



## TECHNICAL NOTE

**To:** Robert Coughlan, Punch Consulting

**From:** Conor O'Donnell

**Re:** Project Metrolink - Refined Phase IIa Building Damage Assessment for Arthur Cox Building at 13-14 Earlsfort Terrace – Addendum No.1

**Date:** 26/2/2024

**Ref:** 22-232A-TN002 (Rev.0)

### 1.0 INTRODUCTION

This technical note presents updated results for the refined Phase 2a Building Damage Assessment for the Arthur Cox Building to take account of the following additional information that has been submitted during the Oral Hearing for the Metrolink Draft Railway Order:

- Modified Limits of Deviation (LoD) proposed by TII for the vertical tunnel alignment, as set out in page 7 of the Statement of Evidence from Mr. Ronan Hallissey, dated 19<sup>th</sup> February 2024 (Section 5.1.2 – Chapter 5 Metrolink Construction Phase)
- Technical Note by Jacobs/IDOM dated 10<sup>th</sup> November, 2023, assessing the “Impact on the Preliminary Design Building Damage Assessment Results due to Imposition of Limits of Deviation”.

A copy of these documents is included in Appendix A and Appendix B, respectively.

This technical note should be read in conjunction with AGL Technical Note No. 22-228-TN001, Rev.01, dated 26<sup>th</sup> February 2024, which sets out the methodology and criteria for the refined Phase 2a Building Damage Assessment carried out by AGL for the Arthur Cox Building for the original LoD proposed in Article 6 (Deviation) of Part 2 of the Draft Railway Order [6.1(d)].

### 2.0 IMPACT OF MODIFIED UPWARD LoD ON REFINED PHASE 2a BUILDING DAMAGE ASSESSMENT (BDA) FOR THE ARTHUR COX BUILDING

The Limits of Deviation (LoD) on the vertical profile that were originally proposed in Article 6 (Deviation) of Part 2 of the Draft Railway Order [6.1(d)] were **5.0m upwards** and **10.0m downwards** from the design profile shown on the drawings.

During the Oral Hearing for the draft Railway Order, in response to submissions received during the statutory consultation process, TII proposed to amend the upward LoD for the tunnel in the Railway Order to **1.0m**, due to concerns of potential increased impact on buildings if the original upward LoD were allowed (Ref. Expert Witness Statement of Ronan Hallissey p7).

No change is proposed to the downward or horizontal LoD for tunnel alignment, which remain as **10.0m** downwards and **15.0m** horizontally to either side of the centreline, respectively.



We have amended our refined Phase 2a Building Damage Assessment for the Arthur Cox building to assess the damage that could occur for the raised tunnel profile at the maximum LoD of +1.0m.

The criteria for the typical damage and approximate crack widths for each damage risk category is presented in Table 2-1.

The results of the updated building damage assessment calculations are summarised in Table 2-2, specifically for **Case 1B/2B/3B**, which are highlighted in red. The table gives the following values for each analysis case:

- Max limiting tensile strain,  $\epsilon_{\max}$  (%)
- Maximum ground slope on the settlement trough,  $m_{\max}$  (%)
- Max settlement over the tunnel centreline,  $S_v$  (mm)

The ground loss directly due to tunnelling in rock under the building should generally be <0.5%. However, the upper bound calculation for 1.0% ground loss has been included as a sensitivity analysis or risk assessment to account for the potential impact of concentrated building loads on the building foundations and load-bearing secant piles where they are directly over the tunnel.

Case 1A/2A/3A refer to the Design Tunnel Profile & Case 1C/2C/3C refer to the Tunnel Profile lowered by 5.0m. These are unchanged from the results presented in AGL Technical Note 22-228-TN001, Rev.1 (26/2/2024).

