



# CROSSRAIL

## INFORMATION FOR DEVELOPERS

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# 1 Introduction

- 1.1 Crossrail is being constructed using powers granted by the Crossrail Act 2008. The route remains safeguarded under Directions issued by the Secretary of State for Transport to preserve the integrity of the railway assets into the future. Crossrail (the Elizabeth Line) is being delivered by Crossrail Limited (CRL). CRL has the obligation to ensure that the railway assets being built are properly cared for and in a fit state of order to deliver their functional requirements upon completion.
- 1.2 Crossrail's design life is 120 years which is considerably longer than the planned lifespan of typical commercial, retail and residential developments and so Crossrail Safeguarding seeks to protect the railway both in the short term during its construction and against possible risks long into the future. At the same time CRL recognises the significance of growth and regeneration catalyzed by the new railway and it is the Safeguarding team's policy to provide guidance to Developers to help them realise their ambitions without adversely affecting the railway.
- 1.3 The Safeguarding process requires local authorities to consult CRL before determining planning applications where these fall within Safeguarding limits. This is to ensure that future developments do not create adverse impact on the tunnels or other railway infrastructure.
- 1.4 As part of the consultation process, CRL can:-
  - recommend that the Local Planning Authority (LPA) place conditions on a planning permission which must be complied with/discharged before construction of the approved development can commence on site; or
  - recommend that the LPA refuse the application.
- 1.5 For discharge of applied planning conditions the developer must be able to demonstrate to CRL that the foundations of new development proposals do not adversely impact on Crossrail assets or impede operation of the railway. New developments therefore should be designed to mitigate the possible effects of ground movement on the tunnels and other Crossrail infrastructure.
- 1.6 It is advisable that new developments are designed also to be resilient to the impact of groundborne noise and vibration transmitted from the underground operating railway.
- 1.7 Key criteria about Crossrail are presented in this document to help developers safeguard Crossrail and to meet conditions that may be applied by an LPA.
- 1.8 This document provides technical guidance to developers wishing to undertake works close to Crossrail assets. It describes:
  - the planning conditions that may typically be applied to safeguard the railway;
  - the process for consultation with CRL or the period leading up to handover (i.e. the period before the Elizabeth Line becomes operational);
  - details to be included in submissions to demonstrate protection of infrastructure;
  - significant development interface risks and issues that might need to be managed during the construction of any development;
  - railway asset serviceability compliance criteria which should be adhered to; and
  - suitable methods for the assessment of transmission of groundborne noise and vibration that may impact development.
- 1.9 In this document the term developer is used in a generic sense and refers to all parties involved in delivering development and who may be accountable or responsible for safeguarding Crossrail assets within the zone of influence of development works.
- 1.10 Crossrail is in the final stage of its delivery. It is envisaged that responsibility for protection of Crossrail's infrastructure will transfer from CRL to Transport for London (TfL) following handover, whereupon it is expected that this guidance will be replaced or subsumed into TfL's Infrastructure Protection guidance, and TfL standards and licenses shall apply.

1.11 It is intended that development proposals accepted by CRL before, but finishing after, handover, are not penalized by the transition of duty from CRL to TfL. It is further envisaged that;

- unless there are compelling safety critical reasons not to, acceptances granted by CRL will be accepted by TfL;
- agreements, such as Monitoring Agreements, signed between CRL and a developer, will, following handover, be managed by TfL;
- CRL and TfL will coordinate with developers' agents to clarify any changes in interface personnel, review processes, processes to access the railway, to minimize disruption.

## 2 General information about Crossrail assets

2.1 The outside diameter of the Crossrail running tunnels should be taken as 7.0m.

2.2 Dimensions vary considerably for other structures including shafts, headhouses, portals, ticket halls, deep tunnel and box stations, etc. Developers will need to engage with CRL to ascertain further details (Section 3 describes this process)

2.3 Crossrail design life:

The railway is designed to achieve a 120-year design life which may well exceed the design life of the development. Developers' designs must also consider and reasonably demonstrate that the structural integrity and operability Crossrail assets would not become critically compromised at some time in future should there be further demolition and redevelopment on the same site.

2.4 Tunnel Exclusion Zone

Developers should note that the land, including subsoil, TfL acquired for the purposes of constructing the railway assets includes land and subsoil beyond which the physical assets have been constructed (the Exclusion Zone). Developers structures and works are not permitted to encroach into the Exclusion Zone owned by TfL.

Where the limit of the Exclusion Zone is less than 3m horizontally from the tunnel edge and less than 6m above the tunnel it will be necessary to demonstrate to CRL's reasonable satisfaction that the proposed development will not adversely impact Crossrail assets. For heavily loaded piles or pile groups or for excavations or other works that may have significantly impact, these dimensions may need to be greater.

The developer must also make adequate allowance for the construction tolerance of the proposed development foundations in determining their proximity to the Exclusion Zone.

If there are constraints which prevent these limits being met, advice should be sought from CRL. (for details of engagement see Section 3)

2.5 Legacy temporary works left in the ground

CRL's contractors installed such things as crane base piles, boreholes, grout shafts, compensation grouting arrays in strata above its deep tunnel stations, etc, which if present may need to be considered in developers' designs and construction planning.

2.6 Permissible loads from development foundations

Development foundations must be designed so that stresses and strains induced in the Crossrail structures do not exceed acceptable levels.

In general, this will be achieved if the overall loading imposed on the tunnels:

- a) does not exceed the existing ground overburden plus the loading from any existing development (as would be the case for redevelopment of an existing site); or
- b) does not exceed the existing ground overburden plus 50kN/m<sup>2</sup> imposed at ground level over the footprint of the development (as would be the case in development of a vacant site). CRL tunnels have been designed to account for existing surcharge loads; and
- c) any unloading of the ground does not cause excessive ground movement. (this is discussed further in Section 5)

## 3 Engagement with Crossrail

- 3.1 The developer is advised to consult CRL prior to submission of planning applications within the safeguarded limits to maximize opportunity for understanding and consideration of project interface constraints and opportunities, and the conditions which CRL may seek to impose on planning permissions relating to the development.
- 3.2 CRL's principal point of contact is: [CRL\\_safeguarding@crossrail.co.uk](mailto:CRL_safeguarding@crossrail.co.uk)
- 3.3 Alternatively, CRL can be contacted through its Helpdesk (contact number: 0345 602 3813). The developer may then request consultation with a representative of the Crossrail Safeguarding team.
- 3.4 CRL expects developers to submit evidence of satisfaction of Crossrail imposed planning conditions demonstrating adherence to the guidance given in this document. Suitable evidence will enable CRL to issue a letter to the LPA setting out its opinion as to the acceptability of the evidence which the LPA may consider when determining the discharge of the condition.
- 3.5 The developer will be required to enter into a confidentiality agreement with CRL where it requests CRL to disclose confidential or sensitive information regarding Crossrail assets close to development sites.
- 3.6 CRL reserves the right to charge developers for costs reasonably incurred in reviewing and responding to development proposals, particularly if CRL considers it necessary to consult with engineering specialists. The developer will be expected to provide its invoicing instructions and a commitment to reimburse CRL before costs are expended.
- 3.7 Evidence submitted to CRL should be structured to demonstrate progressive assurance, i.e. demonstrating that the Crossrail safeguarding objectives are achieved as the development project progresses through its life cycle.
- 3.8 To that end a list of generic submission components is set out in Section 3.11.
- 3.9 It is envisaged that evidence may need to be revised and re-issued as necessary to reflect any changes arising during progress of any development project. The submissions for the key project development stages are as follows:
  - conceptual design submission
  - detailed design (issue for construction) submission
  - completion (as-built) submission
- 3.10 It is envisaged that submissions will also
  - a) set out the compliance objectives met to ensure that the development will not unduly affect Crossrail infrastructure;
  - b) provide a stand-alone overview of the development interface, describing:
    - the scope of redevelopment and end use;
    - proximity in respect of Crossrail;
    - narrative to identify the key interface considerations and assumptions.
  - c) include details of company names, registered addresses and key project personnel and contact details, for
    - the development client;
    - structural and geotechnical engineers;
    - architect;
    - project manager
    - contractor (demolition and main works contracts and ground investigation contractor)
    - outline project programme including key milestones dates (accuracy commensurate with knowledge at planning stage of development);
    - include standards and references used.

3.11 Generic interface deliverable components to demonstrate safeguarding of Crossrail assets (also refer to Section 5 for further guidance on content of submissions)

	Development Phase Compliance Criteria	PRE-PLANNING RIBA Stage 1-3 Development to Concept Design	POST-PLANNING RIBA Stage 4 Technical Design (Final Design for Construction Submission)	CONSTRUCTION RIBA Stage 5	COMPLETION RIBA Stage 6-7 Handover & Close Out
A	Evidence of Spatial Compliance (avoidance of Crossrail Exclusion Zone (Crossrail Line 1), and Tolerance Zone (Crossrail Line 2))	A.1.1 Concept Design Statement including General Arrangement drawing plans & sections relating the spatial envelope of development to the position of Crossrail	A.2.1 Detail Design amendments Statement and General Arrangement drawing plans & sections relating the spatial envelope of development to the position of Crossrail	A.3.1 Contractor's Design spatial envelope amendments, including designed pile toe levels and pile positions to OS grid coordinates	A.4.1 As-built foundation design details: pile grid coordinates and pile toe levels, relative to OS grid coordinates
				A.3.2 Method statements and details of site investigations to prove the geology, demonstrating consideration of location of Crossrail buried assets.	
B	Evidence that Surcharge Loading or transferred pile loads imposed on Crossrail assets is < 50kPa,	B.1.1 Concept Design load analysis report including schedule of foundation design loads and calculations before and after development, demonstrating compliance	B.2.1 Detailed Design amendments report including schedule of foundation design loads and calculations demonstrating compliance	B.3.1 Contractor's Design amendments report including schedule of revised foundation design loads and calculations, maintaining compliance	B.4.1 Outturn statement of confirmation of adherence to designed loads
			B.2.2 Category 2 or 3* Check Certificate verifying foundation design loads  * level of prescribed check is dependent on severity of interface risk	B.3.2 Category 2 or 3* Check Certificate verifying foundation design loads  * level of prescribed check is dependent on severity of interface	
C	Evidence of Compliance with Crossrail Policy on mitigation of Groundborne Noise & Vibration	C.1.1 Concept Design Groundborne N&V assessment report	C.2.1 Designer's Groundborne N&V assessment and design of mitigation measures (if assumptions differ from Concept Design)	C.3.1 Evidence, if required, of assurance that any designed Groundborne N&V mitigation measures have been constructed in accordance with specified requirements	

D	Construction Interface Management and Mitigation of Concurrent 3rd Party Impacts		D.2.1 Evidence that Developer's collocated works causing settlement are not scheduled concurrently with Crossrail works causing ground movement, settlement impact, that might have a compounded impact on 3rd party assets. If works concurrency is scheduled are unavoidable then evidence of measures enforced to control sources of settlement		
			D.2.2 Agreement to enter into shared access or shared workspace agreement or protocol to help mitigate Health & Safety and logistical risks		
		D.1.3. Draft Construction Logistics Plan or Design & Access Statement	D.2.3. Updated Draft Construction Logistics Plan or Design & Access Statement	D.3.3. Updated Construction Logistics Plan, if significantly amended.	
		D.1.4 Draft Development Implementation Programme	D.2.4 Updated Development Implementation Programme	D.3.4 Updated Development Implementation Programme	
			D.2.5 [where 3rd Parties' assets are impacted by compounded ground movement from Development and Crossrail] Evidence of 3rd Parties' acceptance of Developer's assessment and mitigation for compounded impact on assets.	D.3.5 If applicable, documented confirmation of agreements to mitigate possible disturbance / damage to Crossrail monitoring equipment	
E	Crossrail Settlement impact on Development (if constructed before Crossrail) < Damage Cat 2	E.1 Checked Draft Ground Movement Structural Impact Assessment to prove that predicted settlement impact from construction of Crossrail < Damage Category 2, as defined in Crossrail Paper D12.	E.2 Final Ground Movement Structural Impact Assessment to prove that predicted settlement impact from construction of Crossrail < Category 2		



F	Settlement impact from Development acceptable to Crossrail	F.1.1 Checked * Draft Ground Movement Impact Assessment, including details of technical assumptions to prove that predicted settlement impact on Crossrail assets from construction of Development does not exceed prescribed asset and systems performance acceptance criteria. Include references, standards and guidelines used	F.2.1 Checked * Final Design Ground Movement Impact Assessment (aligned with Contractor's installation method statements) to prove that predicted settlement impact on Crossrail assets from construction of Development does not exceed prescribed asset and systems performance acceptance criteria. Include details of GI undertaken to support assumptions.  Include details of construction sequences  Include references, standards and guidelines used	F.3.1 Checked Contractors' Construction Method statements demonstrating compliance with settlement and vibration acceptance requirements Contractor's method statements Ground Investigations planned near to Crossrail assets	
			F.2.2 Category 2 or 3* Check Certificate for GMIA  * level of prescribed check is dependent on severity of interface risk	F.3.2 Category 2 or 3* Check Certificate for GMIA  * level of prescribed check is dependent on severity of interface risk	
			F.2.3 Monitoring Agreement		
		F.1.4 Draft Tunnel Monitoring Plan, if necessary for control of ground movement impact on Crossrail assets	F.2.4 Updated Monitoring Plan		
			F.2.5. Developer's Monitoring Plan (Reference Design)		
			F.2.6 Monitoring Action Plan		
		F.2.7. Deliverables to demonstrate EMC compliance (refer to Addendum to Information for Developers)			
			F.3.7 Monitoring Results Interpretive Reports		
			F.3.8 ERM and EERM Meeting minutes		
		F.2.9 Pre-commencement CRL asset condition survey		F.4.9 Post-construction CRL asset survey	
G	Project Interface Coordination & Risk Mitigation	G.1.1 Design & Planning Interface Coordination Meeting Notes	G.2.1 Design & Planning Interface Coordination Meeting Notes	G.3.1 Construction Interface Coordination Meeting Notes and Site Inspection Notes	
		G.1.2 Interface Risk Register	G.2.2 Updated Interface Risk Register	G.3.2 Updated Interface Risk Register	G.4.2 Close-out Interface Residual Risk Register

H	Miscellaneous	H.1.1 Confirmation of 3rd Party Developer Organization Details			
				H.3.2 Evidence of Designer's Warranty to Crossrail	
		H.1.3 Crossrail issued Information Disclosure Agreement			
		H.1.4. Agreements to recover fees in respect of services or information provided or ovated to Developers, including Invoicing Instructions			
				H.3.5 Agreements to coordinate Construction interface health & Safety, e.g. <ul style="list-style-type: none"> <li>• Crane oversail</li> <li>• Shared access</li> <li>• Hoarding boundaries</li> </ul>	
		H.2.6. Check of the development maintenance regime to consider and de-risk activities which might interfere with the operation of the Crossrail station nearby.		H.4.6 Agreement of protocols to control any interference of planned maintenance activities significantly affecting the operating Crossrail	

## 4 Standard Crossrail planning conditions

- 4.1 CRL has the right to be consulted on all development occurring within the Safeguarding Limits. Planning application for development within such limits are referred to CRL by the LPA for comment.
- 4.2 Typically, the following conditions would be recommended to LPA in order to protect the Crossrail infrastructure.

