Barrell (and Ms Milne) does not have readily available copies of the references cited in the Bartlett Consultancy reports.

11.39 In my experience Bartlett Consultancy have always acted professionally, and with integrity. I consider that the criticism made about Bartlett Consultancy by Mr Barrell to be opposite to my experience.

The interpretation of the RPAs

11.40 I disagree with the assertions by Mr Barrell in relation to the RPAs. I have explained my rationale about the selection of circular and polygon RPAs, and their displacement previously in this report. I do not consider that the use and placement of the RPAs by Bartlett Consultancy to be an inconsistency.

11.41 Mr Barrell appears to be of the opinion that the overlapping RPAs give an unrealistic interpretation of where the RPA of each tree is likely to be. He states the following:

“Each square obviously overlaps with adjacent RPAs quite significantly to the extent that some RPAs extend beneath the trunks of adjacent trees, which is clearly a practical nonsense.” (Bolding added by Dr Hope).

11.42 In my opinion, the comment made by Mr Barrell is incorrect. The RPAs are simply notional and are used as a design tool to provide guidance on the rooting pattern of trees. It would simply be illogical, and unnecessary, to distinguish between the overlapping RPAs on the plans, and the areas directly beneath the tree trunks. I note that Mr Barrell has provided no examples of overlapping RPAs on sites, isolating/distinguishing the areas beneath the trunks of trees.

11.43 In my opinion, there is no doubt that the roots of the trees will intermingle, between each other, and I find it difficult to appreciate why Mr Barrell has made such an assertion.

11.44 Mr Barrell States:

*“Although I accept that the BS is silent on this matter, **it might be more realistic to reduce that sideways overlap and extend the length of the RPAs out into the open area of the park, unless investigations proved that there were no roots in that area.**”* (Bolding by Dr Hope).

11.45 The above comment is clearly Mr Barrell’s personal opinion, and as such can only be considered as speculation. In my opinion, there is no justification to alter the RPAs produced by Bartlett Consulting in any way. I consider that the comment by Mr Barrell is an attempt to extend the RPAs towards the proposed development, so as to bolster his claim to prevent the development.

11.46 Mr Barrell continues:

*“In the absence of any reliable evidence that there are no roots at depth within the three-dimensional excavation envelope, **the safest approach is to consider the whole of the Park as RPAs until proven to the contrary...**”* (Bolding added by Dr Hope).

11.47 I find the above statement by Mr Barrell to be unrealistic, as he appears to be saying that no development whatsoever should be carried out in the Victoria Tower Gardens. I find no justification for his views on this matter.

The production of a Method Statement

11.48 There is no requirement to produce a detailed Method Statement at the present time, and if Mr Barrell’s various assertions were correct (which I

disagree with), there would be no need to produce a detailed method statement at all.

11.49 I consider that the Developer could provide a suitable Method Statement whenever the Local Planning Authority requests one.

11.50 In my view the lack of a Method Statement at this time should not be a reason for refusal. One could be produced once the scheme has been accepted so as to show how the work will be carried out. It should not be made prematurely, as some flexibility could be required.

Mr Barrell's supplementary report

11.51 Following on from a site meeting with Ms Milne and Mr Donncha O'Shea on the 17th of May 2019, Mr Barrell produced a small updated report on the proposed development, dated the 18th of May 2019.

11.52 Having read Mr Barrell's supplementary report, I find it adds nothing significant to the proposed development.

12.0 CONCLUSIONS.

12.1 The current proposal is to construct the United Kingdom Holocaust Memorial and Learning Centre within the grassed area at the southern end of Victoria Tower Gardens.

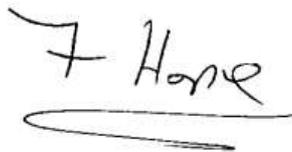
12.2 The Planes along the eastern and western sides of Victoria Tower Gardens are large, mature specimens with a high visual amenity to the Conservation Area. They are an important feature and should be retained on the site.

12.3 The Planes have been inspected in detail by Bartlett Consultancy, and they appear generally healthy, i.e. they are making acceptable annual extension growth, and are showing no signs of any significant disease activity. They contain very little dead wood in their canopies, and new healthy growth has been produced around the previous pruning points.