For the raised tunnel profile at the new upward LoD of +1.0m:

- As expected, limiting the upward LoD to +1.0m eliminates the potential for the TBM to hit the toe of the secant pile wall, which is only 4.0-4.9m above the crown of the tunnel at the design profile level.
- At +1.0m the integral pad foundations for the interior columns will be 7.1 to 7.6m above the tunnel. Therefore, the anticipated settlements would be expected to be closer to the lower bound values for 0.5% ground loss, i.e.:
  - Lower Bound (0.5% Ground Loss) – **Risk Category 2 (Slight)**
- However, the toe of the piles for the perimeter wall, which supports the façade, will only be 3.0-3.9m above the tunnel crown. Therefore, the concentrated load on the load bearing piles could increase the building settlement and distortion so that the estimated values for 0.5% and 1.0% ground loss represent a lower and upper bound estimate of the potential damage that could occur to the secant pile wall and building façade, i.e.:
  - Lower Bound (0.5% Ground Loss) – **Risk Category 3/2 (Moderate to Slight)**
  - Upper Bound (1.0% Ground Loss) – **Risk Category 4/3 (Severe to Moderate)**

This is a slight increase in the level of damage estimated for the design tunnel profile (Case 1A/2A/3A). The increase is most noticeable for the façade and perimeter secant pile wall on Hatch St. (Case 1B) where the levels of building strain and distortion extend further over the threshold limits for Risk Category 3 [Moderate].

When compared to the original upward LoD of +5.0m, limiting the upward LoD to +1.0m reduces the level of damage that could potentially occur to the building if the tunnel was raised



to the maximum extent of the LoD. At +1.0m the potential for Moderate to possibly Severe damage is limited to an upper bound worst-case scenario for the façade on Hatch St. where there is a concentrated load from the structural piles directly over the crown of the tunnel.

However, the level of building damage that could still occur for the raised tunnel profile at +1.0m would still exceed the threshold of acceptable damage for the building façade and basement waterproofing system, which would be more sensitive to building distortion and damage than indicated by the criteria and corresponding risk categories in Table 2-1.

**Table 2-1 – Criteria for Building Risk Category and Damage Classification (Table 4-4 in Building Damage Report by Jacobs/IDOM – Appendix A5.17 of the EIAR)**

Building and Structure Damage Classification (after Burland et al (1977) and Boscarding and Cording (1989))					Approximately Equivalent Ground Settlements and Slopes (after Rankin 1988)	
Risk Category	Degree of Damage	Description of Typical Damage and Likely Forms of Repair for Typical Masonry Buildings	Approx. Crack Width (mm)	Limiting Max Tensile Strain (%)	Max Slope of Ground	Maximum Settlement of Building (mm)
0	Negligible	Hairline cracks	<0.1	Less than 0.05		
1	Very Slight	Fine cracks easily treated during normal redecoration. Perhaps isolated slight fracture in building  Cracks in exterior brickwork visible upon close inspection	0.1 to 1	0.05 to 0.075	Less than 1:500	Less than 10
2	Slight	Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible some re-pointing may be required for weather tightness. Doors and windows may stick slightly	1 to 5	0.075 to 0.15	1:500 to 1:200	10 to 50
3	Moderate	Cracks may require cutting out and patching. Recurrent cracks can be masked by suitable linings.  Re-pointing and possibly replacement of a small amount of extent brickwork may be required. Doors and windows sticking. Utility services may be interrupted.  Weather tightness often impaired	5 to 15 or a number of cracks greater than 3	0.15 to 0.3	1:200 to 1:50	50 to 75
4	Severe	Extensive repair involving removal and replacement of sections of walls, especially over doors and windows required. Windows and frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably. some loss of bearing in beams. Utility services disrupted.	15 to 25 but also depends on number of cracks	Greater than 0.3	1:200 to 1:50	Greater than 75
5	Very Severe	Major repair required involving partial or complete reconstruction. Beams lose bearing, walls lean badly and require shoring.  Windows broken by distortion  Danger of instability	Greater than 25 but also depends on number of cracks	Greater than 0.3	Greater than 1:50	Greater than 75