### Crossrail condition for foundation design and settlement

C1 None of the development hereby permitted shall be commenced until detailed design and construction method statements for all of the ground floor structures, foundations and basements and for any other structures below ground level, including piling, any other temporary or permanent installations and for site investigations, have been submitted to and approved in writing by the Local Planning Authority which:-

- (i) Accommodate the location and of the Crossrail structures including temporary works,
- (ii) Accommodate ground movement arising from the construction thereof,
- (iii) Mitigate the effects on Crossrail, of ground movement arising from development

The development shall be carried out in all respects in accordance with the approved design and method statements. All structures and works comprised within the development hereby permitted which are required by paragraphs C1(i), C1 (ii) and C1 (iii) of this condition shall be completed, in their entirety, before any part of the building[s] hereby permitted is/are occupied.

### Crossrail Informative - transmitted groundbourne noise & vibration

I1 The Developer is recommended to assess and mitigate the possible effects of noise and vibration arising from the operation of Crossrail. (the future Elizabeth Line)

### Crossrail condition – concurrent working

C2 None of the development hereby permitted shall be commenced until a method statement has been submitted to, and approved in writing, by the Local Planning Authority to include arrangements to secure that, during any period when concurrent construction is taking place of both the permitted development and of the Crossrail structures and tunnels in or adjacent to the site of the approved development, the construction of the Crossrail structures and tunnels is not impeded.

# 5 Considerations for complex development close to Crossrail assets completed or under construction

## 5.1 Introduction

5.1.1 The construction of deep or complex foundations close to Crossrail infrastructure may generate significant ground movements which, if unchecked, may adversely impact such infrastructure.

## 5.2 Compliance Criteria

5.2.1 If there is considered to be a significant risk of impact to Crossrail's assets then developers are expected to provide evidence to demonstrate that their construction impacts do not breach Crossrail systems compliance requirements, thus:

- Loads induced in tunnels, portals, box and shaft below-ground structure, do not exceed permissible stress limits (their designed envelopes);
- above-ground Crossrail structures are not loaded or relied upon for support (unless this has been agreed);
- station (including other surface intercepting infrastructure) and completion works (including dynamic testing and commissioning of the railway and reinstatement of urban realm), operability and serviceability are not compromised;
- waterproofing (particularly of tunnel segment joints and at tunnel-box connections) is not impaired;
- minimum gauge clearance (between the tunnel lining and railway systems), is not infringed;
- predicted distortion of the track geometry resulting from any movement of the tunnel lining, does not exceed the 'No Mandated Requirement' threshold described in Appendix A of the Network Rail Standard NR/L2/TRK/001/C01 or current NR Standard if replaced;
- Access and egress to the railway and CRL worksites are not impaired;
- The safe operation of the railway and CRL worksites are not compromised;
- As a guide the minimum predicted curvature (radial distortion) induced by ground movements along the axis of the running tunnel in any plane should not reduce below a radius of 10km. This radius is considered the minimum not requiring potential maintenance intervention (e.g. track adjustment) and applies across the whole of the central section of the Crossrail railway, except in the area of the Barbican estate between Farringdon and Liverpool St stations, where tighter constraints are required for the specialized track system in this area;
- (within influence of running tunnels housing standard track slabs) The magnitude of predicted ovalisation across the tunnel diameter (diametric distortion) does not exceed 15mm deviation in any direction measured from the theoretical detailed design profile. Reduced distortion limits apply for tunnels installed with floating track slab. The Developer is advised to consult Crossrail to confirm the compliance relevant in its case;
- (within influence of station platform tunnels) The magnitude of predicted ovalisation across the tunnel diameter (diametric distortion) does not exceed more than 10mm deviation in any direction measured from the theoretical detailed design profile;
- predicted movements do not exceed the serviceability limits of any sensitive equipment and systems (e.g. escalators) enclosed within the tunnels;
- Radio and electronic railway systems are not put at risk

- Limits on permissible distortion of station tunnel and shaft linings are subject to movement tolerance of the systems (escalators etc.) within and will be considered on a case by case basis
- The Developer's below ground structures are detailed and constructed in a manner that ensures that Crossrail assets are not put at risk. Figure 2 illustrates risks to tunnels from piling nearby.

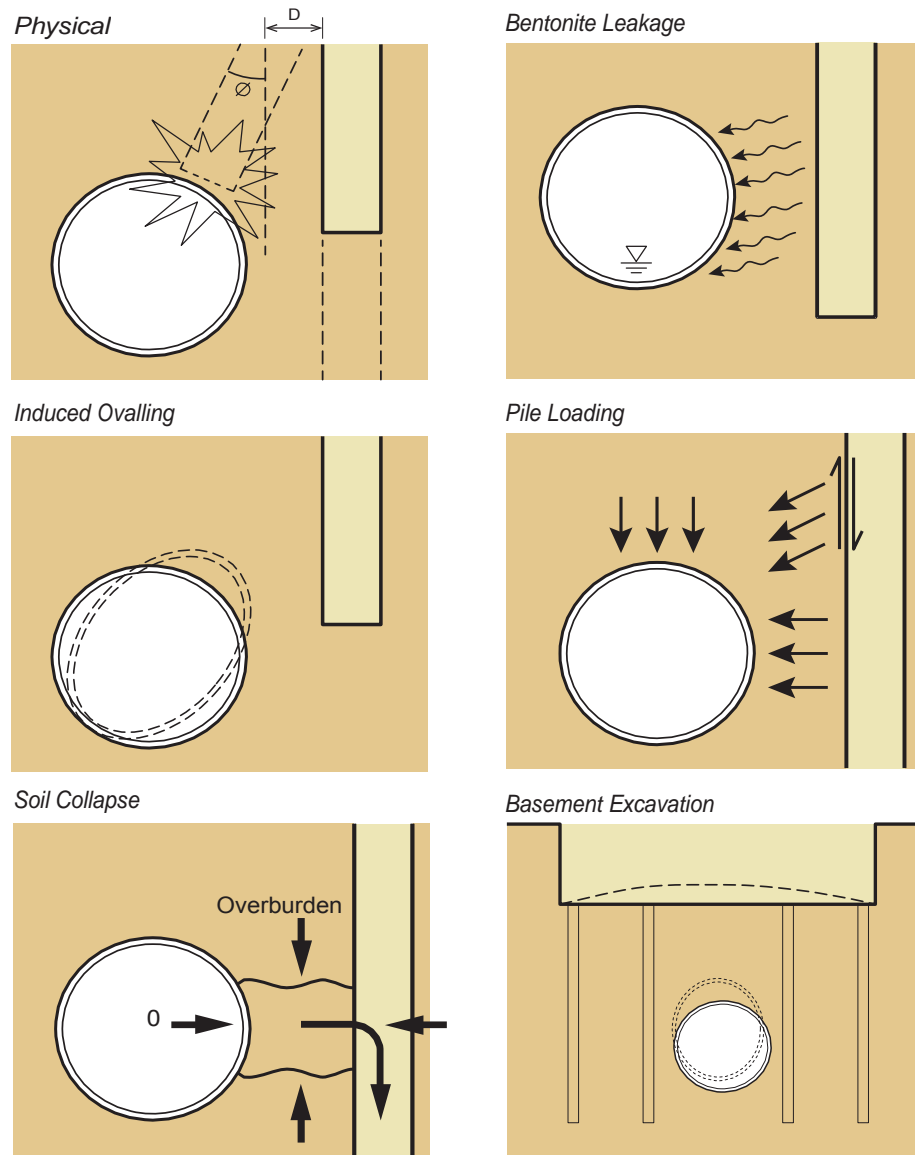


Figure 2. An illustration of potential tunnel risks induced by large diameter piling in close proximity

### 5.3 Developer's Ground Movement Impact Assessment

5.3.1 CRL will issue engineering details of affected assets to help assess the ground movement impact on Crossrail, to prove compliance and to develop risk mitigation plans as necessary. The developers' competent engineers are free to choose their own methods of modelling and analysis provided that:

- methods and models are based on proven geotechnical engineering principles and practice for ascertaining the soil-structure interaction in London ground conditions;
- methods account for the underlying geology and sequence of construction of the development, the influence of temporary works such as temporary unloading and loading and dewatering, and the effect of incremental loading and unloading effects and;
- CRL gives its 'No Objection' to the proposed analysis strategy (basis and assumptions) prior to commencement of detailed analysis;
- 'Standards' are complied with;
- if design tools are used (software packages etc.) then these have a proven track record in the UK industry;
- analysis takes into consideration site-specific constraints (e.g. other nearby structures and concurrent influential works), where these are likely to significantly influence impacts from the development;
- results are clearly presented to CRL, in a format that does not require further interpretation to prove compliance.

### 5.4 Deliverables for the demonstration of Crossrail safeguarding infrastructure protection

5.4.1 The developer will be expected to submit a Development Impact Assessment for review to CRL, which shows that the Crossrail assets are suitably protected. The impact assessment will contain:

- a) a narrative describing the analysis basis and technical assumptions underpinning the detailed design for construction.
- b) a narrative describing the detailed analysis, results and conclusions of the impact assessment, also explaining any significant effects resulting from the construction sequence;
- c) a register of interface risks including tabled recommendations (if required) for risk-based control measures, to contain significant risks to Crossrail's assets, throughout the development programme, including such considerations as unexploded ordnance (UXO) and transmission of groundborne vibration. The register is to be issued initially and thereafter it should be maintained and updated and be made available to CRL upon request
- d) NOTE: for all risks potentially catastrophic to the construction or operation of Crossrail (e.g. discovery of a UXO),
  - the developer shall ensure provision in its emergency response planning to contact the Crossrail Helpdesk immediately (0345 602 3813) to enable CRL's implementation of its emergency response
  - the developer shall alert contacted Emergency Services (including bomb disposal) to the presence of Crossrail buried assets nearby;
- e) a commitment by the developer to adopt designer's recommendations (or valid reasons if clients choose not to adopt recommendations);
- f) a Category 3 Check Certificate (reduced to 2 or 1 at the discretion of CRL and pending risk), countersigned by a senior company representative of the developer's independent checker, which certifies the accuracy and validity of the soil-structure interaction model, the load take-down, the ground movement impact assessment and results (taking into account the construction strategy and site-specific constraints), as verified by the checker's competent specialists;

- g) construction method statements and details as necessary to explain the construction sequence; to demonstrate that it is consistent with the assessment engineer's modelled assumptions, and to demonstrate that site planning for permanent and temporary works duly considers the protection of Crossrail assets;
- h) the Monitoring Plan and Monitoring Response Action Plan (see 5.5)
- i) Readiness Review note so far as required (see 5.5.10)
- j) a monitoring Close-out report explaining the extent of movement experienced by the Crossrail asset and demonstrating that stable conditions were reached following completion.
- k) details / method statements of all site investigations to be issued to CRL prior to commencement of works demonstrating SI contractor's awareness and due consideration of the location of Crossrail's buried assets and significant assets of others.

5.2.2 Table 3.11 presents a generic list of deliverables, the final choice of which will depend on the development scope. It is recommended that a list of deliverables be agreed during consultation with the CRL.

5.4.2 CRL may charge for the time of specialist resources commissioned to review and advise it on the findings of the Developer's Assessment.

## 5.5 Monitoring of Ground Movement

5.5.1 Pending the severity of impact determined from the Developer's Ground Movement analysis, the developer shall implement an agreed asset Monitoring Plan prior to commencement of impacting works. The plan will verify that actual movements realised during construction to aid the developer's control of ground movement.

5.5.2 The developer is expected to enter into a monitoring agreement with CRL where monitoring is undertaken in TfL's premises before handover of the railway to TfL (shortly before the Elizabeth Line becomes operational).

5.5.3 A Crossrail Monitoring Agreement template is presented at Appendix B

5.5.4 The grounds for deploying monitoring and extent along which tunnels are to be monitored will depend on the significance and certainty of predicted ground movement impact.

5.5.5 As a guide, it is suggested that monitoring be considered in tunnels where predicted diametric or radial distortion exceeds 3mm in cases of conventional demolition and basement excavations founded in well determined and understood ground, free of other significant risk factors (such as nearby large subterranean assets/structures within, suspected unfavorable geological features or where close to movement-sensitive structures).

5.5.6 Unless agreed otherwise with CRL, developers' agents will implement their own monitoring plans within CRL assets, working under CRL's prescribed rules and regulations for carrying out works on the energized railway, and working within any schedule constraints dictated by works to finish Crossrail.

5.5.7 The developer's monitoring system must be electro-magnetically compatible with the 'energised' (25KV OHLE) railway. Requirements are presented in in Appendix C.

5.5.8 The developer shall provide CRL with a monitoring installation report complete with pre- and post-installation photographic records and drawings showing the location of the system components and the testing and commissioning certificates.

5.5.9 The Developer is required to submit details of its monitoring plan for review and acceptance prior to implementation of works. The Monitoring Plan developed in consultation with CRL shall include

- a) A narrative detailing the Instrumentation and Monitoring (I&M) scope, developed in consultation with CRL and including performance requirements, type and layouts for instrumentation, as well as for power and communications infrastructure for data transmission between the parties. CRL will provide guidance on constraints affecting the choice and installation of monitoring equipment installed in its assets. The scope shall consider the findings of the Developer's ground movement analysis, state of completion of the asset and construction operations during monitoring and sensitivity to movement;
- b) a plan showing the tunnel, development and limits of predicted ground movement impact at tunnel axis level, superimposed on OS mapping and showing the monitored tunnel extents, dimensioned and referenced to mapped setting out points;
- c) the agreed monitoring schedule including the period and frequency of measurement readings for baseline calibration for the construction period and thereafter. Monitoring frequency shall be governed by the severity of impact risk for each significant stage of construction;
- d) A specification outlining the monitoring system design, including spatial layout and details of all system components referenced to the Crossrail chainage or Ordnance survey grid;
- e) Installation method statements;
- f) the Stability Acceptance Criteria agreed between the Developer and CRL, defining when monitoring may cease after completion;
- g) the Monitoring Action Plan, including defined orders of movement for relevant green, amber, red, black trigger response actions to mitigate adverse observed in-tunnel movement trends. The developer will consult CRL to agree the green, amber, red and black (if affecting operational track) movement trigger levels, and to advise response actions to arrest adverse in-tunnel movement trends which might otherwise have long term consequences on the operation of the Crossrail asset. It is worth noting that CRL in its construction of tunnels and shafts assumed nominally 75%, 100% and 125% of the predicted movement for its green, amber and red trigger alerts respectively;
- h) a communication plan including template(s) for regular reporting and interpretation of monitoring results and response actions and arrangements for CRL review and discussion if necessary;
- i) provisions for pre- and post-construction visual inspections of the Crossrail asset to ascertain the condition of the asset before and after completion of the developer's works;
- j) provisions for a testing and commissioning report and a close-out report.
- k) all monitoring equipment installed on the railway must be suitably robust, reliable and compatible so as not to introduce any risk to the 25kV operating railway environment. Requirements particularly governing electromagnetic compliance, as set out in Appendix C.

5.5.10 The Monitoring Plan shall be submitted to CRL for review and acceptance prior to the start of construction of the influential development works.

5.5.11 Monitoring results shall:

- a) Verify designer's modelled predictions for in-tunnel movements;
- b) Allow early detection of aberrant movement trends;
- c) Inform the developer's risk-based Response Action Plan which is to be developed in conjunction with CRL, and which informs CRL's Emergency Response Plan which serves to protect personnel present in the asset at the time.