12.4 I consider that the inspection of the Planes carried out by Bartlett Consulting was carried out to a high standard, and complies with British Standard 5837. In my opinion the inspection followed good Arboricultural practice.

- 11.5 The assessment of the site and trees by Bartlett Consultancy was largely based on British Standard 5837, which is the generally recognised publication in relation to the juxtaposition of trees and construction. It was bolstered by specific site and soil investigations.
- 11.6 There are no current visual signs to indicate that the Planes are being adversely affected by any soil, or site-related features.
- 11.7 The extent of root activity was initially based on the use of theoretical Root Protection Areas as described in British Standard 5837. In my view the assessment of the RPAs of the trees carried out by Bartlett Consulting complied with British Standard 5837.
- 11.8 Root investigations were carried out by independent companies. However, in my opinion, the depths of all the inspections should have been between 1500mm and 2000mm, and located at the edges of the proposed building. This would have provided a more detailed assessment of any roots that would actually need to be severed.
- 11.9 No verifiable evidence has been provided to indicate that the roots of the Planes would be up to 300mm in diameter at depths of between 5.0 metres and 6.0 metres, i.e. at the position of the excavations for the proposed buildings. In my opinion, there is no justification to go excavate to such an extreme depth.
- 11.10 I see no justification to question the experience and qualifications of the personnel carrying out the site investigations and reports, and I consider the adverse comments about Bartlett Consulting to be unwarranted.
- 11.11 In my opinion, there is no available evidence to confirm that the Plane trees would be harmed, or killed, if the proposed development were to go ahead.
- 11.12 It should be noted that prior to, and during, the production of this peer review I have not discussed any issues with the Local Planning Authority personnel, Bartlett Consulting, Sharon Hosegood Associates, Canopy Consultancy, or Mr Jeremy Barrell.

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16th August 2019

DR. FRANK HOPE

APPENDIX -A-

FORENSIC ARBORICULTURAL CONSULTANT

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Victoria Tower Gardens, Westminster, London.*

Dr. Frank Hope

PROFESSIONAL QUALIFICATIONS AND EXPERIENCE

Dr. Hope has been involved with the land-based industries for the past 48 years. During this time he has worked for local government, the Royal Horticultural Society, the Institute of Groundsmanship and private industry. In the early 1970's he trained at the RHS Gardens Wisley and later became a practical arborist in the gardens. For four years he was a lecturer in Horticulture and Arboriculture at the Cheshire College of Agriculture, and has more recently been a part-time lecturer to the BTEC National Diploma course in Countryside management, at the Cambridgeshire College of Agriculture. He has been an Arboricultural and Horticultural examiner for the Royal Forestry Society, the Royal Horticultural Society and the Institute of Groundsmanship.

The majority of his work is based in East Anglia, and London, although he has taken commissions throughout the world. For example, in the 1980's he was involved in the management and harvesting of a 26,000 acre hardwood crop in Malaya. He carries out technical projects for a range of organisations on both Arboricultural and general Horticultural subjects, and has been involved in the proposed re-development of the Elephant and Castle, and the area around Waterloo station in London. He specialises in both legal and planning aspects of trees.

He has been a technical adviser to the Jockey Club and Racecourse Association, and organised all their training courses for over five years.

During 1997, Dr. Hope was one of three people commissioned by the Arboricultural Association to develop a computerised model capable of assessing the future risk of subsidence damage to buildings when trees are growing close-by. He has also given the Association advice on the Arboricultural Appendix to the ISE handbook.

Over the past 25 years, Dr. Hope has been involved in over 3,500 cases involving trees and subsidence damage to buildings. He regularly gives evidence in court, and has experience as a single joint expert. Notable cases in which he has been involved are Siddiqui & Sohanpal -v- London Borough of Hillingdon, Loftus Brigham -v- London Borough of Ealing, Dayani -v- London Borough of Bromley, Berent -v- Family Mosaic & The London Borough of Islington, Robbins -v- London Borough of Bromley, Battley -v- Wycombe District Council, and Middleton – v- Surrey County Council.

For five years (until April 2003), Dr. Hope acted for the Office of the Deputy Prime Minister as an Inspecting Officer on Tree Preservation Order Appeals, which provided him with a detailed insight into this topic.