Table 2-2 - Summary of Building Damage Assessment

Analysis	Details	Depth to Tunnel Axis ( $z_0$ )/ Cover to Foundation Subgrade (m)	Lower Bound ( $V_l = 0.5\%$ )					Upper Bound ( $V_l = 1.0\%$ )				
			Lim. (Max) Tensile Strain	Max Ground Slope	Max Settlement	Risk Category	Degree of Damage	Lim.(Max) Tensile Strain	Max Ground Slope	Max Settlement	Risk Category	Degree of Damage
			$\epsilon_{tmax}$ (%)	$m_{max}$ (%)	$S_{max}$ (mm)			$\epsilon_{tmax}$ (%)	$m_{max}$ (%)	$S_{max}$ (mm)		
Design Tunnel Profile												
Case 1A	Ch. 18+945 (Hatch St.) Secant Pile Wall/Bldg. Façade Design Vertical Alignment	$z_0 = 9.6m$ Cover= 4.9m	-0.15%	0.58%	37	2/3	Slight to Moderate	-0.30%	1.16%	74	3/4	Moderate to Severe
Case 2A	Ch. 18+970 (Centre) Internal Building RC Frame Design Vertical Alignment	$z_0 = 13.3m$ Cover= 8.6m	-0.08%	0.30%	27	2	Slight	-0.16%	0.61%	53	3	Moderate
Case 3A	Ch. 18+995 (South Side) Basement Floor Slab Design Vertical Alignment	$z_0 = 12.9m$ Cover= 8.1m	-0.10%	0.32%	28	2	Slight	-0.21%	0.65%	55	3	Moderate
Raised Tunnel Profile (Max. Proposed Vertical Deviation = + 1.0m)												
Case 1B	Ch. 18+945 (Hatch St.) Secant Pile Wall/Bldg. Façade Raised Vertical Alignment (+1.00m)	$z_0 = 8.6m$ Cover= 3.9m	-0.19%	0.70%	41	3/2	Moderate to Slight	-0.38%	1.40%	82	4/3	Severe to Moderate
Case 2B	Ch. 18+970 (Centre) Internal Building RC Frame Raised Vertical Alignment (+1.0m)	$z_0 = 12.3m$ Cover= 7.6m	-0.09%	0.40%	29	2	Slight	-0.19%	0.70%	58	3	Moderate
Case 3B	Ch. 18+995 (South Side) Basement Floor Slab Raised Vertical Alignment (+1.0m)	$z_0 = 11.9m$ Cover= 7.1m	-0.13%	0.40%	30	2	Slight	-0.25%	0.80%	60	3	Moderate
Lowered Tunnel Profile (Max. Proposed Vertical Deviation = - 5.0m)												
Case 1C	Ch. 18+945 (Hatch St.) Secant Pile Wall/Bldg. Façade Lowered Vertical Alignment (-5.0m)	$z_0 = 14.6m$ Cover= 9.9m	-0.07%	0.25%	24	1/2	Very Slight to Slight	-0.13%	0.50%	49	2	Slight
Case 2C	Ch. 18+970 (Centre) Internal Building RC Frame Lowered Vertical Alignment (-5.0m)	$z_0 = 18.3m$ Cover= 13.6m	-0.04%	0.16%	19	1	Very Slight	-0.08%	0.32%	39	2	Slight
Case 3C	Ch. 18+995 (South Side) Basement Floor Slab Lowered Vertical Alignment (-5.0m)	$z_0 = 17.9m$ Cover= 13.1m	-0.05%	0.17%	20	1	Very Slight	-0.10%	0.34%	40	2	Slight

Note: this is an updated version of Table 5-9 in 22-228-TN-001 to reflect the new upward LoD of 1.0m for the tunnel alignment



### 3.0 ADDITIONAL INFORMATION ON IMPACT OF IMPLEMENTING THE LIMITS OF DEVIATION (LoD) ON THE BUILDING DAMAGE ASSESSMENT

The Wider Effects Report (WER) in Appendix 5.19 of the EIAR assesses whether the power to deviate the tunnel alignment within the LoD would alter the predicted significant impacts assessed and reported in the EIAR.

The report gives a high-level qualitative assessment of the impact of implementing the LoD for relevant Chapters of the EIAR. However, the impact on building settlement and damage is not addressed for Chapter 5 of EIAR (Metrolink Construction Phase), which contains the Building Damage Report.

This is a very notable omission from the EIAR because it does not address the likely significant impacts to the Arthur Cox Building if the level of the tunnel is raised.