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- 5.5.12 Unless agreed otherwise the developer shall fund the costs of installation, implementation and eventual removal of monitoring to protect the Crossrail asset from its construction impact plus the costs of Crossrail personnel engaged in the review of monitoring results.
- 5.5.13 Developers are advised to consult CRL well in advance of scheduled monitoring to understand constraints that might impact the Monitoring Plan. Methods for installation of Monitoring equipment shall be submitted to CRL in advance for review and acceptance and to help in the coordination of access.
- 5.5.14 Unless agreed otherwise Monitoring equipment must be commissioned prior to commencement of impact on the monitored assets.
- 5.5.15 Unless agreed otherwise the developer shall regularly report monitoring results to CRL throughout the course of its works. Monitoring results reports shall include:
- a) graphs and plots prepared to a format to be agreed with CRL for each monitored array as defined within the Monitoring Plan including:
    - the displaced cross-sectional shape of the Crossrail tunnels referenced to the baseline cross-sectional shape as measured at the start of the monitoring of the Phase 2 Works to reflect differences from base readings;
    - the displaced cross-sectional shape of the Crossrail Tunnels referenced to the previously reported cross-sectional shape to reflect differences from previous readings;
    - changes in easting and northing grid coordinates for prisms on the left and right hand side extremities of each tunnel referenced to baseline coordinates (plotted against time);
    - changes in vertical height measured at the crown of the Crossrail Tunnels and at track slab level, referenced to the baseline levels (plotted against time);
    - changes in all the chord lengths extrapolated across the arrays (plotted against time).
  - b) A graph showing the accumulated radius of the Crossrail Tunnel curvature induced by ground movement along the length of each tunnel referenced to the baseline
  - c) Graphs showing the accumulated displacement of monitored piles within the basement retaining walls referenced to the baseline
- 5.5.16 The Crossrail Safeguarding team will facilitate the interface engagement between the developer and the wider Crossrail team to minimise delay.
- 5.5.17 The developer shall provide evidence that it has undertaken a review prior to commencement of influential works, which certifies the readiness of systems installed to mitigate predicted impacts on Crossrail and procedures to establish and expedite corrective actions in the event that monitoring shows breaches of trigger levels.
- 5.5.18 Groundborne vibration impact from development construction: CRL would have cause to object to methods of construction carried out within 15m plan distance of its assets with potential to transmit heavy vibration (dynamic force) into the ground. As a guide the maximum intensity of continuous vibration should not exceed 15mm/s PPV (applying this criterion to the nearest source of activity). Prior to commencement the developer shall provide evidence to CRL of its assessment and mitigation of the risk, including works method statements and details of vibration management and monitoring as necessary.
- 5.6 Defect Surveys
- 5.6.1 Depending on the nature of risk imposed by the development construction CRL may require that pre- and post-construction visual defects inspections of its impacted asset be undertaken jointly with the Developer's representative.
- 5.6.2 The Developer's engineer will prepare annotated photographic inspection reports which are to be agreed jointly with CRL and which will provide evidence of any change in the condition of the asset during development.

- 5.6.3 Unless advised otherwise defect reporting shall adhere to the requirements for condition inspections, set out in TfL Standard S1055 (Civil Engineering Deep Tube Tunnels and Shafts), and the accompanying LU good practice guidance document G-055.
- 5.6.4 It is envisaged that defect surveys will be arranged and undertaken under terms agreed between the parties.
- 5.6.5 Inspectors shall unless otherwise agreed, be required to hold a valid CSCS card to access Crossrail's worksites.
- 5.6.6 CRL will facilitate access and egress for inspection and in the first instance inspections shall be coordinated with CRL's Safeguarding team. Inspections will at all times be conducted under the supervision of the occupying Crossrail contractor. All participants shall adhere to joining instructions, safety briefings and any specific rules and requirements instructed for working in the energized railway environment.
- 5.6.7 Developers shall reimburse CRL for all reasonable costs incurred in completing inspections.
- 5.6.8 The developer should note that the lead time required to undertake surveys is dependent on Crossrail works contractors' planned construction activities taking place in the assets concerned. Surveys will need to be timed to minimise interference with scheduled in-tunnel works and any dynamic testing of the railway.

## 6 Noise and Vibration

- 6.1 Operation of Elizabeth Line trains may cause vibration and re-radiated noise to be transmitted from the tunnels to the foundations of the development. Therefore, foundations should be designed so that the level of noise generated within the building by this vibration remains within limits acceptable to the Developer.
- 6.2 Crossrail is subject to a range of requirements including Undertakings and Assurances given during the passage of the Crossrail Bill through Parliament. There are also legal agreements which determine the degree of provision for controlling vibration and groundborne noise. These requirements apply in some respects system-wide although the design limits involved are specific to the class of use of the building (e.g. a general limit for residential development). Additionally, there are locally specific requirements for individual buildings.
- 6.3 In most areas where new development is proposed, it will either be planned to take place on the site of a previous building which will have already been the subject of a Crossrail design limit for vibration and groundborne noise according to its use, or be situated between other existing buildings to which a Crossrail design limit applies.
- 6.4 In the case of redevelopment of a site previously occupied by a building subject to an existing Crossrail design limit for vibration and groundborne noise it does not automatically follow that the likely level of vibration and groundborne noise in the new building will meet the Crossrail design limit for the previous building, because the foundations of the new building may differ in ways which increase the transmission of vibration and groundborne noise into the building. Likewise, the proximity of an existing building to a newly developed site does not automatically ensure that the Crossrail design limits will not be exceeded in the proposed new buildings, because of differences in foundations, local geotechnical conditions, differences in train speeds and other parameters.
- 6.5 The system-wide, use-specific limits to which Crossrail is subject are set out in [Information Paper D10](#) which is published on the Crossrail website. In summary, the requirement is that CRL has had to design the permanent track support system so that the level of groundborne noise near the centre of any noise-sensitive room is predicted in all reasonably foreseeable circumstances not to exceed the levels in Table 1 (page 10). CRL has also had to use reasonable endeavours to adopt mitigation measures that further reduced any adverse environmental impacts to any residential property in which the level of groundborne noise arising from the operation of the Elizabeth line passenger service near the centre of any noise-sensitive room was predicted to equal or exceed 35dB LAmax,S.
- 6.6 CRL has also been required to design the permanent track system, in accordance with the guidance in the 1992 version of British Standard 6472 “Guide to evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz)”, so that operational vibration arising from it at buildings identified in Table 1, expressed as vibration dose value (VDV), is predicted in all reasonably foreseeable circumstances not to exceed the levels presented in Table 2 (page 10). Note that since the 1992 version is used the VDV values use weighting Wg for z-axis vibration for guidance only.
- 6.7 The levels of vibration at the tunnel wall caused by the passage of a single train travelling at 100 km/h and at 80 km/h are presented in Tables 1 and 2 in Appendix A. The same data are also presented in graphic format in Figures 1 to 4 in Appendix A. It should be noted that these data are based on conservative assumptions of track stiffness and should be used for guidance only. For further information, contact the CRL Safeguarding team.
- 6.8 With regard to vibration, it is normally the case that where groundborne noise criteria are satisfied, vibration criteria are also satisfied. The data in Appendix A relate to vibration down to the 20Hz 1/3 octave band. In cases where a development involves particular sensitivity to vibration, predictions down to 1Hz may be required and further information should be sought from the CRL Third Party Development Manager.

Table 1: Construction<sup>1</sup> and Operational Groundborne Noise Criteria

Building	Level/Measure
Residential buildings	40dB $L_{A_{max,S}}$
Offices <sup>2</sup>	40dB $L_{A_{max,S}}$
Hotels <sup>2</sup>	40dB $L_{A_{max,S}}$
Theatres	25dB $L_{A_{max,S}}$
Large Auditoria/Concert Halls	25dB $L_{A_{max,S}}$
Sound recording studios	30dB $L_{A_{max,S}}$
Places of meeting for religious worship <sup>3</sup>	35dB $L_{A_{max,S}}$
Courts, lecture theatres	35dB $L_{A_{max,S}}$
Small Auditoria/halls	35dB $L_{A_{max,S}}$
Hospitals, laboratories	A40dB $L_{A_{max,S}}$
Libraries	40dB $L_{A_{max,S}}$

## Notes

1. Excluding the groundborne noise from the passage of the tunnel boring machine (TBM).
2. Significance criteria not included in the Scope and Methodology set out in Appendix A2, Vol. 5 of the Crossrail Environmental Statement, added here for clarification.
3. Meaning a place the principal use of which is for people to come together as a congregation to worship God or do reverence to a deity.

Table 2: Construction and Operational Vibration Criteria

In the Absence of Appreciable Existing Levels of Vibration		Appreciable Existing Levels of Vibration <sup>1,2</sup>
VDV $ms^{-1.75}$ Daytime (07:00 - 23:00)	VDV $ms^{-1.75}$ Night-time (23:00 - 07:00)	% increase in VDV
0.31	0.18	40

## Notes:

1. Highest impact category used, daytime or night-time.
2. There is an appreciable existing level of vibration where daytime and night-time vibration dose values (VDVs) exceed  $0.22 ms^{-1.75}$  and  $0.13 ms^{-1.75}$  respectively.

# Appendix A

## Noise and Vibration Assessment Summary



## Crossrail

Contract XR/K/680

Noise and Vibration Assessment and Mitigation

Report No 075/14

Resilient Slab Track

Tunnel Vibration Predictions

Revision 3

March 1998

<b>Crossrail</b>						
Contract XR/K/680 Noise and Vibration Assessment and Mitigation						
Report No 075/14 Tunnel Vibration Predictions						
Issue and Revised Record						
Issue	Date	Originator	Checked	Approved	Description	Status
1	11/06/96	RMTT	FLT	RMTT	Report	1st Issue
1	10/07/96	RMTT	JSP	RMTT	Report	Revision 1
1	31/07/96	RMTT	JSP	RMTT	Report	Revision 2
1	16/03/98	RMTT	FLT	RMTT	Report	Revision 3

Rupert Taylor Ltd

Consultants in Acoustics,

Noise and Vibration Spring Garden, Fairwarp,

Nr Uckfield, East Sussex, TN22 3BG

Telephone: 01825 712435 Fax: 01825 712542

## 1 Introduction

- 1.1 This report provides predictions of the vibration of the wall of the tunnels in the Crossrail central section, for use in the assessment of groundborne noise in adjacent buildings.

## 2 Description of the Model

- 2.1 The prediction model used for these predictions employs an algorithm for the solution of the wave equation for the propagation of waves in bars, plates and solids, using finite difference methods. The model computes vibration of each element as a function of time, which is then subjected to Discrete Fourier Transform using a standard Fast Fourier Transform algorithm. The bandwidth of the prediction results covers the 1/3 octave bands centred on 20Hz to 160Hz.
- 2.2 The model consists of a section of tunnel the length of one rail vehicle, connected end-to-end to create an infinitely long tunnel and train. In view of the fact that the length of a 12-car Crossrail train is 47 times the tunnel diameter, the modelling of an infinitely long train is valid. The tunnel is modelled as a rolled-up curved plate surrounded by soil. Each rail is modelled as a beam supported on periodic resilient supports. The train is represented by the unsprung masses of the wheels and associated equipment, the sprung bogie masses, the secondary suspension and the car body.

## 3 Assumptions

- 3.1 The following assumptions were made:

Track	rail mass	56.4kg/m	per rail
	rail stiffness	4.665MNm <sup>2</sup>	per rail
	rail damping	0Ns/m	per rail
	rail pad stiffness (dynamic)	25.6MN/m	per metre of rail
	rail pad damping ( $\eta$ )	0.1	dimensionless
	Hertzian contact stiffness	1.2GN/m	per wheel
Vehicles	unsprung mass	835kg	per wheel
	sprung mass	815kg	per wheel
	primary suspension stiffness	1.3MN/m	per wheel
	primary suspension damping	10kNs/m	per wheel
	secondary suspension stiffness	117.5kN/m	per wheel
	secondary suspension damping	11.651kNs/m	per wheel
	body mass	5705kg	per wheel

Note: where the Crossrail design aim for groundborne noise of 40dB  $L_{Amax,S}$  due to the passage of one Crossrail train cannot be met using baseplates having the dynamic stiffness and damping quoted above, a baseplate with a lower stiffness of 14MN/m per metre of rail may be considered.

- 3.2 The baseplate specification used in the above assumptions has a higher dynamic stiffness than CRL is currently proposing to adopt, in order to ensure that a conservative prediction of noise level is considered in the developer's design.

### 3.3 Tunnel Design

The tunnel assumption was a 6m inside diameter tunnel with 300mm thick concrete linings.

### 3.4 Rail Roughness

A roughness spectrum of 30dB re 1 micron in the 1/3 octave band centred on a wavelength of 2m, sloping at a rate of -15dB per decade to 0dB in the 1/3 octave band centred on 0.02m. This spectrum was used to represent the combined effects of wheel and rail roughness.

### 3.5 Soil

The soil characteristics used were those of London Clay.

## 4 Prediction Results

- 4.1 The results are presented in tabular form in Tables 1 and 2 for two train speeds of 80km/h and 100km/h respectively, in terms of 1/3 octave spectra of radial tunnel wall velocity in decibels r.e. 1 nanometre per second, for 26 positions around the tunnel circumference. The same data are also plotted in Figures 1 to 4.

## 5 Application of the Results

- 5.1 The results may be used for estimating the likely level of groundborne noise inside buildings above the tunnel alignment. For this purpose it is necessary to take account of the effect of vibration propagation through the soil, of coupling loss factor between the soil and the building, and the dynamic response of the building. After applying corrections for these effects, the results in terms of the root-mean-square (rms) velocity in 1/3 octave bands can be used to estimate the sound pressure level inside a typical room. In many cases, the relationship between room sound pressure level and 'rms' velocity of the room surfaces is approximately equivalent to  $L_p = L_v - 27dB$ , where  $L_p$  is the 1/3 octave band sound pressure level:  $L_v$  is the 'rms' vibration velocity in dB re 1 nanometer per second.
- 5.2 Propagation through the soil is a very complex phenomenon, since the vibration is propagated in three ways — as shear, compression and surface waves, and as shown by the results given in this report, the source strength varies around the tunnel circumference. A worst-case approach would be to take the highest levels in the tunnel wall 'visible' to the receiving structure, and use a distance function as follows:

$$L_r = L_t - 4.34 \frac{\omega \eta r}{c_s} - 10 \log_{10} \left[ \frac{r_0 + r}{r_0} \right]$$

Where  $L_t$  is the tunnel wall radial velocity for a tunnel of radius  $r_0$  and  $L_r$  is the soil radial velocity at distance  $r$ , both in dB re 1 nanometer/second,  $c_s$  is the phase speed of compression waves in soil with loss factor  $\eta$  and  $\omega$  is the angular frequency of each 1/3 octave band in radians per second. The coupling loss factor and building response generally have opposite sign and as a first order approximation they may be assumed to cancel. In the case of piled foundations, if  $r$  is taken to be the shortest distance to any part of the nearest pile, a worst-case estimate will be obtained. Any distance units may be used, provided they are consistent throughout.

- 5.3 The overall 1/3 octave spectrum may be converted to dB(A) by decibel addition of the band levels after applying the value of the 'A-weighting' curve of each band centre frequency.
- 5.4 To obtain a more precise prediction of groundborne noise levels in buildings, it is necessary to use numerical modelling methods based on finite-difference or finite-element techniques.