In addition to having a Doctorate and a Masters degree in Biological Sciences (based on Arboricultural and Horticultural research), Dr Hope holds the National Diploma in Arboriculture (RFS), which is the premier practical qualification for Arboriculture, and the National Diploma in Horticulture (now the Master of Horticulture), administered by the Royal Horticultural Society. The Master of Horticulture is the world premier qualification for general horticulture. Dr. Hope is a past examiner for the final stages of the Master of Horticulture qualification. His personal qualifications are at the highest level; the major ones are as follows:

Doctor of Philosophy (Ph.D): University of Bath, Biological Sciences Dept. The Development of a computerised Plant Establishment and Growth Model for use with Landscape Trees and Shrubs.

Master of Philosophy (M.Phil): University of Bath Biological Sciences Dept. The Development of a Computerised Information Retrieval System for Decorative Plant Selection.

National Diploma in Horticulture: Administered by the Royal Horticultural Society.

National Diploma in Arboriculture (N.D.Arbor): Royal Forestry Society.

*Gustafson, Porter and Bowman – Holocaust Memorial and Learning Centre,
Victoria Tower Gardens, Westminster, London.*

National Certificate in Arboriculture (Distinction): Wisley Diploma in Horticulture:	Royal Forestry Society. Royal Horticultural Society.
Advanced Diploma in Horticulture:	Writtle Agricultural College.
Certificate of Education:	Wolverhampton Teacher Training College, (Wolverhampton Polytechnic).

SOME PUBLISHED WORKS

Recognition and Control of Pest and Diseases of Farm Crops	Blandford Press 1980 ISBN 0 7137 0995
The Garden Planner	Hardback - Collins 1981 Softback - Fontana 1981 Softback - Pilot 1983 ISBN 0 00 4116622 Co-author of each edition
QL Gardener Manual	Sinclair Research 1985 ISBN 1 850 160449
The New Organic Grower	Cassall Publishers 1990 ISBN 0 304 34013 8
Turf Culture	Blandford Press 1978 ISBN 0 7137 0873 5
Turf Culture - A manual for the Practising Groundsman	Cassall 1990 ISBN 0-304-31854-X
Rasen	German Edition of Turf Culture ISBN 3-8001-5038-7
NVQ Levels 1 & 2 manuals	Technical author for the British Association of Landscape Industries (BALI) instruction manuals for general horticulture and turf culture at levels 1 and 2, for the National Vocational Qualifications.

Numerous articles on Horticulture, Arboriculture and computers in a range of magazines, e.g. Horticulture Week, The Groundsman, Personal Computer World.

SOME PUBLISHED SOFTWARE

Horticultural Key	Quanta magazine.
Plant Selector II	A.J. Harding Molimerx Ltd.
Computerised Ornamental Plant Retrieval System	University of Bath.
Genus Plant Selector	Intersearch Ltd.

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DR. FRANK HOPE

APPENDIX -B-

FORENSIC ARBORICULTURAL CONSULTANT

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Tree Root Systems

by Martin Dobson, Arboricultural Advisory and Information Service

Summary

The development and structure of tree root systems are described. They are wide spreading, extending radially in any direction for distances often in excess of the tree's height. Roots grow predominantly near the soil surface - over 90% of all roots, and virtually all the large structural supporting roots, are in the upper 60cm of soil. Soil disturbance within the rooting area should be avoided, as this can significantly affect tree stability and moisture uptake.

Introduction

1. This Note provides an overview of the development and structure of tree roots. Useful reviews can also be found in Perry (1982, 1989), Helliwell and Fordham (1992), Sutton (1969, 1991) and Dobson and Moffat (1993).



Figure 1. This is the commonly held idea of what a tree's root system is like. In fact it is quite wrong.

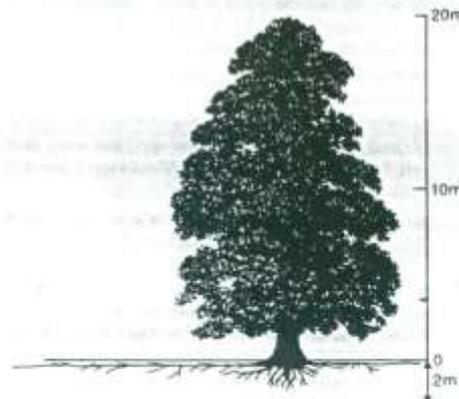


Figure 2. A tree's root system is typically fairly shallow (frequently no deeper than 2 m), but is wide-spreading, with the majority of roots found in the upper 60cm of soil.