It also does not assess the *mitigating* effect that lowering the level of the tunnel will have on ground movements and building damage due to tunnelling.

During the Oral Hearing Jacobs/IDOM issued a Technical Note that addresses the impact of imposing the revised LoD for the tunnel alignment on the results of the “Preliminary Design Building Damage Assessment”, under the following heading in the “Documents Issued during Oral Hearing” section of the Railway Order website:

[Updates Appendix 8 Impact on the Preliminary Design Building Damage Assessment Results due to Imposition of Limits of Deviation](#)

A copy of the technical note is included in Appendix B. The technical note relates to the conclusions in the Building Damage Report in Appendix A5.17 of the EIAR (the “BDR”). However, it is not issued as an addendum to the Wider Effects Report (the “WER”) and the BDR and WER have not been updated.

I would have the following comments on the assessment in the technical note:

- Technically, this means that Jacobs/IDOM have now carried out an assessment of implementing the LoD on the Building Damage Assessment. However, I would consider that the assessment is very generic, does not properly assess the impacts and is not fit for purpose in the case of the Arthur Cox Building, i.e.
  - The assessment has been carried out on a generic project-wide basis for buildings that fall into Damage Category 1 (DC-1), Damage Category 2 (DC-2) and Damage Category 3 (DC-3) so there is no specific assessment for the Arthur Cox Building.
  - The assessment for the raised tunnel profile has been carried out for the revised upward LoD of **+1.0m** but also at the maximum Lateral LoD of **15.0m**. It does not assess the impacts separately or state in which direction the lateral LoD is applied. Vertical and horizontal changes to the tunnel alignment can have different impacts on the extent and characteristics of building damage.
  - The technical note states that “*quantitative assessments have been carried out*” for buildings in the DC-2 category, which would include the Arthur Cox Building. However, there is no information on the methodology and criteria



that were used and the results are not provided, so we can only assume that the methodology is the same as the Phase 2a assessment in the BDR.

- The technical note concludes that
  - there will be no increase in the damage category level for any of the DC-2 buildings;
  - Different and/or additional impacts from the assessment are *below* “Slight” (i.e. below Risk Category 2). Therefore, there will be
    - no change to the required mitigation measures set out in the EIAR;
    - no change to the residual impacts arising from the application of these mitigation measures; and
    - no additional significant impacts.

However, our assessment demonstrates that raising the tunnel level could increase the impact on the building and façade to Risk Category 3 (Moderate) or possibly higher, particularly if the concentrated loads from the pad foundations and perimeter secant piles are taken into account.

- The technical note generically concludes that lowering the vertical alignment could only improve on the damage potential in all cases. They have not properly assessed the *positive* impacts of lowering the tunnel profile as a mitigation measure.
- Fundamentally, the methodology is still based on Risk Category 2 [Slight Damage] being considered an acceptable threshold of damage for the Phase 2A assessment in the Building Damage Report.
- This generic methodology is not fit for purpose for the Arthur Cox Building because it does not reflect the lower limits of acceptable building distortion and damage that would apply to the building façade and basement waterproofing system, which are particularly sensitive to differential settlement and cracking.



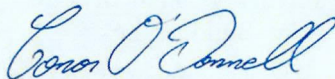
## 4.0 CONCLUSIONS

Based on the results of the revised Refined Phase 2a BDA for the Arthur Cox Building we would recommend that:

- Reducing the upward LoD to +1.0m has a positive impact on the level of building damage that could occur if the vertical alignment of the tunnel is raised to the maximum level, i.e.:
  - It eliminates the potential for the TBM to hit the toe of the secant pile wall, which is only 4.0-4.9m above the design profile of the tunnel;
  - It results in a lower level of damage than estimate for the original upward LoD of +5.0m.
- However, the level of damage that could occur would still exceed the threshold of acceptable damage for the building façade and basement waterproofing system of the Arthur Cox Building, which would be more sensitive to building distortion and cracking than indicated by the generic criteria used in the building damage assessment.
- The technical note prepared by Jacobs/IDOM assesses the potential impact of implementing the LoD on the results of the building damage assessment in the BDR. However, in my opinion it does not properly assess the likely significant impacts on the Arthur Cox Building, i.e.
  - The assessment is very generic and does not include a specific assessment for the Arthur Cox Building;
  - The methodology and results of the analyses are not presented in the note;
  - It does not treat changes to the vertical and horizontal alignment separately.
  - It is still based on an acceptable threshold of building damage at Risk Category 2 (Slight), which is not fit for purpose for the Arthur Cox Building as it does not reflect the lower limits of acceptable building distortion and damage that would apply to the building façade and basement waterproofing system;
  - The positive impact of lowering the tunnel alignment has not been properly assessed.
- Therefore, our conclusions for the refined Phase 2a assessment in Technical Note 22-228-TN001 (Rev.1) are still applicable, e.g.
  - The level of the tunnel should be lowered by at least 5.0m to reduce the impact of tunnelling related ground movements on the Arthur Cox Building;
  - The Wider Effects Report should be revised to include a constraint to on the application of the Limits of Deviation for the tunnel under the Arthur Cox Building so that there is no scope for upward vertical deviation of the lowered tunnel alignment due to the potential for significant adverse impacts on the building;
  - TII and Jacobs/IDOM should liaise with the structural designers of the building and façade to determine the acceptable threshold of building distortion, damage and ground movements related to tunnelling;



- A more detailed Phase 3 analytic assessment should be carried out to confirm that the building distortion due to tunnelling induced ground movements is within acceptable limits taking account of concentrated foundation loads;

Document Approval Form		
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<b>Made by:</b>	Conor O'Donnell	



**Appendix A**  
**Details of Revised LoD for Upward**  
**Changes to Proposed Tunnel Alignment**  
(Expert Witness Statement of Ronan Hallissey p7)



**IN THE MATTER OF AN APPLICATION TO  
AN BORD PLEANALA**

**For Approval of the Railway (Metrolink – Estuary to Charlemont via  
Dublin Airport) Order [2022]  
ABP-314724-22**

**ORAL HEARING**

**STATEMENT OF EVIDENCE**

**on**

- (i) Amendments to the Railway Order and Schedules / drawings and  
modifications to the scheme**
- (ii) Errata**
- (iii) Agreements presented to the Oral Hearing**
- (iv) Updates to the EIAR**

**By**

**Ronan Hallissey**

**19 February 2024**



**MetroLink Oral Hearing  
Brief of Evidence of Ronan Hallissey**

**(i) Amendments to the Railway Order and Schedules / drawings and modifications to the scheme (ii) Errata (iii) Agreements presented to the Oral Hearing (iv) Updates to the EIAR**

5.1.2 Chapter 5 MetroLink Construction Phase

(a) The proposed reduction in the vertical upward limits of deviation.

Chapter 5 of the EIAR presents details of the construction methodology and programme for the proposed project. TII wish to make a single amendment to this chapter in regard to the proposed Limit of Deviations

**Limits of Deviations**

In the Draft Railway Order for MetroLink Limits of Deviation (LODs) are proposed and these LODs are the same as those approved by the Board for "Old Metro North" and "Dart Underground". (Refer to Tables below)

Project Element	Vertically (upwards) (m)	Vertically (downwards) (m)	Horizontally (in all directions from centre line) (m)
Surface works (not impacting on public roadways)	2	2	5
Surface works (impacting on public roadways)	1	1	2.5
Tunnel Alignment	5	10	15

Project Element	Vertically (upwards) (m)	Vertically (downwards) (m)	Horizontally (in all directions from centre line) (m)
Retained Cut and Cut and Cover Alignment	1	2	2.5
Station Box Locations	5	10	2

However a number of submissions received from the statutory consultation process raised concerns with regard to the LODs, particularly those that allowed for movement upwards as it was identified that there was potential for increased impact on buildings should the LOD upwards be allowed.

In response to this, TII proposed to modify the proposed LOD to restrict any potential deviation upwards to just 1m.

These new limits will further reduce potential impacts above the alignment, specifically on:

- a) Settlement Effects;
- b) Groundborne Noise & Vibration;
- c) Effects on future site development potential.