Table 1 – 1/3 Octave band spectra of vibration velocity of tunnel circumference (0 degrees = crown), dB re 1 nanometre per second. Train speed: 80km/h

Hz	Degrees																										
	0	14	28	42	55	69	83	97	111	125	138	152	166	180	194	208	222	235	249	263	277	291	305	318	332	346	360
20	90	89	86	85	89	92	94	96	98	99	100	99	99	98	99	99	100	99	98	96	94	92	89	85	86	89	90
25	91	90	85	84	90	92	93	96	99	101	103	102	102	102	102	102	103	101	99	96	93	92	90	84	85	90	91
31.5	100	99	95	96	101	103	104	106	108	110	111	110	110	110	110	111	110	108	106	104	103	101	96	95	99	100	
40	103	102	96	99	104	105	106	107	110	112	113	112	112	112	112	113	112	110	107	106	105	104	99	96	102	103	
50	95	92	85	92	96	96	95	98	101	103	104	103	102	102	102	103	104	103	101	98	95	96	96	92	85	92	95
63	92	90	83	91	93	93	93	95	97	99	99	98	97	97	97	98	99	99	97	95	93	93	93	91	83	90	92
80	88	85	79	88	89	86	88	91	91	93	94	92	92	92	92	92	94	93	91	91	88	86	89	88	79	85	88
100	90	86	82	89	90	88	90	92	93	95	95	92	90	90	90	92	95	95	93	92	90	88	90	89	82	86	90
125	94	89	89	93	91	93	94	94	97	98	98	95	93	92	93	95	98	98	97	94	94	93	91	93	89	89	94
160	88	83	84	87	86	88	88	89	90	91	91	85	82	81	82	85	91	91	90	89	88	88	86	87	84	83	88

Table 2 – 1/3 Octave band spectra of vibration velocity of tunnel circumference (0 degrees = crown), dB re 1 nanometre per second. Train speed: 100km/h

Hz	Degrees																										
	0	14	28	42	55	69	83	97	111	125	138	152	166	180	194	208	222	235	249	263	277	291	305	318	332	346	360
20	92	91	88	86	89	92	94	96	97	99	99	99	99	99	99	99	99	99	97	96	94	92	89	86	88	91	92
25	94	93	89	88	93	96	97	99	101	103	104	103	103	103	103	103	104	103	101	99	97	96	93	88	89	93	94
31.5	101	100	96	97	101	103	105	107	109	112	113	112	111	111	111	112	113	112	109	107	105	103	101	97	96	100	101
40	104	103	98	101	105	107	107	109	111	114	114	114	113	113	113	114	114	114	111	109	107	107	105	101	98	103	104
50	94	92	86	92	96	96	96	99	102	104	104	103	103	102	103	103	104	104	102	99	96	96	96	92	86	92	94
63	93	90	83	91	94	93	93	96	98	99	100	99	98	98	98	99	100	99	98	96	93	93	94	91	83	90	93
80	90	86	80	89	90	88	90	93	94	95	96	94	93	92	93	94	96	95	94	93	90	88	90	89	80	86	90
100	93	89	85	93	92	90	93	94	94	96	96	94	92	92	92	94	96	96	94	94	93	90	92	93	85	89	93
125	95	89	90	94	90	93	95	95	99	100	100	97	95	94	95	97	100	100	99	95	95	93	90	94	90	89	95
160	89	84	84	87	85	87	87	88	90	91	91	85	82	82	82	85	91	91	90	88	87	87	85	87	84	84	89

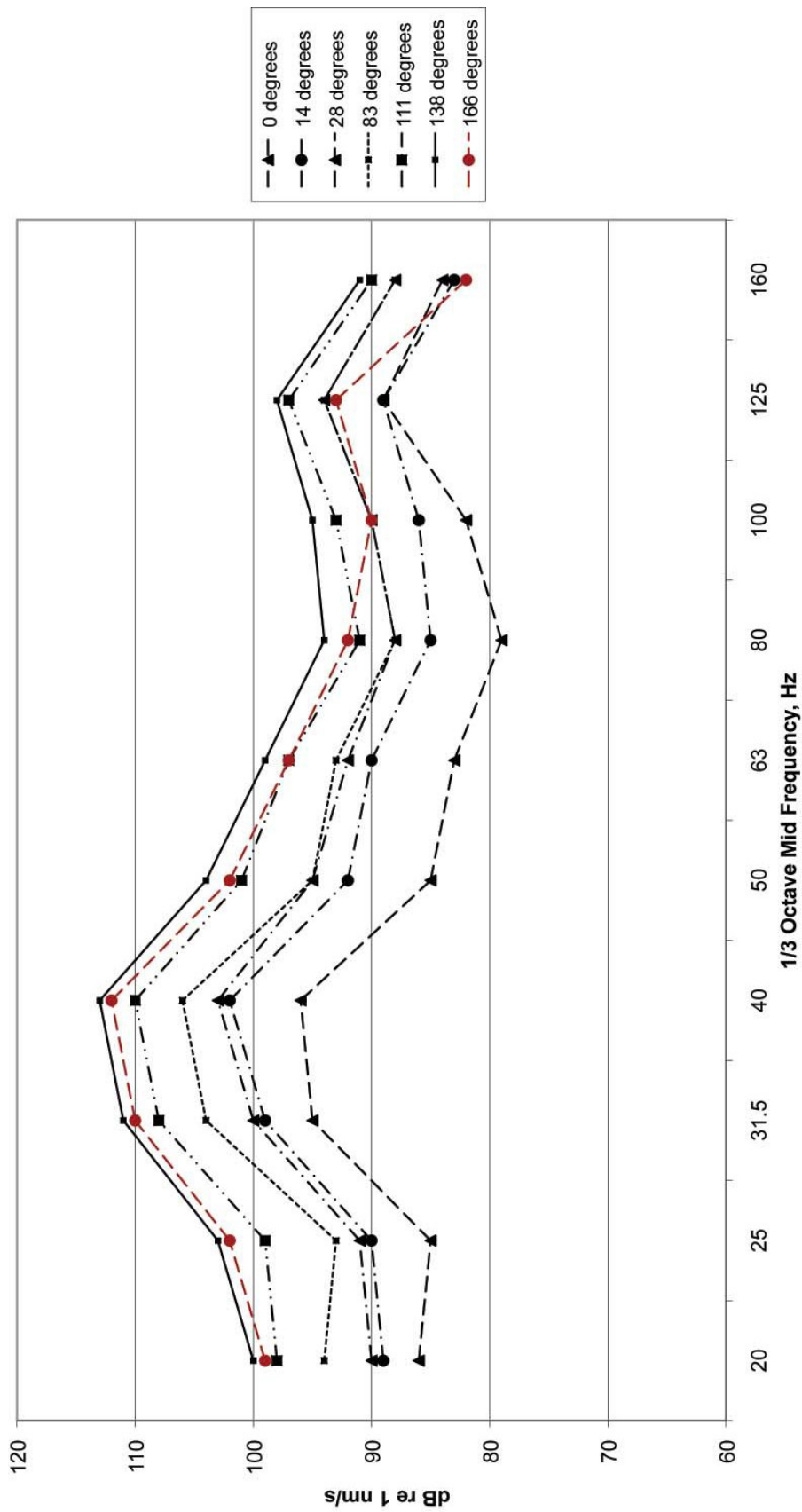


Figure 1 Distribution of vibration levels around tunnel circumference (0 degrees – crown) RST 80 km/h

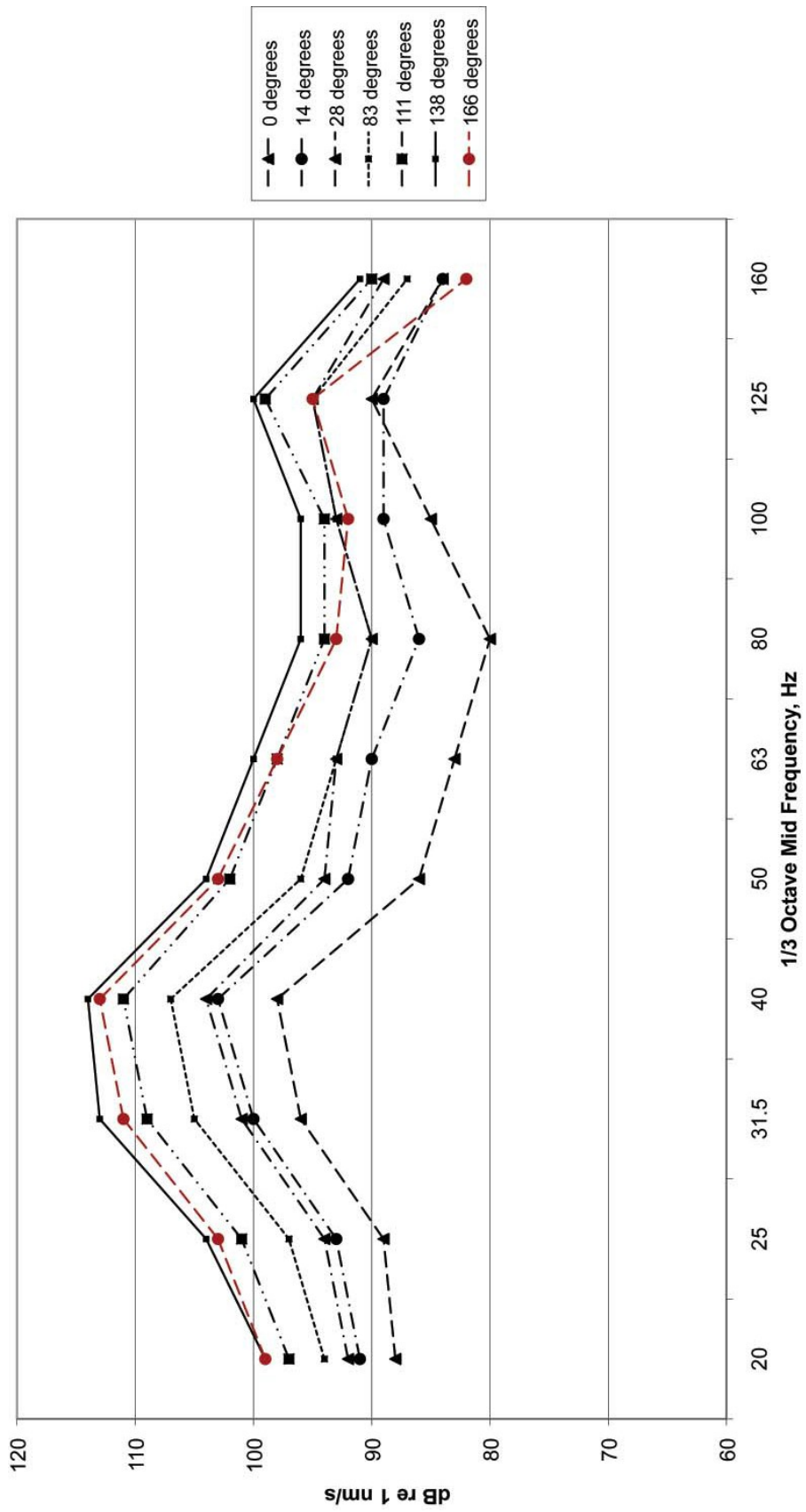


Figure 2 Distribution of vibration levels around tunnel circumference (0 degrees – crown) RST 100 km/h

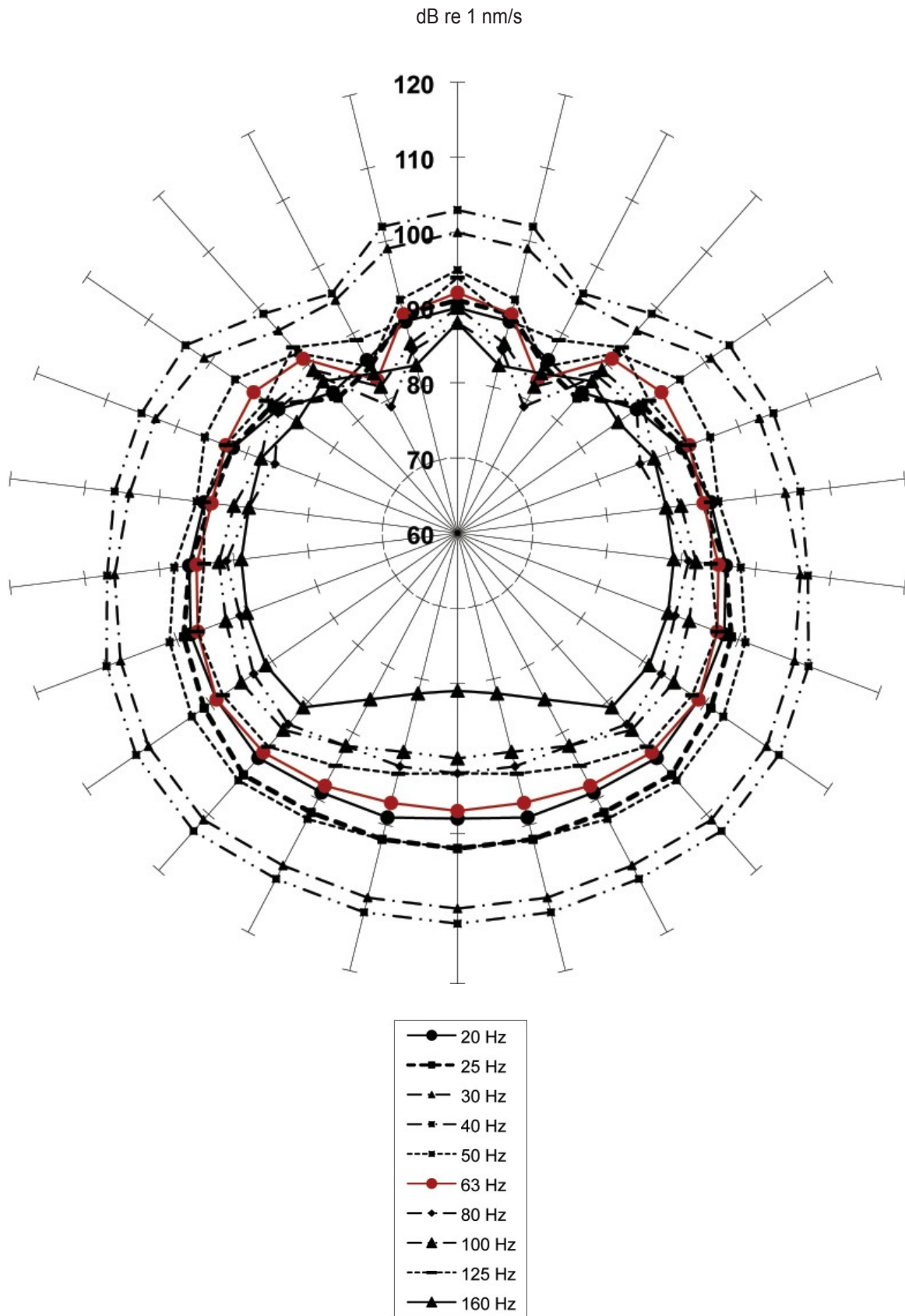


Figure 3 Distribution of vibration levels around tunnel circumference – RST 80/km/h