2. Tree roots absorb water and nutrients from the soil, serve as a store for carbohydrates and form a structural system which supports the trunk and crown. The nature of this system is frequently misunderstood, probably because it is concealed below ground. A common misconception is that the root system is a 'reflection' of the trunk and branches (Figure 1). In fact, *a tree's root system is surprisingly shallow, dominated by long, relatively small, lateral roots spreading out close to the soil surface* (Figure 2) rather than by a deeply penetrating taproot. It is uncommon for trees to have roots deeper than about 2m, though exceptionally some small (a few mm in diameter) roots can extend to 5m or more. Most roots are found close to the soil surface, with 90% or more of all roots located in the upper 60cm. Whilst the typical depth of tree roots has been exaggerated, root spread has often been underestimated - they usually extend outwards well beyond the branch spread ('drip line').

Root system development

3. Initially a germinating seed has a single root, the radicle, or taproot, which grows vertically downwards provided soil conditions are suitable. Elongation is most rapid during the first 2 or 3 years but decreases with tree age and increasing soil depth. Horizontally growing side roots (laterals) form at an early stage and soon become largely responsible for structural support. Development of the taproot then declines with the result that only a small proportion of trees have a sizeable taproot at maturity. In fact, it is hard to distinguish a taproot at all in many mature trees, as injury to the juvenile taproot tip often occurs, for example, by the browsing of soil fauna, root rot, failure to penetrate hard or compact soil layers, or for nursery stock, by undercutting/transplanting. Species often thought of as 'taprooted', such as oak (*Quercus* spp.), pine (*Pinus* spp.) and fir (*Abies* spp.), appear to have a stronger inherent tendency to retain a distinct taproot, than species such as poplar (*Populus* spp.), willow (*Salix* spp.) and spruce (*Picea* spp.), but frequently the taproot does not persist even in these species. Intact taproots are usually largest just beneath the trunk and taper until they reach a depth of 0.5-1m, where they often divide into several smaller, but nevertheless downwardly growing, roots.
4. Lateral roots near the soil surface thicken over successive years, eventually becoming the large woody roots of the framework root system of a mature tree - there are usually between four and eleven such roots which may become 30cm or more in diameter close to the stem. They taper rapidly until at 2-3m distance they are usually only 2-5cm in diameter, by which stage they have lost much of their rigidity and physical strength. It is here that they tend to break when root plate failure occurs, e.g. in a storm (Cutler *et al.*, 1990). Beyond the 'zone of rapid taper', lateral roots extend outwards in a broad zone for many meters, without appreciable further decrease in size - typically maintaining a diameter of 1-2cm. They are sparsely branched, perennial, woody and rope-like in appearance. In some species, e.g. ash (*Fraxinus* spp.), cherry (*Prunus* spp.), thorn (*Crataegus* spp.) and some pines these roots tend to grow within the upper 10cm of soil. In other species, e.g. birch (*Betula* spp.), lime (*Tilia* spp.) and oak, the lateral roots descend diagonally ('oblique laterals') to a depth of 20-50cm at a distance of about 2m from the trunk and then continue growing outwards horizontally. Near the trunk, some branches of these deeper laterals grow upwards to form a wide-spreading superficial system of rope-like roots, usually restricted to the upper 15cm of soil. Although most rope-like roots are only 5-15m long, some can be 25m or more in length.
5. Roots branching from the upper side of laterals grow upwards and divide profusely in the surface soil, which is usually well-aerated, to form fans or mats of thousands of fine (<2 mm diameter) non-woody 'absorbing' or 'feeder' roots. In woodland, they grow horizontally between the 2 to 3 year old fallen leaves. Root fans permeate and hold together the litter over a considerable area; each one can occupy a thin horizontal layer of 300 cm² or more. Associated with these roots are much finer, thread-like, mycorrhizae. Mycorrhizae are symbiotic fungi which grow on or in roots, an association which is mutually beneficial to both the tree and the fungus. They are extremely efficient at nutrient absorption, especially phosphorus, and many trees cannot survive without them. Fine roots and their mycorrhizae are jointly responsible for moisture and nutrient uptake, whilst the perennial woody roots primarily act as conducting vessels to and from the trunk. Fine roots have a life span ranging from a few days to several years - on average surviving for 1-2 years.