## **Appendix B**

### **Technical Note by Jacobs/IDOM on Impact of Implementing the Revised Limits of Deviation on the Results of the Building Damage Assessment in the Building Damage Report**



<b>Project:</b>	Dublin MetroLink		
<b>Doc No:</b>	ML1-JAI-GEO-ROUT_XX-RP-Y-00034		
<b>Subject:</b>	Impact on the Preliminary Design Building Damage Assessment Results due to Imposition of Limits of Deviation		
<b>Revision No.</b>	P01		
<b>Prepared by:</b>	Alberto Jaen-Toribio	<b>Date:</b>	10.11.23
<b>Checked by:</b>	Mahee Maheetharan	<b>Date:</b>	10.11.23
<b>Reviewed by:</b>	Mahee Maheetharan	<b>Date:</b>	10.11.23
<b>Approved by:</b>	Paul Brown	<b>Date:</b>	10.11.23

## 1. Background and Purpose

The building damage assessment work carried out and reported in ML1-JAI-GEO-ROUT\_XX-RP-Y-00034 P03 [Ref. 1] is based on the draft Railway Order (RO). The Draft RO includes for Limits of Deviation (LOD) for proposed MetroLink infrastructure that can be availed of, if practicable. This Technical Note assesses the potential impact on the Preliminary Design building damage assessment work should the LOD set out by the Draft RO (Article 6) be availed of.

## 2. Basis of Assessment

The impact of settlement has been assessed assuming that the LOD set out by the Draft RO Article 6 might be availed of, except for the tunnel vertical alignment, which it is assumed will only be moved upwards by 1m from that shown by the RO application.

## 3. Assessment Approach and Findings

A review of buildings within Damage Category 1 or below and those buildings not currently impacted by the RO design alignment has been undertaken to ascertain sensitivity to change due to alignment alterations within the horizontal LOD set out by the Draft RO. Based on the analysis of selected worst-case buildings, it has been concluded that any buildings assessed as falling into Damage Category-1 (DC-1) or below based on the Draft RO are unlikely to fall to above DC-2 level due to the imposition of the horizontal LOD or vertical LOD limited to 1m.

Further, the damage category of buildings in the vicinity of the proposed station boxes is unlikely to be affected due to the restriction in the LOD for station boxes; i.e. maximum of 2m. It is also concluded that the buildings currently outside the 10mm green-field contour line based on the RO design alignment are unlikely to be impacted above DC-2 level due to the imposition of the LOD, hence there are no significant impacts predicted.

For the buildings away from the proposed station boxes and showing DC-2 level based on the RO application tunnel alignment, quantitative assessments have been carried out with the tunnel horizontal alignment at the extremity of the LOD together with a vertical upwards LOD of 1m; this exercise showed that there will be no increase in the damage category level.



Further, for the buildings currently falling into DC-3 level, it has been confirmed by inspection that they are already at their worst possible position in relation to the RO application tunnel alignment and therefore the imposition of horizontal LOD with an upwards vertical LOD limited to 1m is unlikely to have any adverse impact.

In all cases, lowering of the vertical alignment could only improve on the damage potential.

#### **4. Conclusions**

The building damage assessment carried out and reported in ML1-JAI-GEO-ROUT\_XX-RP-Y-00034 P03 [Ref. 1] is based on the RO application tunnel alignment.

The analysis carried out in this TN has concluded that there will be no additional buildings that would qualify for Phase-3 Assessment to that reported by the EIAR should the LOD set out by the Draft RO be availed, including the vertical upwards tunnel LOD limited to 1m.

Potentially different and/or additional impacts (below "Slight") associated with possible deviations to the route within the LOD have been identified. Based on this analysis, it is concluded that there would be no change to the required mitigation measures or residual impacts arising from the application of the mitigation measures set out in the EIAR and no additional significant impacts.

#### **5. References**

[1] Jacobs Engineering Ireland Limited (2022), Damage Assessment Report of Buildings and Other Assets ML1-JAI-GEO-ROUT\_XX-RP-Y-00034 P03 (Dated 22/06/2022)