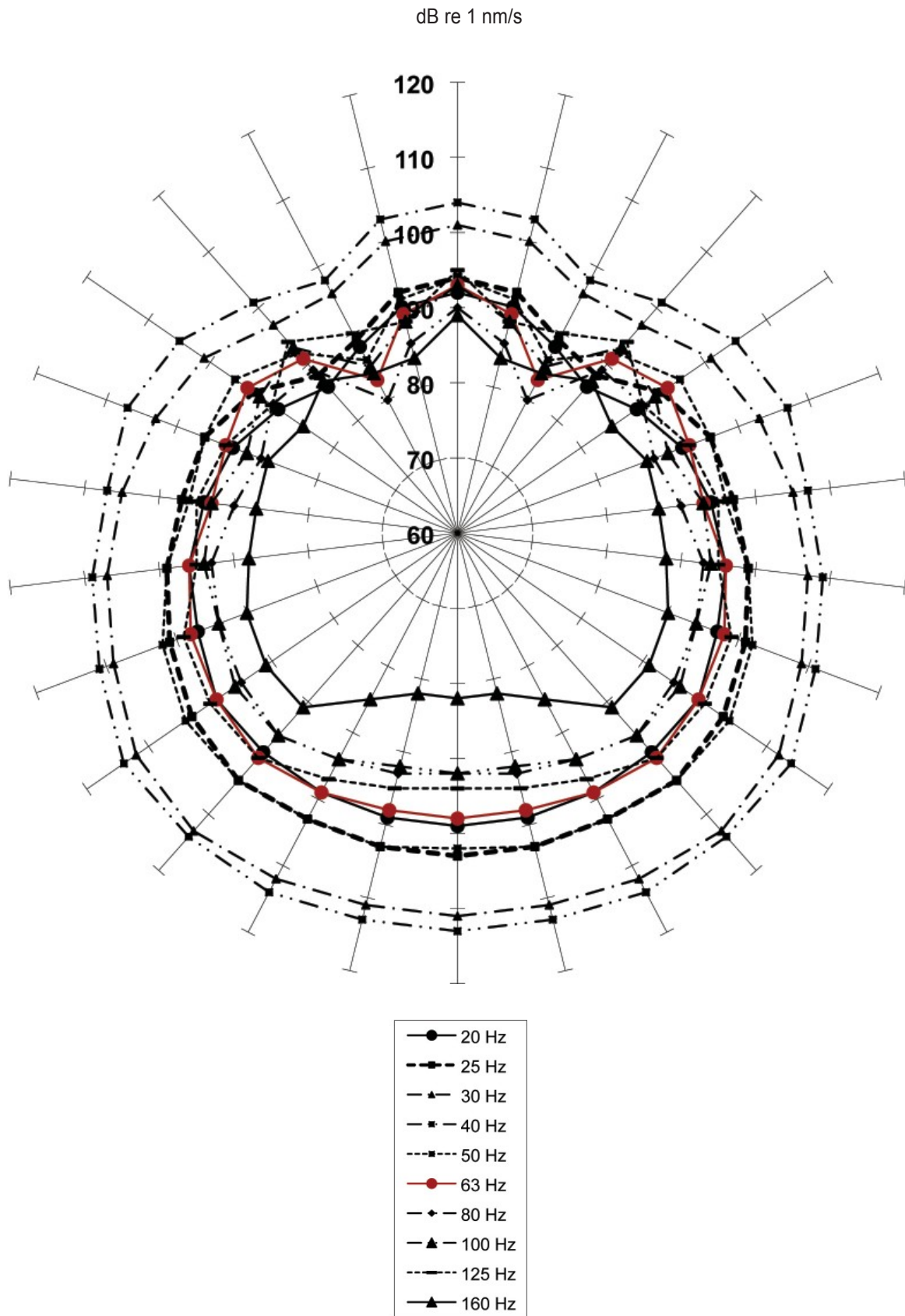


Figure 4 Distribution of vibration levels around tunnel circumference – RST 100/km/h

# Appendix B

## Licence to Install and Retain Monitoring Equipment



DATED \_\_\_\_\_ 20

TRANSPORT FOR LONDON (1)

and

CROSSRAIL LIMITED (2)

and

[Name of Outside Party] (3)

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LICENCE TO INSTALL AND RETAIN MONITORING EQUIPMENT

on TfL land in the vicinity of

[Development address/ location]

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This Licence is made the \_\_\_\_\_ day of \_\_\_\_\_ two thousand and [●]

BETWEEN:

- (1) TRANSPORT FOR LONDON of 55 Broadway, London, SW1H 0BD (“TfL”) and
- (2) CROSSRAIL LIMITED (company registration number 04212657) whose registered office is at 5 Endeavour Square, London, E20 1JN (“CRL”)
- (3) [Name of Outside Party] (company registration number [●]) of [registered address] (“the Licensee”).

WHEREAS:-

1. TfL owns or is responsible for the land buildings structures and airspace in the vicinity of [Development address/ location];
2. Until Handover CRL and its contractor are responsible for the land building structures and airspace comprising Paddington Station and Eastbound and Westbound Running tunnels (the “Crossrail’s Railway”) which are shown edged red on the Plan being part of TfL Land;
3. The Licensee wishes to [description of development] (hereinafter the “Main Works”);
4. To carry out the Main Works the Licensee is desirous of entering that part of Crossrail’s Railway [shown shaded blue/between the points marked "A" and "B"] on the plan for the purpose of installing, commissioning, maintaining repairing retaining and decommissioning monitoring equipment (hereinafter called “the Licensed Works”);

IT IS AGREED as follows:

## 1. DEFINITIONS

In this Licence the following expressions shall, unless the context requires otherwise, have the following meanings: -

- 1.1. “Contractor’s All Risks Insurance” means insurance against damage caused by any of the following events:- fire lightning earthquake subsidence heave explosion terrorism aircraft (other than hostile aircraft) and aerial devices or articles dropped therefrom riot and civil commotion and malicious damage storm tempest bursting or overflowing of water tanks apparatus or pipes flood impact theft and such other usually insurable risks as TfL shall reasonably prescribe;
- 1.2. “Crossrail’s Railway” has the meaning given to it in recital (b);



- 1.3. “Engineer” means the authorised person notified to the Licensee in writing from time to time and who is responsible for exercising the Engineer’s powers under this License.
- 1.4. “Handover” means handover of Crossrail’s Railway from CRL to TfL;
- 1.5. “Insolvency Event” means any one or more of the following:
  - 1.5.1. an encumbrancer takes possession of or a receiver is appointed over any property or assets of the Licensee;
  - 1.5.2. the Licensee makes any voluntary arrangements with its creditors or is subject to an administration order;
  - 1.5.3. being an individual, the Licensee is the subject of a bankruptcy petition;
  - 1.5.4. being a company, the Licensee is insolvent and/or goes into liquidation; or
  - 1.5.5. the Licensee ceases or threatens to cease carrying on business;
- 1.6. “Licensed Works” has the meaning given to it in recital (d);
- 1.7. “Main Works” has the meaning given to it in recital (c);
- 1.8. “Monitoring Action Plan” means a plan which meets the requirements set out in clause 3.3.1.
- 1.9. “Monitoring Proposals” means calculations to demonstrate the predicted movement or distortion of railway assets as a direct or indirect result of the Main Works and proposals for a suitable system of monitoring any such movement or distortion including details of any power or telephone connections, electromagnetic compatibility studies, reporting intervals, proposed location of targets, instrumentation or other equipment and size of equipment to enable gauging approval;
- 1.10. “Railway Standards means those documents produced or varied from time to time and which apply to TfL’s railway undertaking or TfL’s railway assets (including the Crossrail’s Railway) and premises generally and contain requirements or guidance on:
  - 1.10.1. matters of safety in respect of the railway undertaking or railway assets and premises;
  - 1.10.2. the design, construction or operation of railway assets and premises and/or the operation of any part of railway undertaking; and
  - 1.10.3. works carried on over or near railway assets and premises; such documents being made available to the Licensee as required from time to time.

- 1.11. "TfL's Land" has the meaning given to it in recital (a);
- 1.12. "Works Documents" means the Monitoring Proposals the Monitoring Action Plan, design drawings specifications programmes method statements risk assessments relating to the monitoring equipment to be installed, ground movement monitoring results and any other information (including temporary works drawings, supported calculations, programme dates and hours of working) reasonably required by the Engineer in relation to the Licensed Works and (insofar as they have the potential to affect TfL assets) the Main Works prepared in accordance with the relevant Railway Standards;
- 1.13. Where the Licensee is more than one person, all such persons shall be jointly and severally liable for the obligations and liabilities of the Licensee arising under this Licence;
- 1.14. Words importing one gender include all other genders words importing the singular include the plural and vice versa and any reference to a person includes a reference to any legal or natural person or authority board department or other body;
- 1.15. The clause headings do not form part of this Licence and shall not be considered for the purposes of its construction or interpretation;
- 1.16. Any covenant by the Licensee not to do or omit any act or thing shall include not permitting or suffering it to be done or omitted;
- 1.17. References to clauses without further designation are references to the respective clauses of this Licence;
- 1.18. References to "TfL" include TfL's employees, contractors and agents;
- 1.19. References to "CRL" include CRL's employees, contractors and agents.

## **2. LICENCE**

- 2.1. In consideration of the payment referred to in clause 4.1 and of the obligations on the part of the Licensee in this Licence, TfL and (until Handover occurs) CRL grant to the Licensee its employees contractors and agents licence and authority to carry out the Licensed Works on Crossrail's Railway in accordance with the terms of this Licence.
- 2.2. The licence hereby granted shall commence on [●] and (subject to earlier determination provided for herein) shall continue until and including [●] or as may be extended by agreement in writing signed by the Engineer and the Licensee on the same terms and conditions herein (subject to any additional licence fee agreed between the parties).

### **3. LICENSEE'S OBLIGATIONS**

The Licensee covenants with TfL (and until Handover occurs) CRL to observe and perform the obligations and conditions in this Licence as follows:

#### **3.1. Approval of Works Documents**

- 3.1.1. The Licensee shall submit the Works Documents to the Engineer.
- 3.1.2. The Licensee shall not commence the Licensed Works without the Engineer's prior written approval of the Works Documents which approval may be granted subject to such conditions as the Engineer considers in his absolute discretion necessary for the safety protection and operation of Crossrail's Railway or for the protection of TfL's Land.
- 3.1.3. Any approval of the Works Documents given by the Licensee shall not constitute a warranty as to the fitness for purpose of any design or specification submitted by the Licensee and neither TfL or CRL shall have any liability in relation to such approval.

#### **3.2. Licensed Works**

- 3.2.1. The Licensee shall carry out the Licensed Works in a good and workmanlike manner and in accordance with the Works Documents approved and any conditions imposed by the Engineer pursuant to clause 3.1.2 and with all relevant Railway Standards.
- 3.2.2. For the duration of this Licence, the Licensee shall appoint suitably trained and experienced representatives who are identified to and approved by the Engineer (such approval not to be unreasonably withheld or delayed) as the designated "site point of contact" to whom the Engineer can raise any issue in connection with the Licensed Works. The Licensee shall procure that any one such appointed person is available at all times.
- 3.2.3. The Licensee its employees agents and contractors shall comply with all directions that the Engineer may make from time to time
- 3.2.4. concerning the Licensed Works and may be required by the Engineer to stop work or remove from the Licensed Works any scaffold material machinery plant or equipment which in the Engineer's opinion may cause damage or be a hazard to

Crossrail's Railway or which does not comply with the details of the Licensed Works previously approved by the Engineer.

3.2.5. The Licensee shall at its own expense always maintain in a good and safe condition and keep in repair anything installed, built or used on TfL's Land in connection with the grant of this Licence.

3.2.6. The Licensee shall continue to monitor the Crossrail's Railway for such period as is approved by the Engineer as part of the Works Documents under clause 3.1.2.

### **3.3. Monitoring Action Plan**

3.3.1. The Licensee shall prepare in collaboration with the Engineer and shall submit to the Engineer for approval a Monitoring Action Plan to deal with the implications arising from any emergency or unplanned interference with the safety or operation of Crossrail's Railway caused by the Main Works.

3.3.2. The Licensee shall implement and act in accordance with the approved Monitoring Action Plan.

3.3.3. The Licensee shall provide the Engineer with sufficient information in order for the Engineer to prepare an emergency response plan addressing the actions for TfL and CRL in response to events caused by the carrying out of the Main Works.

### **3.4. Consents and approvals**

3.4.1. The Licensee shall obtain and comply with all relevant consents and approvals required under all legislation in connection with the Licensed Works and shall provide copies of such consents and approvals to the Engineer upon demand.

3.4.2. The Licensee shall make available for inspection by the Engineer at all reasonable times all registers forms and certificates that the Licensee and its contractors are obliged to hold or maintain under any legislation in respect of any scaffold material machinery plant equipment or operation used in connection with the Licensed Works.

### **3.5. Access**

- 3.5.1. The Licensee shall give the Engineer not less than six weeks or such other earlier period of notice as the Engineer may require of commencement of the Licensed Works and thereafter not less than four weeks' notice of each occasion that anyone authorised by this Licence intends to enter upon TfL's Land to carry out the Licensed Works. The Licensee shall not enter upon TfL's Land without the prior written consent of the Engineer.
- 3.5.2. Every person who enters upon TfL's Land in pursuance of this Licence will be required to have undergone basic training organised by TfL or CRL and to carry a permit issued by TfL or CRL and will be required to produce the permit for inspection by any employee contractor or agent of TfL or CRL upon demand. If a person fails to produce such a permit he shall be refused access to TfL's Land notwithstanding this Licence or if he has entered, shall leave TfL's Land immediately upon being requested to do so.
- 3.5.3. Every such person who is to enter TfL's Land shall comply with any requirements or instructions which may be given by TfL's and (until Handover occurs) CRL's employees contractors or agents as to the time of entry and as to their conduct whilst upon TfL's Land. Any person who has been hereby authorised to enter shall leave TfL's Land immediately on being requested to do so.
- 3.5.4. The Licensee its employees agents and contractors shall observe such rules and regulations as TfL or (until Handover occurs) CRL may make and of which the Engineer shall notify the Licensee from time to time governing the use of TfL's Land.
- 3.5.5. Notwithstanding anything in this clause, no access shall be granted to the Licensee in respect of the initial installation, testing and commissioning of the Licensed Works until all costs expenses and disbursements incurred or suffered by TfL or (until Handover occurs) CRL and payable pursuant to clause 4 have been paid.

### **3.6. Outgoings**

The Licensee shall pay all taxes rates charges and other outgoings payable in respect of the Licensed Works.

### 3.7. **Damage to Crossrail's Railway**

Subject to the grant of access in accordance with clause 3.5, the Licensee shall immediately make good to the satisfaction of the Engineer any damage (including decorative damage) to any land or building structure plant or machinery owned or controlled by TfL or CRL or any contractor of either of them on or comprising Crossrail's Railway and which is caused in the exercise of the rights granted under this Licence.

### 3.8. **Indemnity**

3.8.1. The Licensee shall indemnify TfL and CRL and their respective employees and agents from and against all expenses liabilities losses and claims whatsoever in respect of: -

- (a) death or injury to any person;
- (b) loss or damage to property (which shall include both real and personal) (including such property belonging to TfL or CRL or any of contractor of either of them or for which any of them is responsible);
- (c) any other loss damage cost or expense arising from or in consequence of the Licensee's performance or non-performance of its obligations under this Licence or the presence of the Licensee, its employees contractors or agents on TfL's Land whether such injury loss damage cost or expense be caused by negligence or otherwise.

### 3.9. **Insurance**

3.9.1. Without prejudice to the Licensee's liability to indemnify under clause 3.8 the Licensee shall at its cost procure and maintain

- (a) public liability insurance with an indemnity of not less than **[£10,000,000]** per incident or series of incidents arising out of one event; and
- (b) Contractor's All Risks insurance in an amount sufficient to cover as a minimum the removal of debris and making safe the site if the Licensed Works are damaged or destroyed by an insured peril.

3.9.2. Such insurances shall:

- (a) be maintained with a reputable insurer authorised to underwrite risks in the United Kingdom; and

- (b) include a provision whereby in the event of any claim in respect of which the Licensee would be entitled to receive indemnity under the policy being brought or made against TfL or CRL the insurer will indemnify TfL and CRL against such claim and any costs charges and expenses in respect thereof.