6. Roots branching from the lower side of the laterals are known as 'sinkers roots' and usually occur within a few metres of the stem. They are usually 1-2cm in diameter, grow downwards, and in contrast to the taproot or oblique laterals, divide at their extremities into fine, non-woody roots.

Root distribution

7. The variability of soil conditions and the presence of obstacles and barriers to root growth result in variable and unpredictable distribution within the general overview already presented. This is because *root growth is opportunistic, occurring only where the soil environment can sustain it*. Roots proliferate wherever they encounter favourable conditions, which is why the greatest root concentration is found close to the soil surface where the soil is loosest, and water, oxygen and nutrients are most readily available. Soil bulk density increases and aeration decreases with increasing soil depth and consequently root numbers and size decline sharply with depth (see paragraphs 11-13), thus below 1m it is rare to find many roots which are larger than a few mm in diameter.

Root depth

8. The deepest roots are usually found directly below, or near to, the trunk as tap, oblique lateral or sinker roots. Maximum root depth varies greatly, from only 10-20cm in waterlogged peaty soils to, exceptionally, tens of metres in loose, well-aerated soils or fissured rock. However, there is no such thing as an intrinsically 'deep rooted' or 'shallow rooted' tree species (Sutton, 1969). All trees can develop a deep root system (2-3m deep) if soil conditions allow. Apparent differences in rooting ability depend on the genetically determined capacity of roots to tolerate difficult soil conditions such as poor aeration and compaction. It is this propensity which results in the root systems of some trees being deeper than others under the same conditions.
9. Whilst genetic characteristics of a tree play some part in rooting pattern, soil conditions are of overriding importance. Thus, downward penetration of tree roots can be halted by excessive stoniness, ironpans, compact soil layers (especially compact clays), bedrock, poor aeration and high or perched water tables. Even taproots are unable to continue downwards when they reach such conditions - they either turn horizontally or die back. Where deep roots die, several replacement root tips can develop just behind the dead tissue and these in turn either become horizontal or die. Obstructions in the soil at shallow depths are common in the UK, and thus it is not surprising that a survey of the root plates of windthrown trees in southern England after the storms of 1987 and 1990 revealed that 44% of root plates were shallower than 1m, 95% were shallower than 2m and the deepest root plate was only 3m (Cutler *et al.*, 1990). This pattern accords well with the large amount of data available from excavations of root systems which indicate that *average root depths are typically in the range 1-2m*.

Root spread

10. Root spread is not confined to the area delineated by a downward projection from the branch tips as has often been supposed. Excavation has revealed that roots can grow for a considerable distance beyond the branch spread; typically extending outwards for a distance equivalent to at least the tree's height, and in some cases (particularly in infertile or compacted soils) up to 3 times tree height. Roots distant from the trunk are usually very close to the soil surface (Figure 2). Obstacles in the soil such as rocks, kerbs or building foundations provide a physical barrier to root extension (see Marshall *et al.*, in preparation). Roots meeting such obstacles are typically deflected by them and once clear of the obstruction they often resume their original direction of growth.

Factors affecting root distribution

Soil bulk density

11. Root growth declines sharply with increasing density of soil; optimum growth being achieved at approximately 1.2 g cm^{-3} or less. In heavy clay soils, growth effectively ceases at a bulk density of about 1.6 g cm^{-3} , and in lighter sandy soils at about 1.7 g cm^{-3} . Compaction can be a natural feature on some sites, e.g. caused by glaciation, or it can be induced, e.g. by repeated passage of vehicles over the soil surface. Where soils have been compacted it is often difficult to establish trees because the roots fail to penetrate into the soil effectively. Trees growing in such soils develop a very shallow root system with a greater number of lateral roots in the relatively less dense surface soil (Dobson and Moffat, 1993). Roots reaching a compact subsurface horizon tend to deform or branch profusely and continue laterally above the plane of compaction. If these roots encounter a pathway through the compact layer, e.g. following a fissure or decayed root channel, they may resume downward growth. If soil beneath the obstruction is favourable then roots may proliferate, producing a two-tier root system. Established trees that experience sudden compaction of the soil (for example by movement of machinery on construction sites) frequently suffer root death, and crown dieback often occurs because of the inability of the tree to adapt quickly to the rapid change in soil conditions.