3.9.3. The Licensee shall produce to the Engineer satisfactory evidence that the insurances referred to in clause 3.9.1 is in effect before this Licence comes into force and whenever reasonably requested to do so by the Engineer.

3.9.4. Without prejudice to the Licensee's obligations to insure and produce evidence thereof if the Licensee shall fail to produce such evidence TfL or CRL shall have the right to effect such insurances as it considers appropriate in the circumstances and to pay the associated premium and the said premium shall be repaid by the Licensee to TfL or CRL on demand.

**3.10. Confidentiality and use of information supplied by TfL or CRL**

3.10.1. The Licensee shall not at any time disclose to any person any confidential information concerning the business, affairs, assets, infrastructure, customers or suppliers of TfL or CRL except as permitted by clause 3.10.2.

3.10.2. The Licensee may disclose the information described in clause 3.8.1:

- (a) to its employees, officers, representatives or advisers who need to know such information for the purposes of carrying out the Licensed Works provided that the Licensee shall ensure that its employees, officers, representatives or advisers to whom it discloses TfL's or CRL's confidential information comply with this clause 3.10; and
- (b) as may be required by law, court order or any governmental or regulatory authority.

3.10.3. The Licensee shall not use TfL's or CRL's confidential information for any purpose other than in connection with the Licensed Works or the Main Works.

### **3.11. Monitoring reports and access to monitoring data**

- 3.11.1. The Licensee shall provide the Engineer with access to automatically relayed monitoring data and copies of the monitoring reports (including an interpretation of the raw data) produced at
- 3.11.2. such intervals and for such period as are approved by the Engineer as part of the Works Documents under clause 3.1.2.
- 3.11.3. The Licensee shall not without the Engineer's prior written approval share or provide copies of the monitoring reports to any person not connected with the carrying out of the Main Works.

## **4. COSTS**

- 4.1. The Licensee shall pay to each of TfL and CRL on the signing of this Licence the sum of one pound (£1.00) plus Value Added Tax (if demanded).
- 4.2. The Licensee shall pay to TfL and (until Handover occurs) to CRL within twenty working days of written demand by either:
  - 4.2.1. all proper fees costs and disbursements (including any Value Added Tax payable thereon) of professional advisers and agents properly incurred by TfL or CRL in connection with the preparation, negotiation and completion of this Licence; and
  - 4.2.2. all proper costs charges or expenses (including any Value Added Tax payable thereon) properly incurred or suffered by TfL or CRL in connection with the grant of this Licence and the carrying out or facilitation of the carrying out of the Licensed Works (regardless of whether or not the said works proceed) including, without limitation, all proper costs incurred or suffered by TfL or CRL and its contractor in the review or approval of the Works Documents, monitoring of the Licensed Works or the provision of flagmen inspectors or other persons who in the Engineer's opinion are necessary for the safety and protection of Crossrail's Railway or any person working thereon.
- 4.3. Without prejudice to TfL's rights or CRL's rights under this Licence if any amount payable hereunder is not paid within seven days of becoming due (whether formally demanded or not) then the Licensee shall pay interest on such amount calculated on a simple basis at the rate of five per cent (5%) per annum above HSBC Bank plc's base lending rate from time to time from the day the amount becomes overdue until the date of actual payment.



- 4.4. Where, under the terms of this Licence, a supply is made that is subject to Value Added Tax, the person receiving the supply is to pay the Value Added Tax to the person making the supply and a valid Value Added Tax invoice is to be issued by the person making the supply.

**5. TfL'S and CRL'S RIGHTS**

- 5.1. The Engineer may temporarily obstruct the Licensed Works or on not less than two weeks' notice (save in case of emergency where the Engineer shall give such notice as is reasonably practicable) from the Licensee shall remove and thereafter have the right to reinstate anything installed on TfL's Land as part of the Licensed Works (at the Licensee's expense) where in the reasonable opinion of the Engineer such obstruction or removal is necessary for the carrying out of works on or testing and commissioning of TfL's Railway. In case of emergency the Engineer may elect to carry out the works to remove anything installed on TfL's Land as part of the Licensed Works.
- 5.2. If at any time the Licensee shall fail to perform its obligations pursuant to clause 11 or any of its obligations contained in this Licence relating to the repair or reinstatement of TfL's Land TfL may elect to carry out such works at the expense of the Licensee and such costs shall be repaid by the Licensee to TfL within twenty working days of demand.

**6. NO WARRANTY**

- 6.1. Neither CRL or TfL gives any warranty as to the condition of TfL's Land or as to its suitability for the Licensed Works.
- 6.2. Nothing in this Licence implies any warranty as to the purpose for which the Licensee is permitted to use TfL's Land under planning legislation or any other statute.
- 6.3. Neither TfL nor CRL shall not be required to show any evidence of title and the Licensee shall not make any requisition or objection in respect of the power of TfL and CRL to grant this Licence.

## **7. EXCLUSION OF LIABILITY**

7.1. TfL and CRL shall not be liable by way of indemnity or otherwise in respect of any loss (including economic loss) damage or delay to the Licensee its employers employees contractors or agents or any other person resulting from:

7.1.1. the review or approval by Engineer of the Works Documents;

7.1.2. the Licensee its employees contractors and agents being prevented or delayed entry to TfL's Land for whatever reason; or

7.1.3. the obstruction or removal of anything installed on TfL Land in connection with the Licensed Works.

7.2. Nothing in clause 7.1 shall exclude or limit TfL's liability and CRL's liability for death or personal injury caused by its negligence or for fraud or fraudulent misrepresentation.

## **8. TfL'S UNDERTAKING**

8.1. The safety and operation of TfL's railway undertaking shall be a primary concern and shall not be subordinated to any other requirement under this Licence.

8.2. The Licensee shall raise no objections to TfL in the carrying out of its lawful undertaking notwithstanding that this may interfere with the permissions granted by this Licence.

## **9. NUISANCE AND INTERFERENCE**

9.1. The Licensee shall not do any act matter or thing which would or might constitute a breach of any statutory requirement affecting Crossrail's Railway or which might reasonably be expected to vitiate in whole or in part any insurance effected in respect of Crossrail's Railway from time to time.

9.2. The Licensee its employees agents and contractors shall not use TfL's Land or exercise the rights granted under this Licence in such a way as to cause any nuisance damage obstruction disturbance to or interference with Crossrail's Railway or its officers servants or agents or any adjoining or neighbouring operations or property (whether owned or operated by TfL, CRL or otherwise).

## **10. DETERMINATION**

10.1. TfL may determine this Licence at any time with immediate effect by written notice of such determination to the Licensee (TfL and CRL not being liable for compensation for any loss or inconvenience caused to the Licensee because of such determination):

- 10.1.1. for any purpose connected with TfL's railway undertaking or property;
  - 10.1.2. if the Licensee is in breach of any of the terms of this Licence and shall have failed to remedy the breach (if capable of remedy) within the timescales specified in any notice served on the Licensee by TfL or CRL specifying such breach;
  - 10.1.3. in an emergency; and
  - 10.1.4. where TfL or CRL shall be required to do so by another statutory authority.
- 10.2. This Licence shall determine immediately upon an Insolvency Event.
- 10.3. Any determination of this Licence shall be without prejudice to the any accrued rights or remedies which either party may have against the other in respect of any antecedent claim or breach of the terms hereof.

## **11. OBLIGATIONS ON EXPIRY OR EARLIER DETERMINATION**

Before expiry or earlier determination of this Licence, the Licensee shall remove anything installed built or used on TfL's Land as part of the Licensed Works make good any damage to the Crossrail's Railway caused by the Licensed Works and reinstate TfL's Land to TfL's or (prior to Handover) CRL's satisfaction. For the avoidance of doubt, this clause shall survive termination of this Licence.

## **12. NOTICES**

- 12.1. Any notice required to be given under this Licence shall be in writing and shall be sufficiently served if delivered by hand or sent by recorded delivery to the other party at the following address or as otherwise specified by the relevant party by notice in writing to the other party:

### **TfL**

Transport for London

FAO: TfL's Principal Infrastructure Protection Engineer

[7<sup>th</sup> Floor, Endeavour Square

Stratford

London E20 1JN]

**CRL**

FAO: Manager of Engineering

Crossrail Limited

5 Endeavour Square

Stratford

London E20 1JN

Attention: Paul Readings

**Licensee**

[•]

12.2 Any notice shall be deemed to have been duly received if delivered by hand, on the date of delivery and if sent by recorded delivery, at 9.00am on the second working day after posting.

**13. BENEFIT OF LICENCE**

This Licence is personal to the Licensee and may not be assigned transferred novated or otherwise disposed of.

**14. LEGAL EFFECT**

14.1. It is not the intention of either party to create between them the relationship of landlord and tenant in relation to TfL's Land or to confer such rights upon the Licensee as would amount in law to a tenancy of TfL's Land or to create any estate or proprietary interest therein.

14.2. Control and regulation over TfL's Land shall always remain vested in TfL and TfL and all others authorised by TfL shall be entitled to enter TfL's Land in any way at any time.

**15. THE CONTRACTS (RIGHTS OF THIRD PARTIES) ACT 1999**

A person who is not a party to this Licence shall not have any rights under the Contracts (Rights of Third Parties) Act 1999 to enforce any term of this Licence.

**16. GOVERNING LAW**

This Licence shall be governed by English law and disputes or differences arising under or in connection with this Licence (save in connection with railway safety matters where the Engineer's decision is final and binding) shall be referred to the exclusive jurisdiction of the English Courts.

This Licence has been signed by parties on the day and year written above.

Signed by

For and on behalf of  
**Transport for London**

Name (in capitals):

Position:

Signed by

Signed by

For and on behalf of  
**Crossrail Limited**

Name (in capitals):

Position:

Signed by

For and on behalf of  
**[•]**

Name (in capitals):

Position:

Crossrail Land

[insert 'Agreement' plan showing monitoring extents]

# Appendix C

## Requirements for Monitoring System compatibility with the Elizabeth Line

The advice in this document is the product of consultation with discipline leads from CRL Chief Engineer's Group and CRL Systemwide discipline leads.



Commensurate with LUL's requirement that contractors installing monitoring systems demonstrate by supporting evidence, that there will be no introduction of interference to tunnel operating systems, Crossrail also requires 3<sup>rd</sup> party contractors to prove that any Radio Frequencies emitted by their monitoring equipment shall not have a detrimental effect on any Railway communication or other CRL systems, or tunnel infrastructure.

This Technical Note seeks to capture constraints for consideration in 3<sup>rd</sup> Party contractors' planning and installation of any in-asset monitoring systems. These are only guidelines issued without prejudice to CRL and they do not diminish the Developer's responsibility to mitigate risk imported to the railway.

**In addition to the guidelines on constraints it is highly advisable that Monitoring system designers and contractors make arrangements at an early stage to visit their monitoring sites to understand constraints particular to the site and which may not be recorded elsewhere.**

### 1. General

- a. The 3<sup>rd</sup> Party Developer's Contractor (the "Contractor") shall select a system (either Wi-Fi or hard wire) that reasonably affords the lowest cost to the Employer; the lowest safety risk to install, maintain and decommission, and which avoids interference with the operation of other in-tunnel infrastructure, whilst also providing good resilience and reliability.
- b. Prior to installation the Contractor shall submit a Concept Design Statement (CDS) describing the system to CRL for acceptance. The design submission is to be a "single source of truth" thus including drawings for setting out and evidence (emails etc.) of any consultation with CRL contractors to qualify any assumptions on such things as setting out, system integration compliance, response planning and maintenance, risk management, and decommissioning.

- c. The Contractor is responsible for demonstrating that the Monitoring System:
  - i. meets Crossrail requirements for System Integration;
  - ii. is robust and fit for inclusion in the operating railway environment without importing risk to the operation of the railway;
  - iii. is consistently reliable and consistent in its recording of monitoring data;
  - iv. has sufficient repeatability accuracy to match the performance requirements required to inform the Monitoring Plan;
  - v. That the materials used comply with LUL fire standards S1-085;
  - vi. Installation and Implementation reasonably mitigates any risk of delay to the Delivery of the Crossrail Works Programme;
  - vii. mitigates risk of damage to Crossrail Infrastructure or risk of unplanned interference railway operation during installation, implementation and decommissioning;
  - viii. Prior to installation, testing and commissioning the Contractor shall submit RAMS demonstrating a safe system of work and setting out any specific requirements for logistical support from Crossrail contractors or others.
  - ix. Access for installation, or decommissioning of works in the railway environment are subject to the Contractors' completion of inductions, and to Crossrail's review and acceptance of the CDS and RAMS.

## 2. Guidelines for performance of instruments

- a. ATS instruments installed must achieve an accuracy of at least 1" angular and 1mm+1pp EDM precision. (e.g. Leica TM30/50 model or similar, approved.)
- b. Other automated measuring systems (Tiltmeters, electrolevel beams etc) must achieve a repeatable accuracy of +-1mm resolved displacement in any direction.
- c. The system shall include provision for automatic thermometer reading of the prevailing temperature in the tunnels at the time of surveys
- d. Prism targets (or similar approved) to be provided on each ATS bracket installation as necessary to maintain survey control.
- e. The reflector prisms (monitoring targets) shall be similar to that illustrated below, and shall be attached by means of M10 or similar sockets drilled and secured into the segments, with spigots.
- f. Where sockets are drilled into precast segmental concrete tunnel linings, no holes should be drilled within 150mm from any edge of a segment.
- g. Where sockets are drilled into fireproofed station infrastructure, fixings into the fireproofing (nominally 50mm thick) shall be specified to ensure that the fireproofing performance is not diminished as a consequence of installation.
- h. The reflector prism and ATS installations shall be sufficiently robust to withstand the effects (e.g. buffeting) of the Crossrail temporary and operational railway environment.

## 3. Guidelines for decommissioning of Monitoring equipment

This section is applicable if works are undertaken before handover of Crossrail to the future Infrastructure Manager (IM). It is presumed that the IM's compliance regulations will take precedence after Handover.

Prior to commencement of decommissioning the Contractor shall

- a. Propose a safe system of work and RAMS for acceptance, taking into account COSHH requirements necessary for completion of the work. Working at height may be necessary given prisms are also located above tunnel axis;
- b. As soon as reasonably practicable, provide the Employer and the 3rd Party Developments Manager with start and end dates for the work;

- c. All equipment, including fixings are to be removed carefully to minimise further spalling and cracking of tunnel segments. Works may only proceed upon the receipt of the Employer's acceptance.
- d. For holes below tunnel axis, make good holes after removal of equipment: Once fixings have been removed, any open holes below tunnel axis are to be filled with Renderoc HB or similar approved in LU Standard S1-085 compliant cementitious material. Holes above tunnel axis are to be left unfilled.
- e. All fixings above tunnel axis are to be carefully removed avoiding damage to the tunnel lining. Fixings below tunnel axis such as drop-in anchors are to be left in situ, and the cavities filled with the fixing in place using Hilti CFS-IS intumescent sealant (formerly CP 611a) or similar approved on the LUL Register (compliant with LUL Standard S1-085). This filler is to be levelled flush with the parent substrate using a trowel or similar
- f. Works shall be undertaken in good time and with due attention to planning so as not to jeopardise Crossrail's handover to the future Infrastructure Manager.
- g. C610 to advise the Employer upon completion



#### 4. Guidelines for demonstration of Compliance Evidence

Consideration	Guidelines for compliance	Compliance Evidence
Installations in the railway environment	<p>The 3rd Party Developer's Contractor (the "Contractor") shall select a system (either wi-fi or hard wired), and components that reasonably afford the lowest cost to the Employer; the lowest safety risk to install, maintain and decommission, and which avoids interference with the operation of other in-tunnel infrastructure, whilst also providing good resilience and reliability.</p> <p>The system shall consider generally that the running tunnels include a 25kV overhead line traction power supply (OHLE).</p> <p>Also there is no low voltage power supply within the running tunnels, however low voltage (110V) supplies are available within cross passages and in stations, shafts, portals and depots.</p> <p>Generally the operating railway environment (the Trace) is not readily accessible to personnel unless the track has been isolated and a work area procured in accordance with the trackside access regulations ruling at the time of installation.</p> <p>It is recommended at the outset that a preliminary site investigation be undertaken to assess constraints</p> <p>Where non removable anchors have to be used, the materials shall be corrosion resistant (Stainless Steel). At the end of use the anchor shall be cut back to below the surface of the segment (eg. cut and driven below segment surface) and made good with approved repair mortar.</p>	<p>Monitoring System Conceptual Design Statement (CDS )to include drawings and product and material details</p> <p>RAMS to consider practical means of installation within the current railway environment</p> <p>Monitoring installation report capturing installation</p> <p>Testing and commissioning certificates for installed equipment and validating the reliability and performance of the system as a whole.</p>
Intrusive installations in Segmental Precast Concrete (PCC) Tunnel Linings	<p>The following should be noted regarding drilled fixings for instrumentation:</p> <ol style="list-style-type: none"> <li>1. On the precast concrete segments of the tunnel lining, no holes should be drilled within the greater of;               <ol style="list-style-type: none"> <li>a. 150mm from any edge of a segment or</li> <li>b. 7.5x the bolt/anchor diameter to the edges of the segment and 4x the bolt / anchor diameter to bolt holes and grout holes etc. (also complying with product guidance for minimum edge distance).</li> </ol> </li> <li>2. Maximum drilling depth anchor / bolt not to exceed 150mm into the PCC segments.</li> </ol>	<p>Monitoring System Conceptual Design Statement (CDS )to include drawings and product and material details</p> <p>RAMS to include provision to meet the compliance requirement.</p> <p>Monitoring installation reports to include pre- and post-installation photographs showing compliance</p>
Intrusive Installations in Segmental	<ol style="list-style-type: none"> <li>1. Tunnel lining segments supporting FTS may contain steel reinforcing bars in addition to the steel fibre reinforcement below the tunnel axis. Therefore the contractor will need</li> </ol>	<p>Monitoring CDS to include drawings and product and material details</p>

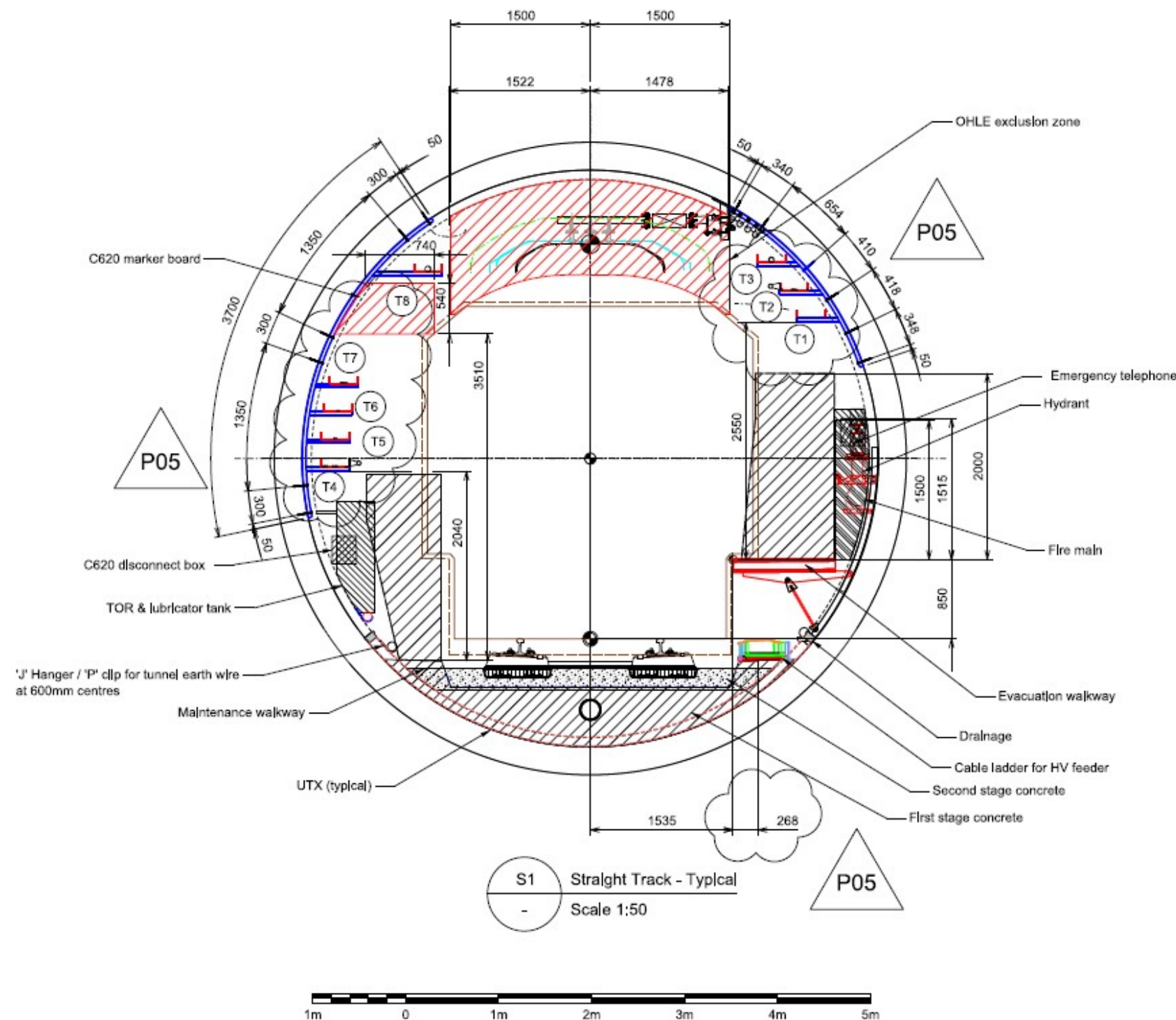
Concrete Tunnel Linings with Floating Track Slabs (FTS)	to do a rebar detection survey prior to drilling any hole, to mitigate risk of intersecting reinforcement.	RAMS to include provision to meet the compliance requirement.  Monitoring installation reports to include findings of the rebar detection survey, and details of any reinstatements which need to be approved in advance.  Monitoring Installation reports to include pre- and post-installation photographs showing compliance
Intusive installations in Sprayed Concrete Linings (SCL)	1. Maximum drilling depth anchor / bolt into SCL shall not to encroach within 100mm of waterproofing layer in SCL linings.	Monitoring System Conceptual Design Statement (CDS )to include drawings and product and material details  RAMS to include provision to meet the compliance requirement.  Monitoring installation reports to include pre- and post-installation photographs showing compliance
Intrusive Installations at Running Tunnel / Adit Connections	<p>There are many different structural configurations in a variety of materials, for cross-passage and adit openings in Crossrail tunnels.</p> <p>Prior to any installation the Contractor shall consult the 3rd Party Developments Manager to discuss and obtain acceptance for proposals for fixings.</p> <p>Generally, no fixings should be drilled in the zones of the SGI segments.</p> <p>Generally, no fixings may be drilled into reinforced concrete until rebar surveys have been undertaken.</p> <p>Before any drilling and into surfaces coated with 50mm (nominal) fire proofed layer, contractors must establish what the underlying structural substrate is, and prescribe for acceptance, fixings that do not adversely affect structural or function performance.</p> <p>Drilled holes are not to encroach anywhere close to any embedded waterproof membranes</p>	Monitoring CDS to include drawings and product and material details  RAMS to include provision to meet the compliance requirement.  Monitoring installation reports to include pre- and post-installation photographs showing compliance.
Space proofing	<p>1. The setting out of the Monitoring System components must mitigate any intrusion into;</p> <ul style="list-style-type: none"> <li>• the Railway gauge envelope,</li> <li>• the Emergency Evacuation walkways</li> <li>• space allocated to preserve functionality and maintenance of Crossrail systems</li> </ul> <p>2. The Setting out and method of installation must consider and mitigate as far as practically feasible the risk of interference - damage or disturbance of nearby railway systems. Any incidence of interference must be notified to the work supervisor and the Crossrail Designated Engineer ASAP for consideration of response action.</p>	Monitoring CDS to include drawings demonstrating setting out compliance  RAMS to include provision to meet the compliance requirement.  Monitoring installation reports to include pre- and post-installation pho-tographs showing compliance
	3. In the absence of any other constraint no parts of the monitoring system shall be installed closer than 50mm to any other railway components.	

Space proofing around OHLE	<p>The monitoring system should be designed to avoid encroachment on the 25 kV OHLE as far as reasonably practical.</p> <p>All parts of the installed Monitoring System must maintain a clear distance of at least 300mm to OHLE equipment, to avoid risk of arcing.</p> <p>Generally works are not permitted in the tunnel if the OHLE is energised. Elsewhere subject to approval of RAMS, no works may be undertaken within 3.0m distance of the OHLE when energised.</p> <p>Clearly any incidence of interference with OHLE during installation must be notified to the work supervisor and the Crossrail Designated Engineer ASAP for consideration of response action.</p>	<p>Monitoring CDS to include drawings demonstrating setting out compliance</p> <p>RAMS to include provision to meet the compliance requirement.</p> <p>Monitoring installation reports to include pre- and post-installation photographs showing compliance</p>
Hard Wire fire proofing	<p>Any power feeds installed for monitoring shall not increase fire risk.</p> <p>Any cables installed by Thames Tideway would need to be compliant with LUL Standard S1-085. This is regardless of it being temporary. If they require a power supply, then I believe the correct procedure will be to submit a LOAD APPLICATION to the relevant IM. The IM will of course require a fully detailed design, including discrimination study to ensure these loads and their protective devices do their job, thus avoiding a small fault with their kit affecting the station, shaft or portal upstream circuit protective devices.</p>	<p>Monitoring CDS to include drawings demonstrating setting out compliance and materials compliance</p> <p>Fully detailed design supporting a Load Application</p> <p>Evidence of acceptance from IM</p> <p>RAMS to include provision to meet the compliance requirement.</p>
Communications Interference	<p>Radio frequency intermodulation (IM) can seriously impact the performance of radio systems by generating harmonic frequency components, that are of sufficient magnitude and fall within a radio system channel receive band that can block or degrade the operation of that channel by swamping the legitimate signals on that channel. It is therefore, important to determine the nature of the harmonic frequency components produced by intermodulation, known as "products", in order to evaluate a means of minimising the impact of IM on the Crossrail Radio systems.</p> <p>The Monitoring Contractor is required to provide proof that any radio frequency emissions (intentional or spurious) from the Monitoring System shall not have a detrimental effect on any railway communications systems.</p> <p>Details for Crossrail report C660-SMN-R3-RGN-CR001-50106 Rev 4.0 (<i>RF Intermodulation Study - Radio Systems</i>). This report</p> <ul style="list-style-type: none"> <li>Describe the generation of intermodulation products;</li> </ul>	<p>Intermodulation Study</p> <p>Monitoring CDS to include drawings, system and product information demonstrating compliance</p> <p>Monitoring installation reports to include pre- and post-installation photographs showing compliance</p> <p>Evidence of compliance to the Radio Equipment Directive 2014/53/EU such as a valid Declaration of Conformity or test reports.</p>

	<ul style="list-style-type: none"> <li>• Describe the calculation of intermodulation products;</li> <li>• Outline practical measures to mitigate the generation of IM products, including installation and test practices;</li> <li>• Identify radio system channels used by Crossrail that could be susceptible to interference from IM products.</li> </ul> <p>For acceptance and following best practice the Monitoring Contactor is required to submit an intermodulation study for CRL review and acceptance along with evidence that the radio system meets the requirements of the Radio Equipment Directive 2014/53/EU.</p>	
EMC Interference	<p>Monitoring Systems shall mitigate the risk of Electromagnetic Interference, both on the monitoring system itself and on the railway systems.</p> <p>The principal sources of EMI from Crossrail Infrastructure are generated by the 25 kV traction power supply system, the rolling stock, the signalling system, electrical &amp; mechanical systems and the control &amp; communications systems. In addition equipment located within Depots and stations contain similar control and communications systems together with other EMI sources such as lifts and escalators in the stations and wheel lathes within the depot. Each of these systems is also susceptible to EMI together with any 3rd Party electrical and electronic infrastructure located adjacent to the Crossrail route</p> <p>In order to protect Crossrail Infrastructure the monitoring system shall, as a minimum, meet the EMC emissions standard EN 61000-6-4:2007+A1:2011. In order to protect the monitoring equipment it is recommended that the monitoring equipment meets the immunity requirements given in EN 50121-4:2016.</p> <p>Should the monitoring system meet other EMC standards to those given above the Monitoring Contractors shall carry out a gap analysis which will identify the difference between the standards. Once the gaps are identified either a justification shall be given on why the gap is acceptable or appropriate mitigations shall be implemented.</p> <p>Guidance of good EMC installation practice can be found in IEC 61000-5-1 and IEC 61000-5-2 and it is usual to use single point earthing and bonding in an electrified rail environment to stop circulating currents.</p> <p>For acceptance and following best practice the Monitoring Contactor is required to submit, for CRL review and acceptance, evidence that the monitoring system meets the requirements of the EMC Directive 2014/30/EU which shall include details of the emissions and immunity standards that the systems meets. Installation instructions and drawings shall also be submitted which will detail how the equipment is earthed and how any cable screens are bonded.</p>	<p>Monitoring CDS to include drawings, system and product information and evidence of compliance to the EMC Directive 2014/30/EU such as a valid Declaration of Conformity or test reports EMC Gap Analysis, Details of installation instructions including earthing and bonding.</p> <p>Monitoring installation reports to include pre- and post-installation photographs showing compliance</p>

## **5. AS BUILT LAYOUT DRAWINGS TO ILLUSTRATE SPATIAL CONSTRAINTS ALONG THE TRACE**

- RUNNING TUNNELS
- SPRAYED CONCRETE STATION PLATFORM TUNNELS
- PADDINGTON STATION BOX
- RUNNING TUNNELS - Space Allocation for temporary installations (pre-Handover and commissioning of the Elizabeth Line)



**Safety, Health and Environmental Information**  
 Notes below are additional to hazards/risks normally associated with this type of work:

**Construction**  
 CI.  
 CII.  
 CIII.

**Operations**  
 OI.  
 OII.  
 OIII.

**Maintenance**  
 MI.  
 MII.  
 MIII.

**Dismantling/Demolition (Future)**  
 DI.  
 DII.  
 DIII.

These notes are based on the use of experienced and competent contractors carrying out the work using an approved safe method of working.