Soil aeration

12. In order for roots to survive, oxygen must be available in the soil immediately surrounding them. Oxygen supply to roots is governed by soil structure and texture; in loose or coarse textured soils the air gaps between the soil particles are relatively large and so atmospheric oxygen diffuses readily into the soil, and the waste product of respiration, carbon dioxide, can diffuse away. This process is inhibited in fine textured (clayey), waterlogged and compacted soils because pore spaces are small and may also be filled with water - gaseous diffusion is 10,000 times quicker in air than in water.
13. Poor soil aeration, especially that produced by prolonged waterlogging inhibits the growth of new roots, and can result in the death and decay of a large proportion of the existing root system. Trees standing in such conditions tend to be characterised by very shallow, plate-like root systems where roots are confined to the upper, more aerobic soil. The roots of dormant trees tolerate periods of poor aeration better than those of actively growing trees because their respiration rate is reduced and they need less oxygen.

Fertility

14. Fertile soil encourages the growth of shoots relative to roots and increases the branching of roots. Roots of established trees proliferate in areas of moist soil that are rich in nutrients, especially nitrogen and phosphorus. In general, soils with low fertility produce root systems characterised by long, slender, poorly branched surface roots, whereas sites with higher fertility produce root systems that are well branched and descend deeper into the soil (provided it is sufficiently loose and oxygen is available).

Tree roots and the water table

15. It is a common misconception that trees are heavily dependent upon the water table for moisture during dry summer months. In most parts of the UK the water table is situated deep in the soil, well beyond the reach of tree roots, and contributes nothing to meeting the water demand of trees. Trees, and other vegetation, are usually wholly dependent on recent rainfall and the water stored in the soil (Helliwell and Fordham, 1992). Moffat (1995) has demonstrated that the water requirement of trees in most parts of the UK and for most soil types, even during dry summers, is available in a soil depth of about 1.5 m. In the rare cases where roots are within reach of the water table, they quite often proliferate just above it, in the 'capillary fringe' but they are unable to grow into the saturated pores of the water table because of poor aeration. Helliwell (1993) gives further information about water tables and trees.

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Practical implications

16. *Tree roots may extend radially a distance equivalent to at least the height of the tree and are located primarily in the upper 60cm of soil.* The main structural roots are usually found in the upper 30cm, and taper substantially within about 3m of the trunk. The vast majority of fine absorbing roots are even closer to the soil surface. Thus, *any soil disturbance within the rooting zone will damage tree roots and should be avoided.* Within the rooting area the following should especially be avoided:-

- soil stripping and site grading
- trenching, even a shallow (<150 mm) trench (see NJUG, 1995)
- soil compaction by movement of vehicles or storage of materials
- deposit of toxic or impermeable materials

The nearer to the trunk that such operations occur, the greater the damage and loss of roots. This will increasingly reduce the ability of the tree to absorb sufficient water to sustain the foliage - dieback of the crown may result. *If roots greater than 20cm are cut within 2-3m of the trunk, stability may be affected and the tree made dangerous.*

17. There is considerable misinformation about the damage that can be caused by tree roots. It is true that under some circumstances they may cause damage to built structures. However, direct damage is rare and usually only occurs when trees are situated less than 1-2m away from lightly loaded structures such as boundary and garage walls, paving slabs and kerbs (BS 5837: 1991). However, the direct pressure exerted by tree roots can be measured and is surprisingly small (MacLeod and Cram, in preparation). Indirect damage to structures may occur where tree roots contribute to the drying of shrinkable clay soils where foundations are inadequate to accommodate movements (see Biddle, 1992 for more detailed information). Guidelines exist for determining the appropriate depth of foundations for new houses on clay soils (NHBC, 1992).

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-6-