Rev.	Date	Description	By	Chkd	App	Auth
P01	28/08/2015	First Issue	DR	GD	GD	-
P02	20/01/2016	Top CMS bracket extended to 750mm	DR	SC	GD	-
P03	01/02/2016	Train gauge changed to plain line	DR	SC	GD	-
P04	20/10/2016	MPG Gauge removed	DR	SC	GD	-
P05	30/05/2017	Dimensions and tray annotation added	DR	SC	GD	-

**Notes:**  
 1. C620 Alrlink equipment not shown, Awaiting Information from C620 contractor

**Legend:**  
 ——— Train gauge zone 1  
 - - - - - Train gauge zone 2

 **Crossrail Limited**  
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Contract : Systemwide Main Works		
Originator : Alstom TSO Costain Joint Venture		
Location : Central Sections General		
Title : Space Proofing Typical Cross Section - Straight Track Bored Tunnel		By : D.ROSS
Scale : 1:50 @ A3		Chk : S.CAMPBELL
Drg No : C610-ATC-R-DDB-CRG03_Z-10003		App : G.DUVAL
Rev : P05	Suit : S4	Auth : —

Fit for authorisation  
RESTRICTED

**Safety, Health and Environmental Information**  
 Notes below are additional to those normally associated with this type of work

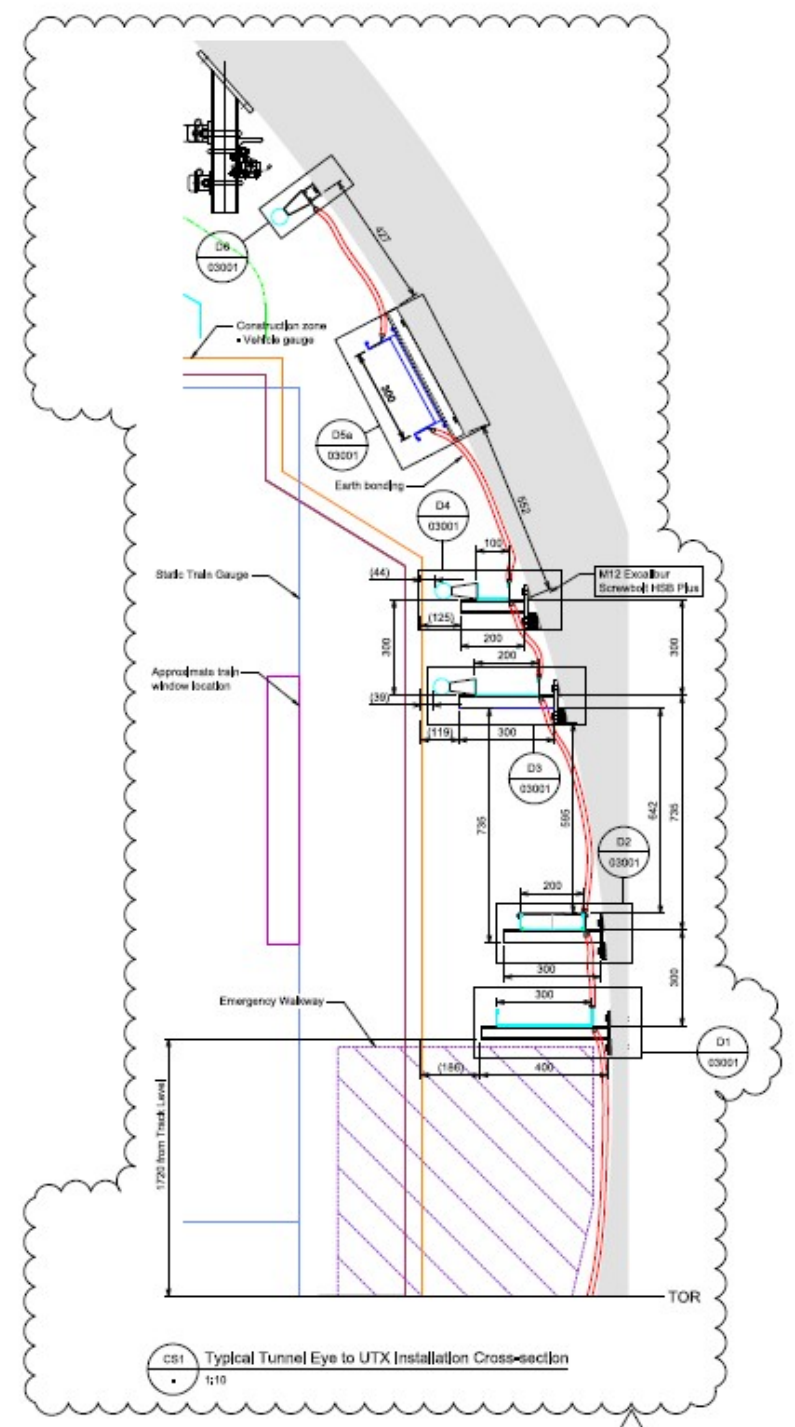
**Construction**  
 CL  
 CL1  
 CL2

**Operation**  
 OL  
 OL1  
 OL2

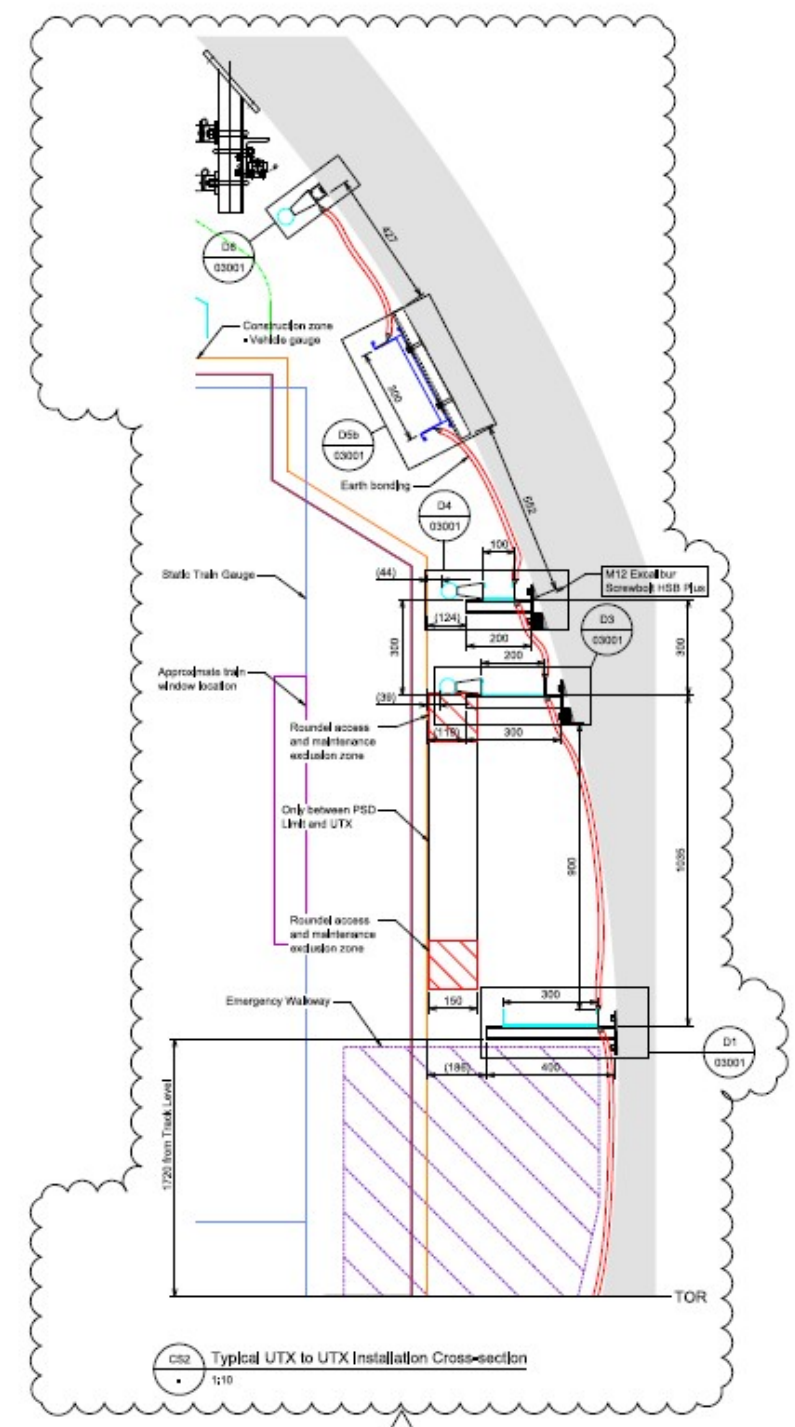
**Maintenance**  
 ML  
 ML1  
 ML2

**Demolition/Deconstruction (Future)**  
 DL  
 DL1

These notes are based on the use of experienced and competent contractors carrying out the work using an approved safe method of working.



CS1 Typical Tunnel Eye to UTX Installation Cross-section  
 1:10

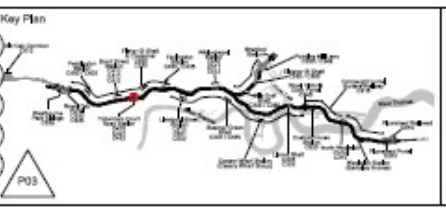


CS2 Typical UTX to UTX Installation Cross-section  
 1:10



Rev	Date	Description	By	App	Auth
P01	04/07/2017	Final Issue	MR	LA	-
P02	05/07/2017	Revised to add support note added	MR	LA	SD
P03	05/07/2018	Revised to show updated ATC SCL bracket configuration	MR	LA	SD
P04	14/02/2018	Reference to SCL in Project notes, restrictions required	MR	LA	SD
			By	App	Auth

- Notes**
- For reference drawing please see ATC drawing CB10-ATC-E-DOB-N105\_Z-03000
  - For bracket details please see drawing CB10-ATC-E-DOB-N105\_Z-03007
  - All bolted connections to be secured against self-loosening and suitable in railway environments
  - All steel connections to be designed as full moment connections
  - Supporting structures to be able to sustain design loading at the anchor locations
  - Loads are defined in tray schedule. Other non-rectored loads considered in joint. A 125kg temporary weight has been considered as an accidental load applied 50mm from the end of any horizontal P25637 bracket. This load was applied in conjunction with the respective cable self-weight loads without additional contingency. All pressure of 0.2kN/m<sup>2</sup> due to passing train
  - Concrete is assumed to be C25/34 grade.
  - For details of cables refer to Cable Schedule CB10-ATC-E-TSC-CR03-00033
  - Earthing of the CMS shall be in accordance with Earthing and Bonding Strategy CB10-ATC-E-RGN-CR023-00054
  - Cable separation shall be in accordance with Guidelines for EMC Cable Management and Separation (CB10-ATC-E-RGN-CR001-00041)
  - For round details refer to drawings C100-ATK-XSK-CR006-00096 and C100-ATK-XSK-CR002-00097
  - Design of M12 Excavator Screws: HSB Plus fittings based on design information provided by fitting manufacturer.
  - Bracket designed for normal use only.
  - No brackets to be installed within 750mm from round.
  - Installation tolerance to be +10mm, EMC requirements to be adhered to. See note 10.
  - All dimensions in millimetres.



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**Systemwide Main Works**  
 Abtorn TSO Costain Joint Venture  
 Tottenham Court Road Stn

**Location:** Tottenham Court Road Station  
**Back wall CMS**  
**SCL bracket detail**  
**Cross-sections**

Scale: 1:10 @ A1  
 Drawing No: CB10-ATC-E-DOB-N105\_Z-03000  
 Rev: P04  
 Sub: S4

Rev: 1: MGRWORTH  
 Rev: 2: LALEXANDER  
 Rev: 3: MGRWORTH  
 Rev: 4: ...

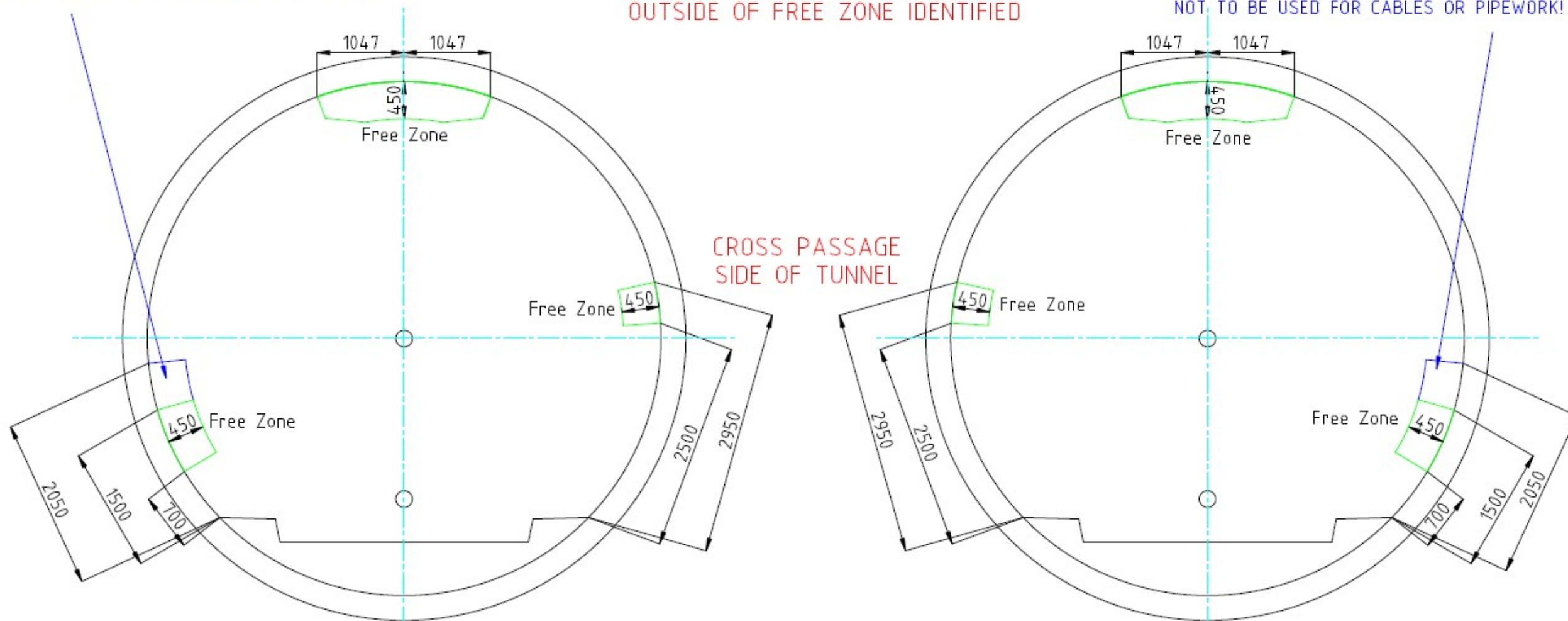




Area between bottom of bracket and underside of lowest tray.  
NOT TO BE USED FOR CABLES OR PIPEWORK!

DO NOT FIX TEMPORARY SERVICE  
OUTSIDE OF FREE ZONE IDENTIFIED

Area between bottom of bracket and underside of lowest tray.  
NOT TO BE USED FOR CABLES OR PIPEWORK!



All dimensions from intersection of First Stage Concrete and Tunnel Lining in a straight line.  
Do not follow tunnel curve

Rev.	Date	Description	By	Chkd	App	Auth
P01	25/06/2015	First Issue	TAK	SG	NL	

Notes:  
1) Spaceproofing applies to Standard Track Slab areas ONLY  
2) Spaceproofing applies for all track cants

**atc**  
Alstom TSO Costain  
2nd Floor, Mermaid House  
2 Puddle Dock, London, EC4V 3DB

Contract : C610 Systemwide Main Works  
Originator : Alstom TSO Costain Joint Venture  
Location : Systemwide  
Title :  
Running Tunnels  
Standard Track Slab Areas  
Free Zones for Temporary Services Installations

By : T Kelly  
Chk : S Gilmour  
App : N Ludlow

Scale : 1:50 @ A3

Dwg No : DRW-000074

Rev : C01

Suit :

Auth :





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